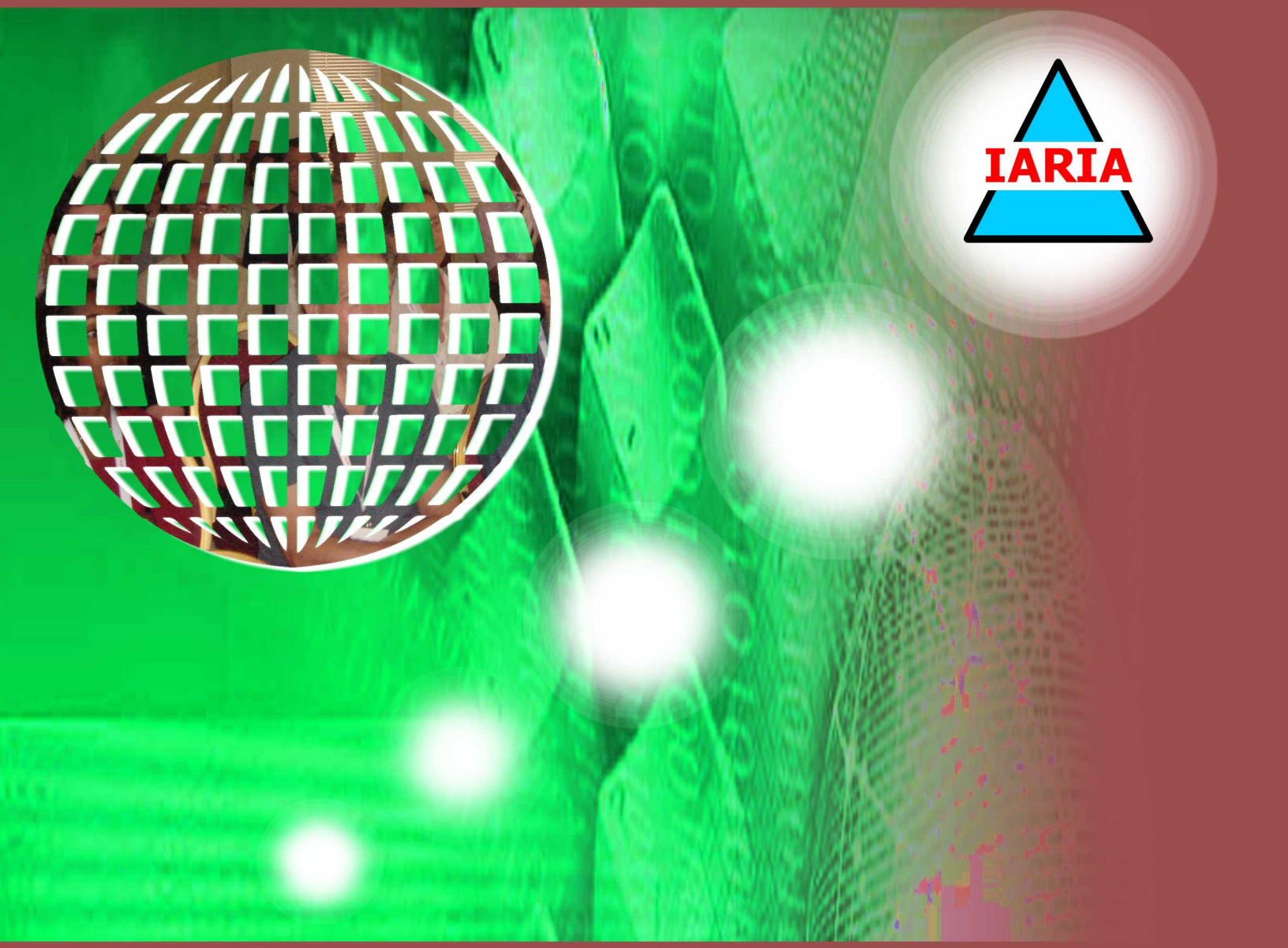
# International Journal on Advances in Life Sciences

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**International Journal on Advances in Life Sciences**
**Volume 2, Number 1 & 2, 2010**

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# Realistic Large Scale ad hoc Animal Monitoring

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***Abstract*— Automated cattle monitoring with wireless devices installed on animals is important for profitability of animal production as well as welfare of animals and farmers. In this paper we define requirements for such monitoring on the basis of questionnaires distributed to potential users and processing data from long term animal monitoring. Then we discuss a practical store and forward architecture that allows data retention, issuing notifications and answering remote as well as in situ queries. The core of this architecture - disruption tolerant mobile ad hoc routing protocols allows minimizing and balancing energy utilization, which is crucial for labor intensity of animal monitoring. We achieved that by dynamic adaptation to the behavior of monitored animals, in particular utilization of heterogeneity of nodes' mobility. We evaluate the proposed protocol to show how it satisfies our requirements and then discuss precautions against security threats, which are essential for feasibility of the deployment of the proposed architecture.**

***Keywords- Animal Monitoring, DTN, Energy Conservation, Wireless Routing, Security***

## I. INTRODUCTION

There is a proliferation of interest in using wireless ad hoc technologies to monitor health and behavior parameters of wild as well as domestic animals [2-8] and the environment as a whole [9]. This paper focuses on cattle monitoring because timely detection of cattle health problems can prevent spread of diseases such as mastitis and other infection diseases, metabolic diseases and lameness, which can lead to decreased productivity and death of valuable stock [3], as well as endanger health of the humans. The productivity of a farming enterprise can be also extended by timely detection of the oestrus in order to efficiently perform insemination of cows. Currently most of the farms practice manual observation, whereas the most advanced enterprises utilize milk monitoring by stationary sensors, or animal mounted sensors read over a single hop communication having very short [10] to medium range [11] leading to disconnections. These solutions are simple and easy to implement but require expensive infrastructure to provide full coverage or they offer only limited reliability. Current state of the art research for monitoring cattle behavior and metabolism in the Wireless Sensor Networking (WSN) research community are largely pragmatic proofs of concepts [12]. More precisely they utilize single hop [5, 6] or GSM communication [3]. The latter is expensive and not reliable in agricultural areas, where GSM operators have limited incentives to provide complete coverage.

In this paper, we discuss practical feasibility of the deployment of the delay store and forward architecture introduced in [8, 13], that provides data retention, detecting custom events, notification issuing, remote and in-situ queries answering. The core of this architecture, a novel energy efficient, disruption tolerant Mobile Ad Hoc Network (MANET) routing protocol provides offloading data for long term storage by sending data to farm servers via sinks that are a part of a MANET and handles in-situ queries issued by users collocated with the animals. The advantages of this protocol are following: (1) we significantly optimize energy efficiency of control traffic by identification and utilization of animal movement patterns as well as graceful degradation of data traffic energy efficiency, (2) the protocol can dynamically adapt to the current behavior of the animals carrying the mobile devices by utilizing heterogeneity of nodes' mobility, (3) it can work with any type of bovine animals. Reducing and balancing energy utilization of the mobile nodes is essential from the perspective of farming industry because it allows decreasing labor necessary for changing the batteries installed in the animal mounted devices.

In this paper, we demonstrate practical feasibility of this algorithm by extended monitoring of behavior of 5 animals over 1 year. Our results are based on significantly larger data set than normally used for this kind of application domain. The usual data size would sometimes include a somewhat bigger number of nodes but would in turn have much shorter time span of the data capture (weeks rather than months or years). Finally we address the challenges of the practical deployment of the proposed algorithm by proposing mechanism for dealing with disconnections and discussing the security issues. We argue that security issues are at the core of allowing deployment of the cattle monitoring in the commercial environment. Competitors are likely to disrupt functioning of the target farming enterprise or put it into a less favorable position. Buyers of the animal products (e.g., supermarkets) may want to lower the price of the products they buy or gather intelligence about the sellers to better evaluate their offer. The impact of the utilized security precautions on the energy efficiency of the animal mounted devices should be minimized.

This paper is an extended version of [1]. More precisely, it gives more information about the proposed algorithm and also provides its detailed evaluation. The paper is organized as follows. Section II discusses and categorizes related work. Section III presents the proposed architecture. Section IV reports on the setup and results of our field experiments we performed to collect realistic data sets and requirements necessary to evaluate the proposed architecture and the MANET routing protocol. The cattle movement data from these experiments was uploaded [14] to the Community Resource for Archiving Wireless Data At Dartmouth (CRAWDAD). Section V presents our practical protocol that provides data off-load and in-situ queries extending the discussion about combating disconnections. Section VI reports on our evaluation of the proposed protocol. Section VII identifies potential security threats, proposes feasible precautions against them and discusses impact of these precautions on the proposed protocol. Finally, Section VIII identifies future challenges.

## II. Related Work

This Section reports and classifies the existing work related to cattle monitoring.

### A. Criteria

We begin with defining and motivating the set of criteria used for reviewing existing work. They can be divided into satisfying user requirements and addressing environmental constrains. Satisfying user requirements includes: (1) increasing reliability, (2) managing delays, (3) increasing scalability, (4) lowering costs. Addressing environmental constrains means handling high mobility of nodes. Further within this section we discus each of these criteria in a greater detail.

*a) Increasing Reliability.* This is an important requirement that affects the usability of the monitoring system and should not be limited to the best effort level due to the nature of ad hoc type of communication. We target to increase the reliability by applying the appropriate techniques such as extending range of transmitters with multi-hop communication, utilizing redundant data storage and feedback. Due to lower time constraints it is easier to increase reliability of sending data for retention and delivering notifications about detected events than answering in-situ queries.

*b) Managing Delays.* Different types of traffic have different time constrains. According to the users' requirements the acceptable delays for sending data from animal mounted devices to farm servers via sinks depend on the type of data. The urgent data includes for example information about the detected oestrus or an animal disease. Such events should be reported as quickly as possible. Non-urgent data is for example a periodic update necessary for detecting the reduced efficiency of pastures. Reduced efficiency of pastures should be reported within 24 hours. Delays for answering in-situ queries should allow the users to work interactively.

*c) Increasing Scalability.* The target system should comprise multiple MANETs where each MANET can comprise from several up to approximately hundred of animal mounted devices. We consider scalability in terms of the number of MANETs in the overall topology, the number of animal mounted nodes within each of the MANETs and of the density of the topology of a single MANET. The system should maintain the required parameters such as delays and energy efficiency within the dynamic range of topology size and density. In the case of lower densities of the topologies the major challenge are disconnections because the topology can split into separated islands of connectivity, e.g., this may happen when an animal becomes ill or injured or the herd splits into separate groups. Such disconnections are challenging for the wireless communications because the multi-hop path between a pair of nodes does not necessarily always exist. Handling disconnections means thus detecting the existence of the multi-hop path and when it appears, performing necessary data exchanges or routing the data in the store and forward manner or caching data and answering queries within the network partition. In the case of higher densities of topologies or higher numbers of nodes the major challenge is combating network congestion that is usually caused by broadcasts. Therefore the most promising approach to combating congestion is optimizing the broadcasts by differentiating the roles of nodes in rebroadcasting packets.

*d) Lowering Costs.* This refers to lowering the financial and labor costs of installation and maintenance of the target cattle monitoring system. More specifically, we focus on lowering the costs of utilizing the third party communication services such as GSM, satellite telephony or human labor. The major constituent of maintenance costs of the target system is replacing batteries of the animal mounted nodes and we aim to minimize and balance energy utilized for wireless communication by animal mounted nodes.

*e) Handling High Mobility.* Animal mounted nodes have movement patterns that are difficult to predict and this results in frequent changes of topology. Handling high mobility thus means using soft state topology data, which is collected in the demand driven way, i.e., when there is data to be routed and the topologies change in the self organized fashion.

### B. Existing Approaches to Animal Monitoring

This section discusses existing Wireless Sensor Networks (WSNs) for animal monitoring. The WSNs [15] consist of hundreds to thousands of inexpensive wireless nodes, each with some computational power and sensing capability, operating in an unattended mode. The hardware technology for these networks are low cost processors, miniature sensing and radio modules. Sensor data includes continuous sensor readings of physical phenomena, audio and video streams.

*a) Stationary Wireless Sensor Networks.* The initial WSNs were purely stationary. The sensor data was archived in a powerful server geographically collocated with the sensors (usually referred to as a base station) that was usually fully replicated on the pre-determined powerful servers in the labs. Users could query the databases to get information about sensor data. An example stationary WSN was the WSN deployed on the Great Duck Island [16] to monitor the ecology of Leach's Storm Petrel. It used single-hop communication and had a multi-layer architecture. The fist layer consisted of multiple sensor networks that were deployed in dense patches that were widely separated and measured various physical phenomena and had cameras and microphones. Each sensor patch had sensor motes that were capable of various forms of filtering, sharing and combining sensor measurements. Sensor motes transmitted sensor data to the second layer that is referred to as a gateway. A gateway was then responsible for transmitting the packets to the third level referred to as the base station and some further data processing. The base station in the third level provided full database services and connectivity to the database replicas across the Internet. Fourth layer usually refers to services that provide multi-user access to sensor data including services for supporting analysis, visualization and web content. Once deployed, most base stations are intended to remain stationary and in a densely packed configuration. WSN deployed on the Great Duck Island comprised 43 sensor nodes and its maintenance was characterized by low labor intensity. Its stationary character allowed simplification of the routing and avoiding problems with mobility and disconnections. The simple routing and lack of disconnections helped in avoiding problems with energy saving. Lack of disconnections and problems with energy saving allowed short delays. This approach because of its stationary character does not apply to our scenario.

*b) Animal Mounted.* In a typical animal mounted WSN mobile nodes send measurements to a centralized server over a GSM or satellite network. Alternatively the measurements are collected by a mobile base station carried by a human or mounted on a vehicle and then manually processed [2]. The oldest form of animal mounted wireless sensors are radio tags, which send VHF beacons [17]. Their measurements are retrieved by a base station, which can be fixed, carried by a human or mounted on a vehicle. This approach is not optimal for our scenario because using fixed base stations is expensive in the case of covering larger areas. Using base stations carried by humans or mounted on vehicles is very labor intensive. In both cases potentially data from only a subset of tagged animals can be retrieved. The more recent variant of this method [17] is using satellite telephony instead of VHF beacons. This is much less labor intensive and more reliable but also very expensive and energy inefficient. One of the first examples of animal mounted WSNs was ZebraNet [2] that consisted of animal mounted collars collecting and exchanging GPS locations, which were retrieved by a mobile base station. The collars, were opportunistically exchanging all stored measurements with all encountered nodes. This addressed disconnection but had low scalability – the maximal envisaged number of the deployed animal mounted nodes was 30 and involved human labor. The authors of [3] mounted various sensors on a single steer to monitor temperature inside its rumen, location, acceleration, as well as external temperature, humidity and pressure. The measurements from the sensors were transmitted to the gateway mounted on the animal, which forwarded them on via GPRS. The presented approach was expensive and not energy efficient because of extensive utilization of GPRS. Low energy efficiency increased the labor intensity of its maintenance. The GSM telephony can have limited coverage in rural areas where the cattle is kept [3]. This approach does not address our requirements because due to heavy utilization of GSM it has high costs and low energy efficiency. Butler et al. [4] proposed using animal mounted devices to force bovine animals to move or stay within virtual fences but did not address the energy efficiency of the wireless communication. Researchers at CSIRO [5, 6] fitted 13 cows with collars containing accelerometers, GPS receivers and wireless networking interfaces in order to examine reliability of the communication and usability of the data collected by GPS receivers and accelerometers. The authors did not give the details about the utilized routing protocol and did not consider the energy efficiency. The later work of these researchers [7] concerns using animal mounted devices to prevent bulls from fighting with each other. The animal mounted collars have GPS receivers, wireless network interfaces and are capable to apply electric shocks to the animals wearing them. The utilized wireless communication is a simple single-hop one without considering energy efficiency. Small et al. [18-20] proposed using whale mounted sensors to collect data about whales and their habitat. They utilized a combination of the Infostation [21, 22] paradigm and a DTN approach similar to Gossiping [23]. This work is similar the ZebraNet [2] but limits the probability of forwarding data to other nodes. In our scenario animal mounted devices form a much denser topology than in the case of whale monitoring. Therefore, gossiping would increase the network overhead and thus affect energy efficiency.

*c) DTN networks for rural areas.* There is intensive ongoing research in DTN networks for rural developing areas [24-27]. However, this research typically concerns providing connectivity between villagers or between villagers and local authorities rather than monitoring farm animals and does not consider energy efficiency.

## III. Architecture of the Cattle Monitoring System

This section describes the architecture of the target cattle monitoring system, more fully described in [13, 28]. The scope of the monitoring system is a farming enterprise,

which comprises several pastures and barns where animals are kept. The cattle can be kept all the year continuously in the pastures or all the year in the barns but the most common practice is to keep them in the pastures during the warmer half of the year and indoors during the other [29]. The proposed system can be used to monitor animals regardless if they are kept continuously in the pastures or in the barn and regardless if they currently yield milk or not.

Oestrus, animal diseases, reduced efficiency of pastures can be detected by measuring, collecting, and analyzing walking and feed intake intensity [10, 30]. Relying on both factors can decrease the number of false positive errors [30, 31]. In the proposed system, animal mounted device has the form of a collar with a built-in accelerometer measuring the intensity of feed intake. Walking intensity is measured by a pedometer mounted on the animal's leg. Measurements from the pedometer are acquired by the collar over wireless communication. Measurements from the pedometer and accelerometer are stored and processed by the collar. Both the collar and the leg mounted pedometer are battery powered. Data processing performed by animal mounted devices aims to detect oestrus, pregnancy, animal diseases etc. They have wireless network interfaces and regularly transmit raw and processed data to the farm servers over the sinks. Sinks are members of the MANET, which forward the data collected and processed by animal mounted devices to farm servers. Animals wear the same devices regardless if they are kept in pastures or barns.

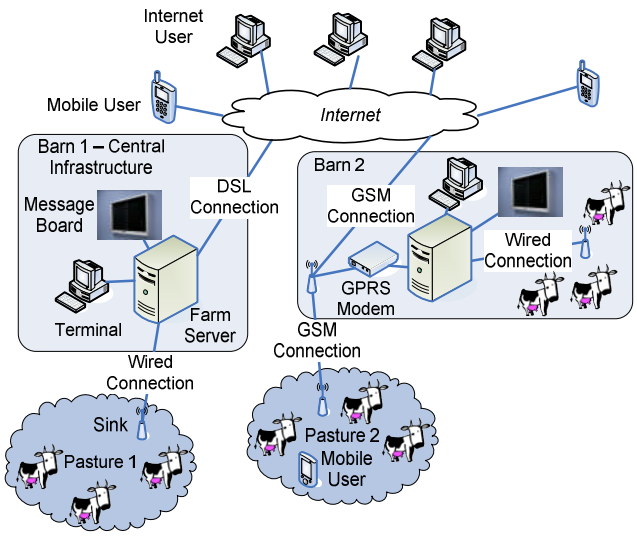


Figure 1. Example deployment

The typical amount of data for each update sent from animal mounted devices to sinks is 32B. As shown in Figure 1, sinks can be connected to farm servers over a wired network connection or GSM telephony. In the latter case, the sink can be stationary or animal mounted. The farm servers store the real time and historic data, detect the user defined events and issue notifications about these events.

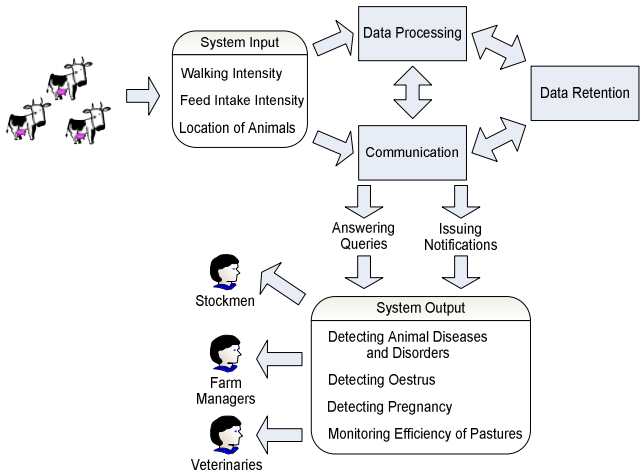


Figure 2. Functional overview of the cattle monitoring system

As shown in Figure 2, the users can query the data stored on the servers, including raw and processed data, either locally at the farm or remotely over the Internet. Users located in a pasture, stall or in its close proximity may want to query data about the animals located there. This can be achieved by querying the data from a PDA or a smart phone connecting directly to the animal mounted devices, or via the sinks over the wireless communication.

## IV. FIELD EXPERIMENTS

In this section we describe field experiments we performed at the University of Nottingham's Dairy Centre in collaboration with School of Biosciences. The purpose of these field experiments was collection of realistic data sets and requirements necessary to design, develop and evaluate the delay tolerant architecture and the energy efficient MANET routing protocol for the cattle monitoring system. The cattle movement data from these experiments was submitted [14] to the Community Resource for Archiving Wireless Data At Dartmouth (CRAWDAD). CROWDAD is an international repository of real wireless data for wireless network research community.

### A. Quantitative Experiments

Quantitative experiments comprised cattle movement and behavior monitoring in order to gather the realistic environmental constrains.

#### 1) Experiment Setup

We received one year long walking intensity data from 5 pedometers mounted on the cows located in the division of a modern dairy housing 100 animals, shown in Figure 3. One year length of the pedometer data allows for enough variability of continuing patterns that could be used by our algorithm to enhance its performance. Cows could move freely in the area with feeder, water tank, resting bays and milking robots available 24 hours a day. Their measurements were automatically collected by milking robots whenever a cow was milked.

We also monitored behavior of the animals using animal mounted GPS receivers and cameras. In particular we

mounted on the monitored cows five collars, each comprising a neck strap and an aluminum instrument enclosure containing a Bluetooth GPS and a Bluetooth enabled mobile phone. Mobile phones were logging data from the GPS receivers including positions and timestamps. Monitoring started at 11:10. The collars were removed at 18:10. GPS receivers worked until 18:24 (manually turned off), 12:23 (probably jammed), 18:51 (manually turned off), 15:09 (exhausted battery), 15:33 (exhausted battery). Later we submitted [14] the collected GPS and pedometer data to the Community Resource for Archiving Wireless Data At Dartmouth (CRAWDAD). Concurrently we were filming the part of the dairy where the monitored cows were kept. We placed the camera on two ramps above this area. These locations offered the most complete view. We received the plan of the dairy and then captured the coordinates of the characteristic locations on the plan using a handheld GPS receiver. GPS receivers and filming were utilized only for the purpose of our field experiments. Their utilization is not intended for the target monitoring system.

*2) Results*

Our field experiments show that cows typically react well to the animal mounted collars weighting 1075g. This is very promising for the practical feasibility of the target cattle monitoring system. Figure 4 shows the average daily walking intensity of five cows, calculated from the one year long pedometer data as arithmetic weighted mean of walking intensities per each cow and each day. We can see that the animals' mobility can differ significantly among different animals and for each animal among different days. However, from this picture we cannot judge how the walking intensity is reflected in the spatial mobility. Figure 5 shows probability distribution of speeds for a subset of cows wearing GPS receivers. They were calculated by dividing the time a cow used the given speed range by the length of time the GPS receiver was enabled. We can see that not only walking intensity but also the preferred spatial movement speed can significantly differ among animals. These considerable differences in the animals' walking speed can be utilized in the routing protocol. Figure 5 also shows that the animals rarely move faster than 0.8 m/s, which is important for the wireless communication.

Figure 6 shows average walking intensity over the day for five different animals, each average walking intensity was calculated as a weighted arithmetic mean for each animal and for each hour of the day (i.e., one hour time frame) throughout all the days for which we had pedometer data (one year). Figure 7 shows the probabilities of milking happening at a given hour, calculated as a ratio of milkings number at given hour of the day to the number of all recorded milkings. We can see that cows are active all the day and night including walking and milking but they show similar 24 hours patterns. In particular, walking and milking activities tend to be less intensive between 0 and 6 a.m. These periods can be utilized for scheduled data exchanges.

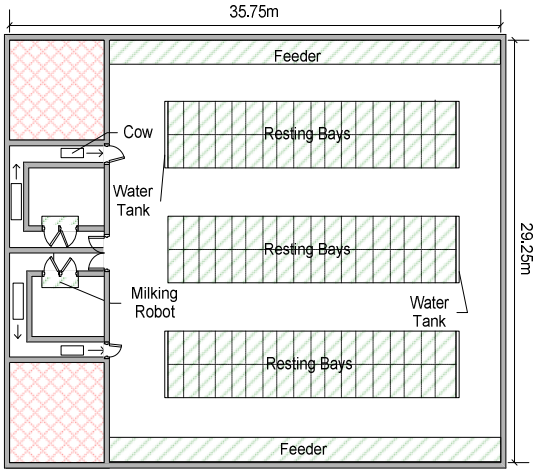


Figure 3. Layout of the dairy division

The quantitative experiments were performed in the dairy but this is only an example deployment scenario of the target monitoring system. The target monitoring system is also intended to monitor beef cattle animals kept continuously on the pastures even all the year. Such cattle may never be taken to the farm buildings.

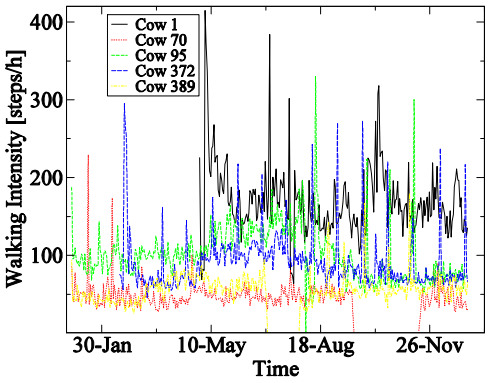


Figure 4. Walking intensity (pedometers)

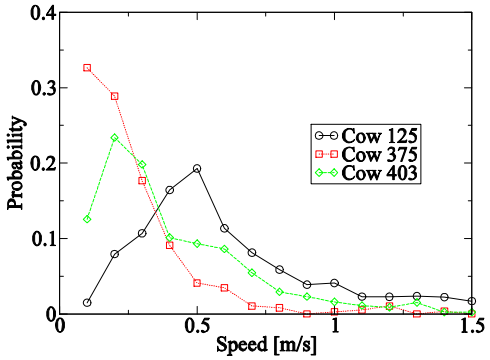


Figure 5. Probability distribution of animal speed (GPS receivers)

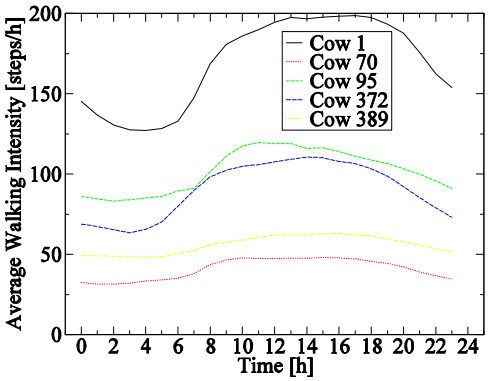


Figure 6. Activity over the day (pedometers)

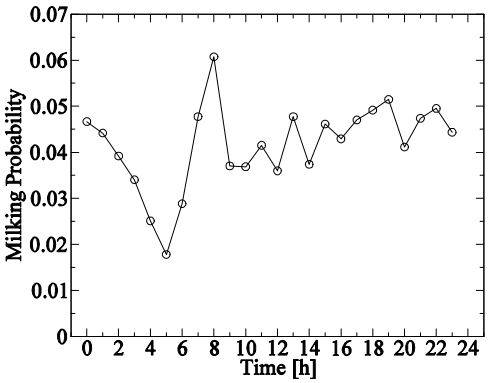


Figure 7. Milking probability (pedometers)

### B. *Qualitative Experiments*

The objective of the qualitative experiments was gathering of the realistic user requirements.

#### 1) *Experiment Setup*

Our qualitative experiments comprised distributing an anonymous questionnaire to the farm personnel and researchers working on the farm. We received four filled questionnaires. One of them was filled by a regular herdsman, one by the head herdsman (farm manager) and two by researchers working on the farm.

#### 2) *Results*

From the performed questionnaire we learnt that the most required functionality of the system is detection of oestrus, pregnancy and animal diseases. Users have to be informed about oestrus and a newly detected disease as quickly as possible. The pregnancy should be reported within 48 hours from detection. Detection of reduced efficiency of pastures is less essential but more urgent – it should be reported to users within 24 hours from detection.

In order to inform users about the detected oestrus and animal diseases as quickly as possible, animal mounted nodes should be able to detect oestrus and animal diseases on their own and send this information over the sink as soon as it is detected. When no particular event is detected, data from collars should be transmitted via sink at least every 24 hours to allow server its aggregation and detection of reduced performance of pastures.

The users recognize sending notifications to their mobile phones as very useful and have to receive them any time, not only when they are collocated with the animals. This requires sending the notifications using the GSM network as, e.g., SMS messages. The users need to perform in-situ queries up to several times a day. This means that energy saving is relevant not only for sending data to sinks but also in-situ queries.

The head herdsman recognized also as useful measuring body temperature of the animals. This however requires using sensors mounted inside animal body because externally mounted sensors do not provide reliable measurements [3]. The regular herdsman recognized as useful detection of calving but feasibility of this requires further research in animal physiology.

## V. Energy Efficient Route Discovery

This section describes realistic, energy efficient MANET routing protocol, Energy Efficient Route Discovery (EERD), for the cattle monitoring system we introduced in [8, 13] and proposes energy efficient mechanism for dealing with disconnections. EERD concerns sending data from animal mounted nodes to sinks and performing in-situ queries. It significantly optimizes energy efficiency of control traffic by identification and utilization of animal movement patterns as well as graceful degradation of data traffic energy efficiency. We concentrate on energy utilized for wireless communication because the progress in the energy efficient microcontrollers with high computation power made the energy utilized for data processing negligible [32] in relation to energy spent on wireless communication. Simulation based analysis of delays, latency and package loss are presented in Section VI. They show that EERD not only decreases energy utilization but also improves success ratio of packet delivery in relation to DSR [33] and a generic routing protocol ESDSR [34]. This is achieved by decreasing packet loss caused by congestion.

### A. *Design Space*

In order to allow extending coverage while preserving energy efficiency (i.e., low transmission power) and to allow circumventing of obstacles in radio propagation we need the multi-hop ad hoc connectivity between mobile nodes. This can be achieved by a MANET routing protocol. Due to characteristics of our scenario such protocol should be optimized for energy efficiency and handling disconnections.

The design space for the energy efficiency of the routing protocol is shown in Figure 8. The Broadcast Optimization axis represent saving energy on broadcasting queries and route discovery control packets. The relevant approaches here include Passive Clustering with Delayed Intelligence [35] and utilization of heterogeneity of nodes' mobility we propose. The Route Selection Axis represents proposed selecting routes, which potentially have the maximal lifetime. The vertical axis, Transmitter Power Control represents saving energy by minimizing transmitter power. The relevant approach here is similar to the transmitter power control utilized in Energy Saving Dynamic Source Routing (ESDSR) [34] or Distributed Power Control (DPC)

[36]. The proposed routing protocol is a combination of these techniques.

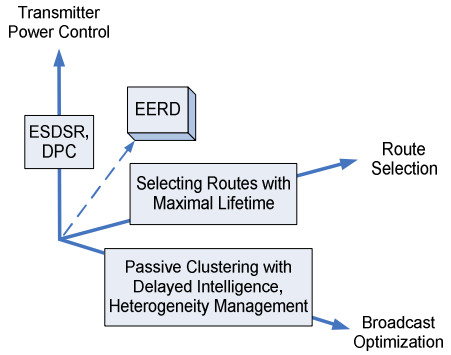


Figure 8. Energy efficiency design space

## B. Overview

Energy Efficient Route Discovery (EERD), for cattle monitoring system minimizes and balances energy consumption in the face of low data traffic and high mobility of nodes. It decreases energy spent on route discovery and in-situ queries by utilization of the tailored PCDI broadcasting. The number of necessary route discoveries is decreased by utilization of heterogeneity of nodes' mobility, selecting routes with longest lifetime and opportunistic route discovery. This protocol also deals with disconnections by cooperative detection of route availability. It is based on the established MANET routing protocol, DSR [33]. DSR was selected instead of Ad-hoc On-demand Distance Vector Routing (AODV) [37] because due to the application of PCDI the duration of the route discovery is difficult to estimate, which collides with expiry times of AODV dynamic routing table entries. Too long expiry time of these entries would highly increase the amount of soft state maintained by the nodes. In contrast too short expiry time would prevent routes with higher number of hops from working. The only advantage of AODV over DSR are shorter control packages in the case of routes with higher number of hops [37], which were not experienced in the evaluation reported in Section VI.

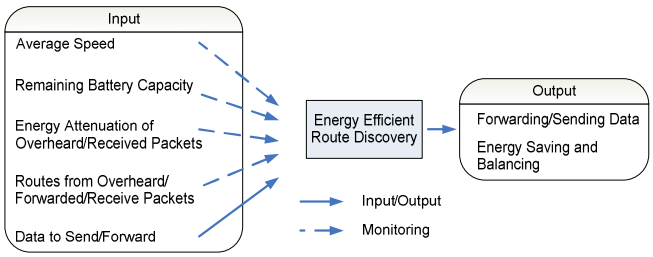


Figure 9. Input and output of the Energy Efficient Route Discovery

Figure 9 shows that EERD balances and saves energy on routing data by monitoring average speed of the nodes, remaining battery capacity of the local node, energy attenuation of the received and overheard packets, as well as acquiring routes from overheard and forwarded packets.

## C. Energy Saving and Route Discovery Techniques

This subsection describes energy saving and route discovery techniques utilized in EERD.

### 1) Decreasing and Balancing Energy Spent on Route Discovery

As in ESDSR [34] nodes put the utilized transmitter power in the packets so that each node can track power necessary to contact its single-hop neighbors using the following formula:

$$P_{min} = P_{tx} - P_{recv} + P_{threshold} + P_{margin} \quad (1)$$

where $P_{min}$ is the minimal required power for the sender to use, $P_{tx}$ is the current transmit power, $P_{recv}$ is the current received power, $P_{threshold}$ is the threshold power level for the application, and $P_{margin}$ is the margin to safeguard against changes such as channel fluctuation and mobility. All the values are in dBm. Note that only route requests and other broadcasted packets are sent using the maximal power of the transmitters.

