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CONTENTS

Improving Cross-Curricular Skills in Web Services: Virtual vs. Attendance Environments

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Abstract— ***Web services* is a mainly practical software engineering subject which is followed by Computer Science and Telecommunication Engineering students at the University of Extremadura. It is an advanced topic and therefore it is taught in the last years of the engineering, in which the student already has the capacity of learning a lot of concepts by themselves. Although the transmission of the main theoretical and practical concepts of the subject in question must remain the main focus, the improvement of students' general skills claims for special attention with a view to business requirements. Besides, the mobility of teachers and students among European universities has increased notably, which is a very positive experience for both communities. In this regard, new educational alternatives have to be found for this purpose, not only to provide the possibility of studying a subject abroad, but also to improve cross-curricular skills. It is also a reality to be taken into account that an increasing number of students are already working in the industry while following up their studies. E-learning environments are the perfect answer to these requirements, where a varied range of activities and methodologies can be used to follow the subject virtually as well as promote general cross-curricular skills such as addressing an audience, team work and preparing documentation. In this sense this paper describes the author's experiences with e-learning environments in the situations described above and compares them with previous experiences in which only attendance lectures where available for students.**

Keywords- **Virtual Environments; Attendance Environments; Web Services; Teaching Experience; Cross-Curricular Skills.**

I. INTRODUCTION

Web Services is a mainly practical subject, specially focused on the development of distributed applications which will be implemented and will communicate with each other under the Service-Oriented Architecture. It is an advanced subject which is followed by advanced students, that is, students in their last year of the Computer Science or Telecommunication Engineering degree. In this scope, it is quite common that students start working before they have finished the degree, or even that they start studying a new one once they have started working and this induces that the subject students might have schedule problems to attend the lectures on a regular basis due to their work commitments.

On the other hand, the mobility of teachers and students among European universities has increased notably: regarding the teachers they often have to attend several conferences to exchange their research ideas with other experts in the matter and it is also becoming quite common for teachers to go for research or teaching stays abroad for several months. In the case of students, the most common situation is that they are awarded an Erasmus scholarship and spend at least one year in a foreign university. Both positions are very positive for teachers and students and shouldn't be avoided for the sake of not missing lectures.

On the other hand, the European Higher Education Area (EHEA) demands the inclusion and improvement of student cross-curricular skills [2, 6]. The lack of experience of technical professors in this area, as well as the innovation of this proposal, makes it difficult the correct adoption of the named capacities by the students. Even more, since most of the cross-curricular capacities involve the interaction with other persons, the development of such abilities in a non-attendance situation becomes a real challenge.

In this regard, we have to look for new alternatives under the scope of the EHEA, so that education can be followed up without a mandatory requirement of attendance to lectures, and which, at the same time, lets us improve students' cross-curricular skills. Both tasks are already a challenge, but when faced together the challenge is even bigger. Education through e-learning environments was already approached by several authors in various interesting approaches [3, 4, 7, 9, 12] and we can also find some comparisons between virtual and attendance environments [1, 5, 8, 14]; however, most of them do not consider cross-curricular skills.

In this paper, we are going to see how this problem was tackled for an optional subject called *Web Services* offered in the Computer Science and Telecommunication Engineering at the University of Extremadura in Spain. We will describe the experience of the author and what the results obtained were. We will extend our previous work in [11] by comparing this experience with previous years experiences, in which virtual environments where not available, evaluating the benefits and drawbacks of virtual lectures versus attendance ones.