The proposed protocol minimizes and balances energy spent on route discovery control traffic at the cost of the energy efficiency of data traffic. This is promising because the amount of exchanged data is low and power spent on sending data packets is minimized by limiting the transmitter power. The latter is possible because the power necessary to send data over each hop is known from monitoring power attenuation between neighbors. The power of route discovery broadcasts cannot be similarly decreased because it would decrease the probability of finding any route.

Energy spent on route discovery is minimized and balanced by applying Passive Clustering with Delayed Intelligence (PCDI) [35] to route request broadcasts. Note that broadcasted packets are sent using maximal transmitter power so power of the received broadcasts can still be utilized to calculate PCDI waiting time. In PCDI nodes with higher battery capacity are more likely to route broadcasted packets so discovered routes lead through these nodes. This results in more fair energy utilization of data traffic.

### 2) Decreasing Number of Route Discoveries

Energy spent on route discovery is further minimized by decreasing number of route discoveries achieved by utilization of the following techniques.

*a) Utilizing Heterogeneity of Node's Mobility.* The field experiments reported in Section IV show that there are considerable differences between typical movement speeds and typical walking intensities of animals carrying wireless nodes. The proposed protocol decreases chances that faster wireless nodes become members of the route by delaying their rebroadcasting of PCDI broadcasts. In this way the lifetime of the discovered routes is extended so repeated sending of data, route failure packets and route discovery broadcasts can be minimized.

Each mobile node stores the 24 hour time series of its momentary speed received from the pedometer – expressed as number of steps per time unit. An average speed is calculated over this time series discarding time when an animal did not move. The 24 hour time period is motivated by limited resources of the nodes and the 24 hour movement pattern cycle of the animals indicated by the pedometer data (see Figure 6). Each transmitted packet has a piggybacked maximal and minimal average speed of a node. These values are updated and stored by the forwarding nodes. Each node resets these stored values after a timeout to account for the changing conditions. This data allows nodes to asses their mobility in relation to other nodes. In EERD the PCDI formula calculating waiting time is extended by taking into account the average speed of the node in relation to average speeds of other nodes:

$$W = \delta \times \frac{receivedPower}{localEnergy} + \varepsilon \times \frac{V_L - V_{MIN}}{V_{MAX} - V_{MIN}} \quad (2)$$

where $\delta$ and $\varepsilon$ are constants adjusted for the particular hardware, $V_L$ is the average speed of the local node, $V_{MIN}$ and $V_{MAX}$ are minimal and maximal average speeds of the neighborhood nodes. In this way, relatively faster nodes wait longer to rebroadcast PCDI broadcasts so their probability of becoming PCDI clusterheads or gateways and later forwarding data traffic is smaller.

*b) Selecting Routes with Longest Lifetime.* The number of route discoveries is further minimized by selecting routes with potentially longest lifetime. Because of the high mobility of the nodes the life of a route is typically terminated not by the exhausted battery capacity but by the change of the topology.

Utilizing received, forwarded and overheard packets a node monitors how the energy attenuation changes between the one hop neighbors. In this way a node can count how many links within the multi-hop route are increasing their energy attenuation (deteriorating). In particular each forwarded route request and acknowledgement packet contains a counter of deteriorating hops.

Finally, as shown in Figure 10, a node selects routes, which have (1) *the least number of hops*. For routes with the same number of hops, a node chooses these with (2) *the least number of deteriorating links*. If this is equal one with (3) *the minimal total power* (i.e., sum of the transmitter power necessary to send data over each hop) is selected. The rationale behind (1) is that on average the fewer nodes are required to take part in routing the longer it takes before one of them moves out of the wireless range of its neighbors. (2) is used to avoid routes comprising hops between nodes moving away from each other. (3) is motivated by assuming that the power attenuation between two nodes is in most cases proportional to square distance between them. Therefore, selecting routes with minimal total power tends to select the routes leading through nodes, which are closer together. Such nodes are likely to need more time to leave each other's range.

Note that selecting a more optimal route does not involve exchanging additional packets. The selection of a route is performed in two cases. The first case is when a node wants to send data and finds multiple routes to the target node – one of them can have been acquired from a route discovery and the rest from forwarding or overhearing packets. The second case is when a node, which is due to rebroadcast a route request, finishes waiting enforced by Delayed Intelligence [35].

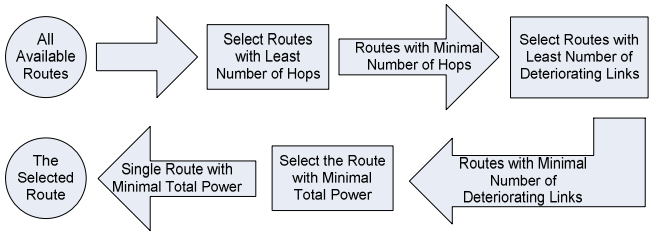


Figure 10. Route selection algorithm

Overall power of a route is calculated incrementally by adding the power necessary for sending data over subsequent hops. The partial result is carried by packets such as route requests, route replies and acknowledgements. In the case of route requests this is necessary for selecting the optimal route for further forwarding. In the case of route replies and acknowledgements this is necessary for opportunistic route acquisition from forwarded and overheard packets. A node rebroadcasts more than one route reply for a single route discovery attempt only if subsequent replies contain better routes.

*c) Opportunistic Route Acquisition.* An important way of limiting the number of route discoveries is collecting routes from overheard and forwarded packets such as route replies and data traffic. The gain from overhearing depends on the utilized wireless networking interface, in particular how much the power consumed by transmitting is greater than the power consumed by receiving and what is the difference in power consumption between promiscuous and non-promiscuous mode.

The sink always acknowledges receiving data. In order to account for possible disconnections, if no acknowledgement is received delivery is repeated after a timeout. In this way it is possible to opportunistically collect routes not only from forwarded or overheard route replies but also acknowledgements. For that purpose acknowledgements similarly to route replies carry aggregated power of the route and the counter of deteriorating links.

*3) Saving Energy on Broadcasts in In-situ Queries*

A mobile user collocated with the animals can issue both regular queries and directed queries. The answer to a regular query is a group of animal ids (or their custom nicknames) that fulfill a given logical condition (e.g., all animals, which are sick). The user broadcasts the query using PCDI with the proposed optimizations. All the nodes that know any partial answer to the query send the answer back to the user, together with the timestamp of the data based on which the answer was generated. The answer is sent back along the

route traversed by the query. Nodes that forward the queries assemble and filter these answers according to their timestamps in order to reduce redundant traffic. The final assembly is performed by the user's device.

Directed queries concern data about a particular animal (e.g., predicted date of the next oestrus). To receive the answer to such a query a user's device sends a broadcast using PCDI with the proposed optimizations to retrieve the route and the hardware address of the node that has the most recent data about the animal of interest if the user's device does not already have this information in its cache. This node could be a device that produced or caches the required data, or a sink, which can retrieve this data from a server. Then the user's device sends the query along the discovered route selected according to the cost metric proposed above. Finally, the queried device sends the answer back along the same route.

### *D. Handling Disconnections*

We propose extending EERD with the following mechanism for handling disconnections, which within this paper mean splitting of the network topology into separated islands of connectivity. The proposed protocol is intended to adapt to different environments, where the cattle is kept, dairy, pasture, etc. Therefore, it is not possible to present fixed boundaries of disconnection time.

In the case of sending data to sinks the data is sent only when the multi-hop path between an animal mounted node and any of the sinks exists. It is detected using the proposed *cooperative detection of route availability*, shown in Figure 11. More precisely, if the route discovery is unsuccessful it is repeated after a certain timeout with a small random delay. The purpose of the random delay is preventing the broadcast storm caused by multiple nodes initiating route discovery at the same time. In order to save energy on the repeated unsuccessful route discoveries if the route discovery is unsuccessful the node that initiated it broadcasts a negative acknowledgement. In this way all the nodes within its island of connectivity know that the route to the sink is not available and the route discovery should be repeated no sooner than after the predefined timeout. Otherwise if a node receives a route request packet but no negative acknowledgement, this means that a route to a sink exists so the node can try to discover it. The negative acknowledgements are preferred here over positive ones to save energy in circumstances when no disconnections take place – e.g., animals are located in a barn.

When a sink receives data from an animal mounted node it sends an acknowledgement. If no acknowledgement is received the animal mounted node resends the data over a different path and if it does not know any alternative path it initiates route discovery.

In order to answer the in-situ queries in the face of disconnections the animal mounted nodes should be able to answer the query within the island of connectivity (network partition). To achieve that, nodes cache data sent to sinks, which they forward or overhear. This caching is performed according to their available storage space. The proactive caching, i.e., the proactive exchange of the data for the purpose of caching, is not advisable here due to the energy constrains [38]. If the sink is connected to the farm server over an expensive third party connection such as GPRS, it may also cache the data forwarded to farm servers. In this way the sink can support answering in-situ queries without the need to query the farm server.

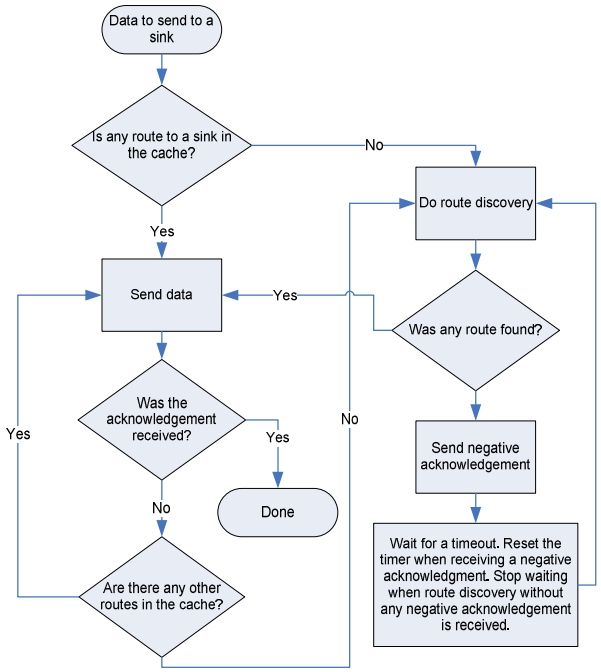


Figure 11. Cooperative detection of route availability

Nodes receiving an in-situ query answer it whenever they have at least a partial answer to this query. This answer can come from locally produced or cached data. If the in-situ query is received by the sinks, the sink may answer it after fetching appropriate data from the farm server or its local cache. In the case of direct queries nodes forward the answers to the queries only when the answer was based on the data, which is newer than in the case of answers already forwarded.

### *E. Sending Data from Farm Servers to Animal Mounted Nodes*

Sporadically the farm servers may need to send data to the selected or all animal mounted nodes. This data can be for example a firmware or configuration update. Such communication is similar to sending data from animal mounted nodes to farm servers. In particular the farm servers keep track of associations between the animals and pastures or barns where they are kept so they know to which sinks data should be forwarded. After receiving this data a sink performs route discovery (similarly as an animal mounted node) and sends the data to the given animal mounted nodes. If a route does not exist it retries after a timeout.

If there is more than one sink collocated with the target animal mounted node, the first sink, which manages to successfully deliver data to the target node can inform about this other collocated sinks so that the target node does not receive duplicates. To prevent duplicates being delivered at the same time each sink can wait a random delay before sending the data. If the instant communication between sinks is not possible, e.g., they are connected to farm servers by data couriers or GSM then the animal mounted nodes may receive duplicates but this type of communication is sporadic so these duplicates do not make a considerable difference for energy efficiency.

## VI. EVALUATION

This section reports on the evaluation of the proposed architecture for the cattle monitoring system, and its core, MANET routing protocol - EERD. As the method of evaluation we selected emulation, i.e., simulation utilizing data from the real experiments. This approach offers a satisfactory compromise between realism, variety of examined conditions, number of observed parameters and utilization of resources. In particular it offers higher realism than the purely stochastic simulation. Whereas in comparison to purely experimental evaluation emulation offers higher variety of examined conditions and more observed parameters for the same constraints (i.e., time and funds). We compared the proposed routing protocol with DSR [33] – a classical MANET routing protocol and ESDSR [34] – an example energy efficient routing protocol. We emulated the communication scenarios, which are realistic for the proposed cattle monitoring system but also sufficiently challenging for the emulated protocols to demonstrate benefits of the proposed protocol. In order to increase realism of the simulation the movement patterns of mobile nodes are emulated utilizing data from the field experiments instead of utilization of generic stochastic models such as Random Waypoint Model [33] or Reference Point Group Mobility Model [39]. These models were devised to simulate mobility of people and it is very difficult to adjust their parameters to make them reflect mobility of bovine animals.

### A. Bovine Movement Emulator

In order to make a realistic packet level emulation involving up to 100 nodes we implemented an emulator of bovine movements. This emulator is informed by field experiments described in Section IV and utilizes animal movement data from these experiments.

The emulation area is similar to the dairy where the field experiments were performed (see Figure 3). Each of the emulated cows is for most of the time in one of three states: (1) resting in a bay, (2) eating/drinking, (3) being milked. These states are associated with groups of locations within the division of the dairy and transitions between the states are connected with moving between locations. Selecting the next state is restricted in the following way. There is a minimal period allowed between milkings and a cow goes to a milking robot only when any of them has a queue shorter than three animals. If after reaching the robot the queue is longer than two animals, the cow changes the target state.

Speeds, which the emulated cows randomly select, were acquired from the GPS data. This makes the emulated cows move with similar distribution of speeds as the real animals. Speeds higher than 1.5 m/s were filtered out under the assumption that they were unavailable to the bovine animals [40] and were recorded because of GPS drift. Two different speed profiles utilizing real speeds from cows 375 and 403 were utilized (see Figure 5). These profiles are distributed evenly between the emulated cows.

The times a cow stays at any of the locations were acquired from the video footage. These are randomly selected for the cows during the emulation to achieve the distribution close to reality. GPS data is only utilized for acquiring resting times because in other cases the accuracy of GPS data is too low in relation to the distances between different types of locations such as feeder, water tanks, milking robots and bays. The patterns of eating and drinking and the times the cows spent performing these activities were also determined from the video footage. These patterns are also randomly selected during the emulation. The minimal period between milkings for a cow we calculated from the timestamps of the pedometer readings taken during the milkings.

### B. Comparison with Existing Approaches

The proposed MANET routing protocol was compared with the existing approaches including DSR [33] and ESDSR [34]. DSR was selected as a classical MANET routing protocol and ESDSR as an example energy efficient MANET routing protocol.

#### 1) Emulation Setup

The proposed protocol was evaluated using the ns-2 [41] network simulator, best suited for the MANET character of our scenario. The protocol was implemented in C++ as a wireless routing agent [42]. In order to allow processing of the packets overheard by nodes the tap function was enabled.

As shown in Figure 12, Bovine Movement Emulator (BME) described earlier was utilized to generate mobility traces for ns-2. Ns-2 generated wireless traces, which were then processed using Python scripts to measure the observed parameters. Then in the case of one of the emulated scenarios, which were emulated in several iterations to average the results, statistics from all the iterations were aggregated.

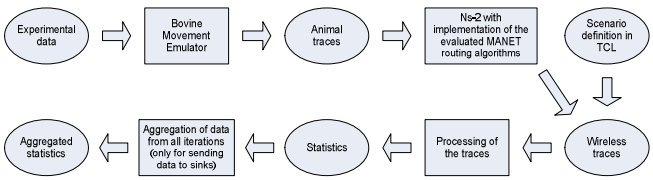


Figure 12. Emulation environment

We emulated two scenarios, which reflect realistic communication patterns within the proposed cattle monitoring system and are sufficiently challenging for the simulated routing protocols to demonstrate differences in

their performance: (1) animal mounted nodes sending data to a sink, (2) one stationary user querying animal mounted nodes. In both cases data traffic starts after 1 hour to let the emulated animals leave their initial positions. At the beginning of simulation the animal mounted nodes already know their average speed in relation to the maximal and minimal average speed of the other nodes.

In the first scenario animal mounted devices try to send once 32B of data to the stationary sink, which models the regular daily update sent to the farm servers (see Section III). 32B reflects the amount of data from animal mounted pedometer, accelerometer and results of processing made by animal mounted nodes such as detected animal diseases, date of last oestrus etc. They start after 1 hour, randomly distributed over 5s to take advantage of passive acquisition of routes. They perform the route discovery if they do not already have a route to the sink in their cache (from overheard or forwarded packets). The whole emulation lasts for 3 emulated hours. In this scenario for each set of parameters we repeat the emulation 5 times with different random values for BME and ns-2 and then average the results. In the second case the user broadcasts 20 queries. Each node replies to the query with probability 0.25 with 32B of data. This emulates range queries. Each subsequent query is submitted 10s after receiving the last answer to the previous query.

To evaluate the scalability of the evaluated routing protocols the number of animals was altered. The observed parameters include: minimal, average and maximal energy usage per node over the course of the emulation and its standard deviation (we consider only the animal mounted nodes); number of nodes with exhausted battery capacity at the end of emulation; minimal, maximal and average delays and their standard deviation; success ratio.

Delays mean here in the case of sending data to sinks the time from the moment when data is sent until successful receiving of the acknowledgement by an animal mounted node. In the case of in-situ queries delays mean time from sending the query to receiving the answer. Success ratio means in the case of sending data to a sink the fraction of nodes that successfully delivered data to sinks. In the case of in-situ queries we measured two different success ratios. Success ratio for queries is calculated using the following formula:

$$SR = \frac{N_{RQ}}{N_Q \cdot N_A} \tag{3}$$

where $N_{RQ}$ is the number of receptions of a query by an animal mounted node, $N_Q$ is a number of issued queries and $N_A$ is a number of animal mounted nodes. If the animal mounted node receives the same query more than once only the first case is considered. Success ratio of responses is the fraction of responses that were successfully returned to the user. The standard deviation was calculated using the following formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \tag{4}$$

where $N$ is the number of samples, $x_i$ is the sample value and $\bar{x}$ is the value of the arithmetic average.

The maximal power of the transmitter is 0.85872mW (i.e., power consumed by the transmitter and power of the transmitted signal), which gives the maximum transmission range of 40m. According to [43] this gives parameters closer to those found in sensor radios. Since the receiving power is constant and a fixed amount of energy is dissipated when a node receives a packet, receiving power is ignored (modeled as zero). The authors of ESDSR made a similar assumption [34]. At the beginning of emulation the sink and the user have 1000J each (effectively infinite energy) and animal mounted nodes have 1J each. $P_{margin}$ in Formula 1 is 1. We use the following EERD parameters: $\alpha$=1, $\beta$=1, $\delta$=10000s, $\varepsilon$=0.5s (see Formula 2), reverting to the initial state and discarding received states of neighbors after 60s. The route validity period is 60s and waiting for route replies lasts 1s. We used Two Ray Ground propagation model, IEEE 802.11 MAC layer and standard ns-2's implementation of priority queue and omni-directional antenna.

*2) Emulation Results*

Emulation results are shown in Figure 13 and 14. Points and lines show average values per node or standard deviation. Error bars show minimal and maximal values. In each examined case no node exhausted its battery capacity.

Figure 13a shows energy utilized by animal mounted nodes for sending data to the sink. EERD considerably decreases average energy usage in comparison to DSR and ESDSR (48%-75%). The proposed protocol considerably balances energy utilization compared to DSR and ESDSR. Figure 13b shows that EERD has standard deviation of energy utilization by 76%-91% smaller than DSR and ESDSR. These improvements can be attributed to PCDI with proposed optimizations and proposed metrics for selecting routes.

Figure 13c shows delays for sending data to the sink. We can see that in the case of DSR and ESDSR the delays grow with the number of nodes, whereas in the case of EERD the delays are almost constant. Figure 13d shows the average deviation of delays. In the case of DSR and ESDSR it grows much faster with the increasing number of nodes than in the case of EERD. This means better scalability of the EERD in comparison to DSR and ESDSR, which can be attributed to reduced network overhead achieved by utilization of PCDI.

Figure 13e shows the success ratio (SR) for delivering data to sinks. We can see that in all examined cases the SR is very high. Nodes do not repeat failed attempts otherwise the SR would be even higher. In the case of DSR and ESDSR SR drops slightly for the higher numbers of nodes (to 0.94 and 0.95 respectively for 100 nodes). It is not the case with EERD. This can be attributed to avoiding congestion achieved by utilization of PCDI.

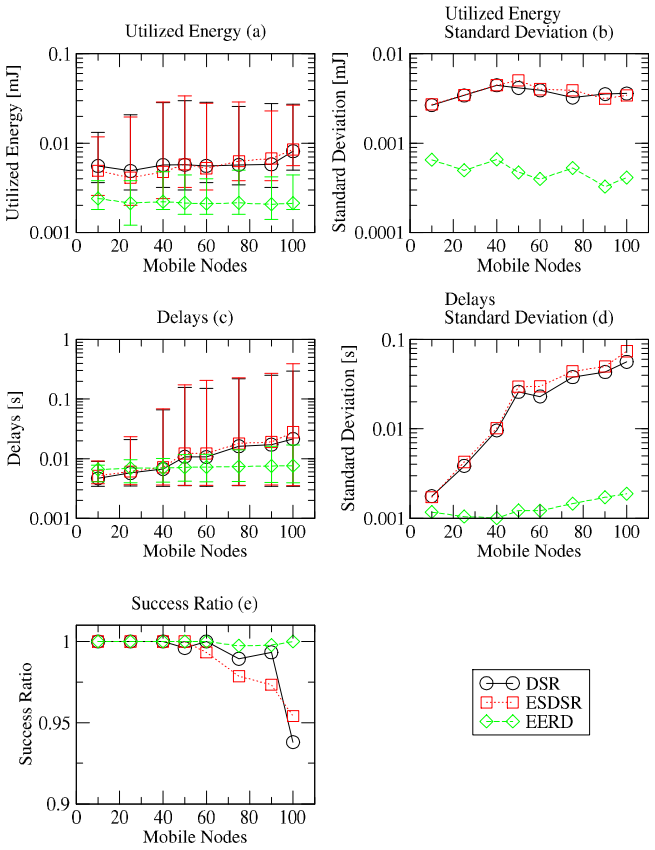


Figure 13. Comparison with existing approaches – statistics for sending data to sinks

Figure 14a shows the energy utilized by animal mounted nodes for answering in-situ queries. The amount of utilized energy is comparable to the case of communication with the sink, which justifies optimization of this type of communication. The amount of utilized energy is almost constant for each of the protocols regardless of the number of nodes. The considerable decrease of average energy utilized by the proposed protocol in relation to the existing routing protocols (by 77-82%) is achieved by optimization of broadcasting queries. Figure 14b shows that the standard deviation of utilized energy is much higher for EERD than for other compared protocols for the very sparse topology (10 nodes). Then the EERD's standard deviation drops sharply for 25 nodes and stays almost constant. In contrast the standard deviation of DSR and ESDSR grows with the number of nodes. This demonstrates better scalability of EERD in terms of energy usage achieved by optimized broadcasting.

Figure 14c shows delays in answering in-situ queries. The delays grow linearly with the number of animals. In the case of the proposed routing protocol this increase is lower, which means better scalability. This can be attributed to the decreased network congestion caused by the proposed optimization of broadcasting. For 100 mobile nodes EERD achieves up to 57% of decrease in average delays and up to 29% in maximal delays. The decrease of delays in answering in-situ queries is very important as this improves usability of the system. Figure 14d shows the average deviation of delays. It grows linearly with the number of nodes but this growth is much higher in the case of DSR and ESDSR than in the case of EERD. This gain is achieved by utilization of Passive Clustering and is very important for scalability.

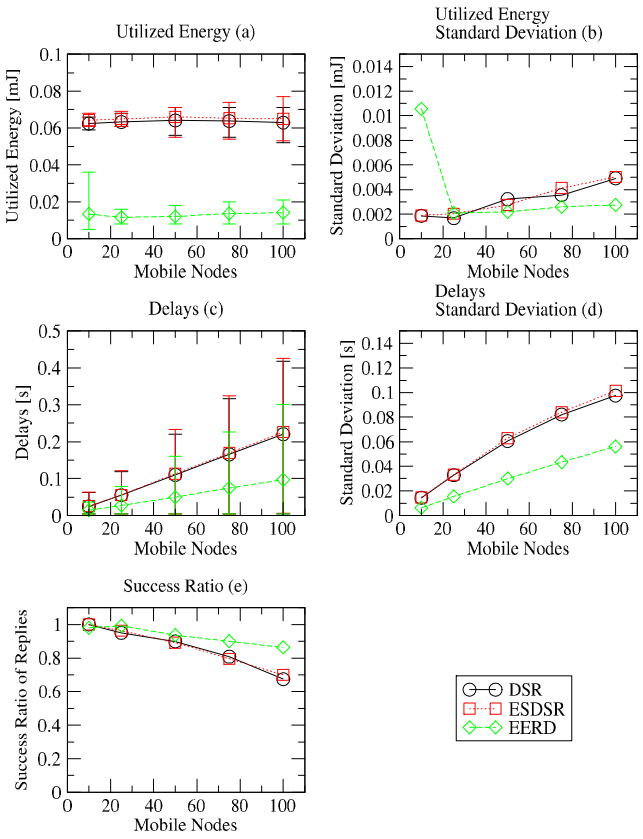


Figure 14. Comparison with existing approaches – statistics for in-situ queries

For all examined number of nodes and routing protocols the in-situ queries were delivered to all mobile nodes. The success ratio of delivering answers to the user's device is shown in Figure 14e. We can see that this success ratio decreases almost linearly with the increasing number of animals, which can be attributed to the network congestion. The proposed protocol offers however a higher success ratio for higher numbers of animal mounted nodes. This is due to the decrease in network traffic achieved by utilization of Passive Clustering. For 100 nodes the proposed protocol has success ratio higher than DSR by 22% and higher than ESDSR by 19%.

To summarize, the proposed MANET routing protocol has lower and more balanced utilization of energy than the other compared routing protocols. In the case of in-situ queries it also offers better scalability in terms of delays and success ratio.

### C. *Evaluation of the Specific Techniques Utilized in EERD*

In order to better understand the influence of the specific techniques utilized in the proposed MANET routing protocol

on its performance, the protocol was emulated with certain its features disabled.

*1) Emulation Setup*

The simulation setup was similar to the one described in Section VI.B.1. Instead of comparing the proposed protocol with the existing approaches, the performance of the fully functional protocol was compared with the performance of the same protocol with certain its features disabled, including:

- Power control – all packets are sent with the maximal power
- PCDI [35] – the flooding similar as in DSR [33] is utilized instead
- Utilization of heterogeneity of the nodes' mobility – the original PCDI formula [35] for calculating delays is utilized instead of the one we propose (Formula 2)

*2) Emulation Results*

Emulation results are shown Figure 15 and Figure 16. Points and lines show average values per node or standard deviation. Error bars show minimal and maximal values. In each examined case no node exhausted its battery capacity.

Figure 15a shows energy utilized by animal mounted nodes for sending data to the sink. We can see that without PCDI the utilized energy grows with the number of nodes. Utilization of PCDI makes the energy consumption almost independent of the number of nodes. This can be attributed to the energy saved on route discovery broadcasting. Utilization of transmitter power control gives the constant advantage in average utilized energy of 22% to 31%. Heterogeneity management extension to PCDI does not make any considerable difference here. Figure 15b show standard deviation of the average utilized energy. Utilization of PCDI and transmitter power control increases standard deviation. This is the cost of achieving lower average energy usage.

Figure 15c shows delays for sending data to sinks. Without utilization of PCDI delays grow slightly with the number of nodes otherwise their average is almost constant. Figure 15d shows standard deviation of delays. We can see that utilization of PCDI make it grow slower with the number of nodes.

Figure 15e shows the Success Ratio (SR) for delivering data to sinks. The SR is very high. The nodes do not repeat failed attempts otherwise the SR would be even higher. We can see that utilization of PCDI slightly improves SR.

Figure 16a shows the energy utilized by animal mounted nodes for in-situ queries. For all the examined cases the amount of utilized energy hardly depends on the number of mobile nodes. We can see that the most important decrease of energy utilization results from using PCDI and transmitter power control. PCDI decreases average energy utilization by 57-64% and transmitter power control by 33-40%. Figure 16b shows the standard deviation of the energy utilised for answering in-situ queries. We can see that PCDI highly increases this deviation for small topologies (10 nodes) but decreases it for topologies of medium size (25-75 nodes). The reason of high influence of PCDI on limiting utilized energy is decreasing network overhead caused by broadcasting of queries.

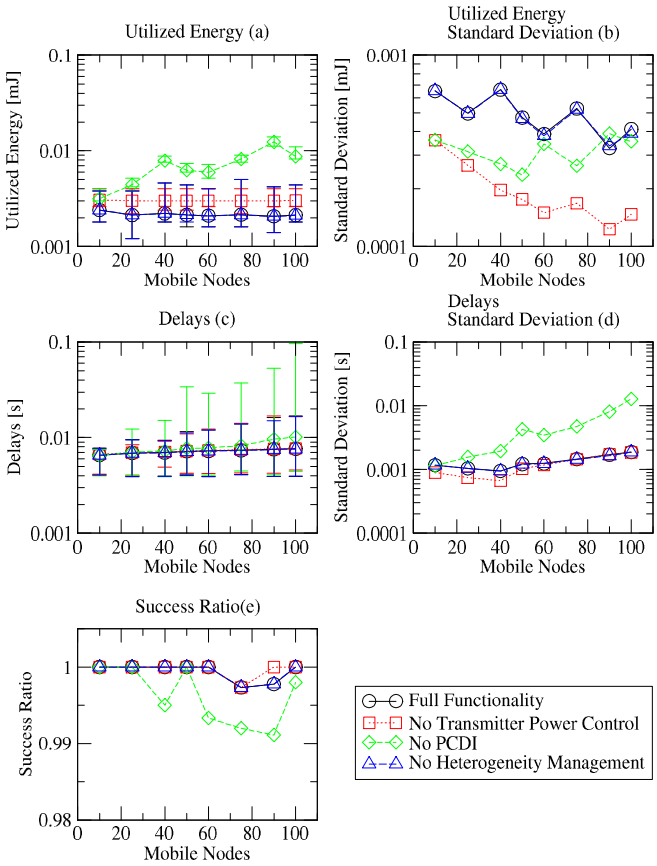


Figure 15. Evaluation of the utilized techniques – statistics for sending data to sinks

Figure 16c shows the delays of answering in-situ queries. We can see that they grow linearly with the increasing number of nodes but utilization of PCDI makes this growth smaller. Figure 16d shows that PCDI also decreases the standard deviation of the delays. These gains can be attributed to the decreased network congestion resulting from optimization of broadcasting.

For all examined cases the in-situ queries were delivered to all mobile nodes. The success ratio of delivering answers to the user's device is shown in Figure 16e. We can see that this success ratio decreases with the increasing number of animals, which can be attributed to the network congestion. Utilization of PCDI decreases the network congestion and thus improves the success ratio.

To summarize, the proposed MANET routing protocol EERD provides lower and more balanced energy usage than the classic, non-energy aware DSR and the more generic existing energy aware routing protocol ESDSR. In the case of in-situ queries EERD makes success ratio and delays deteriorate slower with the increasing number of nodes thus improving the scalability in comparison to DSR and ESDSR.

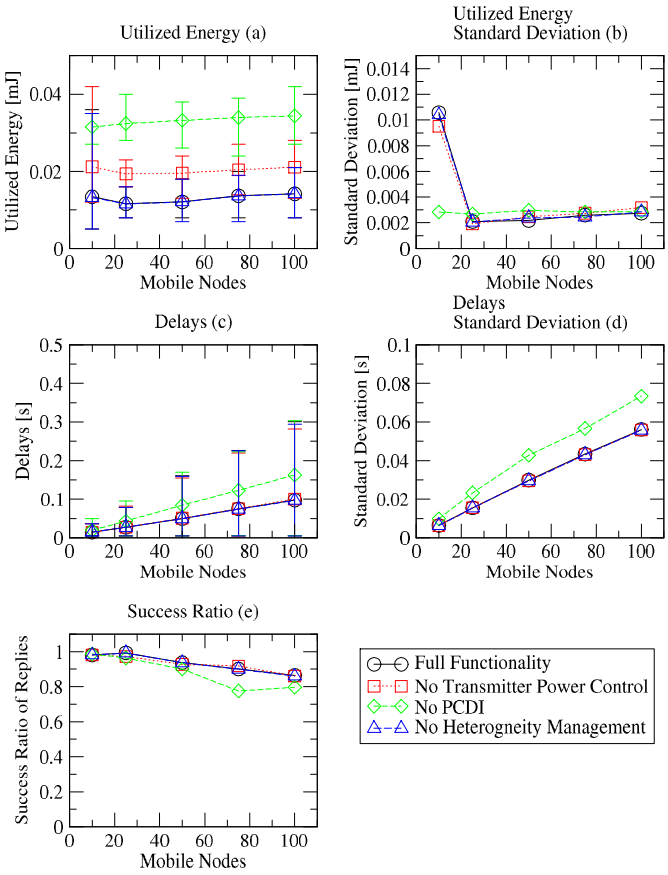


Figure 16. Evaluation of the utilized techniques – statistics for in-situ queries

The most important impact on saving and balancing energy has utilization of PCDI to optimize broadcasting of route discovery packets and in-situ queries. In the case of in-situ queries PCDI provides shorter and more stable delays as well as higher success ratio.

## VII. SECURITY

This section discusses possible security threats to the target cattle monitoring system including unauthorized retrieval, modification and generation of data as well as denial of service attacks (DoS). We propose ways how the security of the system can be improved and describe how the improved security affects the energy efficiency of animal mounted devices.

Due to the nature of cattle monitoring these solutions employ wireless sensor and mobile ad-hoc networks. They are therefore open to the all types of attacks typical for wireless networks and mobile ad-hoc networks as shown in Table 1.

Farmers who are owners of the system are likely to modify or fabricate data to put their products ahead of competition. They are also likely to suppress the data collection and event detection process, i.e., perform denial of service (DOS) attacks, in order to hide information such as spread of animal diseases.

They are most likely to target data collection process as they have unrestricted and unmonitored access to their animals and sensing equipment. Methods can involve taking animals out of range, temporary or permanently, so that their sensors can not send data to farm servers, refraining from changing batteries or changing data directly on farm servers. They can also perform DOS attacks that would globally disable the functionality of the system during the spread of animal disease. This involves physical layer attacks such as radio jamming.