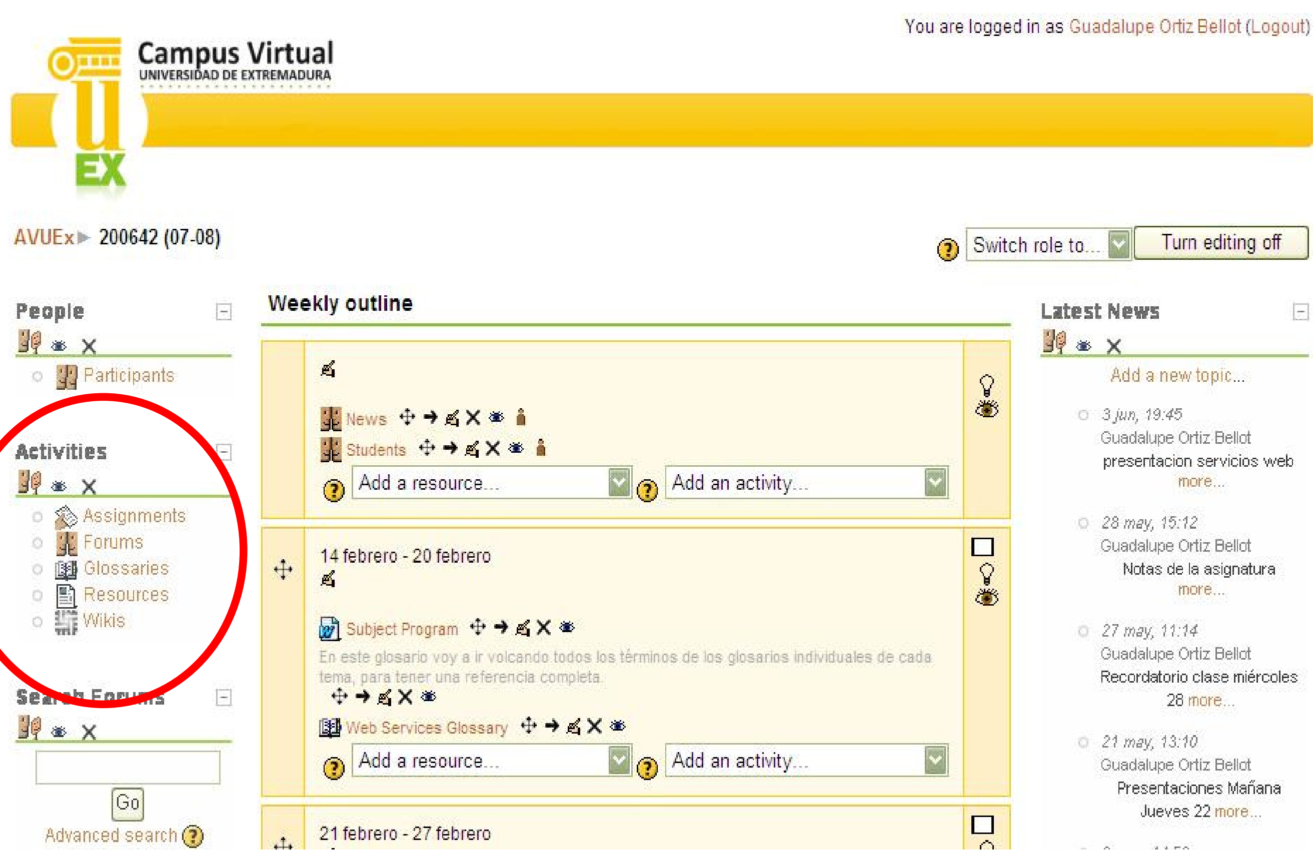

Fig 1. Activities available in the UEX Moodle environment

This paper is organized as follows: chapter 2 describes the subject Web Services according to its professional profiles and associated skills. Then, chapter 3 explains briefly the virtual environment available at the University of Extremadura. Chapter 4 explains the activities which were developed in a virtual and attendance mode in the scope of the mentioned subject during different academic years. Then, chapter 5 discusses the results of the experience and compare the two teaching ways presented. Finally, chapter 6 summarizes our proposal.

II. PRELIMINARIES

In this section we are going to describe the subject in which the e-learning experience has being carried out and which are its curricular and cross-curricular skills in order to analyse in the following sections how virtual environments could be used to improve such skills and carry out lectures virtually.

Web Services is particularly connected to three professional profiles: *design and development of telecommunication services, design of distributed applications oriented to the administration and electronic commerce* and *teaching and research for the development of new technologies and services.* The *skills specific to the qualification* which are mainly linked to this subject are *to know and design tools related to security in communications and networks, designing communication software incorporating the new technologies TIC to productive processes in the business* and *knowing and applying scientific and technological base knowledge to adapt to technological changes.*

Specifically, the content taught in this course is enumerated below:

Unit 1. Web Services Introduction
- 1.1. Web Services Overview
- 1.2. The Interoperability Problem: Walking toward the Web Services
- 1.3. Service-Oriented Architectures.
- 1.4. Adapting Architectures.
- 1.5. Web Service-Oriented Architecture.
- 1.6. Web Services Applications.
- 1.7. Types of Web Services.

Unit 2. Web Service Standards
- 2.1. SOAP
- 2.2. WSDL

2.3. UDDI
Unit 3. Web Service Compositions
3.1. Choreography
3.2. Orchestration
3.3. Enterprise Service Bus.
Unit 4. Web Service Modeling
4.1. WSDL-based Approaches
4.2. Service Component Architecture
4.3. Model-Driven Architecture
Unit 5. State of Art of the Web Services.
5.1. Platforms
5.2. Advantages and Drawbacks
5.3. Limitations
Unit 6. Building and Deploying Web Services with Java-based platforms.
Unit 7. Building Web Services with .NET
Unit 8. Building Web Service Clients for Mobile Devices.

In any case, the content of the subject is not relevant for the purpose of the paper, but the cross-curricular skills and skills are.

The *cross-disciplinary skills* related to the professional profiles to which this subject is normally linked are the following: *development I+D+I*, *design and analysis of telematics applications and services, managing telematics products and services*, *application of the learned technologies and their integration into the socioeconomic structure*, *interaction with users* and *responsibility for own learning*.

Based on these skills, the objectives established with regards to the academic and disciplinary abilities are the following:

- To introduce the student to the Web service technology, their standards and their development tools as well as the way to model and compose them.

- Besides, students have to be able to research on the named technologies and to be able to acquire and apply new knowledge in the area.

After studying the general personal skills of the degree and the specific disciplinary ones considered in this subject we concluded that suitable objectives with regards to personal and professional skills are the following:

- To develop the ability to understand, and enable others to understand, knowledge related with Web service technology, to be able to learn themselves about the named technology.

- To be able to work as a team effectively.

- To be able to acquire Web service related knowledge when provided in English.

III. THE VIRTUAL ENVIRONMENT

This section will describe the virtual environment adopted in the University of Extremadura (UEX) and the different modules which are available in it [16].