Protecting the system against its potential owners may be risky because they may assume that introducing the system is against their business and thus they can be reluctant to that. Therefore, we do not consider this in a greater detail within this paper. The possible approach for creating incentives of such security against the owners' tampering would be granting quality certificates to the farmers who decide to adopt it. Potentially a greater awareness of security issues from farmers, retailers and consumers would be required for this model to be realistic.

Farm workers may want to tamper with the collected data to hide from management their misconduct - e.g., leaving animals on a pasture for too long or not providing them with water. This tampering will involve changing the collected data already stored on the farm servers. This form of attack can be avoided by appropriate securing the access to the databases storing this data, which is outside the scope of this paper.

Competitors are likely to disrupt functioning of the target farming enterprise or put it into a less favorable position. They are likely to modify or fabricate the data as well as perform various DOS attacks. They will perform attacks on physical layer (e.g., radio jamming) or network layer. The latter involves deploying hostile nodes or modifying existing nodes in order to make them send incorrect route request or route reply messages in order to disrupt data delivery to sinks, answering in-situ queries or cause faster battery depletion. The hostile nodes can also send fabricated data or modify forwarded data to disrupt working of the farm. The precautions against these attacks are easier to introduce because owners of the system have strong incentives to support it. These attacks can be prevented by utilization of cryptographic primitives to encrypt and authenticate the exchanged data [44], which can increase energy consumption due to higher computational complexity and increased data traffic. Using cryptography in many cases requires public key infrastructure (PKI), which bares the infrastructureless mode that is otherwise feasible to our system. In the infrastructureless mode the sinks and farm servers are not deployed and users can only access the measurements via in-situ queries.

The deployment of hostile nodes can be detected using intrusion detection methods [45, 46]. Such nodes can be excluded from the system and reported to the personnel. Intrusion detection potentially requires no configuration during the deployment or maintenance, so its utilization would not increase management costs. There are well researched methods of detecting routing attacks within MANETs [46]. They usually rely on continuous analyzing of

network traffic by mobile nodes and looking for known types of attacks. It is considerably more challenging to use intrusion detection methods against application layer attacks such as intercepting or fabricating data. Detecting such attacks would require detecting changes in the typical communication patterns, which can be caused by legitimate events that the monitoring system is meant to detect such as an occurrence of an animal disease.

Excluding hostile nodes from the system can be done in completely decentralized manner as proposed in [45]. In particular a node can only communicate with others if it possesses a token granted and periodically renewed by its neighbors. The disadvantage of this approach is that its performance may be affected by disconnections.

Another stakeholder, who may want to attack the cattle monitoring system are buyers of the animal products (e.g., supermarkets), who may want to lower the price of the products they buy or gather intelligence about the sellers to better evaluate their offer. Similarly as competitors they can perform DOS attacks, as well as modification or fabrication of data. They can also get unauthorized access to data by deploying passive nodes that would perform overhearing or active nodes that would forward the data and collect it. Passive overhearing can be only addressed by encryption of the exchanged data. Deployment of active spying nodes can be prevented by encrypting data or cooperative appraisal [45].

To summarize, there are numerous security threats against the proposed cattle monitoring system. Main feasible precautions include encryption, cryptographic authentication and intrusion detection – all of them are expensive in terms of processing and network traffic. Moreover, cryptographic methods typically require infrastructure, which increases management costs.

## VIII. Conclusions and Future Work

In this paper we proposed the novel practical MANET approach for scalable cattle monitoring system. Ease of use, cheap deployment and maintenance allow its pervasiveness. More precisely, it utilizes the available infrastructure but also works in the fully ad hoc infrastructureless conditions by supporting in-situ queries. The labor intensity of its maintenance is reduced by minimizing and balancing energy consumption in the face of low data traffic and high mobility of the nodes. The proposed routing protocol satisfies the requirements we define basing on literature and our field experiments. In particular we proposed a novel approach of minimizing and balancing energy spent on route discovery at the cost of energy efficiency of data traffic. We significantly optimize energy efficiency of control traffic by identification and utilization of animal movement patterns as well as graceful degradation of data traffic energy efficiency. We also deal with the disconnections in the energy efficient manner.

We evaluate the proposed protocol over an extensive emulation utilizing movement patterns collected during our field experiments. We demonstrate that this protocol offers lower and more balanced energy consumption than the other evaluated protocols. We show that our approach is suitable for high and low densities of topologies. Our field experiments, which produced data for the emulation of the proposed protocol, were performed in a dairy. The proposed protocol however is intended also for monitoring animals kept continuously in the pastures.

Although in this paper we concentrate on the cattle monitoring, the approach presented here can be also utilized for designing other application specific monitoring systems and MANET/DTN protocols. The proposed protocol with some customizations can be used for other applications with high mobility, limited speed of wireless nodes, low data traffic and disconnections including monitoring welfare and behavior of other animals as well as health of people [47, 48].

The results from the experiments presented in this paper are encouraging, validating the efficiency of the proposed routing protocol in terms of energy utilization, delays and success ratio. However there are still issues that have not been fully addressed. They are identified below.

The movement patterns used for simulation were based on real data and observations and thus are close to reality. We tested the correctness of the protocol implementation by analyzing the simulation traces. The potential weak point of our simulation is the validity of the utilized radio propagation model (i.e., two-ray ground reflection model from ns-2 [49]) for the dairy environment. In particular all simulation models make simplifying assumptions about radio propagation, which do not have to apply for all types of environment [50]. The typical method of validating these assumptions and simulation models in general for the given type of environment is comparing the parameters of radio propagation form the model with the measurements from the real environment [50, 51]. Such measurements have to be performed to validate our simulation.

The efficiency of the proposed MANET routing protocol can be further validated by the real world large scale deployment of the devices utilizing this protocol. This will allow considering some parameters that were not considered during emulation such as absorption of radio frequency waves by animal and human bodies [4, 5] or propagation of radio waves in relation to position of the animal and its collar. This will require design of the hardware appropriate for installing on the animals. Such hardware will have to be sufficiently robust not to be destroyed by the animals and will have to provide adequate radio connectivity.

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TABLE I. POTENTIAL ATTACKERS

| Location\Attacker | Owners | Competitors, buyers |
|---|---|---|
| Individual animal being monitored, monitoring hardware | Tampering with monitoring hardware, removing or disabling sensors to change sensed data | |
| Radio waves communication (physical layers) | Signal jamming, moving devices or animals out of network coverage. | Signal jamming, modification and fabrication of data by deploying malicious devices or modifying existing devices |
| Link Layer | | Illegitimate access and fabricating or modifying data |
| Network Layer | | Illegitimate access and fabricating or modifying data, routing attacks |

# Classification on Speech Emotion Recognition - A Comparative Study

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***Abstract*** **- In this paper we present a comparative analysis of four classifiers for speech signal emotion recognition. Recognition was performed on emotional Berlin Database. This work focuses on speaker and utterance (phrase) dependent and independent framework. One hundred thirty three (133) sound/speech features have been extracted from Pitch, Mel Frequency Cepstral Coefficients, Energy and Formants. These features have been evaluated in order to create a set of 26 features, sufficient to discriminate between seven emotions in acted speech. Multilayer Percepton, Random Forest, Probabilistic Neural Networks and Support Vector Machine were used for the Emotion Classification at seven classes namely anger, happiness, anxiety/fear, sadness, boredom, disgust and neutral. In the speaker dependent framework, Probabilistic Neural Network reaches very high accuracy(94%), while in the speaker independent framework the classification rate of the Support Vector Machine reaches 80%. The results of numerical experiments are given and discussed in the paper.**

***Keywords*** **-** ***Emotion Recognition , Artificial Neural Networks, Support Vector Machine, speech processing.***

## I. INTRODUCTION

Recently, the information provided by cameras and microphones enable the computer to interact with the user though advanced image and sound processing techniques in systems similar to the one presented in Figure 1. Therefore, one of these skills that computer potentially can develop, is the ability to understand the emotional state of the person. In the field of human-computer interaction (HCI), emotion recognition from the computer is still a challenging issue, especially when the recognition is based solely on voice, which is the basic mean of human communication. In human-computer interaction systems, emotion recognition could provide users with improved services by being adaptive to their emotions. Therefore, emotion detection from speech could have many potential applications.

Communication is an important capability, not only based on the linguistic part but also based on the emotional part. Therefore, emotion detection from speech could have many potential applications in order to make the computer more adaptive to the user's needs [1] [2].

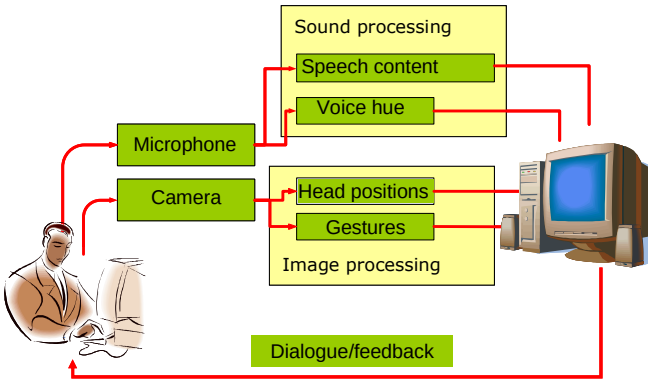


Figure 1. Human-computer interaction modules for emotion recognition.

Nowadays, with the proliferation of the Internet and multimedia, many kinds of multimedia equipment are available. Even common users can record or easily download video or audio data by himself/herself. Can we determine the contents of this multimedia data expeditiously with the computer's help? The ability to detect expressed emotions and to express facial expressions with each given utterance would help improve the naturalness of a computer-human interface. Certainly, emotion is an important factor in communication. And people express emotions not only verbally but also by non-verbal means. Non-verbal means consist of body gestures, facial expressions, modifications of prosodic parameters, and changes in the spectral energy distribution [3]. Often, people can evaluate human emotion from the speaker's voice alone since intonations of a person's speech can reveal emotions. Simultaneously, facial expressions also vary with emotions. There is a great deal of mutual information between vocal and facial expressions. Speech-driven facial animation is an effective technique for user interface and has been an active research topic over the past twenty years. Various audio-visual mapping models have been proposed for facial animation [4] [5].

In the computer speech community, much attention has been given to “what was said” and “who said it”, and the associated tasks of speech recognition and speaker identification, whereas “how it was said” has received relatively little. What kinds of features might carry more information about the emotional meaning of each utterance? Because of the diversity of languages and the different roles and significance of features in different languages, they cannot be treated equally [6]. It is hard to calculate, which features carry more information, and how to combine these features to get a better recognition rate.

Research in automatic detection of expressed emotion is quite limited. Recent research in this aspect mostly focuses on classification, in the other words, mostly aims at ascertaining the emotion of each utterance. This, however, is insufficient for our applications.

Various classification algorithms have been used in recent studies about emotions in speech recognition, such as k-Nearest Neighbor, NN (Neural Network), MLB (Maximum-Likelihood Bayes), KR (Kernel Regression), GMM (Gaussian Mixture Model), and HMM (Hidden Markov Model) [1] [2] [3] [7].

Previous research on emotions both in psychology and speech tell us that we can find information associated with emotions from a combination of prosodic, tonal and spectral information; speaking rate and stress distribution also provide some clues about emotions [2] [3] [8] [9]. Prosodic features are multi-functional. They not only express emotions but also serve a variety of other functions as well, such as word and sentence stress or syntactic segmentation. The role of prosodic information within the communication of emotions has been studied extensively in psychology and psycholinguistics. More importantly, fundamental frequency and intensity in particular vary considerably across speakers and have to be normalized properly [3].

Emotional inflection and modulation in synthesized speech, either through phrasing or acoustic features is useful in human-computer interaction. Such capability makes speech natural and expressive. For example a dialog system might modulate its speech to be more puerile if it deems the emotional model of its current user is that of a child. In e-learning applications, Emotion Recognition (ER) can be used to adjust the presentation style of a computerized tutor when a learner is bored, interested, frustrated, or pleased [10] [11].

Human beings are eminently emotional, as their social interaction is based on the ability to communicate their emotions and perceive the emotional states of others [4]. Designing an automatic system able to express emotions and to detect the emotional state of a user is one of the main aims of the research field defined as affective computing [4]. The acknowledgment of the user’s affective state can improve the effectiveness of a number of computer applications in a variety of fields.

Affective computing, a discipline that develops devices for detecting and responding to users’ emotions, and affective mediation, computer-based technology, which enables the communication between two or more people, displaying their emotional states [12] [5], are growing areas of research [13]. Affective mediation tries to minimize the filtering of affective information carried out by communication devices, due to the fact they are usually devoted to the transmission of verbal information and therefore, miss nonverbal information [1].

Applications of mediated communication can be textual telecommunication technologies such as affective electronic mail, affective chats, etc.

In the development of affective applications, affective resources, such as affective stimuli databases, provide a good opportunity for training such applications, either for affective synthesis or for affective recognizers based on classification via artificial neural networks (ANN), Hidden Markov Models, genetic algorithms, or similar techniques (e.g., [2] [8]). As seen in [14], there is a great amount of effort devoted to the development of affective databases. Affective databases usually record information by means of images, sounds, speech, psychophysiological values, etc. Psychological health services, i.e., counseling, benefit from affective computing applications when determining a client's emotional state. Affective computing sends a message via color or sound to express an emotional state to others. Robotic systems capable of processing affective information exhibit higher flexibility while one works in uncertain or complex environments. Companion devices, such as digital pets, use ER abilities to enhance realism and provide a higher degree of autonomy. Other potential applications are centered around social monitoring. For example, a car can monitor the emotion of all occupants and engage in additional safety measures, such as alerting other vehicles if it detects the driver to be angry. ER has potential applications in human computer interaction, such as affective mirrors allowing the user to see how he or she performs; emotion monitoring agents sending a warning before one sends an angry email; or even music players selecting tracks based on mood [10] [11]. ER is also being applied to the development of communicative technologies for use by people with autism. People with disabilities can benefit from speech emotion recognition programs. There is growing need for technologies to assist with the inhome care of the elderly and people with Alzheimer's, Parkinson's and other disabilities or traumas. Emotional speech processing recognizes the user's emotional state by analyzing speech patterns. Vocal parameters and prosody features such as fundamental frequency, intensity and speaking rate are strongly related with the emotion expressed in speech [13] [1]. However, voice quality and short-term spectral features have also to be considered when studying emotional or affective speech [2] [8] [14] and speech rate are analyzed through pattern recognition [7] [14].

In this work, we used PNN, MLP and SVM to classify seven emotions. There are a variety of temporal and spectral features that can be extracted from human speech. We used

statistical analysis in order to select features relating to the pitch, Mel Frequency Cepstral Coefficients (MFCCs) and Formants of speech as inputs to classification algorithms. The emotion recognition accuracy of these experiments allow us to show, which features carry the most emotional information and which classifier reaches better accuracy.

The paper is structured as follows. The following section describes a dimensional view of emotions. Section III reports analytically the sound features that have been tested and how these features were calculated. Section IV describes the selected classifiers, as well as the two separate testing frameworks (speaker dependent/ independent recognition). The paper ends with the conclusion section, which highlights also several aspects of the emotion recognition task on the basis of sound processing.

## II. BASIC EMOTIONS

According to a dimensional view of emotions, large amounts of variation in emotions can be located in a two-dimensional space, with coordinates of valence and arousal [8]. The valence dimension refers to the hedonic quality of an affective experience and ranges from unpleasant to pleasant. The arousal dimension refers to the perception of arousal associated with the experience, and ranges from very calm to very excited at the other etc. In this paper, the Berlin Emotional database (EMO-DB) [7] was used to conduct our experiments, which contains 535 utterances of 10 actors (5 male, 5 female) simulating 7 emotional states. The above set of seven emotion classes can also be well separated into two hyper classes, namely high arousal containing anger, happiness, anxiety/fear and low arousal containing neutral, boredom, disgust and sadness. The classification of disgust into low arousal can be challenged, but according to the literature disgust belongs to low arousal emotions [14]. In the experiments reported in this paper, always whole utterances have been analysed.

## III. SOUND/SPEECH FEATURES

The fundamental frequency (F0), often referred to as the pitch, is one of the most important features for determining emotion in speech [3] [6] [9] [15]. Pitch represents the perceived fundamental frequency of a sound. It is one of the four major auditory attributes of sounds along with loudness, timbre and sound source location. When the actual fundamental frequency can be precisely determined through physical measurement, it may differ from the perceived pitch because of overtones, also known as upper partials, harmonic or otherwise. The human auditory perception system may also have trouble distinguishing frequency differences between notes under certain circumstances. According to ANSI acoustical terminology, it is the auditory attribute of sound according to which sounds can be ordered on a scale from low to high [16].

Bäzinger et al. argued that statistics related to pitch convey considerable information about emotional status [17]. However, pitch was also shown to be most gender-dependent feature [18]. If the recognition system ignores this issue a misclassification of utterances might be the consequence. It should be noted that most of the features that will be described below are gender-dependent to varying degrees.

Beside pitch, other commonly employed features are related to energy, speaking rate, formants, as well as spectral features, such as MFCCs. Formants are defined by Fant as the spectral peaks of the sound spectrum |P(f)|' of the voice. Formant is also used to mean an acoustic resonance and, in speech science and phonetics, a resonance of the human vocal tract. It is often measured as an amplitude peak in the frequency spectrum of the sound, using a spectrogram or a spectrum analyzer, though in vowels spoken with a high fundamental frequency, as in a female or child voice, the frequency of the resonance may lie between the widely-spread harmonics and hence no peak is visible. MFCCs are coefficients that collectively make up a mel-frequency cepstrum(MFC). In sound processing, the (MFC) is a representation of the short-term power spectrum of a sound, based on a linear cosine transform of a log power spectrum on a nonlinear mel scale of frequency.

They are derived from a type of cepstral representation of the audio clip (a nonlinear "spectrum-of-a-spectrum"). The difference between the cepstrum and the mel-frequency cepstrum is that in the MFC, the frequency bands are equally spaced on the mel scale, which approximates the human auditory system's response more closely than the linearly-spaced frequency bands used in the normal cepstrum. This frequency warping can allow for better representation of sound, for example, in audio compression [16].

Wang & Guan [19] and [20] used prosodic, MFCCs and formant frequency features to represent the characteristics of the emotional speech while the facial expressions were represented by Gabor wavelet features. According to Kostoulas et al. [21], an individual’s emotional state is strongly related to pitch and energy while pitch and energy of a speech signal expressing happiness or anger is, usually, higher than those associated with sadness. MFCCs have been widely used for speech spectral representation in numerous applications, including speech, speaker, gender and emotion recognition [9]. They are also increasingly finding uses in music information retrieval applications such as genre classification and audio similarity measures [22].

In this paper, pitch was extracted from the speech waveform using a modified version of the algorithm for pitch tracking proposed in [23], which is offered in the VOICEBOX toolbox [24]. Using a frame length of 100ms, the pitch for each frame was calculated and placed in a vector to correspond to that frame. If the speech is unvoiced the corresponding marker in the pitch vector was set to zero.

In addition., for each 5ms frame of speech, the first four standard MFCC parameters were calculated by taking the absolute value of the **short-time Fourier transform(**STFT), warping it to a Mel-frequency scale, taking the **discrete**

**cosine transform** (DCT) of the log-Mel spectrum and returning the first 4 components. The Matlab Code, which performs the above calculation was provided in [25]. The **STFT**, or alternatively **short-term Fourier transform**, is a Fourier-related transform used to determine the sinusoidal frequency and phase content of local sections of a signal as it changes over time. A discrete cosine transform (DCT) expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. DCTs are important to numerous applications in science and engineering, from lossy compression of audio and images (where small high-frequency components can be discarded), to spectral methods for the numerical solution of partial differential equations. The use of cosine rather than sine functions is critical in these applications: for compression, it turns out that cosine functions are much more efficient (as explained below, fewer are needed to approximate a typical signal), whereas for differential equations the cosines express a particular choice of boundary conditions.

In particular, a DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), where in some variants the input and/or output data are shifted by half a sample. There are eight standard DCT variants, of which four are common [16].

Energy, often referred to as the volume or intensity of the speech, is also known to contain valuable information. Energy provides information that can be used to differentiate sets of emotions, but this measurement alone is not sufficient to differentiate basic emotions. In [26] it is referred that fear, joy, and anger have increased energy level, whereas sadness has low energy level.

The choice of the window in short-time speech processing determines the nature of the measurement representation. The energy frame size should be long enough to smooth the contour appropriately but short enough to retain the fast energy changes, which are common in speech signals and it is suggested that a frame size of 10–20 ms would be adequate. Two representative windows are widely used, Rectangular and Hamming. The latter has almost twice the bandwidth of the former, for the same length. Furthermore, the attenuation for the Hamming window outside the pass band is much greater. Short-Time energy is a simple short-time speech measurement. It is defined by (1):

$$E_n = \sum [x(m) \cdot w(n-m)]^2 \qquad (1)$$

where m is the overlapping length of the original signal x and Hamming windowed signal w with length n. For the length of the window a practical choice is 160-320 samples (sample for each 10-20 msec) for sampling frequency 16kHz. For our experiments the Hamming window was used, taking samples every 20msecs.

The resonant frequencies produced in the vocal tract are referred to as formant frequencies or formants [27]. Although some studies in automatic recognition have looked at the first two formant frequencies (F1 and F2) [6] [26] [28], the formants have not been extensively researched. For this reason, in our experiments, the first five formant frequencies are extracted using Praat, which offers a formant tracking algorithm [29].

## A. *Feature selection*

Based on the acoustic features described above and the literature relating to automatic emotion detection from speech, 133 prosodic features are calculated based, which are represented as contours: the pitch, the 12 MFCCs, the energy, and the first 5 formant frequencies. From these 19 contours, seven statistics have been extracted: the mean, the standard deviation, the minimum value, the maximum value, the range (max-min) of the original contour and the mean and standard deviation of the contour gradient. All the 133 measurements are shown in Table I (e.g., the mean of derivative for MFCC6 is the feature with ID 45).

TABLE I. THE OVERALL 133 SPEECH FEATURES. SHADED CELLS INDICATE THE SELECTED FEATURES

| *Prosodic Feature* | *Mean* | *Std* | *Mean of derivative* | *Std of derivative* | *Max* | *Min* | *Range* |
|---|---|---|---|---|---|---|---|
| Pitch | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| MFCC1 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| MFCC2 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| MFCC3 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| MFCC4 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
| MFCC5 | 36 | 37 | 38 | 39 | 40 | 41 | 42 |
| MFCC6 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| MFCC7 | 50 | 51 | 52 | 53 | 54 | 55 | 56 |
| MFCC8 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |
| MFCC9 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| MFCC10 | 71 | 72 | 73 | 74 | 75 | 76 | 77 |
| MFCC11 | 78 | 79 | 80 | 81 | 82 | 83 | 84 |
| MFCC12 | 85 | 86 | 87 | 88 | 89 | 90 | 91 |
| Energy | 92 | 93 | 94 | 95 | 96 | 97 | 98 |
| F1 | 99 | 100 | 101 | 102 | 103 | 104 | 105 |
| F2 | 106 | 107 | 108 | 109 | 110 | 111 | 112 |
| F3 | 113 | 114 | 115 | 116 | 117 | 118 | 119 |
| F4 | 120 | 121 | 122 | 123 | 124 | 125 | 126 |
| F5 | 127 | 128 | 129 | 130 | 131 | 132 | 133 |

## B. *Sound feature selection*

In order to select the most important prosodic features and optimise the classification time, the Bivariate Correlation procedure and especially the Spearman's rho correlation

coefficient was used. The Bivariate Correlations procedure computes Pearson's correlation coefficient, Spearman's rho, and Kendall's tau-b with their significance levels. Spearman's rho correlation coefficient is a measure of not linear association. Two symmetric quantitative variables or variables with ordered categories can be perfectly related by Spearman's rho correlation coefficient. If the data are not normally distributed or have ordered categories, the Kendall's tau-b or Spearman are chosen, which measure the association between rank orders. Correlation coefficients range in value from –1 (a perfect negative relationship) and +1 (a perfect positive relationship). A value of 0 indicates no linear relationship [4] [12].

For the method selection, the SPSS statistics software tool was used [30]. Among its features, the user may find modules for statistical data analysis, including descriptive statistics such as plots, frequencies, charts, and lists, as well as sophisticated inferential and multivariate statistical procedures like analysis of variance (ANOVA), factor analysis, cluster analysis, and categorical data analysis. Several correlation coefficients have been tested as shown in Table II in order to assess the feature selection combination that gives the optimum performance for our problem. The shaded cells in Table II shows the feature evaluator and search correlation coefficients that presented the best performance in the data set.

TABLE II. FEATURE EVALUATORS AND SEARCH METHODS THAT WERE CONSIDERED. SHADED CELLS INDICATE THE SELECTED COMBINATION

| ***Feature evaluator (offered in SPSS)*** | ***Feature search correlation coefficient (offered in SPSS)*** |
|---|---|
| Bivariate Correlation | Pearson's |
| | Spearman's rho |
| | Kendall's tau-b |

### *C. Spearman Correlation Coefficient*

For each of the variables X and Y (Bivariate Correlation) separately, the observations are sorted into ascending order and replaced by their ranks. In situations where t observations are tied, the average rank is assigned. Each time t >1, the quantity t3-t is calculated and summed separately for each variable. These sums will be designated STx and STy. For each of the N observations, the difference between the rank of X and rank of Y is computed as seen in (2).

$$d_i = R(X_i) - R(Y_i) \quad (2)$$

Spearman's rho (p) [31] is calculated by (3), (4) and (5)

$$p_s = \frac{T_x + T_y - \sum_{i=1}^{N} d_i^2}{2\sqrt{T_x T_y}} \quad (3)$$

Where: $T_x = \frac{N^3 - N - ST_x}{12}$ (4)

and $T_y = \frac{N^3 - N - ST_y}{12}$ (5)

If Tx or Ty equals to 0, the statistic is not computed. The significance level is calculated assuming that, under the null hypothesis seen in (6), t is distributed as a t with N - 2 degrees of freedom. A one - or two-tailed significance level is printed depending on the user-selected option.

$$t = p_s \sqrt{\frac{N-2}{1-r_s^2}} \quad (6)$$

Two symmetric quantitative variables or variables with ordered categories can be perfectly related by Spearman's rho correlation coefficient. By this way we found the features that are highly correlated with the class variable (Emotion category). Spearman Correlation Coefficient (SCC) was selected as feature selection method, since it was proved after several tests, that it provides the most efficient sound measurements for the training of the Neural Network.

The combination of the above mentioned methods proposed 35 from the total of 133 features that were originally extracted. The shaded cells in Table I indicate the selected features. It can be seen, that 1 feature has been selected from pitch, namely the mean pitch. In addition, 29 features related to Mel Frequency Cepstral Coefficients were found important, while for the third prosodic group (energy) 5 features have been selected. Finally, none of the formant features have been found significantly important.

## IV. CLASSIFICATION

In this research, the first classifier was an ANN, which was implemented following the multi-layer perceptron architecture, using WEKA software [24]. An artificial neural network (ANN), usually called "neural network" (NN), is a mathematical model or computational model that tries to simulate the structure and/or functional aspects of biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data [32]. After experimentation with various network topologies highest accuracy was found with 80 neurons in the hidden layer. The early stopping criterion was used based on a validation set consisting of 10% of the training set in the experiments and the number of training epochs was selected to be 400. This ensures that the training process stops when the mean-squared error (MSE) begins to increase on the validation set

avoiding the over-fitting problem in this problem. The learning and momentum rate were left to the default setting of WEKA (0.3 and 0.2 respectively). Error backpropagation was used as a training algorithm. Moreover, all neurons in WEKA follow the sigmoid activation function, while all attributes have been normalized for improved performance of the network.

In this research, MLP, PNN, and SVM classifiers were also used for classification and were performed by DTREG software [10]. Neural Networks are predictive models loosely based on the action of biological neurons. A multilayer perceptron is a feedforward artificial neural network model that maps sets of input data onto a set of appropriate output. It is a modification of the standard linear perceptron in that it uses three or more layers of neurons (nodes) with nonlinear activation functions, and is more powerful than the perceptron in that it can distinguish data that is not linearly separable [33]. Although the implementation is very different, PNN are conceptually similar to K-Nearest Neighbor (k-NN) models. Probabilistic neural networks are forward feed networks built with three layers. They are derived from Bayes Decision Networks. They train quickly since the training is done in one pass of each training vector, rather than several. Probabilistic neural networks estimate the probability density function for each class based on the training samples. The probabilistic neural network uses Parzen or a similar probability density function. This is calculated for each test vector. This is what is used in the dot product against the input vector as described below. Usually a spherical Gaussian basis function is used, although many other functions work equally well [34].

In pattern recognition, the k-nearest neighbours algorithm (k-NN) is a method for classifying objects based on closest training examples in the feature space. k-NN is a type of instance-based learning, or lazy learning where the function is only approximated locally and all computation is deferred until classification. The k-nearest neighbor algorithm is amongst the simplest of all machine learning algorithms: an object is classified by a majority vote of its neighbors, with the object being assigned to the class most common amongst its k nearest neighbors (k is a positive integer, typically small). If k = 1, then the object is simply assigned to the class of its nearest neighbour [35]. The basic idea is that a predicted target value of an item is likely to be about the same as other items that have close values of the predictor variables.

Support vector machines (SVMs) are a set of related supervised learning methods used for classification and regression. In simple words, given a set of training examples, each marked as belonging to one of two categories, an SVM training algorithm builds a model that predicts whether a new example falls into one category or the other. Intuitively, an SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on. More formally, a support vector machine constructs a hyperplane or set of hyperplanes in a high or infinite dimensional space, which can be used for classification, regression or other tasks. Intuitively, a good separation is achieved by the hyperplane that has the largest distance to the nearest training datapoints of any class (so-called functional margin), since in general the larger the margin the lower the generalization error of the classifier [36].

For PNN classifier with the 10 V-Fold validation method the highest accuracy was found with the Gaussian Kernel function and Sigma values for each variable and class. For the rest of the settings we used the default settings. The highest accuracy by SVM using the 10 V-Fold validation method was found with C-SVC SVM Model using RBF Kernel function.

### *A. Speaker dependent recognition in EMO-BD*

The first experiment in our research corresponds to the problem of emotion recognition when the speakers are known to the classifier (i.e., at least on version of the each utterance/speaker is presented to the training set). Hence, this experiment corresponds to emotion recognition in a speaker dependent framework. For this case, from the 535 utterances provided in the Berlin Database we used four classifiers. First a MLP with 35-80-7 topology was trained using the 10-fold cross validation method. The training rate and the momentum were set 0.9 and 0.2 respectively, while the training stopped in 400 epochs. For the classification experiment the 10x10-fold stratified cross-validation method was employed over the data sets. Table III shows the confusion matrix for the 535 utterances of the Berlin database. Successful recognition is shown in the main diagonal. The overall success rate was 83.17%. However, considering the emotion classification in the two hyper-classes in Table IV, the correct classification reaches 95.1% for high arousal and 95.8% for low arousal emotions. Random Forest (RF) classifier was trained using the 10-fold cross validation method as well. Random forest (or random forests) is an ensemble classifier that consists of many decision trees and outputs the class that is the mode of the class's output by individual trees [37].

For the classification experiment the 10x10-fold stratified cross-validation method was employed over the data sets. Table V shows the confusion matrix for the 535 utterances of the Berlin database. Successful recognition is shown in the main diagonal. The overall success rate was 77,19%. However, considering the emotion classification in the two hyper-classes the correct classification reaches 94.3% for high arousal and 93% for low arousal emotions (as seen in Table VI).

After MLP, a PNN was trained. For the classification experiment the 10x10-fold stratified cross-validation method was employed over the data sets. Similarly as above, Table VII shows the confusion matrix for the 535 utterances of the

Berlin database. Successful recognition is shown in the main diagonal. The overall success rate was 94.1%. However, considering the emotion classification in the two hyper-classes the correct classification reaches 98.1% for high arousal and 97.7% for low arousal emotions (as seen in Table VIII).

Finally, a SVM was trained using the 10-fold cross validation method. Table IX shows the confusion matrix for the 535 utterances of the Berlin database. Successful recognition is shown in the main diagonal. The overall success rate was 84%. Again, considering the emotion classification, Table X depicts that in the two hyper-classes the correct classification reaches 97% for high arousal and 96.27% for low arousal emotions.