The University of Extremadura has embraced Moodle [15] and has offered to the university community several configurations depending on what the virtual environment is going to be taken advantage of. It is important to mention that not all Moodle modules are available for its use in the University of Extremadura system, therefore, according to

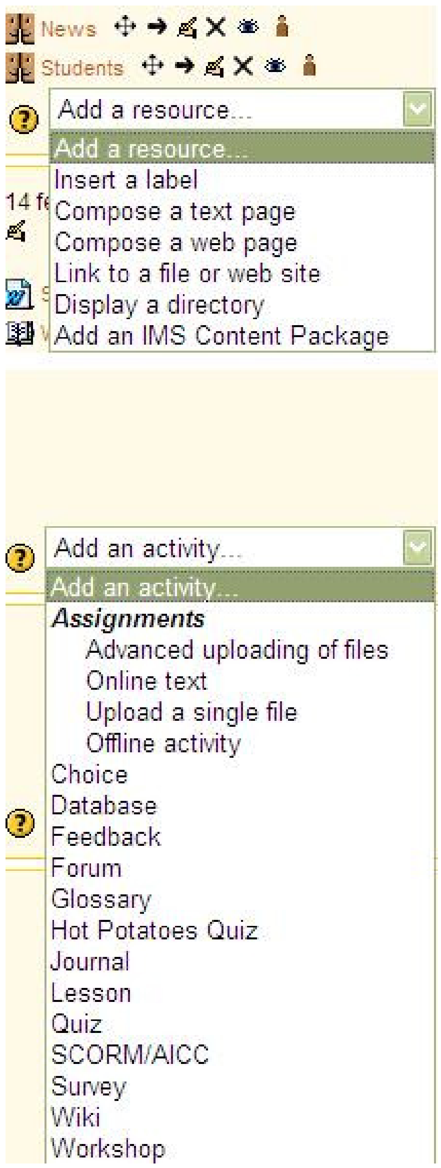

Fig 2. Resources and activities

the university rules, we have had to limit the use to those modules habilitated in this system.

Particularly, for the degree subjects, there are currently several virtual elements available, enumerated in the following lines - and some of them shown in the left-hand side of Figure 1:

- Files repository and resources: the teacher can upload any file and may or may not make it available for the students at any moment.
- Forums: the teacher can create several forums. For each of them he may decide between three different possibilities: forums in which only the teacher can write, forums in which the teacher is the only person authorized to start a topic and the students can comment on it and those where both teacher and students can start a topic.
- Wikis: the tutor can create wikis so that students can interact with them. The platform saves the historical data of the wiki so that the teacher can evaluate the students' progress. Usefulness of wikis has been described in previous works such as [13].
- Questionnaires: the teacher can elaborate several types of questionnaire in this platform –true/false, multiple choice, etc- The students can see at the end of their attempt the mark they got and also what would be the right answers. Limited slots of time can also be established for these activities.
- Delivery activities: some tasks may be requested by the students and uploaded onto the platform. They may or may not be set as "visible" for the rest of the students.
- Glossaries: the teacher can propose to elaborate a glossary for each lesson or for a general topic, so that the students can inspect on detail the meaning of the main terms used in the dealt scope and check them whenever they need to.

There are more resources and activities available, as we can see in Figure 2, but we are not going to describe all of them since they are not relevant to this paper.

IV. ACTIVITIES

In this section we are going to describe the different activities followed during the course Web Services: *Subsection A* in virtual environments and *Subsection B* in attendance ones.

It is important to mark that the different types of activities were being selected during the academic year: since it is a very dynamic subject, depending on the topic of the day and the previous experiences with the students, the more appropriate activities were introduced.

A. Activities in Virtual Environments

For the Moodle configuration, first of all, we opted for a weekly distribution. This way, the topic that is being worked during every week of the course could be easily be identified by those students who cannot attend the lectures. In this regard, every week there were available different kind of documents and activities. For instance, as depicted in Figure 3, first week we only have a planning of the subject and a global glossary, but in second week (Figure 4), we can already find several documents for theoretical and practical

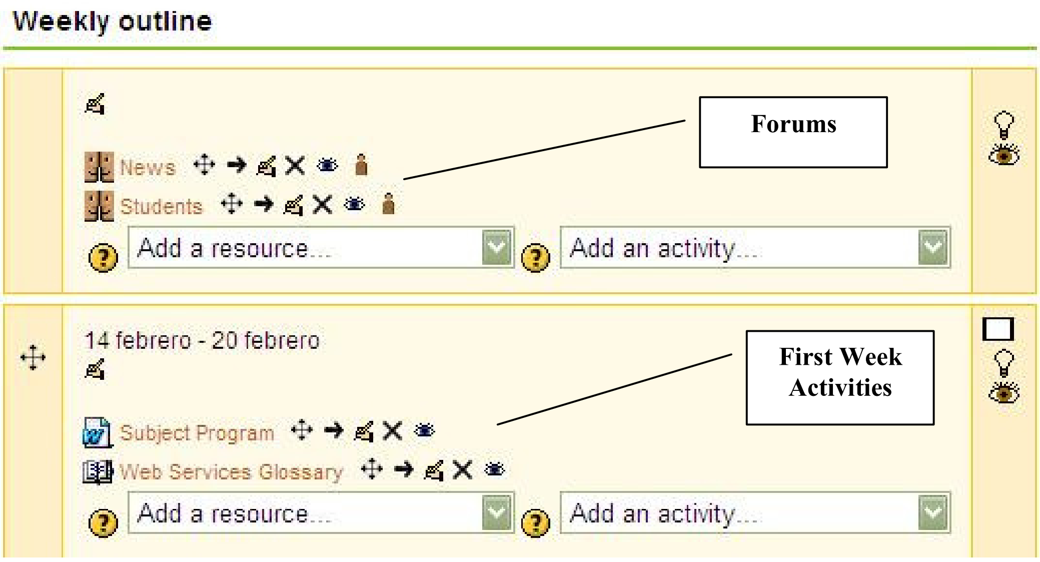

Fig 3. Forums and first week activities

lectures and additional activities, which will be described later on this paper.