TABLE III. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR MLP CLASSIFIER

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | Anger | Happiness | Anxiety/fear | Boredom | Disgust | Sadness | Neutral |
| Anger | **115** (90.5%) | **6** (4.7%) | **5** (3.9%) | **0** (0.0%) | **1** (0.7%) | **0** (0.0%) | **0** (0.0%) |
| Happiness | **5** (7.0%) | **54** (76.0%) | **4** (5.6%) | **3** (4.2%) | **4** (5.6%) | **0** (0.0%) | **1** (1.4%) |
| Anxiety /fear | **8** (11.5%) | **5** (7.2%) | **52** (75.3%) | **0** (0.0%) | **2** (2.8%) | **1** (1.4%) | **1** (1.4%) |
| Boredom | **1** (1.2%) | **3** (3.7%) | **1** (1.2%) | **65** (80.2%) | **2** (2.4%) | **1** (1.2%) | **8** (9.8%) |
| Disgust | **0** (0.0%) | **3** (6.5%) | **3** (6.5%) | **5** (10.8%) | **34** (73.9%) | **1** (2.1%) | **0** (0.0%) |
| Sadness | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **5** (8.0%) | **0** (0.0%) | **53** (85.4%) | **4** (6.4%) |
| Neutral | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **5** (6.3%) | **0** (0.0%) | **2** (2.5%) | **72** (91.1%) |

TABLE IV. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR MLP CLASSIFIER

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | (95.1%) | (4.9%) |
| Low arousal emotions | (4.2%) | (95.8%) |

TABLE V. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR RANDOM FOREST CLASSIFIER

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | Anger | Happiness | Anxiety fear | Boredom | Disgust | Sadness | Neutral |
| Anger | **112** (88.2%) | **5** (3.9%) | **7** (5.5%) | **0** (0.0%) | **3** (2.4%) | **0** (0.0%) | **0** (0.0%) |
| Happiness | **9** (7.0%) | **51** (71.8%) | **4** (5.6%) | **1** (1.4%) | **6** (8.5%) | **0** (0.0%) | **0** (0.0%) |
| Anxiety /fear | **9** (13.0%) | **6** (8.7%) | **49** (71.0%) | **1** (1.4%) | **1** (1.4%) | **2** (2.8%) | **1** (1.4%) |
| Boredom | **0** (0.0%) | **2** (2.5%) | **3** (3.7%) | **55** (67.9%) | **2** (2.5%) | **4** (5.0%) | **15** (18.5%) |
| Disgust | **3** (6.5%) | **7** (15.2%) | **3** (6.5%) | **6** (13%) | **27** (58.7%) | **0** (0.0%) | **0** (0.0%) |
| Sadness | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **7** (11.3%) | **0** (0.0%) | **48** (77.4%) | **7** (11.3%) |
| Neutral | **1** (1.3%) | **0** (0.0%) | **0** (0.0%) | **9** (11.4%) | **0** (0.0%) | **2** (2.6%) | **67** (84.8%) |

TABLE VI. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR RANDOM FOREST CLASSIFIER

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | (94.3%) | (5.7%) |
| Low arousal emotions | (7%) | (93%) |

TABLE VII. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR PROBABILISTIC NEURAL NETWORK

| | **High arousal emotions** | | | **Low arousal emotions** | | | |
|---|---|---|---|---|---|---|---|
| | Anger | Happiness | anxiety / fear | Boredom | Disgust | Sadness | Neutral |
| **Anger** | 95.2% 121 | 0.8% 1 | 2.4% 3 | 0 | 0.8% 1 | 0 | 0.8% 1 |
| **Happiness** | 0 | 93% 66 | 2.8% 2 | 1.4% 1 | 2.8% 2 | 0 | 0 |
| **anxiety /fear** | 1.45% 1 | 1.45% 1 | 97.1% 67 | 0 | 0 | 0 | 0 |
| **Boredom** | 0 | 0 | 1.24% 1 | 91.35% 74 | 1.24% 1 | 0 | 6.17% 5 |
| **Disgust** | 0 | 2.18% 1 | 6.52% 3 | 0 | 91.3% 42 | 0 | 0 |
| **Sadness** | 0 | 0 | 0 | 0 | 0 | 98.4% 61 | 1.6% 1 |
| **neutral** | 0 | 0 | 1.3% 1 | 5% 4 | 0 | 1.3% 1 | 92.4% 73 |

TABLE VIII. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR PROBABILISTIC NEURAL NETWORK

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | (98.1%) | (1.9%) |
| Low arousal emotions | (2.3%) | (97.7%) |

TABLE IX. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR SVM

| | **High arousal emotions** | | | **Low arousal emotions** | | | |
|---|---|---|---|---|---|---|---|
| | Anger | Happiness | anxiety / fear | Boredom | Disgust | Sadness | Neutral |
| **Anger** | 88.9% 113 | 6.3% 8 | 4% 5 | 0 | 0.8% 1 | 0 | 0 |
| **Happiness** | 8.4% 6 | 83% 59 | 2.8% 2 | 0 | 5.8% 4 | 0 | 0 |
| **anxiety /fear** | 4.34% 3 | 5.8% 4 | 85.5% 59 | 1.45% 1 | 2,91% 2 | 0 | 0 |
| **Boredom** | 1.23% 1 | 0 | 1.23% 1 | 81.5% 66 | 4.93% 4 | 0 | 11.11% 9 |
| **Disgust** | 2.17% 1 | 8.7% 4 | 4.34% 2 | 10.8% 5 | 73.99% 34 | 0 | 0 |
| **Sadness** | 0 | 0 | 0 | 4.85% 3 | 0 | 88.7% 55 | 6.45% 4 |
| **neutral** | 1.37% 1 | 0 | 0 | 10.1% 8 | 0 | 2.53% 2 | 86% 68 |

TABLE X. CONFUSION MATRIX FOR SPEAKER-DEPENDENT EMOTION RECOGNITION FOR SVM

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | (97%) | (3%) |
| Low arousal emotions | (3.73%) | (96.27%) |

## B. *Speaker independent recognition in EMO-BD*

Speaker independent emotion recognition in Berlin database by MLP was evaluated averaging the results of five separate experiments. In each experiment, the measurements of a pair of speakers (e.g. , speaker 03 and speaker 08), were extracted from the training set and formed the testing set for the classifier. The pairs were selected in order to include one male and one female speaker at a time (Table XI-XVI).

The confusion matrix of Table XVII reveals that the MLP performance does not reach high accuracy. Overall, we are witnessing approximately 55% correct classification in the seven emotions. The 35-feature vector seems that it is not sufficient enough to distinguish the 7 emotions. However, observing the results in the two hyper-classes (low and high arousal), the recognition rate reach 89.1% for high arousal and 78.8% for low arousal emotions (see Table XVIII).

TABLE XI. TESTING AND TRAINING SETS FOR THE SPEAKER INDEPENDENT FRAMEWORK

| Experiment no. | Testing set Utterances from speakers | Training set Utterances from speakers |
|---|---|---|
| 1 | 10,11,12,15 (male), 09,13,14,16 (female) | 03 (male), 08 (female) |
| 2 | 03,11,12,15 (male), 08,13,14,16 (female) | 10 (male), 09 (female) |
| 3 | 03,10,12,15 (male), 08,09,14,16 (female) | 11 (male), 13 (female) |
| 4 | 03,10,11,15 (male), 08,09,13,16 (female) | 12 (male), 14 (female) |
| 5 | 03,10,11,12 (male), 08,09,13,14 (female) | 15 (male), 16 (female) |

TABLE XII. EXPERIMENT 1: EVALUATION IN SPEAKERS 03 AND 08.

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness | neutral |
| Anger | **5** (19.2%) | **20** (76.9%) | **1** (3.8%) | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) |
| Happiness | **0** (0.0%) | **15** (83.3%) | **0** (0.0%) | **0** (0.0%) | **3** (16.7%) | **0** (0.0%) | **0** (0.0%) |
| anxiety /fear | **0** (0.0%) | **5** (50.0%) | **1** (10.0%) | **4** (40.0%) | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) |
| Boredom | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **12** (80.0%) | **3** (20.0%) | **0** (0.0%) | **0** (0.0%) |
| Disgust | **0** (0.0%) | **1** (100.0%) | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) |
| Sadness | **0** (0.0%) | **2** (12.5%) | **0** (0.0%) | **7** (43.8%) | **2** (12.5%) | **5** (31.3%) | **0** (0.0%) |
| neutral | **0** (0.0%) | **0** (0.0%) | **0** (0.0%) | **11** (52.4%) | **0** (0.0%) | **0** (0.0%) | **10** (47.6%) |

TABLE XIII. EXPERIMENT 2: EVALUATION IN SPEAKERS 10 AND 09

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness | neutral |
| Anger | 18 (78.3%) | 1 (4.3%) | 2 (8.7%) | 0 (0.0%) | 2 (8.7%) | 0 (0.0%) | 0 (0.0%) |
| Happiness | 2 (25.0%) | 2 (25.0%) | 3 (37.5%) | 1 (12.5%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| anxiety /fear | 0 (0.0%) | 0 (0.0%) | 8 (88.9%) | 1 (11.1%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Boredom | 0 (0.0%) | 2 (16.7%) | 0 (0.0%) | 10 (83.3%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Disgust | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (77.8%) | 2 (22.2%) | 0 (0.0%) | 0 (0.0%) |
| Sadness | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (28.6%) | 0 (0.0%) | 3 (42.9%) | 2 (28.6%) |
| neutral | 1 (7.7%) | 0 (0.0%) | 0 (0.0%) | 6 (46.2%) | 0 (0.0%) | 2 (15.4%) | 4 (30.8%) |

TABLE XIV. EXPERIMENT 3: EVALUATION IN SPEAKERS 11 AND 13.

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness | neutral |
| Anger | 14 (63.6%) | 0 (0.0%) | 1 (4.5%) | 0 (0.0%) | 6 (27.3%) | 0 (0.0%) | 1 (4.5%) |
| Happiness | 6 (33.3%) | 2 (11.1%) | 2 (11.1%) | 0 (0.0%) | 6 (33.3%) | 0 (0.0%) | 2 (11.1%) |
| anxiety /fear | 13 (76.5%) | 0 (0.0%) | 1 (5.9%) | 1 (5.9%) | 1 (5.9%) | 1 (5.9%) | 0 (0.0%) |
| Boredom | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (38.9%) | 0 (0.0%) | 1 (5.6%) | 10 (55.6%) |
| Disgust | 2 (20.0%) | 0 (0.0%) | 0 (0.0%) | 1 (10.0%) | 7 (70.0%) | 0 (0.0%) | 0 (0.0%) |
| Sadness | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 9 (75.0%) | 3 (25.0%) |
| neutral | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (5.6%) | 0 (0.0%) | 1 (5.6%) | 16 (88.9%) |

TABLE XV. EXPERIMENT 4: EVALUATION IN SPEAKERS 12 AND 14

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness | neutral |
| Anger | 14 (50.0%) | 2 (7.1%) | 12 (42.9%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Happiness | 5 (50.0%) | 4 (40.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (10.0%) |
| anxiety /fear | 8 (44.4%) | 1 (5.6%) | 9 (50.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Boredom | 1 (7.7%) | 0 (0.0%) | 0 (0.0%) | 5 (38.5%) | 0 (0.0%) | 6 (46.2%) | 1 (7.7%) |
| Disgust | 3 (30.0%) | 0 (0.0%) | 0 (0.0%) | 1 (10.0%) | 4 (40.0%) | 0 (0.0%) | 2 (20.0%) |
| Sadness | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (14.3%) | 0 (0.0%) | 10 (71.4%) | 2 (14.3%) |
| neutral | 0 (0.0%) | 2 (18.2%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (54.5%) | 3 (27.3%) |

TABLE XVI. EXPERIMENT 5: EVALUATION IN SPEAKERS 15 AND 16

| | High arousal emotions | | | Low arousal emotions | | |
|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness |
| Anger | 25 (92.6%) | 0 (0.0%) | 2 (7.4%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Happiness | 9 (52.9%) | 7 (41.2%) | 1 (5.9%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| anxiety /fear | 7 (46.7%) | 0 (0.0%) | 8 (53.3%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Boredom | 0 (0.0%) | 0 (0.0%) | 12 (52.2%) | 9 (39.1%) | 0 (0.0%) | 2 (8.7%) |
| Disgust | 1 (6.3%) | 8 (50.0%) | 2 (12.5%) | 2 (12.5%) | 3 (18.8%) | 0 (0.0%) |
| Sadness | 0 (0.0%) | 0 (0.0%) | 1 (7.7%) | 0 (0.0%) | 1 (7.7%) | 10 (76.9%) |
| neutral | 0 (0.0%) | 0 (0.0%) | 3 (17.6%) | 2 (11.8%) | 0 (0.0%) | 1 (5.9%) |

TABLE XVII. MLP CLASSIFIER- OVERALL PERFORMANCE IN 7 EMOTION CLASSES AFTER THE 5 SPEAKER-INDEPENDENT EXPERIMENTS

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness | neutral |
| Anger | 83 (65.8%) | 22 (17.4%) | 18 (14.2%) | 0(0.0%) | 1 (0.7%) | 2(1.5%) | 1(0.7%) |
| Happiness | 19 (26.7%) | 27(38.0%) | 9 (12.6%) | 3 (4.2%) | 11 (15.4%) | 0(0.0%) | 2(2.8%) |
| anxiety /fear | 23 (33.3%) | 4(5.7%) | 33 (47.8%) | 0(0.0%) | 5(7.2%) | 1(1.4%) | 3(4.3%) |
| Boredom | 1(1.2%) | 1 (1.2%) | 15 (18.5%) | 48(59.2%) | 1 (1.2%) | 5(6.1%) | 10 (12.3%) |
| Disgust | 3(6.5%) | 16 (34.7%) | 4(8.6%) | 3 (6.5%) | 16 (34.7%) | 2(4.3%) | 2(4.3%) |
| Sadness | 0(0.0%) | 1(1.6%) | 1 (1.6%) | 8(12.9%) | 2 (3.2%) | 39(62.9%) | 11 (17.7%) |
| neutral | 1(1.2%) | 10 (12.5%) | 4(5.0%) | 10(12.5%) | 0 (0.0%) | 5 (6.2%) | 50 (62.5%) |

TABLE XVIII. MLP CLASSIFIER

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | **238** (89.1%) | **29** (10.8%) |
| Low arousal emotions | **57** (21.1%) | **212** (78.8%) |

The confusion matrices of Table XIX show that the RF performance reaches lower accuracy than MLP classifier (approximately 49% correct classification in the seven emotions). However, the results is higher for RF in the two hyper-classes (low and high arousal), where the recognition rate reaches 89.4% for high arousal and 82.52% for low arousal emotions (see Table XX).

TABLE XIX. RANDOM FOREST CLASSIFIER

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | Anger | Happiness | Anxiety/ fear | Boredom | Disgust | Sadness | Neutral |
| Anger | 77 (73.33%) | 12 (11.42%) | 6 (5.7%) | 1 (0.95%) | 1 (0.95%) | 5 (4.76%) | 3 (2.8%) |
| Happiness | 24(33.8%) | 23 (32.4%) | 18 (25.35%) | 0 (0%) | 6 (8.45%) | 0 (0.0%) | 0 (0.0%) |
| Anxiety /fear | 15 (21.7%) | 14 (20.2%) | 30 (43.4%) | 2 (2.9%) | 6 (8.7%) | 1 (1.4%) | 1 (1.4%) |
| Boredom | 1 (1.23%) | 2 (2.46%) | 12 (14.8%) | 33 (40.7%) | 7 (8.64%) | 9 (11.11%) | 17 (20.9%) |
| Disgust | 4 (8.5%) | 10 (21.27%) | 10 (21.27%) | 9 (19.14%) | 9(19.14%) | 3 (6.38%) | 2 (4.3%) |
| Sadness | 0 (0.0%) | 0 (0.0%) | 3(4.8%) | 11 (17.74%) | 4 (6.45%) | 32(51.61%) | 12 (19.35%) |
| Neutral | 1 (11.11%) | 2 (2.5%) | 2 (2.5%) | 33 (41.78%) | 4 (5%) | 8 (10.13%) | 29 (36.7%) |

TABLE XX. RANDOM FOREST

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | **219** (89.4%) | **26** (10.6%) |
| Low arousal emotions | **47** (17.48%) | **222** (82.52%) |

TABLE XXI. SUPPORT VECTOR MACHINE - OVERALL PERFORMANCE

| | High arousal emotions | | | Low arousal emotions | | | |
|---|---|---|---|---|---|---|---|
| | anger | happiness | anxiety/ fear | boredom | disgust | sadness | neutral |
| Anger | 84.38% | 6.25% | **9.37%** | 0.0% | 0.0 % | 0.0% | 0.0 % |
| Happiness | **5.55 %** | **88.9%** | **5.55%** | 0.0% | 0.0 % | 0.0% | 0.0 % |
| anxiety /fear | **5.6 %** | 0.0% | **94.4%** | 0.0% | 0.0 % | 0.0% | 0.0 % |
| Boredom | **5%** | **5%** | **10%** | **55%** | **15 %** | 0.0% | **10 %** |
| Disgust | 0.0 % | **27.27 %** | 0.0% | **18.18%** | **54.55%** | **0** (0.0%) | 0.0 % |
| Sadness | 0.0 % | 0.0% | 0.0% | 0.0% | 0.0 % | **80%** | **20 %** |
| neutral | **5%** | 0.0% | 0.0% | **10%** | **0** (0.0%) | **5%** | **80 %** |

TABLE XXII. SUPPORT VECTOR MACHINE

| | High arousal emotions | Low arousal emotions |
|---|---|---|
| High arousal emotions | (89.1%) | (10.9%) |
| Low arousal emotions | (21.2%) | (78.8%) |

Similarly, the confusion matrices of Table XXI and Table XXII reveals that the SVMs performance (approximately 78% correct classification in the seven emotions) reach higher accuracy than MLP (approximately 53% correct classification in the seven emotions). However, observing the results for MLP in the two hyper-classes (low and high arousal), the recognition rate reach 89.1% for high arousal and 78.8% for low arousal emotions, while the results is surprising higher for SVM in the two hyper-classes (low and high arousal), the recognition rate reaches 100% for high arousal and 87% for low arousal emotions. We did not use the PNN classifier for Independent Emotion Recognition because the DTREG Tool had problems during the classification procedures

## V. CONCLUSION AND DISCUSSION

The literature in speech emotion detection is not very rich and researchers are still debating what features influence the recognition of emotion in speech. There is also considerable uncertainty as to the best algorithm for classifying emotion, and which emotions to class together.

The researchers usually deal with elicited and acted emotions in a lab setting from few actors, just like in our case. However, in the real problem, different individuals reveal their emotions in a diverse degree and manner. There are also many differences between acted and spontaneous speech. Speaker-independent detection of negative emotional states from acted and real-world speech, was investigated in [21]. The experimentations demonstrated some important differences on recognizing acted versus non-acted speech, which cause significant drop of performance, for the real-world data.

Although it is impossible to accurately compare recognition accuracies from this study to other due to different data sets used, the feature set implemented in this work seems to be promising for further research.

Concluding this paper, the 35-input vector, seems to be quite promising for speaker independent recognition in terms of high and low arousal emotions when tested in Berlin database. Nevertheless, this vector is not sufficient enough to describe the intra class variations of the two hyper classes.

The major finding in this work is that PNN classifier achieved almost perfect classification (94%) in speaker dependent emotion recognition. This finding suggests that PNN proved to be the most adequate classifier for the dependent emotion recognition field. As well, in speaker independent emotion recognition, SVMs overall success rate was very high (78%), and the surprising finding is that SVM achieved perfect correct classification in High arousal emotions(100%), and significant success rate in Low arousal emotions(87%).

A future work should encompass an Hybrid Mixed Classification Model combining PNN, SVM and maybe

more classifiers so as to recognize emotions in non-acted speech.

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# User Experiences with Mobile Supervision of School Attendance

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***Abstract*—This article presents a field study arranged at a Finnish primary school where two classes and a total of 23 pupils between the ages of 6 and 8 trialed an attendance supervision system supported by Near Field Communication (NFC) technology. In the trial the pupils marked their arrival at and departure from school by touching a reader device or a NFC-enabled mobile phone with a contactless smart card. Parents were able to get their children's attendance details via an online 'citizen's portal' and through text-messages sent to their mobile phones. The system was designed to simplify attendance monitoring and to replace teachers' manual roll calls. Information about user experience was obtained by using a variety of data collection methods. We evaluate how various aspects identified in new technology adoption affect the design processes of home-school interaction systems by examining the findings from the viewpoint of three end-user groups (children, parents and teachers). Our analysis also shows that a technology supported attendance supervision system can bring value for all end-user groups but it seems that the system will serve primarily the teachers and the parents.**

***Keywords-Near Field Communication; attendance supervision; school; children; technology adoption; user experience; value-based design***

## I. INTRODUCTION

This paper introduces a Near Field Communication (NFC) supported school attendance supervision system for school children. Traditionally, teachers conduct pupils' attendance monitoring every morning with manual roll calls, and mark absences and delays in the backend system. This requires time and effort on every school day, which is taken away from teaching. In addition, children beginning school in Finland travel to school largely independently, either on foot, by bicycle, or by bus. Therefore, parents of young pupils regularly call to their child's or teachers' cell phones to ensure that the child has made his/her way to school safely. Answering parents' calls takes up teachers' time that could be used for teaching. The NFC-enabled school attendance supervision system has been designed to simplify attendance monitoring. The system replaces manual roll calls and gives parents information of their children's attendance in real-time.

Related work is described in the next section. Then the research setting is outlined, describing the NFC technology and the developed attendance supervision system. This is followed by the procedures used in the system design with a description of research objectives. The paper continues by introducing methodology used in user experience data collection, and represents and analyzes the field study results. The paper finishes with a discussion and conclusion.

## II. RELATED WORK

Developments in networked and mobile technologies now provide us with more methods than ever for supporting children in their transition between home and school [3]. For example, locational systems can be used to make sure that children are safe on their way to school [4]. Jernström [4] introduces a solution called The Smart-its child Surveillance System, SiSSy, that is an approach to tag children and parents with Smart-Its devices which can sense the environment and determine whether a situation is dangerous or if the child is engaged in something hazardous.

In a study by Fraser et al. [3], family members saw journeys between home and school as an important transition and a big issue for parents in managing their children's time. Information transfer between home and school was also raised as an important matter. Families' reactions to home-school technologies were enthusiastic; they saw benefits in the increased availability of information that can be gained through these technologies. While parents were worried about their children, they suggested that technologies that monitored children's activities, such as the mobile phone tracker and sensors, moved from expressing concern to expressing distrust as children aged. In consequence, Fraser et al. identified as one core issue for future research the discussion of children's privacy in technological design. Not only are there safety concerns about the protection of data collected about children, but also ethical concerns about the rights of children in gathering it. For example, how do we justify increasing links between home and school, when children are often active in resisting such information transfer [5]?

Denmark is traditionally presented as a country where children are able to freely move around and have independent mobility to schools and leisure facilities [11], and Finland can be considered similar to Denmark when it comes to children's mobility. Children beginning school in Finland travel to school largely independently, either on foot, by bicycle, or by bus. A Danish survey by Fotel and

Thomsen [11] states that parents' supervision of children's mobility is bound up with different aspects of their travel conditions, such as the choice of mode of transport. Driving a child, for instance, clearly supports the physical supervision of children's mobility, whereas bicycling or walking can be performed by the child on his/her own and thus leaves room for unmonitored movement.

While statistics show a reduction in the number of road accidents involving children during the past decades, Danish parents report an increase in their concerns about their children's road safety [12]. On top of monitoring children's mobility through escorting them by car or other traffic modes, some Danish parents also monitor their children's mobility from a distance [11]. New technology has made it possible to monitor children by e.g., their cellular phones, and some parents use that deliberately in situations where the children are testing the boundaries of where they can go independently. Monitoring children's movements from a distance seems to provide some parents with a feeling of control and thus seems to ease their risk worries, even though parents' opportunities to save the child from any danger are limited [11]. Fotel and Thomsen [11] state that even though monitoring the mobility of children is often done with a caring rationality, it can transform into a control, which in some cases, the child does not benefit from.

In a small town in the United States a public school children's whereabouts on campus were monitored by a system that used RFID (Radio Frequency Identification) technology. Children wore badges around their necks that contained a photo, grade level and name of the pupil. Within the badge was a chip with an antenna attached. As the chip passed underneath a reader mounted above the classroom door, it transmitted a 15-digit number, which was then translated into the pupil's name by software contained in a handheld device used by teachers to check attendance. Several parents complained that their children's privacy rights were being violated; while the school board defended the system by saying it would keep children in school, free up more time for teachers to teach and increase security for pupils and teachers. The proposal died after protests by parents and privacy and civil-liberties advocates, including the American Civil Liberties Union (ACLU). [6]

Also a Rhode Island school district has announced a pilot program to monitor pupil movements by means of RFID chips implanted into the schoolbags of 80 children. Each chip would be programmed with a pupil identification number, and would be read by an external device installed in two school buses. The buses would also be fitted with GPS (Global Positioning System) devices. Parents or school officials could log onto a school Web site to see whether and when specific children had entered or exited which bus, and to look up the bus's current location as provided by the GPS device. The RFID tag would contain only an ID number, not a name, address, or other personal information, so unauthorized individuals are prevented from gaining an access to pupils' private information. The ACLU has criticized the plan as an invasion of children's privacy and a potential risk to their safety. [7][8]

Qvortrup [9] and Rasmussen [10] argue that the increased protection of children by monitoring them is a central characteristic of modern childhood and we do not yet know all the consequences. According to Rasmussen [10], the possibility of impersonal supervision performed from a distance reduces children's privacy even more, and while some parents approve of it, the majority oppose its prevalence. Williams et al. [13] have presented that society could now perhaps openly question whether (urban) parents are good parents if they don't know where their children are and what they are doing at all times and don't have control over them. Aitken [14] shows how some parents employ a policy of constant supervision of children even up to early teenage years while in any outdoor space. Furedi [15] and Rayner [16] both point out the damage to children and childhood this 'paranoid parenting' might be doing and call for parents to allow children to take more risks.

## III. RESEARCH SETTING

The attendance supervision trial supported by Near Field Communication (NFC) technology began in Oulu, Finland on September 2008, continuing until December 2008. The trialing phase lasted 14 weeks. The trial was conducted at a local primary school, where two classes with a total of 23 pupils between the ages of 6 and 8 (the majority just starting at school), participated in the trial. Parents' permission for their children to participate in the trial and to the adjacent research had been asked in advance. One of the participating classes represented a first grade class (16 children out of 19 participated in the trial; 9 girls and 7 boys) and the other one was a special-needs class consisting of special-needs school children (all 7 boys, 4 first-graders and 3 second-graders, took part in the trial) who were diagnosed with minor special-needs, such as dyslexia, difficulties with concentration or troubles with perceptive skills. At the same time, a similar kind of study was done at a local secondary school with more advanced technology and more complicated application features.

Curtis et al. [28] have argued that disabled children, children excluded from school, and children for whom the discursive nature of conventional interview-based research is less accessible have been less well represented in participatory research than children who are easier to interview. For a range of methodological and practical reasons, children who communicate well, or who are regular school attendees, are more likely to be given a voice in the research literature [28]. Therefore, the class with special-needs children was chosen to participate in the trial along with the 'normal' first grade class.

### *A. NFC Technology*

Touching with a mobile terminal has been found to be an intuitive, natural and non-ambiguous interaction technique that does not incur much cognitive load for users [17]. Välkkynen et al. [18] state that touching is an effortless way to select objects in the environment and easy to learn and use. Near Field Communication (NFC) technology is designed to make communication between two devices very intuitive. NFC is a very short-range wireless technology that

allows electronic devices to interact with other devices simply by touch. The main advantages of NFC are the simple and quick way of using it and the speed of connection establishment

NFC is based on existing radio frequency communication standards, so it is a special case of implementation of RFID technology. The touch-paradigm prevents reading from a distance because a short physical proximity (a couple of centimeters) is needed to transfer information. Even though NFC technology uses a touch-paradigm, it is technologically possible to read information through NFC from a distance with special powerful reader devices. However, in this paper, we assume that NFC is used through a touch-based interaction paradigm. In our attendance supervision field study, we explore a usage scenario where NFC-enabled mobile phones and smart reader devices located in the classrooms are used to read information stored on pupils' contactless smart cards.

### B. System Description

Designed to simplify attendance monitoring and replace manual roll calls, the NFC attendance supervision system does not require teachers to mark absences in the backend system thus leaving more time for teaching. In Figure 1 an overview of the attendance supervision system at school and in extended day care programs is shown.

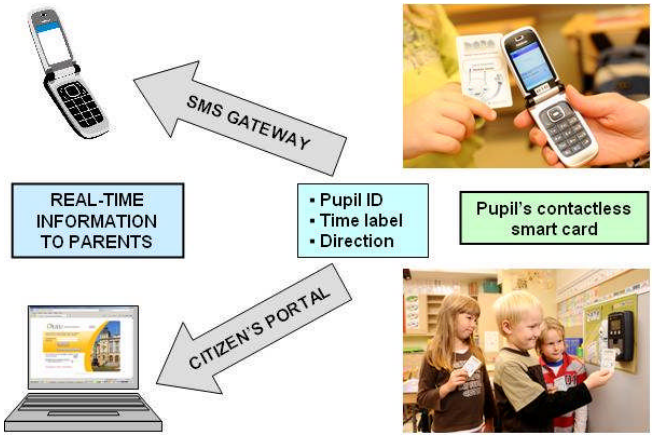


Figure 1. Overview of the NFC school attendance supervision system.

In the attendance supervision trial pupils were given contactless smart cards named "Robo" containing the pupil's ID. Upon arriving at school pupils in the first grade class 'logged in' by touching an NFC smart card to an active card reader device and pupils in the special-needs class logged in by touching an NFC-enabled mobile phone. The reader devices recorded the card ID (the child's name), the direction (arrival at school) and a time stamp in the backend system. The active reader device was chosen for the first grade class because it works faster than an NFC-enabled mobile phone for large groups. The application in both the reader device and the mobile phone recorded the time of the login; it was possible to choose the 'direction' of the pupil registration (in or out) through both devices. At the end of the school day pupils touched the reader devices again to mark their departure.

The attendance supervision system (through NFC phone) was also used in extended day care programs where some children went after school. The day care is held in another building outside the school, so with the help of the supervision system parents were also able to follow how much time it takes for their child to walk to the day care from the school (the time between logging out at school and logging in at day care) and to ensure that their child has safely made his/her way from school to day care.

Figure 2 explains the functionality of the school attendance supervision scenario.

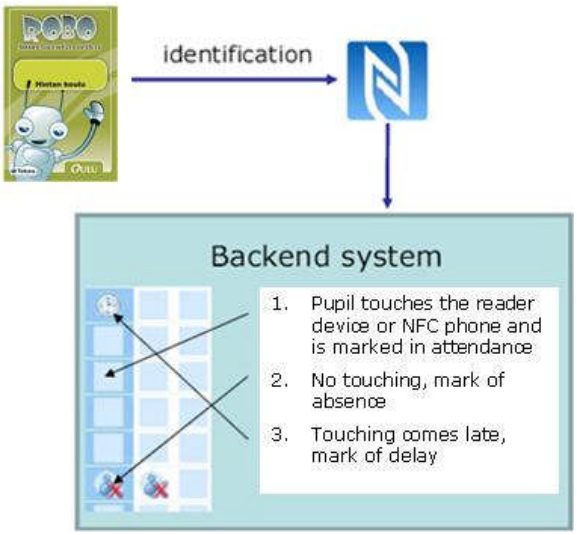


Figure 2. Functionality of the attendance supervision scenario.

The log of arrivals and departures was automatically compiled by a backend system, and could be read by a teacher in a classroom in real time. If a login did not occur, the pupil was marked absent by default. If a pupil logged in late, the backend system recorded the lateness. Parents were able to get information of their children's attendance details via an online 'citizen's portal' and through text-messages sent to their mobile phones. The system prevented truancy by informing tutors, administrators, and parents of absences in real time, enabling instant intervention.

### C. Design Procedure and Research Goals

The attendance supervision concept was planned and designed in close cooperation with teachers, service and technology providers, and researchers. During the design phase the ultimate goal of integrating the concept into normal school practices was especially emphasized, so that the trial would not be an extra effort related to the research project. The aim was to create a viable concept that could also be adopted in the school as a routine to be used after the research trial. This required close involvement of teachers and school administration in planning and implementing the applications, and in organizing and supervising the trial. It was also seen very important that children were given a possibility to participate in the system design to empower

them and get them committed to the use of the system. For example, children participated in the visual design of the system. Information security and privacy issues were also considered in the system design, and precautions were taken to minimize the associated risks. The contactless smart cards only contained a pupil's ID number, not any personal information other that the printed name on the card surface. In addition, in order to handle the pupils' attendance data as confidentially as possible, access to this data online was put under password protection and text-messages about the pupils' attendance details were sent only to parents' authenticated mobile phone numbers. These measures were taken to prevent unauthorized individuals from gaining access to pupils' private information.

During the trial, the researchers were only involved in the data collection activities; teachers took full responsibility for organizing and supervising the actual attendance supervision trial. Participating teachers volunteered for the trial, and it was their responsibility to adopt the attendance supervision system for everyday use in their class. The teachers explored new working practices introduced by the system and were expected to report their experiences and observations regarding the system.

The goal of the concept was to (1) enhance and secure children's independent mobility in home-school transition and (2) to increase the rationalization of home-school communication. The objectives of the field study were to test the attendance supervision system for school children and their parents and teachers, and to examine the value the attendance supervision concept brings to these stakeholders, as well as the attitudes of each user group concerning the use of the system (regarding e.g., privacy issues). The extent to which the service supports the enhancement of school routines and practices and improves information sharing between school and home was also examined in the study.

## IV. USER EXPERIENCE DATA COLLECTION

Druin et al. [21] have argued that design work in a school is subject to difficulty due to the school setting and the embedded power relations between adults and children. Children have so few experiences in their lives where they can contribute their opinions and see that adults take them seriously [21]. When respect is fostered, it changes how children see themselves [24]. Williams et al. [22] implemented an exploratory workshop with ten 11-12 year old children for exploring and developing the interface between children and new mobile 'wearable' ICTs, and found that the children are valuable, adaptive and creative users in the participative design of ubiquitous computing experiences and devices that might enable them.

Druin [23] has developed a typology of roles that children may have in the design of new technologies: a user, a tester, an informant and a design partner. For each role she also presents three underlying dimensions: the relationship to adults, the relationship to the technology and the goals for inquiry. The role we sought from the children was essentially that of an informant. As the trial objective was concerned with the potential of the attendance supervision system, the actual usage of the technology was an essential prerequisite to the children's articulation of potential use and for the informant role as well. Therefore in the case of this trial the children's role was both that of a user and an informant.

TABLE I. SUMMARY OF DATA COLLECTION METHODS AND NUMBER OF VALID CASES FOR EACH METHOD

| Data collection method | Number of valid cases |
|---|---|
| First classroom observation and interviews with first grade class | 16 pupils<br>1 teacher |
| Second classroom observation and interviews with first grade class | 16 pupils<br>1 teacher |
| Classroom observation and interviews with special-needs class | 7 pupils<br>1 teacher<br>1 special needs assistant |
| Phone interviews with the parents of the special-needs class | 6 parents |
| Paper questionnaires for 16 first-graders' parents whose children participated in the trial | 14 parents |
| Paper questionnaires for three first-graders' parents whose children did not participate in the trial | 3 parents |

Given difficulties that need to be overcome for describing and understanding user experience, we decided to collect data during the actual use of the system and to combine a variety of complementary data collection methods [19] in order to increase the reliability and validity of the results [20]. The user experience data collection methods and the number of stakeholders for each method are listed in Table 1. In the next sections we will present the data collection methods in greater detail.

### A. *Classroom Observations*

Classroom observations were made to collect information about how the pupils learned to use NFC technology, what kind of routines they had established after using the system for some time, and what kind of spontaneous reactions and discussion took place in using the attendance supervision system. Children in the first grade class were observed twice over the course of the research. The first visit happened in a very early phase of the trial: the attendance supervision system had been taken into use only a day before the visit. At the time of the second observation the attendance supervision system had been in use for two weeks. The special-needs class was observed when they had used the attendance supervision system for two weeks. Observations with both classes were conducted during a normal school day by attending the first lesson in the morning. The login process was observed from the back of the classroom to minimize the disturbance caused by the researchers' presence. During the observation the children's behavior and actions were videotaped and photographed. The children seemed not to be disturbed or bothered about the researchers' presence.

### B. *Interviews with Children and Teachers*

All the children participating in the trial as well as their teachers were interviewed in order to investigate their thoughts and experiences about the technology and service concept under evaluation. The interviews took place on the

same days as the classroom observations. After login was done and children started their school work, interviews were conducted very informally by chatting with a few pupils at a time either in the classroom or in a separate place. Children in the first grade class were interviewed twice over the course of the research. The teachers were interviewed informally partly in the midst of teaching, partly during breaks between classes.

The following aspects related to the attendance supervision were discussed with the children and the teachers:

- Where the children keep their "Robo" cards
- Do the children remember to bring the card with them every morning to school
- Have the children somehow personalized their cards
- How the children understand the technical details and functionality of the attendance supervision system
- How the children understand the reason behind the use of the system: why do they need to log in and out of the school
- Do the children think that their privacy is violated; that they are being stalked
- Do the children remember to log in when arriving to school and respectively log out when leaving school: does the teacher need to remind them
- How the children manage to use the smart card
- What is the children's general attitude towards the service
- Do the children know if their parents actively follow their attendance information via the system

The children seemed to be proud and excited that adults outside their school had come to their class just to chat with them and ask about their thoughts. The children were very happy with answering the questions and spoke freely and frankly about their own thoughts and opinions.

### C. Phone Interviews with Parents

Since it is feasible to conduct one-to-one interviews with a small user group, the parents of six (out of seven) participating children (two fathers and four mothers) in the special-needs class were chosen to be interviewed via telephone. The parents of one child did not give their contact information for the interview. Interviews lasted from fifteen minutes to half an hour. In order to gain real hands-on experiences by the parents, interviews were conducted one and half months after the beginning of the field study when the parents had had time to experiment for a longer period of time with the attendance supervision system. The aim of the phone interviews was to investigate parents' thoughts on the service concept, opinions about possible added value the attendance supervision service brings to the families, and whether the service could be developed further to have a positive impact on their lives.

### D. Feedback Questionnaires for Parents

As the parents of the first grade class formed a bigger user group and interviewing them via telephone would have been more cumbersome, we decided to create two separate short paper questionnaires, one for the first-graders' parents whose children participated in the trial and the other for the parents who chose not to allow their children to participate in the trial. Questionnaires were delivered to the parents one and half months after the beginning of the trial in order to assure that the parents had already gained real experiences with the attendance supervision system. A total of 17 parents (out of 19) answered the questionnaire. The same things were explored in the questionnaires as in the phone interviews (see Table 2).

TABLE II. QUESTIONS ASKED IN PHONE INTERVIEWS AND FEEDBACK QUESTIONNAIRES

| | **Question** |
|---|---|
| Phone interviews with the parents of special-needs class children and questionnaires for participating first-graders' parents | Have you experienced the attendance supervision service as useful? What kind of benefits have you derived from the service? |
| | If in your opinion the service has not benefited you enough or it would still need more improvement, please tell us your suggestions for service development and improvement. |
| | Would you be ready to pay 30EUR a year for the SMS service? |
| | Have you experienced any problems with the service? If you have, what kind of problems? |
| | By your own estimate, how often have you used the service, i.e. followed your child's logins? (daily, weekly, not so often) |
| | Do you use the service in some specific situations? If so, in what kind of situations? |
| | In your opinion, how has your child experienced the attendance supervision and how has she/he remembered to carry the 'Robo' card with her/him? |
| | In your opinion, has the supervision system had any influence on your family's daily routines? |
| | Other ideas and thoughts regarding the service |
| Feedback questionnaires for non-participating first-graders' parents | Could you explain what factors had an influence on deciding not to participate in the attendance supervision experiment? |
| | If in your opinion the service in its current form would not benefit you enough or it would still need more improvement, please tell us your suggestions for the service development and improvement. |
| | Other ideas and thoughts regarding the service. |

## V. IMPACT FOR THE SYSTEM DESIGN PROCESS

We evaluated the obtained research data from the point of view of how various aspects identified in relation to this study affect the design processes of home-school interaction systems. We present in the following sections experiences and analysis from these findings. Some of these results have been presented earlier in [1] and [2].

### A. Participation

Children, teachers and parents were able to participate in the system design process as well as the adoption process,

and we analyzed our data from the viewpoint of each user group:

*1) Participation of Children:* Three kinds of participatory aspects were identified: (1) Children were able to participate in the visual design of the smart card used for attendance control, (2) children participated in daily use by operating the reader devices and being responsible for logging in and out of school, and (3) children were able to express their opinions throughout the research process through various data collection methods.

Before the beginning of the field trial, one of the pupils in the special-needs class had invented the name "Robo" for the contactless smart card. His idea was used in designing the visual outlook of the card (see Figure 3). Receiving the card had been especially important for the boy who came up with the "Robo" name: the boy had been very pleased that his own idea had been implemented. According to the teacher, for the same boy the start of the school had been especially difficult and for him the opportunity to influence the smart card design had been a very important boost to his self-esteem. Even though the children's role in designing the card was not very big, the other children clearly valued as well that one of them was behind the idea for the smart card name and appearance.


Figure 3. The visual outlook of the "Robo" card and the reader device.

The teacher of the first grade class had shown and taught two pupils how to operate the reader device and what to do when the pupils needed to log out of school at the end of the school day (how to turn the device on etc.) when the teacher was not present. Every Wednesday, operating the reader device was their responsibility. This was also valued by the children, as they saw this as a sign of trust in their skills, and a source of special pride for the whole class, not just for those two children in question. Other children commented on this by saying that, *"…they were chosen because they use the computer also for other things than just playing,"* so the two pupils were regarded to be knowledgeable and skilled in the use of computers.

Interaction systems for children are usually designed by adults who often have very little idea of children's needs and desires [29]. Several authors [24, 29] have identified that involving children in product development is beneficial. Our findings revealed that children valued that they were able to participate and be active in the design, use and evaluation processes. By participating, they could have their voices heard and influence the decisions that affected their school days. Also, our experiences indicate that by participating in the design and use processes the children became aware and internalized the functionalities and goals of the system, which can lower the barriers for adoption and use.

*2) Participation of Teachers:* Participation of teachers was seen to be especially valuable in integrating the application and processes into the daily routines of a school day. The teachers took the responsibility of integrating and supervising the adoption of the new practice. Our experiences indicate that this is essential for the success of adoption.

The teachers were able to observe the use and the user experiences evoked in the children daily. This knowledge was very valuable for interpreting the data collected by interviews and observations.

*3) Participation of Parents:* Parents gave many ideas for the system development and improvement in the phone interviews and questionnaires, and they were identified as important partners for the design and evaluation processes, which is also supported by previous studies [3].

Parents reported that following the children's logins and logouts was not very practical and did not integrate well with their daily routines. Parents needed to separately log in to an online 'citizen's portal' and that took way too much time during a busy workday, in their opinion. The information of children's logins and logouts should be received on the device that is nearly always at hand. Therefore, the text-message service appeared to be a more usable solution in monitoring children's attendance: *"We do not always have an opportunity to be by the computer, so a message to a mobile phone would bring lots of additional value."*

One parent stated that she would preferably receive the attendance data in an email, while another parent did the majority of his work on a PC so he was able to follow his child's attendance information regularly during his work days. He found the text-message service more harmful than useful because a parent could *"be bombarded with text-messages"* during the work days, which could disturb and interrupt working.

In the parents' opinion it would be much better if the children could log in to school immediately when they arrive on the school grounds, for example at the school gate or by the school's front door, as opposed to the login done inside the classroom. Then the parents could get the attendance information as soon as the child arrives to the school area. One parent reported that for their family it would be much more useful to get a message indicating whether or not their child has locked the front door when leaving for school. A desire was expressed that it were possible to send a message from home when the child leaves for school and the device would then react if the child does not log in to school within a time limitation. Also, a child's timetable could be added in the system and a message could be sent to parents if the child did not arrive at school in time.

Several parents mentioned that they hoped to see the attendance supervision service developed further to include more features. For example, in one parent's opinion the paper notebook for home-school communication was already outdated and behind the times, so a web-based counterpart would be much better. An idea was raised that more services could be added to the card (the card functioning also as a library card, for example) as well as important daily information about school. That information could also be checked from the web portal. Parents also stated that they would like to be able to see longer-term statistics about their child's logins and logouts instead of only day-specific data.

### B. Adoption and Use

At the time of the first visit to the first grade class, a routine for the login had not yet had time to develop and the login had not yet been integrated into the children's everyday school routines. As the pupils arrived to the classroom, the teacher had to remind most of them about the login. The children had quite different ways of doing the login procedure; some merely touched the reader device with their card while some carefully placed the card on an exact position on top of the device.

Using the system seemed to be easy according to the children: *"You just put the card there like this," "You can put it either way," "You don't need to wave it, just flash it there quickly," "When it [the device] says OK, login has succeeded."* In Figure 4 there are pupils logging into the school.

Figure 4. Pupils log into the school by touching the reader device with their contactless smart cards.

All the pupils had already allocated some specific place for their card where they always put the card so that it remained safe. Most of the pupils said they kept their cards in their backpacks, and many even had one particular pocket in the bag where they put their cards. Some pupils said that they kept their card in a pen case.

The pupils seemed to remember well to carry the card with them every day, with only a few exceptions. One child said that her Mom took care that the card is with her by putting it into her bag in the morning. On the first observation day one boy had not brought the card with him to school since, *"the card is on the table at home, Mom did not remember to put it with me."*

At the time of the second observation, the attendance supervision system had been in use for two weeks and the login had now become a natural part of the children's school routines. As the children arrived in a classroom, they remembered without a separate notification to take their cards from their backpacks and to log into school. According to the teacher a small line usually emerged behind the reader device and then the latest children remembered the login.

The teacher of the special-needs class said that before the experiment had started pupils had eagerly been asking, *"When do we get the cards? When will the device arrive?"* Similar to the first grade class, the login process appeared to have integrated well in to the school routines after only two weeks use. The teacher did not need to separately remind the children to log in as the children remembered it themselves. The login happened by touching the card with the NFC phone.

In the special-needs class the login seemed to happen quite smoothly, only with some slight bustling and elbowing: *"It's my turn now!" "Wait for your turn!"* Similar to the first-graders, all the pupils said they kept their cards in their backpacks, and most had one specific pocket in their bag in which they always put their card after login.

The classroom observations revealed that the login with the smart card reader device was faster when compared to the NFC phone as children did not need to queue for the reader device. In addition, with the reader device, the children practically did not need the teacher at all for the login. They were able to handle it independently instead, contrary to the login done with the NFC phone. According to the first-graders, login with the reader device at the classroom was easier than login with NFC phone in the day care: *"The cell phone needs to be moved back and forth in a way," "It takes more time."* the children explained. Also the teacher of the first grade class said: *"It worked like an assembly line,"* with the reader device.

The teachers said that the children had been extremely excited when they had heard they could participate in the experiment. The pupils had waited intently to receive their own cards, and after a few weeks' use had only positive thoughts about the attendance supervision: *"This is easy to use, login has worked well."* Teachers reported that the children had easily learned how to use the card, and the login had soon become an integral part of their school day.

### C. Children's Understanding of the Whys and Wherefores

The first-graders' seemed to understand pretty well why they had received their "Robo" cards and what the purpose behind the use of the attendance supervision system was, which is shown in the following excerpts gained from first-graders' interviews: *"Mom and Dad will know that I have arrived at school and at home." "The reason for doing the login in the morning is that the thing starts to transmit information to somewhere, and in the afternoon when leaving school you need to log out so that the thing won't*

*send any more information and so that the information would not proceed anymore."*

The first-graders also had noticed some benefits the attendance supervision system had brought to their lives: *"It's also nice that you don't need to phone when you have arrived at school." "Once when I came to school by bike and Mom tried to call me, my Mom had put my phone in that kind of place in my backpack where I couldn't find it. At that time we did not have this card thing yet, but it's good that we have it now."*

Children in the special-needs class understood also the reason behind the use of the system, and seemed to understand how the system created value for parents and school. However, it is possible that the children's answers partly repeated the same words the teacher and their parents had told them about the attendance monitoring: *"Mom and Dad know at what time you have arrived at school and left home, and if you have stayed in detention." "You need this at your new school, so that they know whether you are late or not." "You do the login because you need to touch the phone." "Parents check at their work place that you have arrived at school."*

When the children were asked whether they knew if their parents had been checking their attendance information, about half of the pupils were aware that their parents had been monitoring their attendance information: *"My parent watches the logins through the Internet." "Mom said that she hasn't checked yet." "Mom sometimes looks, but not every day." "Mom does not check the logins until at home in the evening."*

### D. Children's Understanding of the Technology

Children of the first grade class did not really understand the technical details behind the system, and they did not seem to have thought about it that much. When we asked them what they thought about how the system worked they were rather baffled at first and then some of them were able to give us answers: *"It puts the information on the computer.", "There is some little thing in the cell phone, a kind of strange looking tiny card inside the phone, a plastic one with nothing inside, which takes the information.", "I wonder what does my Mom see? Does some explanation mark like appear, that your son has left home from the day care, that it is a safe journey?" "The cell phone is a bit like a living thing, it reads that information and then it happens."*

Specifics of the technical details and operation of the system were not very clear for the special-needs class children either, even though they had a reasonable understanding about how the technical components involved together and some basic conception of how the system functions: *"It writes names on the Internet, are you at school or where?" "It sends an e-mail or a message and Dad opens his phone and sees a text message." "A message leaves when the card and the phone touch." "A light appears in the machine telling that you are late. Green flashes when you have arrived at the right time."*

### E. Attitudes towards Privacy

When planning and designing the system for children's attendance supervision we were aware of the potential of such technology to increase the debate on the issue of surveillance and privacy invasion. Concerns were expressed even before the actual system was taken into use when the Finnish media published the plans for implementing and testing the NFC-enabled school attendance supervision concept in the city of Oulu. On the web site of the local newspaper many readers expressed their biases and opinions about the system. The following excerpts are from the discussion on the web site (translated from Finnish): *"For real, big brother will also monitor in this case [27]." "Personally, I would certainly not accept stalking through access control at our school, the old, traditional control of non-attendance made by the teacher is enough…we need to really take care that the high technology of the future will be used to help people, not to stalk them [27]." "The next phase is a microchip planted on the back of the hand, the mark of the beast from the Apocalypse of John…[26]"*

However, during the study itself the privacy concerns and negative aspects of surveillance did not play a big role, contrary to the previous studies [3, 5, 10]. The benefits of monitoring were seen as greater than the costs by all the interest groups. For example, one parent stated in the phone interview that in her opinion it is good that you can monitor your children, since, *"…life is changing all the time, it is becoming more fierce."* One family reported that because of the attendance supervision system, they did not need to provide their child with a mobile phone which they would have otherwise done to monitor how the child travels between home and school.

In their interviews, children themselves did not bring up any comments regarding stalking, losing their privacy or being under surveillance. Quite to the contrary, and also according to the parents, the children regarded the attendance supervision as a natural part of the school routines, and did not wonder why they were given the cards and why they had to do the login every day, because, as one of the parents said: *"For a child it is just part of his life."*

NFC technology is a very short-distance technology requiring a close touch to activate reading. Based on our observations, we expect that this increases the feeling of control, and does not trigger the feeling of being under surveillance. Other types of RFID technologies that can be read automatically from a distance without any explicit action from the user side can create a stronger feeling of being under surveillance by "an invisible eye", therefore triggering negative experiences towards the loss of privacy and being monitored. This has become very apparent in earlier surveillance initiatives conducted in school environments [6, 7, 8].

The contactless smart cards used in our study contained only an ID number, not any personal information (other than the printed name on the card surface), pupils' online attendance data was put under password protection and text-messages were sent only to authenticated mobile phone

numbers, and so unauthorized individuals were prevented from gaining access to pupils' private information.

*F. Trust and Respect*

The parents reported that the contactless smart cards and the attendance supervision concept had been received very well by the children. Parents said that their children felt the supervision was important and took a big responsibility for keeping the card safe and carrying it to school every day. One of the parents commented, *"A proud and eager pupil has remembered it well."* For example, one child had gotten really excited when he received the card that was similar to the card his father used at work. The parents said that the children had taken care that they always had their cards with them, and for some of them it seemed to be very important that they had their cards with them all the time. Figure 5 shows some pupils logging into school.

Figure 5. Pupils log in by touching the teacher's NFC-enabled mobile phone with their "Robo" cards.

For many children the possibility to participate in this trial seemed to be a boost for their self-esteem, which is also consistent with previous research [25]. The children were very proud and excited that they were shown trust by giving them their very own contactless smart cards that were their own responsibility, and that adults trusted the children to take care of the cards and the login. This is well illustrated in the following teacher's comment: *"For the children this has been an important and big thing, since not all the classes have these cards in use, so in that way children now have a chance to stand out and they have something that others do not have."*

We had expected that the children would have taken some actions to personalize their cards but the interviews and observations revealed that children had not modified their cards' outlooks in any ways. It seemed that the children placed a high value on the card and showed respect by not modifying the card. The children seemed to appreciate their cards so much that they did not even think of the possibility of e.g. adding any stickers or drawing on them. One girl commented that, *"I wouldn't dare to put a sticker on without asking."* The children also seemed to have developed some misconceptions about the system, which can be partly interpreted as an outcome of the fact that they had not internalized the technical details and functionality of the system: *"When there is a sticker on the card and you log in, the cell phone accidentally takes the sticker and some picture of Winnie the Pooh or something appears there,"* one child said.

However, many of the pupils knew that secondary school students had received NFC mobile phones for attendance supervision and the pupils seemed to be a bit jealous about it. One of the children said, *"Smart cards could have been given to the secondary school students and we could have had the touch mobile phones."* Clearly, mobile phones were valued as devices and status symbols more than smart cards.

The children evidently valued the trust they were given, but they also used this new power to mutiny against teachers and parents. One child had thrown his card away in a burst of anger towards his parents. In general, however, children accepted parents' and teachers' authority in protecting them [30] through attendance control without question. The children could have chosen not to mark their arrival to and/or departure from school as a sign of rebellion, or could have given their card to a classmate to handle the login and logout on their behalf. However, this type of behavior to manipulate the system did not come out in our trial group. We assume that this might be different with older children and teenagers.

*G. Adults' World*

On the web site of the local newspaper many readers commented on the attendance supervision system also in the following way (translated from Finnish): *"A child is not allowed to grow up at her own pace anymore; she will be raised in a real 'Orwellian' spirit [27]," "Here the monitoring, caring and presence of a grown-up is trying to be replaced with a ridiculous mobile phone [27]."*

The children themselves did not wonder why they had to do the login and did not resist new practices; they simply regarded it as a natural part of school routines. This is well illustrated in the following excerpt from one of the teachers: *"Nowadays children have seen so many kinds of things that they don't marvel at things like this."* The children had only positive thoughts about the attendance supervision, it had been *"nice"* and *"easy,"* even *"awfully nice, giant-sized!"* and *"really great!"*

However, those parents, whose children did not participate in the field study, explained that they had considered that, *"The safety of the child is created through the genuine presence of an adult and not through a supervision system."* These parents thought that what children really need is the time of trusted adults, and also considered the trial to be a technology-led project *"Where the effect of the project on a child's everyday life had hardly been thoroughly considered,"* which is also argued in previous research [9, 10]. Parents stated: *"Children of this age should not need to be rushed into the world of cards and codes. They can do that later. The amount of new things in the first-graders' world is already large enough."*

*H. Responsibilities*

The teachers said that the parents had expressed their interest towards the system for practical reasons; to be able

to know where their children were. It often happened that a child had forgotten to phone Mom or Dad, and consequently the parent made a 'check call' to the teacher in order to make sure that the child had safely made his/her way to school. For example, one child had once promised to call his father as soon as he arrives at school but the batteries had died out from his cell phone so he was not able to make the promised call. So, the attendance supervision system facilitated the teacher's work by eliminating the need for a teacher to answer parents' calls during the school day.

However, some parents chose not to participate in the trial, as they thought that the teacher should have full responsibility over the whereabouts of the children, and felt that a computerized system would remove this responsibility from the teachers. One of the parents said, "*If parents cannot trust that the teacher knows where the children are (ill, at school, on vacation etc.) something is really wrong*." One parent argued that in the case that a child does not arrive at school and there has not been any notice about the absence, it is teacher's duty to contact the parents, so, "*What kind of additional value does the service bring to parents?*"

In addition, the parents commented that the system can sometimes cause extra worry, as the child might lose the card or forget to log in upon arrival: "*The login is based on memory, so parents cannot be sure that the child is at school if the child has forgotten to log in or if the child has lost his card.*"

In one parent's opinion all the resources should be directed to preventive work in regard to safety, such as traffic, school environment and social support: "*What does it help to get the information that something has happened, if something could have been done to prevent that from happening!*"

### I. Added Value

About half of the parents who participated in the trial answered in phone interviews and feedback questionnaires that they were satisfied with the system and thought that the system adds value for them. The system was seen as especially useful when both the parents are working and are able to follow through the system that their child has arrived at school and check at what time the child has left for home. The system was also found valuable in that it would notify the parents immediately in situations where the child for some reason does not arrive at school or in day care.

However, the interviews and questionnaires revealed a fact that for some families the attendance supervision system did not bring real added value. In these families one of the parents was always at home when the child left for and arrived from school, enabling the parent to follow the child's comings and goings, or a family lived so near the school that the child had only a short way to school.

Some parents also thought that the service only brings the same feeling of safety as calling with a cell phone when ensuring the child's arrival at school, so the system does not bring real value when compared to an already established practice. In one parent's opinion the attendance supervision for older pupils would bring more benefits, since she considered that a small pupil is already quite well controlled by the school and day care.

One interesting finding was related to situations where the parents were separated. The system could provide a parent not living with the child (at the moment) with a way to know more about the daily activities of the child. This could provide a better feeling of involvement in the life of a child. In our trial, one father not living with her daughter would have liked her to participate in the trial so that he could get more information about his child, but the mother who lived with the child refused the child's participation.

### J. Downsides

Most parents wondered why their child's login always happened so late in the morning, for example the child might have left home to go to school at 7:30 am, but the login however, did not happen until around 8:30 am. As the parents knew that the journey to school should not take this long, it easily caused concern and worry. The delay was caused because the reader devices were located in the classrooms, and some mornings it took some time before the children got inside or remembered to log in. In the parents' opinion it would be much better if the children could log into school immediately when they arrive on the school grounds, for example at the school gate or by the school's front door, as opposed to the login done inside the classroom. Then the parents could get the attendance information as soon as the child arrives on school grounds.

A few parents also expressed concerns about increasing the amount of information they needed to follow: "*In this insecure world it is good to know where the child is, but the information flood and reading of messages is already now fully employing the parents and therefore it feels that the 'traditional' way should be enough. But naturally, if there is a fear that the child is skipping classes or thinks of leaving on his/her own way from school, the attendance supervision service is good.*"

In the first grade class three children did not participate in the trial. The parents of those children justified their decision by saying that the attendance supervision system could cause parents extra worry instead of increasing the feeling of safety and peace of mind, as the child might lose the card or forget to log into or log out of school.

### K. Economic Feasibility

The administrative units of the city of Oulu estimated that if the system with the SMS notification service were adopted at schools for permanent use, it would cost each family using the system approximately 30 EUR per year. Parents' willingness to pay the suggested amount of money for the service was inquired in the phone interviews and feedback questionnaires.

Altogether 11 parents who participated in the trial stated in phone interviews and feedback questionnaires that they would be ready to pay the suggested amount of 30 EUR per year for the SMS service: "*I could also pay for security.*" Five parents said that they were not willing to pay for the service, one parent wasn't sure, and three did not give their answer to the question.

The expenses of the system would include at least hardware and software costs for the backend system and the hardware units (smart card reader devices and NFC-enabled mobile phones) needed in schools, data transfer costs between the backend system and the reader devices, contactless smart cards for the pupils, the price of sending SMSs to parents, deployment costs, and the maintenance costs of the system. However, teachers would need less time for administrative work and could use that time for teaching instead. Parents would also save time since they would not need to make check calls to their children. In this context the time savings is difficult to convert into direct financial savings. Rather, here the time savings means for the teachers the prospect of increasing the quality of education and for the parents the possibility to concentrate better on their work when they do not need to worry for their children's safety.

However, there is a possibility that this kind of fee-based attendance supervision service creates inequality among the pupils, as not all the parents would be willing to pay for the service. The quite low percentage of parents ready to pay for the service (55%) in this study might be partly explained by the fact that Finnish people are accustomed to thinking that school attendance is free and therefore they do not easily, maybe just out of principle, accept the idea that a purely school-related service would be subject to a charge. Also, in a situation where only some of the families were using the attendance supervision service provided by the authorities the teachers would in any case need to also do the manual roll calls thus reducing the time savings for teachers and possibly even causing extra work for them.

In Finland the school system is based on public schools, and basic education is free for citizens. Therefore, public authorities play an important role in adopting new technologies in the school environment. This means that investments are covered with public funding and decisions for adopting new technologies are done through public decision making processes. In the case of public services, goals and criteria for adopting may differ significantly from the private business environment, where the goals usually deal with maximizing profits and can be justified with economic reasons. With public services it can be difficult or meaningless to show the created value only through economic measures.

Evaluating the value of adopting new technology in an environment that is fully financed by public authorities and serves various user groups with different needs is challenging. It would be possible to calculate the actual costs of deployment and continual use of the attendance supervision system in order to make an educated decision on whether or not it is economically feasible to take the system into use. However, the schools do not operate in a business environment, trying to generate revenues and operate at minimum cost level. Instead, schools create value for the society and the families using their services. Benefits of adopting new technology in such a setting must include other value parameters in addition to traditional cost or time savings.

## VI. CONCLUSIONS

In our trial, information about user experience was obtained by combining different data collection methods. The findings were analyzed from the viewpoint of three end-user groups, namely, children, parents and teachers.

The attendance supervision system can reduce unnecessary doubt by allowing parents to receive real-time information on non-attendance or if a pupil is late from school. The main benefits for the home are that parents can follow their children's attendance status in school and day care in real time, thus eliminating the need for calling the child or the teacher to inquire about the child's whereabouts. The service also facilitates teachers' work by offering technology and a system for gathering the information about children's attendance and keeping a log about their possible tardiness at school.

The importance of the role of children in the research process was emphasized throughout the research project to overcome the problems associated with children as research subjects [21]. The children were respected as users of new technology and their contributions and ideas were sought out and valued. All communication was planned to convey a message that the children could trust that adults will listen to their thoughts and ideas, and respectively the adults aspired to learn to elaborate on the children's ideas, rather than merely listen passively or not listen at all [24].

For many children the possibility to participate in this trial was a boost to their self-esteem. The children were very proud and excited that they were shown trust by the adults by giving them their very own contactless smart cards that were their own responsibility and that adults trusted them to take care of. Also, the children valued the responsibility they were given for logging in and out of school and even operating the reader devices by themselves. Similar results have also been discovered in research by Attewell [25].

User research revealed that for the children at this age as well as for their parents, the concept of being monitored by the technology is not something they reject, but possibly welcome. Interviews and questionnaires with parents and children revealed that mobile phone ownership among this age group is closely tied to parental purchases, and motivated by parental and child desires for parents to be able to contact their children when they have to go to school alone. With this new attendance supervision system children would be able to go to school alone even if they did not have their own mobile phone, since the attendance monitoring would enable parents to check that their children had arrived at school safely, thus making check calls between parents and their children (or between parents and teachers) unnecessary.

Main concerns with the attendance supervision system relate to privacy and security issues concerning the collection of pupils' real-time attendance details and the possibility that unauthorized individuals could gain access to children's movements and location and personal data. In this study privacy concerns were not raised, which seems unique when compared to previous research [3, 5, 10]. We expect that one reason for this is the nature of the NFC technology, which enables reading the ID only upon touch.

It also needs to be noted that security at school is improved via an attendance supervision system: it is easy to see which pupils are in which classrooms. Real-time attendance logs are also important for a pupil and for his or her legal protection.

### A. Implications for practice

This study has some concrete implications for practice and research related to technology adoption in a school setting. First, our findings revealed that children valued that they were able to participate and be active in the design, use and evaluation processes. By participating, they could have their voices heard and influence the decisions that affected their school days. Also, our experiences indicate that by participating in the design and use processes the children became aware and internalized the functionalities and goals of the system, which can lower the barriers for adoption and use. In addition, the fact that the teachers took the responsibility of integrating and supervising the adoption of the new practice appears to be essential to the success of adoption.

Also, the children, as well as their teachers, became familiar with the login process very quickly, and the attendance supervision was soon integrated into their everyday school routines, mainly due to the intuitiveness and effortlessness of the NFC touch-based interaction technique [17][18]. However, the interviews showed that the children did not fully understand the technical details or functionality of the attendance supervision system even though they seemed to have a good comprehension of the reasons behind the use of the system, and they knew how the system created value for their parents. For the children to get full value of the technology it is important to give them enough information about the system and how it works.

Comments by the parents clearly showed that when a new technology is brought into a school environment, it needs to be clear for everyone how the adoption of the system affects the responsibilities of school personnel, parents and children. In this case, the responsibilities of the teacher remained the same, and the technology was used only to support and enhance communication. However, many parents felt that the technology would remove responsibilities from the teachers.

If this kind of system were taken into wider use economic feasibility of the system needs to be considered. 55% of the participating parents in this study were willing to pay a small amount of money per year for the use of the system. It is likely that not all the expenses would be covered by the money received from the parents, which means that the rest of the expenses need to be paid using tax money. A fee-based attendance supervision service might also create inequality among the families, as not all the parents would be willing to pay for the service. We think that this is part of the bigger discussion of using tax money to pay for some services versus citizens paying for the services partly themselves in addition to paying taxes.

Even though the children themselves did not get direct benefit from using the system, they valued the fact that they could actively help teachers and parents by creating useful and valuable information. Perhaps surprisingly, the children seemed to be the group most pleased with the system. When describing their experiences with the system, the children's descriptions were positive and enthusiastic. Our analysis shows that a technology supported attendance supervision system can bring value for all end-user groups but it seems that the system will, however, primarily serve the teachers and the parents.

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# Virtual Presentia (VIP) and Virtual Absentia (VIA) Hospitals

## A Novel Approach Based on Virtual Presence and Absence

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*Abstract*—***Medical robots are moving from the benches of laboratories to the bedside of patients rapidly. With advancements in information and communication technology (ICT), these are being used for diagnostic as well as therapeutic purposes. They can assist but cannot replace the doctors. Evolution of new terminologies like tele-presence, tele-medicine, tele-referral, tele-consultation, tele-rounding, tele-diagnosis, telerounding, tele-health centers, tele-doctors, tele-nurses are overwhelming and required to be readdressed. Mostly these terms are overlapping. Definitions of triad of telediagnosis, different ways of communication (real and virtual) and medical robots (Roboscope and Roboop) are given. There is increase demand of teleclinics or telehospitals to absorb these terms to avoid confusion. Our focus here is to review the literature related to telemedicine and discuss new concept of Virtually Presentable or Virtual Presentia (VIP) and Virtually Accessible or Virtual Absentia (VIA) Specialist Hospitals leading to Absolute Virtual Hospitals. Classification of virtual hospitals, identification of available resources (computers), manpower (virtual specialists) and modes of communication (absent or present) will lay down foundation of new aspects for telediagnosis as well as medical educational system.***

***Keywords-telemedicine; remote presence; telepresence; telehospital; virtual hospitals; teleconsultation; telerounding; telereferral; telediagnosis;***

### *I.* INTRODUCTION

A new concept of Virtual Specialist Hospital is promising and required to promote field of telemedicine, medical education and confidence of patients [1-3]. Telemedicine may be as simple as two health professionals discussing a case over the telephone or as complex as using ICT (Information and Communication Technology) to conduct a real-time teleconsultation or telerounding between medical specialists in two different countries. In telemedicine typical scenario, two doctors are involved with the patient i.e., a local attending doctor and a remote tele-doctor who is engaged to do variety of services ranging from tele-consultation to tele-surgery, as well as tele-diagnosis where a doctor diagnoses a sickness [4]. Local attending doctors mostly are medical officers or nurses. Remote tele-doctors are specialists from different disciplines of medicine with in the boundaries of any country but across the borders generally both are specialists to exchange their views. Care at a distan*ce* (in absentia care) is evolved from an old times practice of sending prescription through postal letters to current modern telemedicine by using information and communication technology. Use of whistle, smoke signals, drum beating, loud speakers and two-ways radio powered by dynamo of bicycle to warn about diseases from a distance are established facts [5]. Telemedicine tends to be taken for granted in developed countries but lacking in developing and underdeveloped countries because of shortage of facilities and awareness. Even critics are there to declare it responsible for overburdening of already overburdened doctors in urban areas. Proponents are over-enthusiastic and happy even with only one e-Health specialist in countries like Rwanda [6]. Interrupted and slow internet services with availability of one computer will not stop them from declaring their clinics as tele-clinics. A comparative study is available regarding urban and rural doctors indicating good physicians' perception of usefulness of telemedicine in both groups and is positively related to their intention to adopt this technology [7]. Telemedicine improves the delivery of healthcare to rural and under-served communities as well as reduces the sense of professional isolation often reported by practitioners in these types of communities [8].Telemedicine is a helpful tool to reach people whose voices are not being heard as much us as the peoples in the main cities. Patients from rural areas are in great need of health services without the need of traveling long distances and in a much shorter time, that could mean a matter of life or death [9]. Its role in urban and rural areas is well established fact but commonly focused on rural areas due to lack of proper hospital facilities. Urbanization is directly related to development of infra-structure including hospitals therefore, its significance in cities is comparatively less than remote areas. Telemedicine may be considered as branch of rural medicine. It may turn out to be the cheapest, as well as the fastest, way to bridge the rural–urban health divide [10]. Its role in disastrous situation like Tsunami may be more helpful [11-12] Telemedicine is not well placed speciality, because it is equally shared by electronic and software engineers and medical doctors. It is also considered as branch of engineering in which, knowledge and skills are developed and applied to define and solve problems in biology and medicine [13]. In fact, it is a marriage of convenience between medicine and information and communication technology. Telemedicine system consists of a personal computer with customized medical software

connected to a few medical diagnostic instruments (ECG, X-ray machine or X-rays scanner) [14]. Through this computer, digitized versions of patients' medical images and diagnostic details (such as X-ray images and blood test reports) are dispatched to specialist doctors through the satellite-based communication link. Retrieved information's are analyzed by specialist to reach on diagnosis and therapeutics. The entire system is relatively user-friendly. Dr Devi Shetty an Indian cardiac surgeon with special interest in telemedicine said "99% of non surgical patients are not required to be touched by physicians. Therefore, no need to be there too in terms of disease management and can be managed by telemedicine [10].Another study conducted by Iftikhar and Muralindran suggest that more than 75% acute cases of orthopaedic can be diagnosed by Otorob (orthopaedic robot) through telerounding or teleconsultation[2-3]. On the other side a tele-doctor is sentenced to 9-months in jail after prescribing Prozac to a teen who later committed suicide in Colorado [15]. When it comes to diagnosing and treating new problems, a physical examination and face-to-face meeting is imperative especially when you are un-known to the patient [16]. Once you remove the hotel component from the hospital, you erase 60% of the cost [17]. Therefore, telemedicine is a better alternative to remove hotel component from medical field to make it cost effective. Remote presence, telepresence, distant presence and virtual presence are being used in literature interchangeably [18]. Virtual reality is often used when "actual reality" is expensive to create, dangerous to inhabit, or simply does not exist. Thomas B. Sheridan is one of the first scholars to investigate the concept of presence and let alone a theory of telepresence or virtual presence [19]. The RP2W (Remote Presence 2-Way) is a one of the remote presence robot which, allows professionals in different geographical locations to teleconference and establish a remote presence via a mobile robot [20]. With novel applications of mobile robots in the field of medicine, new terminologies are emerging rapidly too. Telepresence or Remote Presence (RP) is the ability to project yourself to another location (without leaving your current location) and to move, see, hear and talk as though you were actually there [21]. Virtual means the quality of affecting something without actually being that something [22]. In prevailing situation when most of the studies in the field of Telerobotics and Telemedicine are designed by non-doctors, confusions, overlapping and multiple notions for same option are possible. Telerounding [23], telereferral [24], teleconsultation [25], and telediagnosis [26-27] are being used synonymously too. Teleconsultation and telerounding are considered as more effective and efficient by ensuring diagnostic information is gained in advance [28]. Researchers are working without concentrating on model of real hospitals. Presently, there are no concepts of Tele, Remote or Virtual Presence Hospital in literature in their true spirit on the basis of absent presence concept given in this paper.