We can also see in the very top of Figure 3 that we have two available forums:

- News: this forum let the teacher to comment any new about the subject. In this sense this forum may be used not only for indicating which activities to be done are new, but also to establish reminders for those students who can not follow the subject with continuity. Besides, it is very helpful for those students who can not attend the lectures so that they do not have the feeling of being uninformed.
- Students: this forum is especially useful for students to post their opinions, comments and questions for the whole participants of the course. This way it may be the students who answer these questions to their partners or who provide comments or suggestions through this platform.

Figure 4 shows us the current development of the initial weeks of the course. Since we had to give them a theoretical and practical foundation of the course, we provided them with several deliverable documents with this purpose (Lesson 1, Lesson 2, etc). These documents are explained and discussed in the classroom, but can also be followed up by the students who cannot attend them. We can also see that

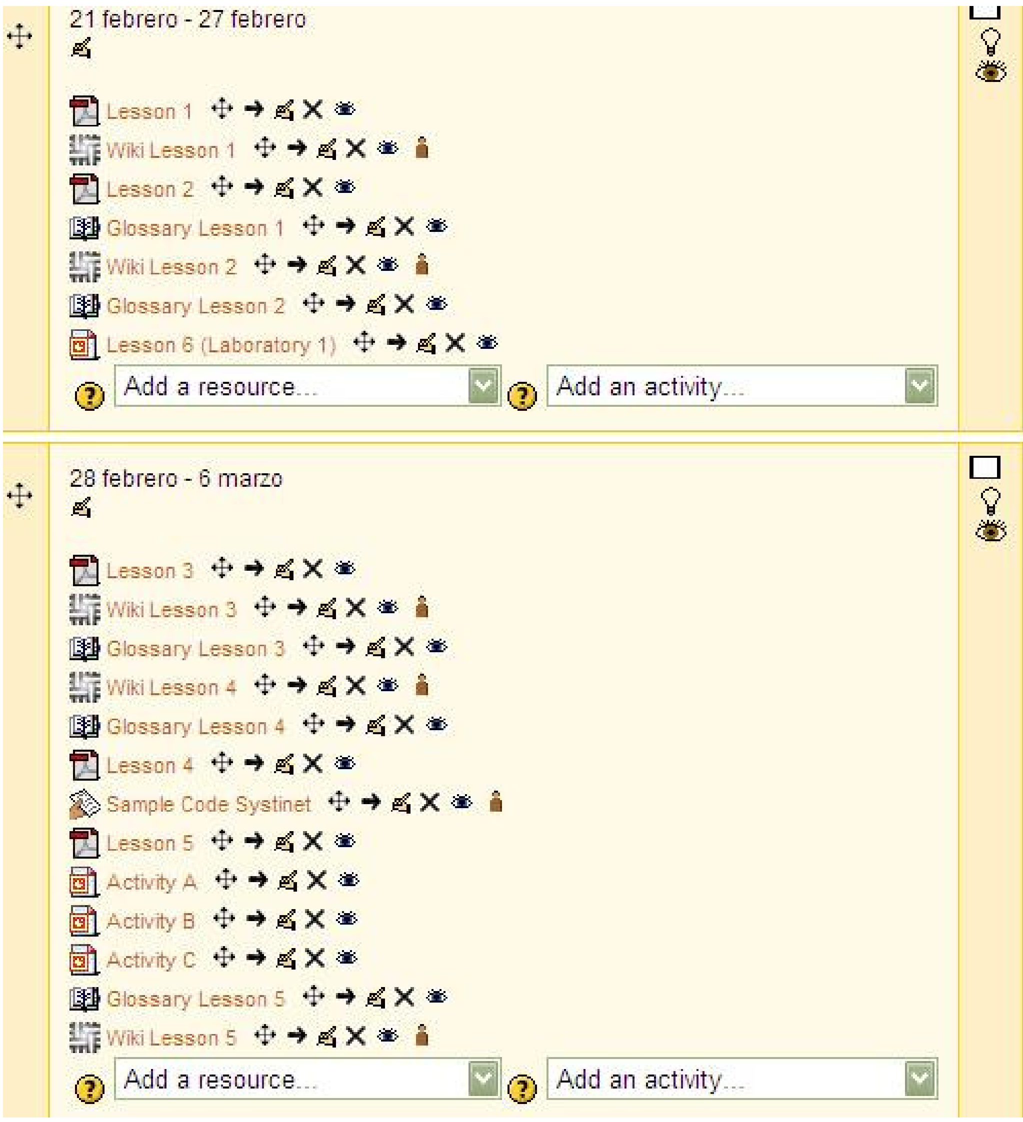

Fig 4. Activities in the initial weeks of the course

for every lesson we proposed two interactive activities to the students: wikis and glossaries:

- A wiki was created for every lesson so that the students could enlarge their knowledge on the topics treated during the lesson in question. The work is done individually but shared with the remaining participants on the course so that the knowledge is built in a collaborative way. Since there is a unique document in the wiki, the students have to read what was inserted in the document by their partners and add new information to it. It may be that some of the advanced knowledge included in the wiki has already been discussed during the lectures, and this is a way to make this information available to the non-attendance students. On the other hand, the latest may also add a different point of view on the advanced knowledge or, even if they are working in the industry, a more business-oriented vision.