TABLE I. DEFINATIONS OF TRIAD OF TELEDIAGNOSIS

| Terms | Definitions |
|---|---|
| Teleconsultation | Dynamic real time examination of patient in clinic |
| Telerounding | Dynamic real time examination of patient in ward |
| Telereferral/ Tele-consolation | Static (Store and Forward) type of medical consultations |

Similarly it is not possible to know whether study is based on virtual synchronous presence (telerounding in wards and teleconsultation in clinics) or asynchronous presence (telereferral) without going in details of study design. Definitions of triad of telediagnosis are given in Table I and can be further clarified by following description. In telerounding mobile robot is controlled by remote physician and drove to the bed of a patient by him for real time (hard or soft) communication depending upon speed of internet. But teleconsultation is being used here for real time tele-examination of patient in clinic. In "Telediagnosis" as practiced by SICOT (international society dealing in orthopaedic and trauma) patient data is collected from 29 countries interlinked to each other [26]. Later experts review the patient data and give their expert opinions regarding diagnosis and management. Data is reviewed by experts depending on their availability and later suggestions are stored for members to enhance their professional expertise. It is better to use tele-referral rather than telediagnosis in this situation. Target of tele-referral, consultation or rounding is to reach on telediagnosis by different means. Telediagnosis is defined as "Determination of the nature of a disease at a site remote from the patient on the basis of transmitted tele-monitoring data or closed-circuit television consultation" [27]. This definition of telediagnosis is mainly emphasizing on telereferral by using transmitted data and teleconsultation but tele-rounding is not being fully corporated. The term absent presence describes individuals who use information and communication technologies (ICT's), while in the physical presence of others, who may or may not be engaged in the same [29]. This can be explained by usage of laptop in a parks or social gatherings. This scenario explained physical presence in the park but his involvement in virtual word. Virtual presence and absence are proper words to explain these situations respectively. It is our common experience while chatting suddenly someone has to logout because of certain work or disruption in connection. Person who is waiting for him is Virtually Present (VP) or Complete Virtual Presence and other is said to be Virtually Absent Presence (VAP) or Partial Virtual Presence. Therefore, it seems meaningful to mention which, organization, hospital, department, facility, doctor and staff is virtually absent or present to avail facilities and giving full benefits to ailing humanity. Here we are using these terms in different context. If internet connection lines are disturbed, then we signed in and out alternatively. In other words we are jumping from real to virtual world alternatively. During this time we are not serving any

purpose for virtual or real worlds. It is better to name it as Virtual Absent Presence or Partial Virtual Absence. In case of Virtual Absence or Complete Virtual Absence, although person is not sitting on internet at all but retrieves data when required. But in reverse situation, i.e., virtual presence, person is lively enjoying with internet in real time. Sometimes, it is part of our duty to sit on computer and reply immediately by internet when required i.e., on-call duty. Although we are not using internet in this situation but with a click of mouse, it is possible to enter in virtual world as a part of duty. This we can label as Virtual Present Absence (VPA). Practically VPA user is just away from click of mouse, i.e., equivalent to Virtual Present (VP). These both (VP and VPA) are grouped under VIP (Virtually Presentable or Presentia). Similarly VA and VAP are grouped as VIA (Virtually Accessible or Absentia). Additionally, we aimed to review literature related to terminologies of telemedicine and to fit them on a hospital model. Re-definition of tele-referral to distinguish it from tele-consultation and tele-rounding will enhance more understanding of these terms for their applications in telemedicine. We commonly send the data of patient only (tele-referral) and wait for physician to reply depending upon his or her convenience (asynchronous). But in reverse situation, remote doctor not only receives data from hospital lively but can see his remote patient too. If the patient is in clinic, we termed it as teleconsultation but in case of ward patient, it becomes telerounding, location of the doctor does not matter except his distant presence. Tele-consultation for out-door and tele-rounding for indoor ward's patients are better choices respectively. Data (patient medical record) is available in the clinic or hospital and accessible to physician easily during video-conferencing (synchronous) to reach on final diagnosis (telediagnosis) with the help of investigations (tele-echocardiography, ECG, X-rays, blood reports and others, etc.).

Similarly in our medical practice, doctors used 2 common words, non-interventional (X-rays, ultrasound, etc) and interventional procedures (intravenous cannulation, endoscopy, etc.). Therefore, it is better to use Roboscope for non-interventional and Roboop ("op" from operation) for interventional medical robots to understand their rule. Active (first) and passive (second) on-call terms are commonly used in hospitals. First or active on-call doctor suppose to stay at duty location and whereas, second or passive on-call doctor can stay outside hospital. Passive on-call doctor will replace or give him support if and when required. Virtually Present Absence (VPA) is equivalent to passive on-call doctor in real practice. If a doctor just receives data of a patient, analyzes it, and sends it back after review, is not actively involved in virtual word and considered as Virtually Absent Presence (VAP). We targeted at following aims and objectives for this study

- To search commonly used medical terminologies in field of telemedicine and review of literature.
- To differentiate between Teleconsultation, Telerounding, Telereferral, and Telediagnosis.
- To rationalize new terms like VIP/VIA Specialist Hospital, Roboscope and Roboop
- To define different ways of virtual communication and their application to new concept of virtual hospitals.
- To rationalize possible role of Virtual Hospitals in web based medical education.
- To prepare algorithm by following web designs of ten state level hospitals to accommodate different terms related to telemedicine .

We explored three different search engines (Yahoo, MSN, and Goggle) during May 2009, to know frequencies of different terms, e.g., tele-medicine, tele-presence, tele-rounding, tele-diagnosis, teleclinics and tele-doctors, etc. IEEE Xplore [30-33] was taken as professional web explorer to search work on telemedicine. IEEE Xplore was selected as a search engine because of its proven contribution for enginers, who are valuable researchers in the field of telemedicine. Review of literature and personnel experience of main author leads us to define new concept of VIP or VIA Hospitals and other terms. Web designs of 10 state level hospitals were taken as a role model to define these terminologies and to prepare algorithm for our virtual hospital. Literature is not available regarding any effort to prepare such classification and algorithm for virtual hospitals. Currently our project is onging under title of SAKIT (Sikuati And Kota Kinabalu Informatics & Teleclinic). Sikuati (village of district of Kudat, Sabah) and Kota Kinabalu (capital of state of Sabah)are representing rural and urban areas of Malaysia. SAKIT is Malay equivalent of pain, representing ailing humanity.

Review of literature is followed by aims and objectives and methodology in Section I . Proposal, discussion and conclusion, consitute Sections II to IV. Discussion section emphasis on clarification and rationalization of our new terminologies in the field of telemedicine. Possible future pivotal role of virtual hospitals for the field of medical education is given too. This concept article will provide basic foundation to researchers for catagorization and standradization of tele or virtual hospitals.

## II. PROPOSAL

### *A. Frequencies of Terminologies*

Telehospitals enteries are less than teleclinics but telehealth centre is more frequent than both of telehospital and teleclinic.Telenurse and teledoctor is equally famous in health sector, representing active participation from both professionals (Table II).Telehealth centres are more in numbers, even by sum of both telehospitals and teleclinics. There were about 2263 search entries on telemedicine and 413 on telepresence out of 2,061,238 online documents on IEEE Xplore digital library [33]. Numbers of search varies by same terminologies in different ways, like telemedicine,

tele medicine (spaced) or tele-medicine (dashed), especially numbers become very high if tele and medicine are written with spacing and should be avoided. One way of writing should be practiced for scientific terms. Most of work in field of medicine is data processing, i.e., telereferral according to our perception but all the search engines showed little literature on it. Although telerounding, teleclinics and other terms are present in IEEE Xplore but only telediagnosis, telepresence and telemedicine can be searched by its engine therefore, search criteria should be revised. Other terms either cannot be explored or their frequency on search engine is negligible. Yahoo, MSN and Google search engines are giving higher numbers of search entries but relevance is limited and non-scientific terms appeared more than scientific e.g., beautician are using teleclinic term quite often. Doctors, nurses and paramedical staff are three actors around patient in a hospital (Figure 2) and search entrees related to them are more than the hospitals, where they are working (Table II). If we summed up all terminologies searched by four engines, telemedicine (90.13%), telepresence (7.69%) and tele-health centers (1.18%) represent about 98%. Other remaining terms are less than 2% and none of them is more than one percent. Therefore, their percentages are not given in Table II. Our data suggests that only telemedicine and telepresence are acceptable but others terms are not well recognized yet. Even telemedicine is still not established speciality in well known medical institutes. Its fate lies between medical and engineering faculties because of multidisciplinary involvement.

TABLE II. FRQUENY OF MEDICAL TERMINOLOGIES IN TELEMEDICINE

| Terms (%) | Web Search | | | |
|---|---|---|---|---|
| | *Yahoo* | *Google* | *Msn* | *IEEE Xplore* |
| Telepresence (7.69%) | 5,490,000 | 1,090,000 | 366,000 | 413 |
| Telemedicine (90.13%) | 80,090,000 | 1,900,00 | 1,080,000 | 2263 |
| Telemedicine *Def. | 715,00 | 219,00 | 228 | 0 |
| Teleround | 1,970 | 4,230 | 315 | 0 |
| Telerounding | 1,120 | 3,410 | 606 | 0 |
| Telerounding *Def. | 120 | 143 | 0 | 0 |
| Teleconsultation | 224,000 | 68,700 | 51,600 | 0 |
| Telerefferal | 250 | 472 | 184 | 0 |
| Telediagnosis | 47,400 | 25,800 | 13,100 | 40 |
| Telediagnosis *Def. | 29 | 3,210 | 0 | 0 |
| Telehealth centre (1.18%) | 599,000 | 178,000 | 311,000 | 1 |
| Teleclinic | 52,800 | 109,000 | 7,110 | 0 |
| Telehospital | 227 | 396 | 111 | 0 |
| Telenurse | 15,300 | 37,000 | 4,610 | 0 |
| Teledoctor | 22,600 | 9,570 | 12,300 | 0 |
| Teleparamedical | 1 | 0 | 0 | 0 |
| Telemedical Staff | 33,400 | 12,300 | 17,200 | 0 |

Terms (not given in Table II) are less than 1% each.
*Def. stands for Definitions

### B. .New Concept of Virtual Hospitals or Teleclinics

We tried to define six ways of communication in telemedicine based on literature, clinical experience of 18 years of main author in the field of medicine, day to day observations while video-conferencing and comparing six ways of communication in real life (Table III). Simply virtual presence and absence are divided into absolute, complete and partial sub-divisions like that of real, making it 6 in numbers. These terms laid down the foundation of our concept of VIP and VIA Specialist Hospitals. Figures 1and 3, represent the pathway to telediagnosis by referral, consultation or rounding. It also explains our concept of Virtual Hospital through synchronous and asynchronous ways of communication.

#### 1) Types of Absolute virtuality

##### a) Absolute Virtual Presence

It is possible in near future when "Simulated Virtual Doctors" would advise theirs patients by automated software programs and Virtual Mr. Bob may work like Real Mr. Bob [22]. Katherine Hayles described a new idea of simulation in her book titled "How we became post-human". According to her, "In future human simulation and its corporeal existence may look similar" [34]. This philosophy may open new chapter in telemedicine by Absolute Virtual Present Hospitals (AVIP Hospitals). How far away we are from this era is difficult to predict or impossible to achieve. But desires and dreams are endless to reach on destination of absolute virtual presence hospitals.

##### b) Absolute Virtual Absence

It is applicable to remote areas of the world where, ICT'S facilities are not available yet [35]. A unique way of communication is documented in spiritual religious books especially QURAN [36] where Prophets can talk to the God (Allah) and even communication between remotely present Holy Peoples (Prophets and Their Friend) is documented without any mediating ICT's. These Holy Peoples may have strong auditory and visual God given brain cortices to perceive such signals which, common peoples could not. This type of communication is not possible to fit on real or virtual criteria's. It is for the researchers to decide, how they take it? Currently we are unable to define AVIA Hospitals because of ambiguous definition of AVIA way of communication (Figures 1and 3). In Table III and Figure 1 our six types of communication leading to concept of virtual hospital are given. But AVIA terminology should be re-defined to make it practical for hospitals. In future neuro-signals enhancement may be possible by exploration of new techniques to improve brain activities especially for visual

and auditory function. In this situation, weak communicating signals may be intercepted by strong auditory and visual cortices of brain. In certain diseases, human beings perceive visual and auditory hallucinations that are non-existing. These may be because of more enhancements of respective brain cortices. Once these methods will be well established transmission of auditory and visual images may be transmitted and perceived without any intervening ICT facilities. There is another established fact that positive feed back to brain leads to establishment of neural interconnections to enhance brain abilities. This is possible area of research in future to make our dream of Absolute Virtual Absence Hospital true. Although theoretically these things look promising but how many decades or centuries are required to reach on this destination is not known. If it becomes true reality then people at distances can talk to each other with out any mediator like Mobile technology, P.C's or Laptops and even doctors can give consultation to their patients from distances.

*2) Analysis of Some Current Virtual Hospitals*

There is no unified structure available regarding types of teleclinics/hospitals in literature. It is difficult to know types of services available in such clinics due to misnomer or confusing terminologies. From skin care clinics to well establish telehospitals are misleading e.g., skin care is domain of beauticians whereas telehospitals are dealt by medical doctors and telediagnosis is phenomenon to reach on diagnosis in a teleclinic/hospital [37-38]. Different services factors in terms of internet speed, static/dynamic way of communication, GP/Specialist consultation, active or passive on call (availability of doctor with in or out side hospital) are the issues to be considered to design telehospitals. Therefore, we will analyze few available teleclinic on the basis of our new concept of virtual hospital and above factors for better understanding. Results are summarized in Table IV.

*a) SICOT Telediagnosis [26]*

Telediagnosis [26] is store and forward type of teleclinic where doctors (GP's/Specialist) report clinical issues to remote doctors, by emails. Data is reviewed, diagnosis are made and available for further referencing. Telediagnosis is a misnomer in a sense that it reflect outcome of any clinical issue but not explain the types of services in terms of static or dynamic modes etc. This project is linking 29 European countries. Therefore, it represents our Virtual Absentia Hospital (VIA).

*b) Virgin Airlines Telemedicine [39]*

The Virgin airline has just announced a deal with Remote Diagnostic Technologies (RDT) that will result in each of Virgin's planes being outfitted with the Tempus telemedicine system which, contains blood pressure and pulse monitors along with an integrated video cam, and transmits data down to medical personnel via the on-board telephone system. This system is based on dynamic video teleconsultation.

TABLE III. TYPES OF COMMUNICATIONS

| NO'S | TERMS | | DEFINATIONS |
|---|---|---|---|
| 1 | Real Presence (RP) | Active | If doctor is within the hospital and available to patient |
| 2 | Real Absence (RA) | On leave | If doctor is absent from the hospital, e.g., on leave or off-hours. |
| 3 | Real Absent Present (RAP) | Active but deviated | If doctor is in the hospital but not available to his patients, i.e., busy in meeting or using laptop etc. |
| 4 | Real Present Absence (RPA) | Passive | If doctor is on duty but not present in the hospital. He will be available when required |
| 5 | Absolute Presence | x | Difficult to define |
| 6 | Absolute Absence | x | Difficult to define |
| 7 | Complete Virtual Presence<br>Virtual Presence (VP)<br>Tele Presence<br>Synchronous | *VIP Hospital | If doctor is virtually present and communicating with his patients in Real Time (Hard or Soft), i.e., online |
| 8 | Complete Virtual Absence<br>Virtual Absence (VA)<br>Tele Absence<br>Asynchronous | *VIA Hospital | If doctor is virtually absent and can analyze data only when he is free. He is not connected to virtual world at all, i.e., offline |
| 9 | Partial Virtual Presence<br>Virtual Absent Presence (VAP)<br>Tele Absent Presence<br>Synchronous<br>Asynchronous | *VIA Hospital | Doctor is available but server is down or internet is very slow. This will not serve the purpose, i.e., disturbed online |
| 10 | Partial Virtual Absence<br>Virtual Present Absence (VPA)<br>Tele Present Absence<br>Asynchronous<br>Synchronous | *VIP Hospital | If doctor is virtually absent and can see his virtual patients when required, i.e., offline but available anytime to come online |
| 11 | Absolute Virtual Presence (AVIP) | *AVIP Hospital | When virtually simulated doctor reply to the patients |
| 12 | Absolute Virtual Absence (AVIA) | *AVIA Hospital | Possible in remote areas of the world where there is no ICT access. |

. "X" difficult to define and "V" / "VI" stand for Virtual

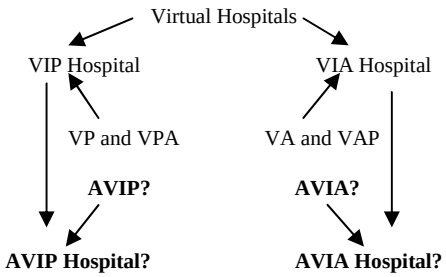


Figure 1. Six types of virtual communication

*c) IHS Telehealth System [40]*

It provides a comprehensive health service delivery system for approximately 1.9 million out of 3.3 million American Indians and Alaska Natives. It comprises of approximately 2,600 nurses, 930 physicians, 390 engineers, 500 pharmacists, 300 dentists, and 170 sanitarians. This provides both dynamic as well as static tele-services along with home care. Its focus is on clinical, educational including public telehealth program too. It represents our Comprehensia Virtual Hospital (VIC). It is not possible to compare Rwanda e-health system where only one tele-specialist is available with such a huge system [6]. Therefore, it is irrational too compare both systems under same category although both are dynamic in nature. It is reasonably good to put later type of hospital under Virtual Absentia Hospital due to shortage of specialists there. It is self-explanatory to declare any hospital as virtual presence hospital dynamic mode of communication, infrastructure, internet speed as well as human resources must be enough to handle the patients. In summary, if dynamic hospitals lack sufficient staff or facilities should be considered as Virtual Absentia Hospital.

## C. Triad of Telediagnosis

Doctors are responsible for diagnosis of different diseases through 3 different ways of communication. We labeled them as Triad of Telediagnosis i.e., Teleconsultation, Telerounding and Telereferral. Theirs definitions are given in Table I. First two are grouped under dynamic and third is considered as static type of communication. Most of the projects having dynamic type also have static component too but it is better to be considered as Hybrid or Combined variety. We tried to isolate different telemedicine projects on this basis in Table IV and pathway to tele-diagnosis is given in Figure 3.

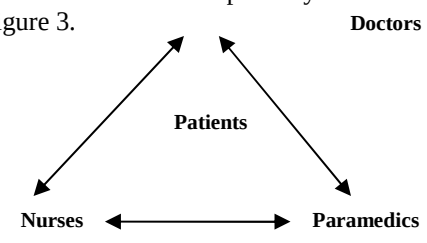


Figure 2. Three actors around patients

TABLE IV. TYPES OF TELEMEDICINE SYSTEM (DYNAMIC, STATIC AND HYBRID)

| System | Clinical Applications |
|---|---|
| Teleconsultation/ Telerounding (Dynamic) [1-4] | 1. For Medical Images in China<br>2. For Instant Treatment, Taipei<br>3. Teleconsultation, Taiwan<br>4. For Self Breast Examination, Malaysia |
| Telereferral (Static) [5-8] | 1. SICOT Telediagnosis<br>2. SWEAT, Egypt<br>3. Telemedical System, Germany<br>4. ImageNet Telepathology |
| Both (Hybrid/Combined) [9-12] | 1. Teleworks, Greece<br>2. Teleconsultation, UK<br>3. Medical Teleconsultation System, UK<br>4. Teleconsultation for CVS, UK |

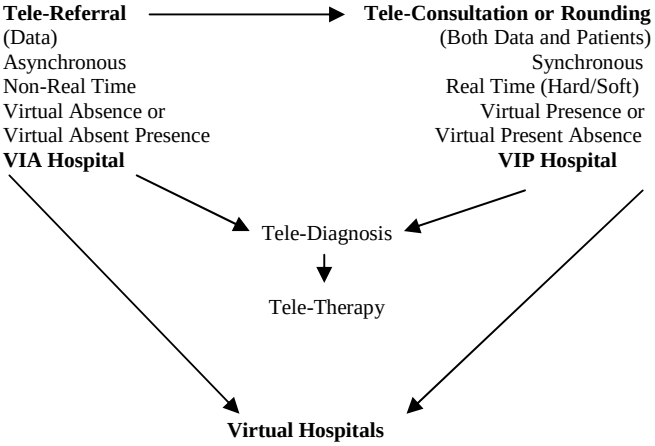


Figure 3. Pathway to telediagnosos

## D. Types of Medical Robots

Medical robots are classified in different ways and one classification is given below [41].

*1) Robot to assist doctors (physicians and surgeons)*

These are helpful for surgery, exploration, diagnosis and therapy.

*a) Surgical robots*

These are commonly used in orthopaedics, neurosurgery and general surgery etc.

*b) Non-surgical robots*

These are popular in tele-echocardiography, tele-ultrasonography and tele X-rays etc.

*2) Robots to assist peoples*

*a) Assistive robotics*

Robots and machines that improve the quality of life of disabled and elderly people, mainly by increasing personal

independence e.g., orthopaedic devices (exoskeletons), robotics aids, smart living spaces and personal assistants.

*b) Rehabilitative robotics*

These are robotics mechatronic tools for clinical therapy in neuro-motor rehabilitation and training etc. These are temporarily used therapeutic tools. Our concept of division of robot for doctors is based on their direct interference to the patient i.e., interventional and non interventional. It is justified below along with definitions in Tables VI and VII.

### *E. Roboscope and Roboop (Medical Robots)*

It is based on two types of procedures in the hospitals, i.e., interventional (endoscopy, arthroscopy, angioplasty and venous or arterial catheterization etc.) and non-interventional (echocardiography, ultrasonography, CT Scans and MRI etc.). Field of medical telerobotics is also following the same tract, i.e., interventional (Telesurgery [42], Doc at a Distance for tele-operations [43]) and non-interventional (RP-7 or RoboDoc [21], and Tele-Echography [44]). Therefore, it is better to use Roboop and Roboscope respectively (Figure 4 and Tables VI and VII). This way ultimate user, i.e., health professionals also can explains to their patients that this robot has no business in direct management of the patient in case of Roboscope. Therefore, robot is an assistant but not the replacement or master of a doctor. In Table VII different medical robot are divided into 2 groups depending upon their applications e.g., Otorob with Docmata is robot only meant for telerounding or teleconsultation but da Vinci is an operating robot and directly involved in surgery by hands-on technique. Therefore, these are considered as interventional robot.

### *F. Algorithm for Virtual Hospitals Web*

Our work related to design a web algorithm for Virtual Hospital is in progress so that different terminologies (Table V) can be adjusted on a standard protocol. Our target is to evaluate web sites of 10 different state level hospitals to design a model for Virtual Hospitals. Due to work in progress, wider applications and lengthy web designing process, it is not possible to cover this objective in this paper. We are progressively moving towards it and will present our results in its second part soon. It is an empty field of telemedicine and will open a new era for researchers and web designers to establish novel websites.

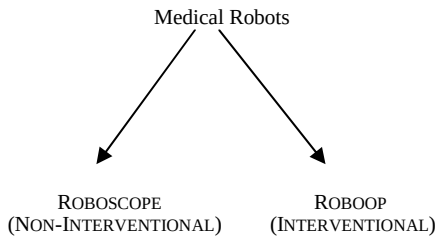


Figure 4. Types of medical robots

TABLE V. TELEMEDICINE AND ITS SUBDIVISIONS

| NO'S | TERMS | SUBDIVISIONS |
|---|---|---|
| 1 | Tele-Medicine | Tele-Paeds.<br>Tele-Cardiology<br>Tele-Neuro |
| 2 | Tele-Surgery | Tele-Ortho<br>Tele-Obs. and Gynae.<br>Tele-Neurosurgery |
| 3 | Tele-Radiology | Tele-Ultrasonology<br>Tele-Imaging<br>Tele-X-rays |
| 4 | Tele-Nonclinical(Basic) | Tele-Pathology<br>Tele-Biochemistry<br>Tele-Anatomy<br>Tele-Physiology |
| 5 | Tele-OT | Tele-Recovery<br>Tele- Assistant<br>Tele-OT Nurse |
| 6 | Tele-Clinic | Tele-Consultation<br>Tele-Referral<br>Tele-Follow up |
| 7 | Tele-ICU | Tele-PICU<br>Tele-NICU<br>Tele-HDU |
| 8 | Tele-Wards | Tele-Rounding<br>Tele-Nursing<br>Tele-Teaching |
| 9 | Tele-Staff | Tele-Doctor<br>Tele-Nurse<br>Tele-Patient |
| 10 | Tele-Education | Tele-teaching<br>Tele-mentoring<br>Tele-monitoring |

TABLE VI. DEFINATIONS OF ROBOSCOPE AND ROBOOP

| Terms | Definitions |
|---|---|
| Roboscope | Non-interventional medical robots for doctors |
| Roboop | Interventional medical robots for doctors |

TABLE VII. DIFFERENT ROBOSCOPE AND ROBOOP

| No | Roboscope | Roboop |
|---|---|---|
| 1 | Otorob | ARTHROBOT |
| 2 | Docmata | da Vinci |
| 3 | RP-7 | Probot |
| 4 | X-ray Robot | Palmbot |
| 5 | SYRTECH<br>(Tele Echocardiography) | Neurobot, |
| 6 | Ultrasound Robot (UBC) | NeuroMate |
| 7 | Robosoft | CASPAR |
| 8 | Telepathology | ACROBOT |
| 9 | Tele-Sonography | MARS |
| 10 | Tele-ECG | BRIGIT |

## III. DISCUSSION

### A. Telemedicine Terminologies

If we look at Table II and V, it is self evident that telemedicine is a branch of medicine and repetition of "tele" is not appealing. Therefore, it is better to bold the 1st letter of terminology rather putting "tele" every time, e.g., **R**eferra**l** for tele-referral and **C**linic for tele-clinic. Another option is encircling of the first alphabet of the word but this way typing options are limited. Encircled letters are only available for R and C on a key board like **®eferral or ©linic.** Other options can be explored like usage of Italic words. With invention of mobile robots telerounding [45-50] is getting popularity in literature as compared to telereferral although, most of the work in telemedince is data processing, i.e., tele-referral. But term telereferral itself is not famous in literature (Table II). In surgical wards telerounding is of two types, i.e., pre and post operative tele-rounding. Pre-operative telerounding is mainly concerned for diagnosis and planning for surgical procedures but post-operative telerounding [51] is concerned with patient care after surgery. In medical wards initially it is concerned with diagnosis by history, physical examination and investigations like pre-operative telerounding but its later part is more focused on the management. Any patient seen in clinic is commonly considered as consultation. In real practice medical record is available near bed side of patient but in clinics, staff nurse provides medical record to the doctor for further management. Therefore for tele-rounding and tele-consultation both data availability and patient presence are pre-requisite. But for referral cases, referring doctor sends a written or verbal requisition to another doctor to see his patient. Appointment for consultation depends upon availability of doctor and severity of disease. Same is the case with Tele-Referral. Once tele-referred case is seen by any doctor should be termed as teleconsultation.

### B. Virtual hospitals

In most of the studies tele-medicine is helpful for the mankind [52-53] but opponents are also there. Maurice Mars at the University of KwaZulu-Natal in the South African coastal city of Durban said, "We may be transferring the problem (of diagnosis and care) from one overburdened doctor to another overburdened doctor by telemedicine" [54]. Therefore, specialists with minor physical ailments for virtual hospitals can be considered as an alternative. This way we will not overburden the already overburdened doctors by using relatively inactive doctors from medical community. Catharine Omaswa of the Ugandan National eHealth Committee noted that her country might only have a modern ICT infrastructure by 2025 but Rwanda's only e-Health Specialist, Richard Gakuba is happy with telemedicine in his country [54]. VIP OR VIA Hospital should be the specialist hospitals. It is pointless to establish virtual hospitals without specialist support because patient may not be satisfied by remotely present medical officers. It is better to name them as VIA rather VIP Hospital if shortage of specialist is there to avoid misleading to the patients. Similarly, where internet services are of poor qualities should be categorizes as VIA hospital. The Philippine health care system is crippled by shortage of doctors and telehealth centres are seen as a tool to bridge this gap [55]. Pakistan, Bangladesh and Tunisia are on the tract of telemedicine too [56-58]. Virgin's Airline is starting telemedicine system in their planes [59]. Even telemedicine has opened the doors in battle fields [60]. Communication may be mediated (telephonic call) or unmediated (face to face). Technology (ICT's) mediated communication is of two types asynchronous (fax, beeper, voicemail, e-mail, or an electronic discussion group) or synchronous (telephone call, videoconference, or electronic chat room) [22]. All these possibilities can be explored from country to country for telemedicine application too.

#### 1) VIP (Virtual Presentia) Hospitals

Virtual Presence (VP) is better term for real-time activity, e.g., tele-consultation or tele-rounding. The on-call doctor, who is off-line but available to his remotely present patient with a click of mouse, is considered as Virtually Present Absence (VPA). He will serve the same role as passive on-call doctor in real practice, therefore should be considered as same functional unit, i.e., VIP.

#### 2) VIA (Virtual Absentia) Hospitals

Virtual Absence (VA) or Virtual Absent Presence (VAP) are responsible for delayed responses, e.g., tele-referral and better to be discussed in another functional unit, i.e., VIA Hospital. Good patient health care system is targeted to reach on Telediagnosis either by VIP or VIA mode of communications followed by treatment. The treatment is either given by the locally available staff or sending support at patient's own location or calling patient to real hospital depending upon circumstances under the guidance of tele-doctor. With better understanding of these terms we can categorize different set-up available in the world, e.g., Remote Diagnostic Technologies based on telerounding and teleconsultation [61] is VIP Hospital and SICOT Telediagnosis project is VIA Hospital based on virtual Absence. This VIP or VIA Hospitals will allow client (patient and their families) to know about facilities available in hospital pre-hand. Establishment of VIP Hospitals in true spirit will become important like VIP peoples too in future. But in VIA Hospitals, patients have to wait for their data analysis first (tele-referral) to consult their doctors (teleconsultation). In other way, patient wills get telediagnosis via data analysis by static or slower path. Therefore, VIA Hospital is preferable term. IHS Telehealth System in U.S.A. divided their clinical services menu as Real-time (mental health, cardiology and rheumatology etc.), Store and Forwarded (cardiology, dermatology and radiology etc.), and Home Care (heart failure and diabetes care) [62]. Its first two terms are comparable to our VIP or VIA Hospitals and third term mimics home care like real practice. Therefore, this systems is combination of all three

VIP, VIA and Real Home care services. In literature, remote presence is used for real things and virtual presence for simulation. Similarly dynamic (synchronous) and static (asynchronous) terms are used for off and online transmission respectively. In this study we used virtual and remote presence interchangeably. In addition to off and online, we also considered the some issues of slow internet and disturbed line to make it more meaningful. Similarly, shortage of specialists and inadequate internet facilities were considered equivalent to offline transmission. These changes will build the confidence of ultimate user (patient and their families) regarding available facilities in Virtual Hospital. Clients (patients) will be in a position to choose VIP or VIA Hospitals depending upon their requirements. If urgent attention is required then VIP Hospital will be better option compared to VIA Hospital. These two broader categories of virtual hospital will also prevent community from cheating (labeling of telehospital by availability of only one computer or one doctor) by further legislation and standardization. In our opinion cell, mobile and hand phones are different names for same product and function. But this paper focused on the matter because same name is being utilized for different modalities or vice a versa. For example in Africa tele-hospital having one computer or one specialist and in USA having 100's of specialists are being placed under same category of telehospital or clinic. Therefore, these should to be standardized for proper understanding.

*Role of Virtual Hospital in Medical Education:* Developing countries are trying to establish educational hubs because of high expenses in developed countries [63]. Medical education is one way to attract overseas students; even USA is trying to attract foreign students [64]. Medical schools and universities are increasing in numbers but proportionate increase in the hospital number is not there. This disproportion is jeopardizing the quality of education [65]. Our concept of VIP Hospital can be extended to non-teaching hospital to use them for teaching purpose to overcome the shortage of hospitals. Similarly VIA Hospitals can be utilized for examination (MCQ'S, MEQ'S and OSCE) and continuous medical education, i.e., CME'S. Simulated dynamic (virtual) and hybrid dynamic (virtual plus real) transmission is commonly used for tele-education and real dynamic (remote) and off-line (static) transmission is for tele-diagnosis. Similarly this new concept of virtual hospital will help us to define utilization of absent and present services in its true spirit for medical education too. Absent services will be used only for information purposes while present services will be better option for live real time teaching and demonstrations.

### C. Roboscope and Roboop

Similarly term Roboscope for non interventional robot will enhance confidence in patients because of familiarity of word "scope" as well as their minimal interference. Their approval from health authorities will be easy compared to interventional robots (Roboop). Safety issues in Roboop will be questioned in more detail by relevant health authorities before their approval compared to Roboscope.

## IV. CONCLUSION

Telemedicine and telepresence are growing fast in their popularity in the field of medicine but medical terminologies are misleading for tele-experts especially telerounding, teleconsultation, telereferral and telediagnosis. Therefore, should be used cautiously, otherwise conflicting situation may arise. VIP and VIA Hospitals are promising terms and required to promote field of telemedicine, medical education and confidence of patients. Although virtual or remote presence terms are commonly used but still wider applications are possible after its proper understanding. Roboscope and Roboop are new terms to differentiate between non-interventional and interventional medical robots. Work is in the progress for model website for virtual hospitals and relevant results will be presented later.

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# Elder Care Architecture – a physical and social approach

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***Abstract*— As we observe society in our days, we can see that people live longer; this means that we have an older population, more likely to have health issues. The special needs presented by the elderly are becoming a major concern for all of us, along with the lack of time demonstrated by society as a whole and, as a consequence, the lack of time is seen when families are not able to take care of their own elders. Many solutions are being presented in order to solve this problem. Some of them are taking advantage of the new technological developments in the body sensor networks area. In this paper we propose the architecture of a system called Elder Care. The Elder Care solution has two primary goals: monitoring vital signs, sending alerts to family and to specialized help and providing a social network in order to help end the elderly's social isolation.**

***Keywords - health monitoring; wireless sensors networks; body area network.***

## I. INTRODUCTION

It is a fact that global life expectancy is rising; therefore, the number of older people is increasing, as shown in TABLE I. and TABLE II. . Because women are working outside the home more and are less time at home, they are no longer able to give support to old family members. Another fact is the scalability of new technologies [2] [3] [4]

TABLE I. COMPARISON OF POPULATION IN 2005 AND 2050 (%) [5]

| Region | Population in 2005 | | | | Population in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | *0-14* | *15-59* | *60-79* | *80+* | *0-14* | *15-59* | *60-79* | *80+* |
| Global | 28.3 | 61.4 | 10.3 | 1.3 | 19.8 | 58.3 | 21.8 | 4.4 |
| Africa | 41.4 | 53.4 | 5.2 | 0.4 | 28.0 | 61.7 | 10.4 | 1.1 |
| North America | 20.5 | 62.7 | 16.7 | 3.5 | 17.1 | 55.6 | 27.3 | 7.8 |
| South America | 29.8 | 61.2 | 9.0 | 1.2 | 18.0 | 57.8 | 24.3 | 5.2 |
| Asia | 28.0 | 62.7 | 9.2 | 1.0 | 18.0 | 58.3 | 23.7 | 4.5 |
| Europe | 15.9 | 63.5 | 20.6 | 3.5 | 14.6 | 50.9 | 34.5 | 9.6 |
| Oceania | 24.9 | 61.0 | 14.1 | 2.6 | 18.4 | 56.9 | 24.8 | 6.8 |

TABLE II. POPULATION/DEMOGRAPHIC INDICATORS IN PORTUGAL [6]

| | **1970** | **1980** | **1990** | **2000** | **2004** |
|---|---|---|---|---|---|
| Population ages 0-14 (% of total) | 28.8 | 25.9 | 20.4 | 16.2 | 15.9 |
| Population ages 15-64 (% of total) | 62.0 | 63.6 | 66.2 | 67.6 | 67.2 |
| Population ages 65 and above (% of total) | 9.20 | 10.5 | 13.4 | 16.1 | 16.9 |

Facing this new scenario, there are many solutions that aim to monitor the elderly in order to provide a higher quality of life in their homes and to decrease health costs.

Wireless communications made remote monitoring of people possible, allowing us to have 24 hours of surveillance with low costs and to obtain a great amount of accurate data about a patient, such as heart-rate, blood pressure, blood oxygenation, carbon dioxide partial pressure or fall detection [3] [4] [7]. This patient's historical record can be a very useful factor in medical decisions, leading to a decrease of errors made by lack of information. It also has a major importance in detecting sicknesses early so that measures can be taken to prevent illnesses from getting worse.

Older people are a target population for the use of these solutions due to their fragile health. They also show a strong determination to live at home as long as possible and have their own independence. Despite of the need for living an independent life, they also demonstrate great fear of feeling unsafe and alone [8] [9].

A solution that involves uniting caring for elderly, with information and communication technologies, was considered because there is an increase in the use of technology by the elderly. Figure 1. illustrates this trend.

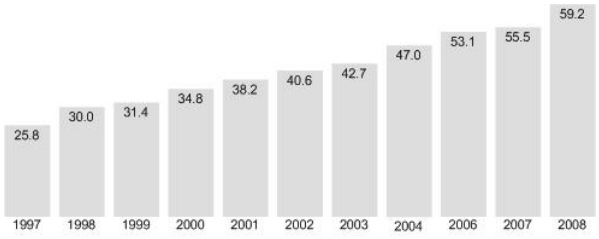


Figure 1. Computer use by elder in home care facilities (in %) [10]

To overcome these questions, we propose an architecture to monitor vital signs and give the proper response in abnormality cases, and also create a social infrastructure to bind older people and make them more valuable to society [1].

This article intends to give an overview of the Elder Care solution, by supplying a global synopsis of related existing solutions and projects (approached in Section 2) and giving a contextualization of the main architecture of Elder Care (shown in Section 3) as well as explaining the different modules in which Elder Care is divided. Section 4 shows a briefing of the interviews made in order to accomplish the requirement analyses. Section 5 presents some conclusions and future work.

## II. RELATED WORK

Many solutions, both academic and commercial, are presented to provide a better life for older people and to be able to reduce health costs. For instance, the solution Alarm-net developed by the University of Virginia is capable of real time and long-term monitoring using wearable sensors, continuously records the information to assist diagnosis and has medication reminders [11].

There are some solutions that use Bluetooth technology like Nonin [12], which developed a bracelet that reads SpO2 and blood pressure. Others use motes, such as the Code Blue project from Harvard University [13] [14] [15]. There are also companies that are developing t-shirts with wireless sensors, for example Sensatex [16] and Vivometrics **Error! Reference source not found.**. In [18] a solution is presented where the routine life of older people can be monitored and alerts occur whenever there are abnormal behaviors.

The importance of solutions to deal with older people is so extreme that there are numerous projects in development referred in [19] and [20]: OLDES (Older People's e-services at home), CAALYX (Complete Ambient Assisting Living EXperiment), K4CARE (Knowledge-based HomeCare eServices for an ageing Europe), ALADIN (Ambient Lighting Assistance for an Ageing Population), ENABLE (A wearable system supporting services to enable elderly people to live well, independently and at ease), SHARE-IT (Supported human autonomy for recovery and enhancement of cognitive and motor abilities using information technologies), EASY LINE+ (Low cost advanced white goods for a longer independent life of elderly people), PERSONA (Perceptive spaces promoting independent aging), SOPRANO (Service oriented programmable smart environments for older Europeans), WAI-AGE (Web accessibility initiative: ageing education and harmonization), ESBIRRO (Bio mimetic actuation, sensing and control technology for limit cycle bipedal walkers), COGKNOW (Helping people with mild dementia navigate their day), ESANGATHAN (Collaborative working environment for ageing workforce).

Most of the found solutions aren't in production and are still in an embryonic state. Some of them are also not focused for a specific population. As some deficiencies are found we can conclude that:

- they don't interact with national health systems, which implies that all the information obtained through monitoring is still not accessed directly by the patient's doctors and, therefore, the potential of providing detailed information to allow doctors to make more accurate diagnosis and prevent illnesses is underestimated;
- many solutions are generalist, and do not include a target population and their special needs. For example, in the elderly's case, interfaces must be simplified and all the tasks have to be intuitive without the necessity of huge memorizing process.
- numerous solutions are concerned with the physical side but neglect the psychological side;
- most solutions do not provide a global response, allowing the senior population to have only one centralized and simplified solution. The fact of having to interact with different products and solutions, in order to have physical monitoring and social support, increases task complexity, causing the elderly to abandon the use of those solutions;
- although the elderly are aware of the fact that their privacy is somehow invaded by a continuous survey and give consent to the use of the obtained information for medical purposes and family alerts, none of the solutions have a pausing ordered by users, for a specified period of time.

The Elder Care solution, besides monitoring physical issues, is also mainly concerned in giving a proper solution to the psychological and social aspects. Elder Care stands out from all other architectures by expanding its purpose to a social level, focusing not on the physical well-being of elderly people, but also by giving an emphasis to the social issues while offering solutions the deficiencies presented above.

## III. PROPOSED ARCHITECTURE

In order to achieve the presented architecture, a qualitative interpretative research method based on semi-structured interviews was used.

In interpretative research, learning comes from interaction with the phenomenon. i.e., through the knowledge that the researcher already has, in interaction with the new aspects of the phenomenon, new knowledge is obtained on the reality that is being explored [21] [22] [23].

In semi-structured interviews, the interviewer follows some guidelines and questions to conduct the interview but gives some flexibility to the interviewee [21].

The process, reflected on Figure 2. , began by making a requirement analysis to allow an architecture sketch. After this step, interviews were conducted in order to validate the identified requirements and add new ones, according to the interviewee's points of view.

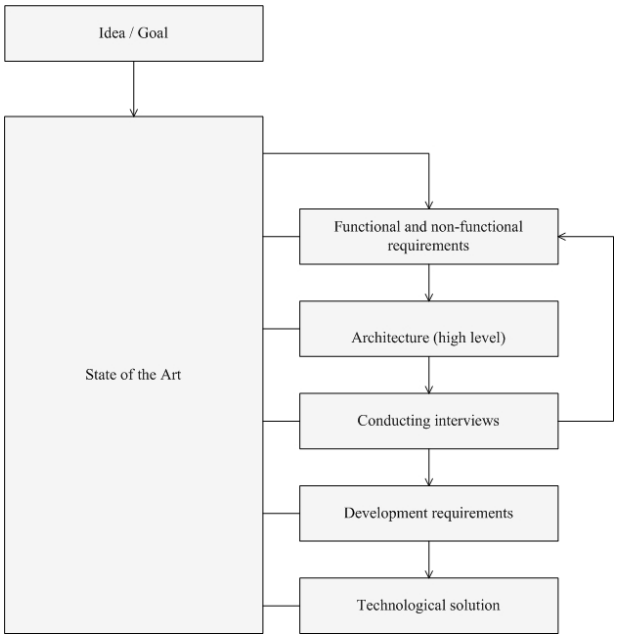


Figure 2. Research guideline

All of the requirements initial and added by the interviews led to the proposed architecture.

Some of the most important requirements are the following:

- each user will have a set of wireless body sensor that will allow continuous vital parameter monitoring;
- the parameter monitoring should not interfere with user's daily routines;
- the system will be responsible in sending alerts to family members and emergency services whenever an abnormality is detected (abnormal parameter values or sudden routine changes);
- the elderly will be able to order pause surveillance during a specific period of time;
- multimedia devices will be installed at the elder's residence in order to provide interaction with a virtual leisure room;
- the multimedia device will also be responsible to inform the elderly to take his medication;
- the virtual leisure room will be divided in areas that will allow communication, knowledge record, hobbies, education and culture and service requests.

To respond to all the requirements, including the ones specified above, the proposed architecture is divided in 3 primary modules: local monitoring, control center and virtual leisure room (visible in Figure 3. ).

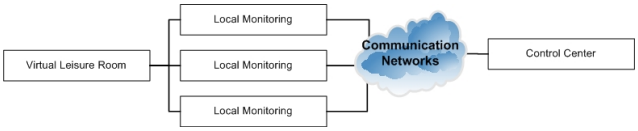


Figure 3. Elder Care block diagram (level 0)

The local monitoring will be installed at the patient's home, obtaining vital signs and sending them to the control center that will be responsible for setting in motion the proper alerts and specialized help in motion as a response to abnormal situations.

The local monitoring will also have a media center in order to allow users to communicate with other users that acquire the Elder Care solution, through the virtual leisure room. This virtual leisure room, as the name indicates, will represent a virtual room where users can meet and interact, creating a social network.

Figure 4. represents how information will be exchange between the different modules.

Local Monitoring will send medical data acquired through wireless sensors, to the control center. This data will be encrypted and sent over Ethernet in XML format.

The local monitoring center will also interact with the virtual leisure room. Inputs will be provided from a web cam, microphone and touch screen device, at the elder's residence, and sent over Ethernet to the virtual leisure room.

The control center will receive all local monitoring center information and manage the alerts, sending SMS alerts to the elderly's family, as well as activating local help support.

As regarding user's information, the control center will also let certified health units access information, with previous authorization from the elderly.

Certified health units and the elderly's family can also upload relevant information to the control center such as clinical analysis, medical exams, allergies and blood type.

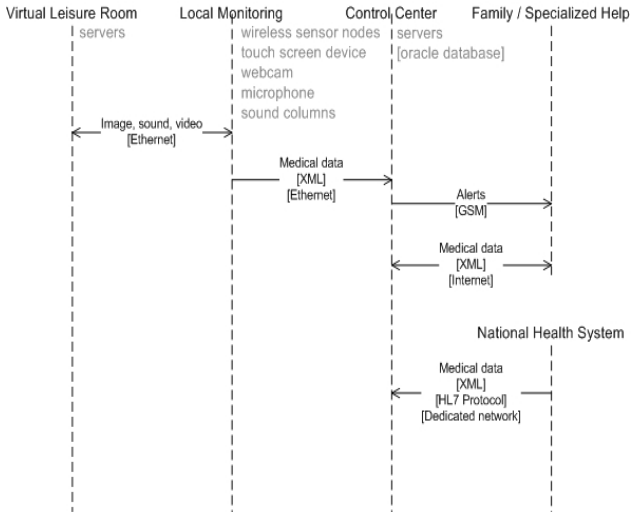


Figure 4. Elder Care information exchange

The subsections bellow explain, in a more detailed perspective, how each one of these three modules works.

### A. *Local Monitoring*

The basic concept of Body Area Network (BAN) is the idea of having a set of compact mobile units, allowing the transfer of patient's vital parameters to the control center or responsible medical staff [24].

This system is based on several sensor nodes, each with its own power supply, processing unit, memory unit, radio, one or more sensors and analog to digital conversion module [25] [26] [27]. Each node is able to communicate with other nodes or a control center through wireless technology. In turn, the control center establishes communication sending all information by Ethernet or cellular network [28]. The basic concept of BAN is used in Local monitoring module.

Local monitoring will be installed in older people's home. It will acquire vital signs from body wireless sensor, in a non-invasive method, and send the abnormal information and samples of normal information to the control center through a communication network. The vital signs to monitor are, for example: blood pressure, heart rate, respiratory rate, temperature and fall detection. This choice was made after some interviews with doctors and nurses that indicated these parameters as the most important to survey in elder people.

As it can be seen in Figure 5. , the elderly will have body wireless sensors communicating with the gateway node. If the elderly are in their own residence, the information will be sent through cable network. When the elderly are outside their residences, the information will be sent through their cell phone. The information will be treated in the control center module.

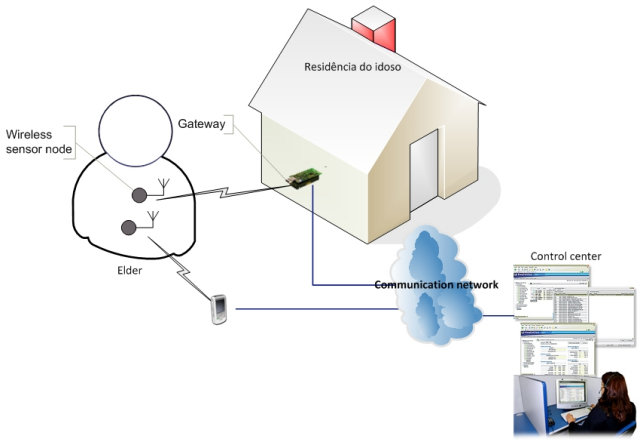


Figure 5. Communication in monitoring vital parameters

Some routines, like the time spent at home and outside by the elderly, will also be monitored. This appraisal is going to be helpful in order to detect unusual behavior. For example, if a person has the habit of being in the garden for 30 minutes every day between 2 and 3 p.m., and the local monitoring module detects that it is 4 p.m. and s/he has not entered home, it will send a message alert to the control center module, that is responsible to manage all the incoming alerts from the different local monitoring modules. As regarding privacy invasion, the possibility for users to pause the routine monitoring will be given.

Local monitoring will also be detecting movement, gas, flood and fire and deploy a trigger to the control center whenever a problem occurs.

Besides, it will have reminders for taking medication, people's birthdays, and other configurable events.

Moreover, the local monitoring module will have a media center composed by a touch screen device, webcam, sound columns and microphone that will allow the user to interact with the virtual leisure room module, which will be approached bellow in this article. The program installed in the device with the touch screen will have a simple interface and few options, in order to guarantee accessibility and easy memorization by older people.

Due to the sensitive nature of the information, this will be encrypted when sent to the Control Center. All the information in the Control Center will be accessible only by the elderly and by people whose access was given consent by the elder, for instance their family and doctors that are treating them.

A representation of local monitoring module can be seen in Figure 6.

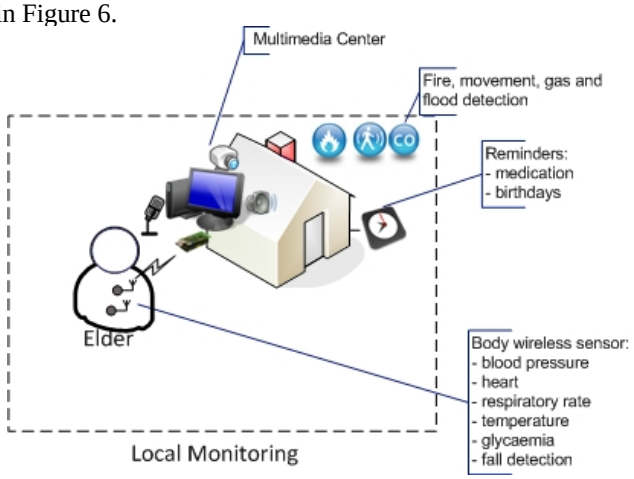


Figure 6. Elder Care local monitoring module

### B. *Control Center*

The control center, represented in Figure 7. , will receive the information from all local monitoring.

In addition to the fact of being an information repository, the control center manages all the alerts. This means that, it is possible to compare current data with the patient records and check what parameters are abnormal. It can, then, inform the family as well as activate proper emergency responses. This allows having a personalized response for each case because, besides the incoming alert, the control center has all the medical records and previous alerts of each patient.

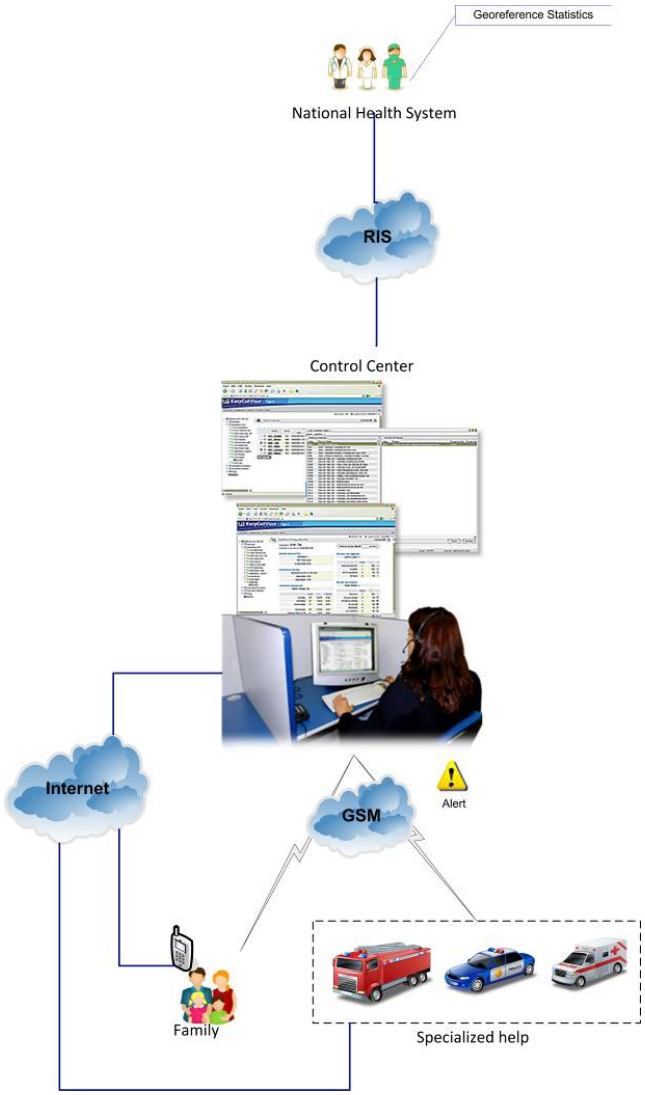


Figure 7. Elder Care control center module

In a more and more frantic life style, sometimes people have no time to take care of their family's elders. With this in mind, alerts will be sent to the elder's family, from control center to their mobile phones. This implies that all families that have adopted the Elder Care solution may rest easy with the assurance that their elders are being monitored and, whenever some irregularity happens they are alerted.

In addition, authenticated family members can access a web site, through personal computer or mobile phone, to consult all the history of the user.

By having an extremely rich information database, the control center may provide data to the National Health System in order to create georeference statistics while providing a complete historical record of the patients with local monitoring module. This may help during medical diagnosis by supplying more complete and accurate data.

The communications with the National Health System is going to be developed by using a standard protocol such as HL7, DICOM, HIPAA, CEN/TC 251 (WGIII) - Security, Safety and Quality, ISO TC 215 (WG 4) - Security, IEEE P1157 Medical Data Interchange (MEDIX), IEEE P1073 Medical Information Bus (MIB) [29] [30], according to the country where the solution will be implemented. The future tendencies are to have common protocols exchanging medical information in order to guarantee the integrity of all systems.

By having a great amount of vital information, the control center will have huge measures to back up information and to provide a no fault tolerant service.

### C. *Virtual Leisure Room*

As people are getting older, they have a propensity to isolate themselves at home, mostly due to physical movement difficulties. As a consequence, they start to feel sad and to be a burden to society by not being able to contribute in some way.

The virtual leisure room promotes a social relationship between the elderly with the Elder Care solution, in order to prevent social seclusion (Figure 8. ). The virtual leisure room is going to be conceived to cover most of the elderly, including illiterate people and with some motor disabilities, but cannot be applied to those who suffer from degenerative mental illnesses, such as Alzheimer.

The virtual leisure room will be divided in areas such as: communication, knowledge recording, hobbies, education, culture and service requests.

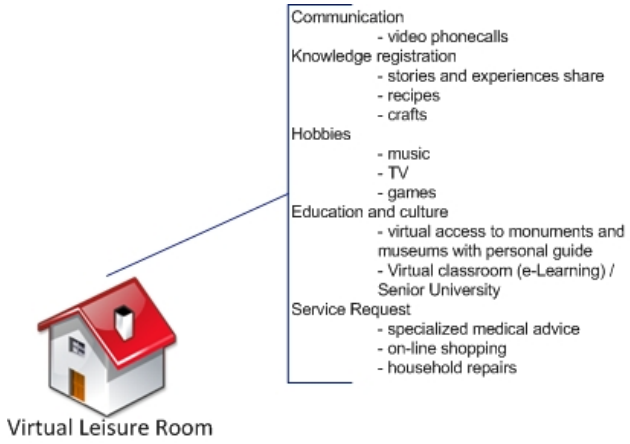


Figure 8. Elder Care virtual leisure room module

Communication will appear in order to allow Elder Care users to interact with each other and with their family and friends by wrapping applications that are already in use, such as Google talk, messenger, blogs and other social web applications.

Another particularity of the virtual leisure room is going to be the possibility for users to post their life experiences, exchange recipes and describe some traditional professions and handcrafts. This will allow for the saving of much knowledge that will be lost if not passed to the generations. The elderly have endless knowledge that is many times lost.

The area for hobbies will provide a way for older people to play some games, listen to some music or watch interactive television.

The virtual leisure room will provide some cultural activities like virtual visits to monuments and, in some occasions, it will also have a tour guide that will inform the visitors by giving historical explanations and responding to questions. This means that the user can visit the monument any time of the day, and interact with other users that are already in that monument, but also has the possibility, in certain stipulated hours to visit the monument with a professional tour guide.

Furthermore, the virtual leisure room will be a platform for e-learning classes, as many older people are returning to schools to obtain knowledge in new subjects.

The virtual leisure room will also offer the opportunity to the users to expose their doubts to doctors, nurses and medical staff. This is a benefit because older people feel, many times, embarrassed to ask some questions to their own doctors in a face to face situation. This feature will allow users to pose some questions without having to meet the doctor in person.

Other services like on-line shopping or household repairs (like plumbing) will also be available in the virtual leisure room.

In summary, the virtual leisure room will provide an open door for those who feel forlorn, by returning some hope, pride and dignity to people who are sometimes forgotten.

The intention of building the virtual leisure room is to centralize most of the social aspects that are important to the elderly. It is also a way to provide these features to users with health problems.

## IV. INTERVIEWS

Six interviews were made to agents that are familiarized with the problem: a hospital director, a social security and elder home care director, a doctor, an older person and two nurses.

As mentioned in the research method, the purpose of these interviews was to validate the identified requirements and add new ones in order to obtain a more robust and complete architecture.

The Leximancer software webpage indicates that "through a rigorous scientific process, Leximancer drills into textual data: documents, e-mails, call center transcripts, blogs, Web sites, etc., and extracts the main concepts, themes and causal relationships to provide the information needed to make critical decisions" [31].

Leximancer was therefore, applied to the interviews made, in order to provide a schematic relationship between concepts and terms spoken during the interview. This allows for a notion of what terms are more important to these interviewed.

### A. *Hospital Director*

The interviewed hospital director belongs to an Integrated Care Coordination Unit.

He mentioned that the elderly don't like to leave their homes nor have a stranger in their own home watching after them; especially in the beginning where no bound has been made.

Even though they are receiving home assistance, there are still periods, mainly at night, where the elderly are alone. The apprehension shown by the hospital director in this matter is not just about lack of monitoring, but also, the loneliness experienced by the elderly. Besides the night period, there is also a main preoccupation with geographic isolation that affects many elderly in our country, making continuous support more difficult.

The hospital director pointed to the urgent need to have something to prevent the elderly social isolation.

Through Leximancer software, it was seen that the most often spoken word during the interview was "Elder", as shown in Figure 9.

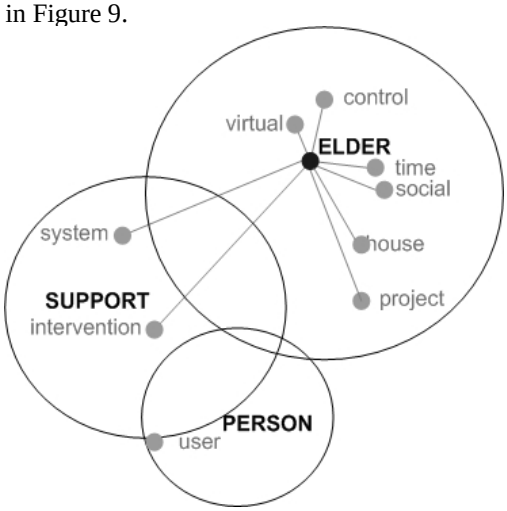


Figure 9. Hospital director interview concept map

As a response to these concerns, the presented architecture has continuous monitoring of vital signs and a virtual leisure room.

### B. *Social security and elder home care director*

The interviewed social security and elderly home care director interviewed works in private home care where 70 older people live.

She usually takes the elderly to a city council program that consists in weekly visits to an internet space. With this continuous contact with the elderly and their interaction with technology, the social security and elderly home care director was able to observe and indicate their biggest difficulties: to work with the keyboard and mouse. But the barrier is overcome by the huge curiosity and interest of being able to search any subject on the web.

The Leximancer concept map, visible in Figure 10. , shows that the most used terms where “Person”, “Home” and “Internet”.

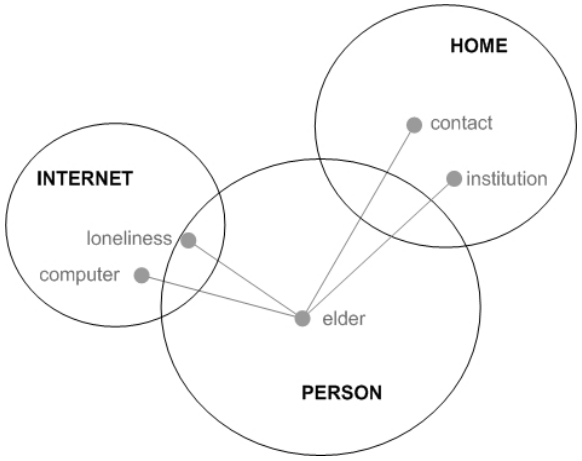


Figure 10. Social security and elderly home care director interview concept map

In order to overcome this hindrance, the proceedings involved in the proposed architecture must be simple and repetitive, attending to the elderly feeble skills and trouble to memorize.

*C. Doctor*

The interviewed doctor has been a doctor in a public health unit for more than 20 years.

He mentioned, as one of his major concerns, the fact that several of his elder patients that live alone, had already a stroke or had fallen and lay on the floor for innumerous hours before neighbors or family missed them. After these episodes, family members, usually daughters and sons become very worried and start making frequent phone calls to their parents in order to check on them. This procedure affects family in their daily tasks.

The Leximancer concept map, represented in Figure 11. , shows that the most used terms where “Elder”, “Talk”, “Home” and “Fall”.

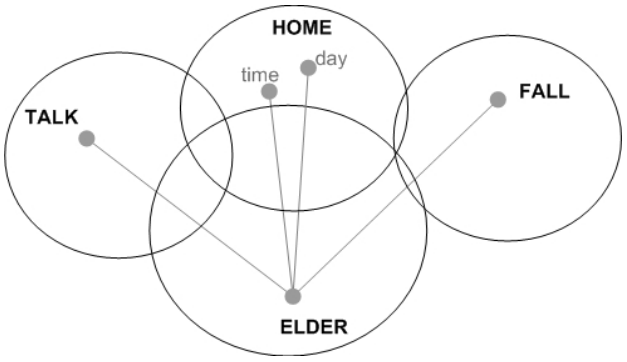


Figure 11. Doctor interview concept map

To solve the problems mentioned above, the proposed solution monitors the elderly leading to increased safety feelings of their own and their family members.

*D. Elder*

The interviewed elder is a 74 year old female widow who lives by herself at home. She retired 3 years ago and used to be a university language teacher.

At the beginning of her professional activity, all processes where made in paper. With the emerging of technologies, many processes started to be developed using computers. She indicated that her biggest fear is to damage the software or hardware and be without the equipment during its repair. She gets anxious whenever the computer responds differently than she is expecting. She referred the use of automatisms, routines and mnemonics in order to do her work properly.

When asked if she sees any problem in doctors accessing her medical record resulting from a continuous monitoring, she doesn’t consider it an issue. As a matter of fact, she thinks that it is very beneficial that doctors can access all her information in order to me more accurate in their decisions. In her opinion, it is important that the medical staff can access the information so as to be able to have a truthful medical diagnosis. It is also important to be continuously monitored in order to have a real time response if an abnormality occurs.

The Leximancer concept map, presented in Figure 12. , shows that the most used terms where “People”, “Time”, “Security”, “Computer”, “Messages”, “Cell phone” and “Phone”.

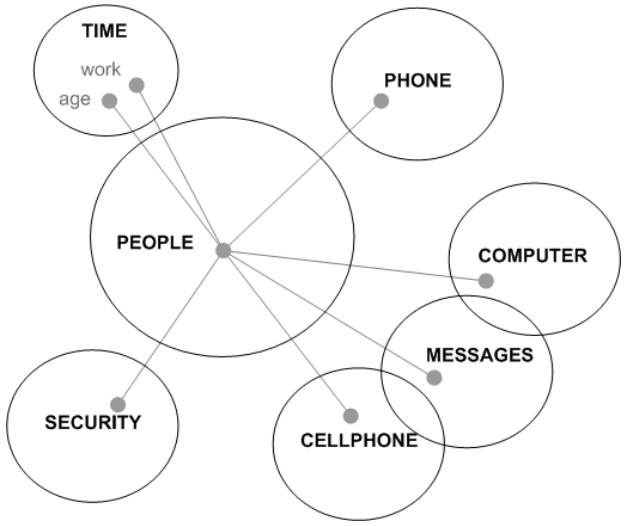


Figure 12. Elder interview concept map

As a result of this interview, the significance of a simple interface in Elder Care can be observed. We can also conclude that it is very important to have training courses to involve Elder Care in their daily routines.

*E. Nurse 1*

The interviewed nurse has been practicing for the last 14 years.

In her opinion, resulting from her experience, the elderly are not likely to use technology. After some years watching older people struggling over cell phones, there are still some of her patients who complain about their inability to use them. Many of her patients can't even read, so they have to memorize proceedings to be able to call 2 or 3 people and to ask for help if they need other functionalities from the cell phone.

Nevertheless, she thinks that having one accessory monitoring vital signs is an advantage, as well as having some device that allows the elderly to communicate is an advantage because, she thinks that isolation is one of the critical problems that should be solved.