- Besides they were also provided with a glossary per lesson. The glossary is also a constructive activity which has to be built in a collaborative way. The students will add all the definitions they consider important for the understanding of the lesson. It is a hard work to be developed by an only person, but when built in conjunction with the remaining partners is a light workload which reports a great compilation of definitions which suppose a wonderful help when studying the lessons.

Finally activities A, B and C are activities to be done in groups of 3 to 4 persons. This work is developed during the classroom schedule so that the teacher can observe the performance on the group. The students works this way in a more relaxed scope and feel confident to go one step forward in their opinions on the lesson, what definitely improve their knowledge. Later on, the group will present the conclusions they have obtained to the remaining of the classroom. Besides, they will make these conclusions available in the virtual platform for the non-attendance students.

Once the basis knowledge has been discussed and assumed by the students, it is time for them to work on their own. For this purpose they will develop several works (see Figure 5):

- On the one hand, they have to do various practical exercises with several development platforms (Axis, Systinet, .and Net). In order to do it they are provided with various documents – in English- with the instructions for installing the software, basic examples to get familiarized with the platform and the information related with the exercise to be developed. This information is available in the wiki and therefore is accessible for both the attendance and non-attendance students. The questions related with these activities can be done through the platform forum, so that other students who may have the same questions can see their answers.

Fig 5. Advanced weeks activities.

Fig 6. Final week activities.

- On the other, they have to do a work in a team "outside" the classroom schedule. This allows students who cannot attend lectures due to their work schedule, to meet their classroom colleagues at a suitable time, therefore improving the interaction among the classroom students. Special groups are done for those students who are abroad: they will have to do separate parts of a work and then to integrate their parts with each other through virtual or collaborative tools.

The practical exercises results will be delivered to the teacher through the platform, so that he will be able to revise them using the online platform by giving marks and making suggestions that will be available for the students who are participants of the online course. In regard with the work in team, the final document and implementation will also be available in the virtual environment, so that the remaining students can benefit from their colleagues research to learn. Besides, every team will do their work presentation to their partners and teacher, explaining the obtained results, generating a final discussion on the topic. Students who cannot attend to the scheduled presentation will be allowed to do a virtual presentation and to answer to the questions the remaining students may do through the platform. Finally, non-attendance students will comment the remaining works in a forum. The authors will also be able to answer through the forum in question (top week of Figure 6).

At the end of the course all the students can follow a final questionnaire, in which to check the knowledge they have acquired in the subject (shown in lower week of Figure 6). The main purpose of this questionnaire is the students to realize that they do know how to answer some questions about a topic they did not know at the beginning of the year. The result of the questionnaire is a minimum part of the assessment of the student. Assessments are built based on their fruitful participation in all the activities proposed in the virtual environment.

B. *Activities in Attendance Environments*

Even though there is not always a clear correspondence between activities in virtual environments and in attendance ones, we explain here how do it in our Web Service module. Table 1 shows the equivalences described below simplified. Further information on attendance activities can be found at [10].

First of all, news and forums, which are easily addressed through a virtual tool, are implemented in attendance environments by simple advices or comments during lectures. This implies that for most of them no written evidence is saved.

On the other hand, attendance activities are mainly based on *magisterial lectures*. Web Services, being a third year subject, needs fewer magisterial lectures than for instance a first year subject. The same theoretical information that was provided through the virtual platform for the students to download and read it is provided here during the lecture and briefly explained to them. Afterwards, a discussion on the topic replaces the quiz we proposed for the virtual platform. A written test could have been followed for this purpose; however, since in the attendance environment we have the chance to discuss openly, we considered it more beneficial for students than the traditional written test.

Besides, in order to elaborate knowledge in common, wikis can be replaced by team work. The team can discuss on the topic during the lecture and afterwards go on searching additional information to complement the original one. With this information they can elaborate a final document which can be presented and discussed with the remaining students during the following lecture.

Regarding glossaries, they can be implemented by different work groups and then distributed in the classroom. It is a nice option to have a printed glossary to discuss during the lecture and make notes on it, but I would say it is even better to build it gradually in the virtual platform and keep it saved for the rest of the academic year.

Additionally, several activities can be carried out in this format during the lectures such as discussion and debates. In this sense, the teacher may propose several topics for discussion and then students have argument their proposed solutions. This way, they improve the skill of addressing an audience strictly speaking, versus the option to do it through their participation in a virtual forum. Role plays are in the same line, once the roles are assigned and the problem is described by the teacher, performance can be developed during the lecture time. This activity could also be conducted through virtual forums, but with extra difficulty. Finally through judgment simulation, professional behaviours can be judged.

Students should also be able to present the learned topics correctly; to do so first of all they can elaborate a presentation through slides and present them in the slot time proposed for it during the lectures. Afterwards a discussion can be followed up. The advantage here is that the discussion is followed up exactly after the presentation when the topic presented in still fresh in their mind; in the virtual environment, the discussion lasts more time and the ideas are not fresh for everybody in order to establish a fruitful debate. However, virtual option provide the students with the possibility of reading again those parts of the presentation in which they are interested or they have doubts and they have more time to assimilate its contents to get ready for discussion.

Virtual Activities	**Attendance Activities**
News and forums	Advices and comments
Theoretical deliverables + quiz	Magisteral lecture + discussion/test
Wikis	Team work
Virtual glossary	Work group glossary
Virtual forum	Open discussion/role play
Presentation slides + forum	Presentation + discussion
Group research	Group research
Laboratory tasks + forum questions	Laboratory tasks + alive questions
Virtual test	Written tests

Table 1. Equivalence between virtual ad attendance activities

Concerning group research, in any case is done outside the classroom, so its functioning is quite similar to the analyzed in the virtual environment. The only difference is that the exposition of the developed work is not virtual. In this case the same considerations described in the previous activity apply here.