The Leximancer concept map shows that the most used term where "Elder", "Nurse", "Phone", "Family" and "Hard" (Figure 13. ).

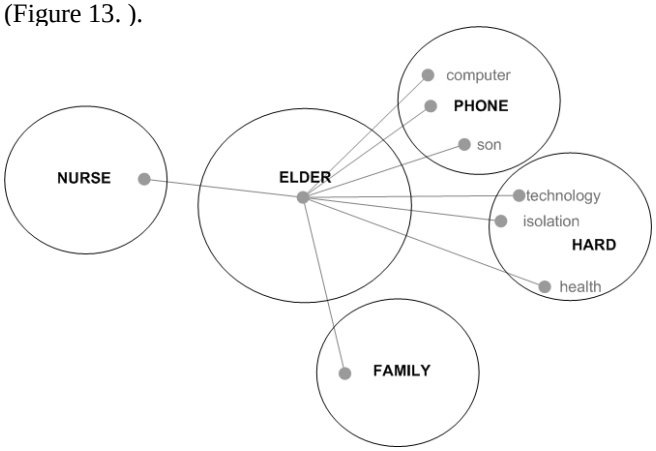


Figure 13. Nurse 1 concept map

To struggle with the problem of interaction between the elderly and technology, Elder Care is designed to have a simple touch screen device with configurable options to show only images or text and images associated with sound. The application on multimedia device will also have few options for easy memorization.

*F. Nurse 2*

The interviewed psychiatric nurse worked with the elderly in a hospital emergency room and, during 3 years, in an elder care home. At the present date he is a university teacher.

His greatest concern is the isolation experienced by many older people. He observed that their social isolation is not a small town phenomenon where people are often geographically isolated, but also in big cities where they do not feel safe on the streets and start to spend more time at home.

He thinks that monitoring the elderly while providing them with security is a very important subject because it increases their welfare. As a nurse, he enumerated the following items as the most important to watch over in an older population: blood pressure, heart rate, temperature, respiratory rate and blood glucose. He also referred that it was crucial to have GPS coordinates of the elderly to precise their location whenever there was a problem outside their residence. These problems occur frequently when they work alone in agricultural grounds frequently using tractors or other agricultural tools.

Adding an idea to the virtual leisure room, he mentioned that, a measure to increase welfare could be to provide an option for the elderly to require services such as small house repairs, on-line shopping and other types of services that could improve the lifestyle quality because the elderly are a population with many needs and without a global and easy access solution.

The Leximancer concept map shows that the most used terms where "Elder", "Health", "Monitoring", "Person", "Hospital", "Technologies" and "Social" (Figure 14. ).

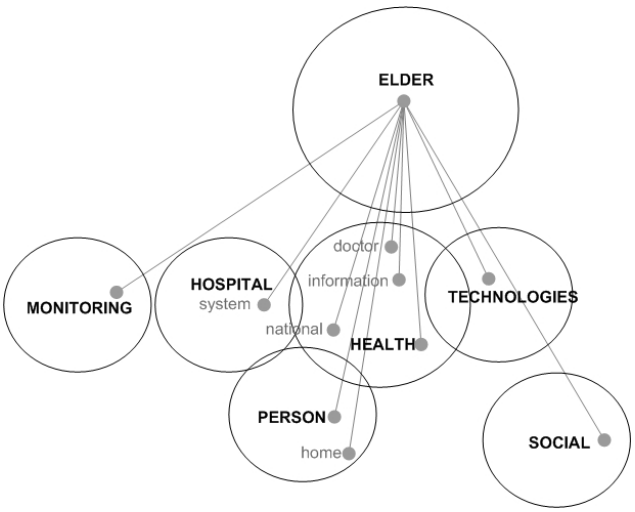


Figure 14. Nurse 2 concept map

As a response for solitude, Elder Care has a virtual leisure room. The idea of having service request was embedded in the virtual leisure room.

*G. Review*

As the interviews were being conducted, a sketch of the architecture was being done. At the end of each interview, this sketch was shown so that more targeted reviews were made.

All interviewed expressed, as the first and main concern, the loneliness experienced by the elderly population, overruled by the existence of the virtual leisure room.

Another feature behind the whole system, and identified as a very important added value, was the sense of security that Elder Care provides due to alert management.

Some interviews also revealed requirements that were not previously planned and the reformulation of existing requirements, such as:

- the inclusion of a blog with social events occurring around the user's residence;
- a device worn by the elderly that obtains GPS coordinates;
- the most relevant parameters to be measured are blood pressure, heart rate, temperature, respiratory rate and glycemia;
- the monitoring users' position must consider that, when at sleep, the elderly are in an horizontal position, but not due to a fall. The sleeping periods must not be a fall alert.

## V. CONCLUSIONS AND FUTURE WORK

To be able to give older people quality of life as long as possible is an emerging problem, which many people are noticing and are trying to develop a proper solution with technological features.

Elder Care is an attempt to give a response to the fact that we have more and more older people and have a lifestyle that prevents us to take care of the elders in our families. This is due to the fact that in most families, active members are workers or students and cannot be at home. Many elders are reluctant to go to care home or accept caregivers' help since they feel that they are losing their independence. Even when the caregivers are their own sons and daughters, they feel reluctant to accept help [6].

With Elder Care solution we will be able to maintain the elderly in their homes, survey their health and make them useful through interaction in the virtual leisure room.

We followed a qualitative research with semi structured interviews in order to obtain the necessary requirements to the proposed architecture.

At this point we have a high level architecture. In the future we will advance with prototype implementation of the proposed architecture, testing it in a real scenario, with elderly who are mostly underprivileged and live in remote areas. This choice of a critical target is going to allow us to get a reliable and robust solution.

It is also our intention to integrate our solution with the elder care in specialized nursing homes, by giving a global coverage to all entities that deal with elderly people.

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# Caring for Physicians and other Healthcare Professionals:

# Needs Assessments for eCurricula on Physician and Workplace Health

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*Abstract*—**The quality and sustainability of the healthcare system in Canada is dependent on the healthcare providers within it. If the system is to remain strong, it is critical that those who provide the services within it are strong and healthy. Unfortunately, downsizing in the Canadian healthcare system has led to extremely heavy workloads and high levels of burnout in healthcare providers, which not only affects their own health but also that of the patients they care for. In an attempt to provide support and resources for healthcare providers to improve their own health and well-being, the purpose of this project is to develop two online programs—one for physicians and medical students and one for other healthcare providers—that will (1) provide access to cutting-edge information related to health and wellness, (2) allow the users to evaluate their current fund of knowledge and health status and take action to improve it, and (3) direct the user to online and face-to-face resources and supports. The first step in the project involved identifying the needs of the target users for the two programs. This paper summarises the findings from these needs assessments and provides recommendations for program design and development.**

***Keywords***—**physician health, workplace health, needs assessment, eLearning**

## I. INTRODUCTION

The content of this paper was first presented at the 2009 International Conference on Mobile, Hybrid, and On-line Learning, Cancun, Mexico [1].

The quality and sustainability of the healthcare system in Canada is dependent on the healthcare providers within it. If the system is to remain strong, it is critical that those who provide the services within it are strong and healthy. Unfortunately, downsizing in the Canadian healthcare system has led to extremely heavy workloads for healthcare providers and high levels of burnout. One study showed that 46% of Canadian physicians are in advanced stages of burnout [2]. Another revealed that many new nurses are leaving their jobs within two years of graduation and have symptoms of burnout, depression, and emotional exhaustion [3]. Dyrbye et al. [4] found an association between burnout and an increased likelihood of suicidal ideation in medical students. These concerns resulting from burnout are not limited to the healthcare providers themselves; the well-being of healthcare providers can also impact patient care and satisfaction. Physician burnout has been associated with lower patient satisfaction outcomes and longer post-discharge recovery time. Further, more days are lost per worker each year in the health sector than for any other occupation in Canada [5]; the average number of days lost due to illness or disability is about double for workers in healthcare than in other sectors. The importance of improving the health of healthcare providers cannot be understated.

According to the CanMEDS 2005 Physician Competency Framework, a key competency of physicians is to demonstrate a commitment to physician health and sustainable practice. This involves "balancing personal and professional priorities to ensure personal health and a sustainable practice; striving to heighten personal and professional awareness and insight; and recognising other professionals in need and respond[ing] appropriately"[6]. Through caring for themselves and their colleagues, physicians are able to demonstrate a commitment to their professional responsibilities [7] [8]. Not only is physicians' health a health issue but also a professional one.

In Canada, each province has its own provincial physician health program that provides support to

physicians and their families. Further, in efforts to improve medical student and physician health and wellness at the University of Ottawa, the Faculty of Medicine created Canada's first Faculty Wellness Program in 2000. However, despite the efforts of these programs, many healthcare professionals and students seeking access to health and wellness resources and services are not able to access them or do not even know they exist. Clinicians and students are busy individuals and, due to time constraints and geographic location, many are not able to attend professional development programs that relate to health and well-being. Consequently, the purpose of this project is to develop two online programs—one for physicians and medical students that focuses on physician health and one for healthcare providers (including physicians) that focuses on workplace health—that will (1) provide access to cutting-edge information related to health and wellness, (2) allow the users to evaluate their current fund of knowledge and health status and take action to improve it, and (3) direct the user to online and face-to-face resources and supports. The first step in the project involved identifying the needs of the target users for the two programs. This paper summarises the findings from these needs assessments and provides recommendations for program design and development.

## II. METHODOLOGY

In order to obtain multiple perspectives to inform the design and development of the programs, interviews were conducted with a sample of end-users of the two programs: physicians and medical students for ePhysicianHealth.com and regulated healthcare providers for eWorkplaceHealth.com. Project stakeholders purposefully sampled individuals in order to obtain a wide variety of perspectives and represent gender, cultural, and occupational diversity. Eleven interviews were conducted in total: Six for the physician health program (five individual interviews and one focus group interview) and five for the workplace health program (three individual interviews and two focus group interviews). A total of 30 individuals were interviewed (13 for physician health and 17 for workplace health; see Table I).

TABLE I. PARTICIPANTS' OCCUPATIONS

| **Physician Health (n = 13)** | | |
|---|---|---|
| **Occupation** | **# of female participants** | **# of male participants** |
| Family physician | 2 | 0 |
| Medical scientist | 1 | 1 |
| Medical student | 4 | 4 |
| Medical resident | 0 | 1 |
| **TOTAL** | **7** | **6** |
| **Workplace Health (n = 16)** | | |
| Dietician | 1 | 0 |
| Family physician | 1 | 0 |
| Hospital management | 0 | 1 |
| Medical administrator | 0 | 1 |
| Nurse | 2 | 0 |
| Occupational therapist | 1 | 0 |
| Pharmacist | 1 | 0 |
| Medical specialist | 0 | 2 |
| Physiotherapist | 1 | 1 |
| Psychologist | 1 | 1 |
| Recreational therapist | 1 | 0 |
| Social worker | 1 | 0 |
| Union leader | 1 | 0 |
| **TOTAL** | **11** | **6** |

Interview schedules (Appendixes A and B) were developed by members of the University of Ottawa Faculty Wellness program; subject matter experts in physician and workplace health, healthcare, and workplace learning; and the research team. The interviews lasted 30-60 minutes, were audio-taped with the participants' permission, and took place at a location convenient for the participants. The interviews were transcribed verbatim and the transcripts analysed. In the initial step of the analysis, the transcripts were read and reread and a preliminary list of relevant emergent categories was developed. The researchers read the data until no additional themes or categories emerged. Once the categories reflected "the recurring regularities or patterns in the study" [9] and the researchers were satisfied the themes reflected the views of the participants, the data were assigned to the categories and the findings compiled into a report. Direct quotations were used to preserve the voice of the participants.

## III. FINDINGS

The findings for the two programs (ePhysicianHealth,com and eWorkplaceHealth.com) were similar and therefore are presented together. Where differences emerged they are highlighted. Five themes emerged from the data: learner characteristics, privacy, usability, convenience, and content.

*A. Learner Characteristics*

The interview participants identified a number of characteristics specific to physicians and medical students that should be taken into account when developing the program on physician health. These included (a) physicians are egotistical and therefore there is a need to "appeal to their ego"; (b) physicians and medical students are adult learners that need interaction; (c) physicians and medical students tend to be impatient; (d) physicians and medical students are under enormous pressure; (e) physicians are exposed to the stress of dealing with pain, illness, and death on a daily basis; and (f) physicians and medical students are incredibly short of time and therefore guidelines and/or suggestions (e.g., for living a healthier lifestyle) need to be realistic and practical.

For both programs, participants foresaw a lack of time due to busy schedules and heavy workloads as the biggest potential barrier to healthcare professionals using the programs. One of the two most commonly cited themes in the interviews was that the key information in the programs must be presented in a concise style that takes no more than 10 minutes to cover but that options for delving deeper into the content are included. One physician emphasised, "Short things are powerful, don't be afraid of being short. I would support short modules and linking to other resources".

Participants indicated that it would be a problem, situation, or crisis involving themselves, a colleague, a family member, or a patient that they did not have the tools to deal with that would prompt them to visit an online program on physician or workplace health. For example, a medical administrator reported:

> What would be motivating me [to use an online program] would be an actual problem. Typically, when I go online it is usually to address an issue.… If I have some problems or my colleagues have some problems and [I] don't know how to deal with them … an online module maybe the first place I would go.

Further, one participant pointed out the privacy that can be provided through an online program offers options for physicians and medical students in vulnerable situations. Other participants hoped the program would be a resource they could use with their patients, colleagues, and friends.

Participants agreed that the programs should be online to ensure they are accessible to this busy population and provide a means of accessing resources anonymously. They indicated the target audiences would all have access to high speed Internet and would possess intermediate to high level computer skills, with the exception perhaps of "older physicians". One medical student expressed it this way: "Some of the older doctors who do not have a lot of computer experience may have some challenges. Our generation, everything is about computers,… it shouldn't be a problem". The participants felt that most users would access the programs from home, while a few said they thought the programs would be accessed from both home and work.

Some physicians noted it would be beneficial to receive CME credits for completing the physician health program and felt this would serve as a motivator to do the programs. However, for students this was not an issue as they would not benefit from this. One physician noted it would be helpful to link the program to the CanMEDS competency roles, which would allow physicians to demonstrate how they are developing competencies within each of the roles.

*B. Privacy*

The second of the two most frequently cited themes related to privacy. Participants indicated that participation in the programs needed to be absolutely anonymous and that online programs could offer this anonymity. It was pointed out that learners coming to the site may be in a vulnerable state: "Clinically speaking, people experiencing depression, anxiety disorder, and so on typically feel cornered. Not all of them, but many of them don't feel that they can reach out to get help" (physician). Another physician noted, "[the online environment] is a controlled atmosphere, less anxiety provoking".

Participants emphasised there should be no tracking or any way of telling who has logged onto the site: "Confidentiality is a big aspect for everyone in medicine.... When something is on the computer, everyone can access it. Ten years down the road, 20 years down the road, the leak can happen. There is always a concern" (physician). A nurse further explained, "Confidentiality would be key. Employees need to feel confident that if they do access the information on managing workplace stress, [it] is not somehow coming back to their employer". Consequently, not having a login name and password was preferred by the participants interviewed.

Online anonymity was not the only privacy concern voiced by the participants. Those talking about the workplace health program were concerned about finding a private physical space to access the

program. An occupation therapist noted, "If a computer is in a common space, people could look over your shoulders". That said, many felt they would not have time to access the program at work as many healthcare professionals are busy caring for patients during the day and do not have access to a computer. One physician suggested that the backing of the department might be beneficial to give healthcare professionals time to access the program. Another participant suggested having more computers that healthcare staff could access: "Our staff in the hospital would tell you that they need access to computers and the Internet" (medical administrator).

*C. Usability*

Another oft-cited theme that emerged from the interviews related to usability and having easy access to the programs. Participants suggested the names of the programs and the URLs should be easy to remember and flagged in prominent places. A couple of physicians pointed out that the program is not just about wellness but also illness and cautioned that in order to attract the intended audience, the title of the program should reflect this: "I wouldn't call it 'the wellness site' or 'physician wellness'. It is not only about wellness, but also about recognising some problems too. You need to catch those people who are not well" (physician). Participants advocated advertising the programs in renowned journals, professional magazines, online media, and newsletters. Using key words that would make the programs appear at the top of a Google search was also mentioned, as was having links to the programs on websites the target audience visit often (e.g., Faculty of Medicine homepages, Canadian Medical Association). Participants indicated the programs should be free of charge with no need to login.

Participants noted the programs need to be appealing to the eye and easy to use and navigate, with minimal scrolling and moving from one page to another. A few participants highlighted the importance of having programs that did not require long wait times for components to download. Although some participants expressed interest in seeing the use of cutting edge technology in the programs, the majority appeared to prefer ease and speed over "bells and whistles" that may complicate the use of the programs due to downloading, uploading, or slow Internet speed. One medical student summed it up as follows:

> It definitely would help when there are things on the website you could click on or interact [with]. Sometimes computers load stuff slowly [though]. You won't want anything that is slow. I would like to not have to download too much.

Participants did not feel there would be much need for technical support. One student suggested: "Maybe include an instruction sheet about how to use the website and [provide] contact information [for] when you have problems. I don't think we need much support".

*D. Convenience*

Several participants said they wanted a program at their fingertips that provided a "one stop", just-in-time resource for healthcare professionals needing help or information at any time of day or night. One medical student pointed out the importance of "having all the information in one spot. You don't have to look in all different places, you know the information you are looking for is reliable". Another reiterated the convenience of "knowing that it is a trusted source. This is not something like a Google search [where] you don't know whether the information is valid or not, or some other information [that is] just very general and doesn't really help". The convenience of such a program is especially relevant for healthcare professionals who may not feel comfortable broaching these topics with family members or colleagues due to the sensitivity of the issue.

*E. Content*

Participants provided great insight into the content for the programs. Their responses can be categorised into five sub-themes: engaging, depth and breadth, organisation and delivery, topics, and cultural sensitivity.

*1) Engaging:* Participants emphasised the content in the programs should be concise, relevant, practical, and up-to-date. The content needs to be interesting and capture the users' attention in the first five minutes. One physician commented: "It's got to have a very attractive lure with a very sharp hook or we won't stay online for very long". Another physician suggested this could be achieved by "tell[ing] me something I don't know.… Give me a point of view I hadn't thought about. Put me in someone else's shoes". Many participants stressed the importance of respecting their current knowledge and not talking down to the user. One physiotherapist explained:

> We are educated and we are educators. We know that to keep our stress down we have to eat right

> and get some exercise. Tell us something we don't know, something new, new findings we should be aware of, good resources.… Don't talk down to me.

Ensuring it is "really focused, high quality, [with] good evidence-based [content]" would further work to ensure the program was engaging (physician). Indeed, participants highlighted the importance of involving experts in the content development to add credibility.

*2) Depth and Breadth:* The depth and breadth of the content included in the programs is an important consideration. One group of participants referred to a program that some of their colleagues had taken that was perceived as "a waste of their time":

> They did a little questionnaire, 'Are you depressed?' or something like that. [They were then given] bits and pieces of information that they could look at. It wasn't sophisticated enough. The information was at such a superficial level that if you pick up any of the magazines at the grocery store, you would have exactly the same information on diet, weight loss, and exercise. People are looking for something that can actually make a difference. (occupational therapist)

Although there was a strong preference for relevant content presented in concise sections, participants agreed that the opportunity to go in-depth and learn more about topics should be an option. Time is an important consideration for the target audiences of these programs. Two participants said they would spend a maximum of 30 minutes on the resource and one physician said she would spend up to an hour. A medical student provided this insight:

> If it is just looking for information during lunch time, 10 minutes would definitely be max. But if you are looking for information for more serious issues, trying to learn something to resolve a growing problem for yourself, then you should spend 20 or 30 minutes or a longer time for in-depth information. But not 2 hours.

Participants suggested links to support groups and resources were essential. In particular, participants wanted guidance on where to go for more help. One physician commented the physician health program should provide information on "where to send their colleagues in the situation that they want to help but not take on the problem [themselves]" (physician). Similarly, a medical student suggested, "[Provide] links to help. For example, if you are a medical student [in a specific town or city] here are places/people you can turn to, here are faculty and departments you can go to". One physician suggested including information on Code 99, which helps physicians find their own primary care doctor.

*3) Organisation and Delivery:* In terms of organising content, the following suggestions were provided by the participants: (1) use a table of contents to make finding information fast and easy; (2) provide "need to know" information followed by resources for those who "want to know" information in more depth; (3) be objective oriented; (4) use point form and key phrases and words; (5) organise the content into ten minute segments; (6) provide an abstract that covers the main ideas; and (7) send emails notifying of updated information in a headline format.

Participants also talked about how they would like to see the content presented. Some expressed that they wanted to be engaged in interactive activities using cutting edge technology: "Show off up-front that you have some magic tricks to 'wow' the [user]" (physician). Others indicated they preferred content that was presented in straightforward text that required little or no downloading nor complex technology to access. These participants wanted something that they could read or easily print either for themselves or their patients; they were looking for "a quick link to information" (physiotherapist). A few suggested interactive activities and multimedia would be nice but should be optional. A physician explained: "Sometimes I just want to skim knowledge, other times I may want to listen to a podcast or watch a video". Most participants indicated that time would be an issue if they had to complete interactive activities.

Participants' ideas regarding what kind of features and activities the programs should include spanned the full spectrum of pedagogical strategies:

> I envision those online learning tools, [such as] check boxes, clicking on things, filling the blanks may be appreciated by some people. Multiple choice, rearranging things. For example, [if] someone is mean to me in 10 different ways, how do I rearrange them and target the most important things? (physician)

Other approaches suggested by participants included problem-based learning rather than a didactic approach; reflective exercises—"some of the more intangible values are often best assessed by reflection" (physician); quizzes—though some

physicians did not want quizzes; Powerpoint slide presentations; flowcharts; graphics and diagrams that demonstrate key points—"sometimes difficult things can be conveyed in a way that it is more visual" (physician); cartoons; audio and video; and role playing—"say one has a certain type of situation, how to deal with this situation, how others reacted" (medical student).

The form of content presentation that all participants were receptive to was short video vignettes portraying stories of colleagues who had overcome similar problems that they might face. One medical student suggested: "two or three minute vignettes for, not a serious problem but sort of a moderate range problem, that could maybe have the individual experience some revelation about the a minor change they can make". Case studies, success stories, and testimonials were also mentioned by participants.

Several participants indicated that self-assessment exercises would be helpful, as would checklists that would allow them to identify warning signs and symptoms. One nurse said she would like self-assessment activities that would allow her to diagnose her problem and then provide solutions to solve it: "I can see some self-assessment questionnaire. For me, if I am feeling obsessively anxious then I would like to have something that tells me, 'Yes, you are anxious and you need this and you can benefit from this'". Self-assessments would also be an effective way of providing feedback on learning. One physician noted, "[Physicians] like getting feedback. They like to feel they have mastered [something] and then go on". Another noted, "Personally, I like real time feedback. Keeping track of how things are going". A medical student suggested that whether or not you provide feedback and what kind of feedback you provide depends on how the resource is being used: "If you use it for self-help or assessment of somebody else, you may not want any feedback. If you are doing it for learning purposes, to get educated, that is different".

Although many participants acknowledged the benefits of having online discussions in the programs, participants recognised that there would be too many issues related to physician or patient confidentiality to include them. One physician reflected, "We could have an area for discussion or blog type post or using a wiki where things could be updated by the users. [But you would need to] take into consideration confidentiality; the question is how it could work?".

*4) Topics:* A variety of topics were suggested for inclusion in the two programs. For the physician health program, four areas related to health emerged: mental, emotional, professional, and physical health. The most common topics mentioned by participants were mental health issues such as depression, suicide, stress, anxiety, burnout, and substance abuse. The second most popular topics mentioned related to emotional health issues and included family management, relationship management, issues associated with different minorities, sexual orientation, the transgender community, culture and gender, emotional intelligence, family illness, and living or working with chronic illness.

Professional health was also deemed extremely important by participants. This category included topics such as disruptive behaviour, time management, financial planning and managing debt, physician-patient boundary issues, choosing a residency and getting through it, legal issues, conflict resolution, and support for international medical graduates to help them transition into the Canadian culture and ensure professionalism. One physician summed up the types of content she would be looking for in the program:

> Not only diagnostic categories but some life management categories, such as how do I manage time?… How do I manage if there is too much work? How do I cope with the stress of family members when I am juggling three jobs? How do I cope with my crazy teenagers? What if I only have 20 minutes to exercise?… In the end, the management category is practical,… not just the illness but the wellness side is helpful.

Physical health issues, although not mentioned as frequently, were also deemed important by several participants. Topics included fitness, relaxation techniques, heart disease, and blood pressure.

Several of the topics suggested by participants for the workplace health program were the same as those identified by participants for the physician health program: stress, physical and mental health, time management, conflict resolution, professionalism, teamwork/relationships, and disruptive behaviour. Additional topics identified for inclusion were bullying, flu vaccine, fatigue management, dealing with the loss of a patient, care for the caregiver, manners, etiquette for sending email, how to run a committee, working in an interprofessional team, pandemic preparedness, and compassion.

Interview participants for the workplace health program were asked what factors in their work life most influenced their mental and physical health. Workload, environment, and relationships were the three factors that emerged. Workload was the most commonly cited stressor. The number of patients the healthcare providers had to see in a day meant that sometimes they were not able to give all the patients the time and attention they wanted to and this was a source of stress for them. Moreover, they noted that not having the autonomy to be able to decide when to eat lunch, when to go on vacation, or when to be able to go to the bathroom affected their health.

The physical environment (e.g., lighting, ventilation, mould, infection control, having an office window, and access to adequate bathrooms) was identified as a cause of workplace stress for many healthcare providers interviewed. One medical administrator stated:

> The type of space you have, whether you have access to external light, clean air, and water [affects your stress level]. We have a number of older facilities and we have facilities that are going through transition, renovation, and whatnot, so that certainly has an impact on [the staff's] stress level.

Relationships in the workplace clearly affect health. All participants discussed how their immediate supervisor, colleagues, and the people they work with have a significant impact on their workplace health. Much of the stress identified appeared to be related to the organisation's administration and management style and policies (e.g., slowing the hiring process to reduce the deficit, establishing policies regarding absenteeism, not being recognised for the contributions made in the workplace). One nurse felt that workplace conflict is one of the highest stressors.

*5) Cultural Sensitivity:* Participants indicated the programs need to be sensitive to gender and cultural issues. One physician said:

> Building something to reach everyone is a challenge. I hope there are a lot of sensitivities to this issue. Maybe the speakers could represent different cultural, religious, and gender groups. People who feel ostracised are likely people who would feel depressed and anxious. Chances are people from different cultures may want the least intrusive way to deal with this online.

Participants pointed out the importance of being sensitive in the materials and resources chosen. One medical student suggested: "If you give out links to articles and those articles always concern white middle-age men that may be a problem. You need variety in the links and examples so that it concerns different genders, cultures, and backgrounds". Similarly, a physician stated: "We have to be really sensitive to the context, the scenario, the vignette, the name chosen. Make sure different culture issues are covered".

Recognising the two official languages of Canada, participants suggested the programs should be bilingual; though they acknowledged the cost of this and thought this could come in a later phase. One physician noted, "It would be interesting to have culturally sensitive vignettes in both official languages".

## IV. CONCLUSIONS

It was clearly apparent from the needs assessment for ePhysicianHealth.com and eWorkplaceHealth.com that the needs for the two programs are very similar. Three possible explanations for the similarities are: (1) the content in both programs will be very similar as it will address the health of healthcare providers; (2) the target audience for both programs is busy adult healthcare professionals; and (3) interview participants for eWorkplaceHealth.com included physicians so the views of physicians were obtained for both programs. However, the other healthcare providers (i.e., nurses, physiotherapists, occupational therapists, psychologists, recreational therapists, social workers, and medical administrators) had similar perspectives to those of the physicians with regards to what they felt they and their colleagues wanted and needed with regards to the online programs.

The two most common findings for the two programs that were voiced loud and clear were (1) that the information must be presented in a concise style that takes no more than 10 minutes to cover with the option of delving deeper into the content if desired and (2) individuals' participation in the programs must be anonymous. Other key findings were that the programs needed to be easy to find and access; be easy to use; and contain evidence-based, meaningful, practical content.

## V. RECOMMENDATIONS

The following is a summary of the recommendations for the design and delivery of the two programs:

- Present content in a concise style that takes no more than 10 minutes to cover
- Provide optional exercises, resources, and activities for learners who want to delve deeper into concepts
- Ensure there is no way of tracking who is using the programs so users are anonymous
- Provide the necessary content in one convenient location
- Minimise scrolling and page turning
- Ensure the programs are easy to use
- Provide options for users to partake in more complex and sophisticated activities
- Include evidence-based, meaningful, practical content
- Make use of videos vignettes
- Provide links to support groups and resources
- Ensure it is easy to print documents for personal use or for use with colleagues or patients
- Ensure gender and culture sensitivity
- Select a URL that is easy to remember
- Tag the programs to ensure they are easy to find through a Google search
- Advertise the programs in renowned journals, professional magazines, online media, and newsletters
- Link the content in the physician health program to the CanMEDS competencies

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APPENDIX A

Interview Schedule for ePhysicianHealth.com

We understand that you are very busy and we really appreciate you taking the time to be interviewed today. In this interview we hope to obtain information that will be used to guide the development of an e-Curriculum in Physician Health in the Faculty of Medicine at the University of Ottawa. The purpose of the program is to provide medical students and physicians with convenient and private access to relevant learning resources that will address issues such as mental and physical health, disease prevention, health promotion, and self-care. It is part of the project's vision that users have access to high quality, cutting edge, and practical learning resources and sources of support anytime, particularly in a time of reflection and/or crisis.

The information you provide in this interview will be shared with the program development team and used to inform program development.

Structure

1. If you wanted or needed information on physician health including topics such as substance abuse, depression, or anxiety either to help yourself or to help others, what would motivate you to access an online learning resource?
2. What characteristics should this program have?
3. Are there specific things that should be considered when designing such an online program for physicians and medical students to ensure that it will address their needs and meet their expectations. If so, what are they?
4. Do physicians and medical students have specific learning characteristics that need to be considered when designing an online program to ensure that it will address their needs and meet their expectations? If so, what are they?
5. What types of learning strategies do you think should be used in this program?
6. What ethical issues need to be considered when designing this program?
7. Are there gender, cultural, or other issues that need to be considered?
8. What type of feedback, if any, would you want about your learning progress during such a program?
9. What type of interactivity would you want in such a program?

Content

1. What content would you like to see covered in this learning resource? What top three to five topics would you like to see included? What would you use?
2. What learning needs do you feel should be covered?
3. Are there language issues that should be considered when designing this course?

Media

1. Do you (or do you think other physicians and medical students) have any concerns about learning online/doing an online program? If so, what are they? Probe: ask specifically about confidentiality and privacy in a follow-up question.
2. What type and amount of interaction would you like to have (or think other physicians and medical students would like to have) with the material online?
3. Where do you see yourself (and colleagues) working online? (Home, at work, or somewhere else)?
4. What is the ideal amount of time that you (and/or your colleagues) would spend working on the program at one time?
5. Would you have access to high speed Internet?
6. What types of tools would you like to see used? (e.g., communication, game-based activities, reflection activities, self-assessment)
7. What level of computer experience would this target audience have?

Service

1. What support do you feel you and/or your colleagues need in order to make the online learning program successful?
2. What benefits could this program offer you if you were to engage in it?
3. Do you have any other comments that may help in the design and delivery of the program?
4. Would this program be of interest as an elective for undergraduate training? Could it supplement existing curricular activities?
5. For physicians only: How important is it to earn CME credits for a program such as this?

Thank you for your time!

APPENDIX B

Interview Schedule for eWorkplaceHealth.com

We understand that you are very busy and we really appreciate you taking the time to be interviewed today. In this interview we hope to obtain information that will be used to guide the development of an e-Curriculum in Workplace Health for the Champlain LHIN. The purpose of the program is to provide all health professionals with convenient and private access to relevant learning resources. The resource will provide an introduction to workplace health and useful information and tips to help you take care of yourself, your colleagues, and function more effectively in the workplace. It is part of the project's vision that users have access to high quality, cutting edge, and practical learning resources anytime, particularly in a time of reflection and/or crisis.

The information you provide in this interview will be shared with the program development team and used to inform the design, delivery, and evaluation of this learning resource.

Structure

1. What are the factors in your work life that most influence your mental and physical health?
2. If you wanted or needed information on workplace health, including topics such as how to take care of yourself, take care of your colleagues, and function more effectively in the workplace, what would motivate you to access an online learning resource?
3. What characteristics should this program have?
4. Are there specific things that should be considered when designing such an online program for health professionals to ensure that it will address their needs and meet their expectations. If so, what are they?
5. Do health professionals have specific learning characteristics that need to be considered when designing an online program to ensure that it will address their needs and meet their expectations? If so, what are they?
6. What types of learning strategies do you think should be used in this program?
7. What ethical issues need to be considered when designing this program?
8. Are there gender, cultural, or other issues that need to be considered?
9. What type of feedback, if any, would you want about your learning progress during such a program?
10. What type of interactivity would you want in such a program?
11. To what extent do the conditions of your work influence your health?

Content

1. What content would you like to see covered in this learning resource? What top three to five topics would you like to see included?
2. What learning needs do you feel should be covered?
3. Are there language issues that should be considered when designing this course?

Media

1. Do you (or do you think other health professionals) have any concerns about accessing an online resource? If so what are they? Probe: ask specifically about confidentiality and privacy in a follow up question.
2. Where do you see yourself (and colleagues) working online? (Home, at work, or somewhere else)?
3. What is the ideal amount of time that you (and/or your colleagues) would spend working on the online resource at one time?
4. Do you have access to high speed Internet?
5. What types of tools/activities would you like to see used? (game-based activities, reflection activities, self-assessment)
6. What level of computer experience would this target audience have?

Service

1. What support do you feel you and/or your colleagues need in order to make the online resource successful?
2. What benefits could this program offer you if you were to engage in it?
3. Do you have any other comments that may help in the design and delivery of the resource?
4. Would this program be of interest as an elective for undergraduate/prelicensure training? Could it supplement existing curricular activities?

Thank you for your time!


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