Regarding laboratory activities, the teacher can provide the students with the main principles and some helpful information and references at the beginning of the lab task. Then the students can start with the task during the lab scheduled lecture and ask any doubts they have. Afterwards they go on with their task on their own. Thus, the main difference here is that doubts are asked presently instead of through the virtual environment.

Theoretical exam and practical exam can be carried out in the traditional way, in a present session.

V. RESULTS OF THE LEARNING EXPERIENCES

In this section we are going to describe the first impression from the results that were derived from the teaching procedure in the virtual environment (subsection A), then we will compare the results with the ones obtained when teaching the same subject in an attendance environment (subsection B) and finally we will summarize the lessons learned.

A. First Evaluation of the Results using Virtual Environments

With the teaching methodology followed through the use of the virtual environment we obtained the following results:

- First of all, the students could successfully improve their cross-curricular activities, thanks to their practice during the virtual environments, in which they had to acquire knowledge by themselves (in English or Spanish), to talk to an audience (small when working in teams, bigger with the whole course), working in team (with and without supervisors), etc.

- Students who were working and had schedule problems to attend the lectures or students who were abroad, that in other situation wouldn't have been able to follow the subjects, finished it normally and even they got good marks. Most of time happens that working students experience in the industry gives them quite a higher view on the subject-related knowledge and therefore, even though they have the handicap of not being able to attend the lectures, they normally are very successful with the subject.

- On the other hand, we are all aware that most of the students are reluctant to participate during the lectures. The virtual environment makes this labour easier for them, since they can take their time to express what they think and then write it in the forum or in the wiki. Besides, once they get comfortable with the interactive activities, and especially when they know that the participation is mandatory, they start providing very interesting comments and analysis.

- Eventually, although they have to work harder from the very beginning of the academic year, they realize that they learn and acquire more concepts more easily than they used to. They soon feel confident enough to ask any doubts; and this is not quite a usual atmosphere in the university scope, even through a virtual environment.

Once the year ended, the results showed that all the students who followed regularly the subject passed it with a good mark. The ones who decided not to participate in the weekly activities did not even show up in the exam. Besides, the students showed a great improvement in cross-curricular skills and self-learning from the beginning to the end of the year, especially in talking to an audience. In this regard students cross-curricular skills were evaluated through their participation and behaviour in the different activities proposed during the module; the results obtained were around 10% better than in previous years, in which they followed a unique final assessment. Therefore, we can affirm that the methodology presented improved not only cross-curricular skills, but also efficiency in learning the subject contents through virtual e-learning environments.

B. *Comparing Results using Virtual versus Attendance Environments*

On the one hand we can compare the marks obtained by the students. According to the Spanish scale, marks are subdivided in the groups shown in Table 2, where marks below 5 are failed, and 10 is the best mark which can be obtained.

Value	NP	[0,5)	[5,7)	[7,9)	[9,10)	10
Mark	NP	S	A	N	S	MH

Table 2. Equivalence between Numeric Assessments and Final Marks

The marks obtained by students in two consecutive courses, the first with attendance lectures and the second with virtual ones, are shown in Figure 7. In it we can see that the percentage of students who decided not to follow the subject and not to present their tasks is bigger in the attendance mode (NP). Some of these students were already working in the industry and they could not attend lectures, therefore it was not easy for them to follow the subject. The students in that situation in the virtual subject, could follow it through Internet and finish the subject successfully.

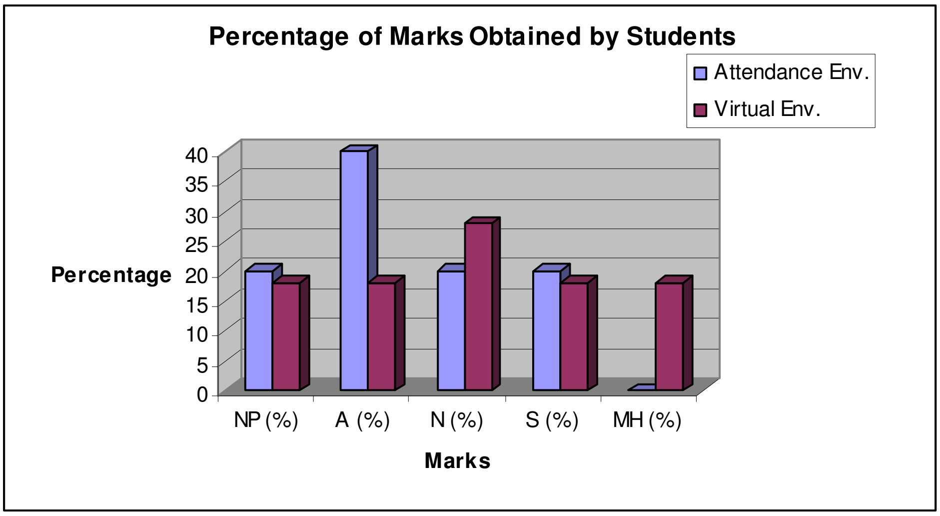

Fig 7. Percentage of Marks obtained by Students in Virtual And Attendance Environments.

We can also appreciate in the mentioned figure that the marks are significantly better in the virtual environment academic year (nearly two points over the attendance year). We consider that this figure is due to the freedom the students feel in order to participate in the activities when working with a virtual tool. We all know students may feel insecure of themselves and are reluctant to participate actively during lectures because of this reason. When they have the option to meditate or document their opinion about a subject previous to their participation (i.e in a virtual forum) they feel more confident and their participation increases.

We can also analyze how they worked and improved the cross-curricular skills mentioned in Section II, taking into account that assessments related to cross-curricular skills are based on the evaluation of their activities in the virtual tool or during lectures:

- *To develop the ability to understand, and enable others to understand, knowledge related with Web service technology, to be able to learn themselves about the named technology*: in both experiences the students had to present their research on a specific topic to their colleagues. Even though, in virtual environments they got better abilities in expressing their opinions and refuting others arguments with good criteria, in attendance environments they got better improvement on their ability to address an audience. This fact is reflected in Figures 8.1 and 8.2, respectively.

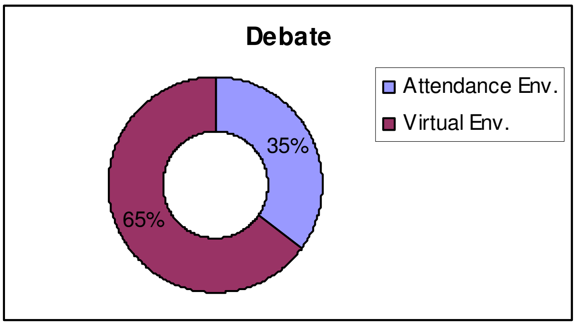

Fig 8.1. Debate Ability Improvement.

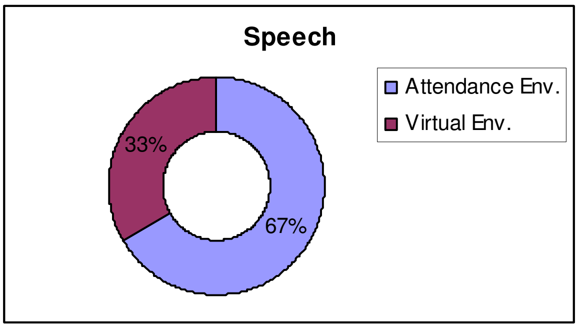

Fig 8.2. Speech Ability Improvement.

Fig 8. Debate and Speech Ability Improvement in Virtual and Attendance Environments.

- *To be able to work as a team effectively*: in both cases they did it properly; they demonstrated to be able to coordinate and deliver a task in the team both having virtual and attendance learning. Nevertheless, it could be appreciated a slightly better distribution of tasks and roles in the attendance option, as shown in Figure 9.

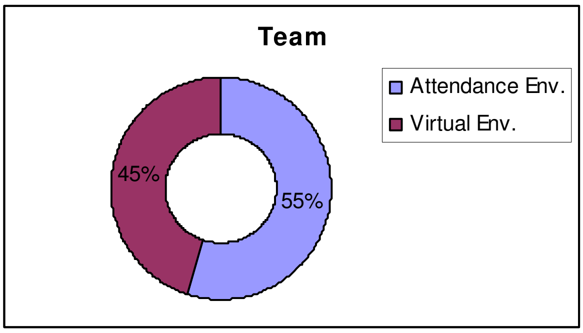

Fig 9. Team Work Ability Improvement in Virtual and Attendance Environments.

- *To be able to acquire Web service related knowledge when provided in English*: in this case, having a virtual or non-attendance environment does not influence the result, since the texts that they have to read and the knowledge they have to acquire by themselves in English is the same. Thus the percentage is the same for both values in Figure 10.

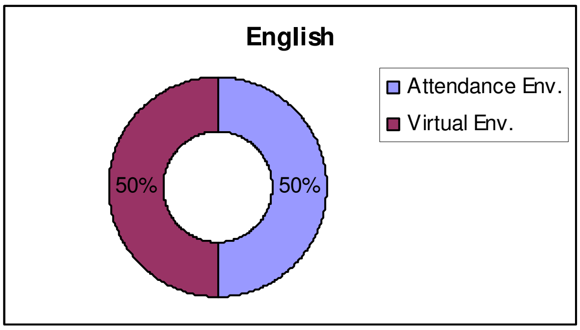

Fig 10. English Ability Improvement in Virtual and Attendance Environments.

C. *Lessons Learned Through the Experiences.*

Students' first reaction to any change in the educational methodology is always negative since they feel very secure doing what they have always done (mainly attending magisterial lectures and studying on their own for a written exam).

Initiatives for the improvement of cross-curricular skills, implement new methodologies which make them participate more during lessons, being especially encouraged by the virtual format, therefore bringing them back from their passive behaviour. Obviously, this also implies a very negative attitude on their part when moving on to a new methodology. Nevertheless, once they get used to it and once hearsay has run from one year to another, they understand there is no other option and face the subject with a much more positive attitude.

However they still have their preferences: it was noticeable that they got used to develop tasks in groups after two or three lessons; however those activities which were developed casually (role play, judgements, PBL, etc) still somehow scared them since they are not used to them and feel out of their comfort zone, therefore lacking confidence to complete the tasks naturally.

In any case, after the experience one can decide which activities work better for the subject and type of students in question, so some of them may not be used some years, to be included other years when the circumstances are more appropriate. An activity which may result in an interesting experience is to organize a simulation of a research conference and assign the different common roles in conferences to different groups of students (program committee, organizing committee, authors, keynotes and so on), the topics being the contents of the subject. This way, as they learn the main concepts of the subject, they work as part of a team and have to talk to an audience. If the experience works it can also be very fulfilling for them to see how they have been able to organize an event with the whole group.

Eventually, although they have to work harder from the beginning of the academic year, they realize that they learn and acquire more concepts more easily than they used to. They soon feel confident enough to ask any doubts and to make comments in the forums, even to spontaneously rebate about a topic to one of their partners; and this is not quite a usual atmosphere in the university scope, even through a virtual environment. This change of mentality alone would make the effort of improving the teaching methodology worthwhile, however, as we well see in the following section, this is not the only improvement.

On the other hand, they seemed to be very surprised when they were told that they did not have to attend lectures regularly in the virtual subject, and they even thought that they might not learn the subject contents properly. However, as soon as they started doing the virtual activities, they realized that they still had to work hard on the subject and that indeed they were going to acquire the correspondent knowledge.

VI. CONCLUSIONS

Virtual environments may not be suitable to any subject, especially if consider cross-curricular skills as specific targets to be met. There is no doubt that these skills will improve our students' training and education, but they make even more difficult to follow a subject objectives in a virtual scope.

However, the greater mobility for both students and teachers and the increase of working student made us consider this option. In this regard, we have presented a case study in which we followed the subject Web Services through a virtual environment and compared its evolution with the experience of teaching the same subject in an attendance way. The results summarized in the previous section let us assert that with our proposal not only do we work cross-curricular skills, but we also dynamize the subjects in question in a virtual environment, providing the possibility of choosing the subject to those who cannot do it presently, and not interrupting lectures during possible teacher absences. Besides, e-learning activities let us focus on students' personal work, and improve their cross-curricular skills, which are useful for their development both at professional and personal level. These methodologies make them participate more during lessons, being especially encouraged by the virtual format, therefore bringing them back from their passive behaviour.

In our future work we plan to follow additional experiment with other modules taught at the University.

VII. ACKNOWLEDGEMENTS

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A Voice-enabled Interactive Services (VòIS) Architecture for e-Learning

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Abstract---Mobile devices have gained global popularity for business and government uses. Yet, these devices are not commonly used in e-learning environments. One reason is the difficulty of interacting with e-learning tools like forums or chats from mobile devices which usually have small screens and limited keyboards. The goal of this paper is to discuss a voice enablement approach that can provide a solution to this problem. This approach can enhance mobile learning with an architecture that can make communication and collaboration easy from mobile devices. The paper discusses a pilot study with voice-enabled mobile learning project which was evaluated with blind students from higher education institutions in USA. The lessons learned from this project enable us to propose a voice-enabled interactive services (VòIS) architecture which can increase use of voice recognition technology in mobile learning. Results from this exploratory study, though small, specific, and culturally biased, will hopefully lead to proper investments in mobile learning applications and more research on understanding the role of mobile devices in education.

Keywords--Distance education, e-learning architecture, speech recognition, interactive voice response, access for the disabled.

I. INTRODUCTION

This paper is an extended version of the presentation at the LMPCNA 2009 conference [1]. According to Gartner survey [2], mobile devices sales were 32.2 million units in second quarter of 2008 with North American market showing fast growth by 78% over the year. Today, smart phones sales have outstripped PC sales. Similarly, computing and mobile devices have become ubiquitous on today's college campuses. According to Harris Interactive College Explorer Study [3], today's college students are connected via digital communication devices throughout the day spending on average eleven hours with their devices and roughly 1.3 million students have smart phones with which they communicate daily. The massive infusion of computing devices and rapidly improving Internet capabilities are altering the learning and teaching pedagogies in higher education [4]. A 2000 Campus Computing Survey revealed that the majority of college professors use email to communicate with their students, and approximately one-third of college courses use Web resources or have a class Web page (National Survey of Information Technology in US Higher Education). Similarly, Jones [5] reports that a great majority of college students using digital media 80 percent believing that Internet use has enhanced their learning experience.

Despite the tremendous growth and potential of the mobile devices and networks, wireless e-learning or mobile learning (*m-learning*) is still in its infancy and in an embryonic stage. *M-Learning* intersects mobile computing and e-learning; it combines individualized (or personal) learning with anytime and anywhere learning [6]. The relationship between a person and their mobile device is usually one-to-one, always on, always there, location aware and personalized [7]. The location independence of mobile devices provides several benefits for learning environments like allowing learners and instructors to utilize their spare time while traveling in a bus or train to finish their homework or class preparations [9]. It also has the potential to change the way students behave and interact with each other because wireless access technology "takes e-learning to the field, where the best hands-on learning takes place." [13]. But, one key problem with these devices is the limited space for data/text display and telephone key-pads for text input. This makes them cumbersome for interactive pedagogies used in learning environments [14].

Online learning tools such as discussion forums, blogs, and wikis are often considered good surrogates for classroom interaction [12]. According to a National Center for Education Statistics (NCES) study [8], 90% of institutions offering e-learning courses used one or more communication technologies such as online discussion forums, blogs, wikis, and chat rooms to facilitate classroom interaction among students and instructors to discuss course materials. This means that interactive tools add value in online learning pedagogy. Research on the introduction of technology in education [9] has shown that it is effective only when developers understand the strengths and weaknesses of technology. One of the major concerns of implementing m-learning technology is the accessibility issue. Mobile devices usually have simplified input devices and smaller screens than normal desktop computers. Typing messages using a cell phone keypad or reading articles on small screen devices can be cumbersome for users. While these tools are relatively easy on computers, they are difficult for people without computers. Voice or speech enablement has the potential for overcoming the cumbersome user interface issues and unlocking the potential use of these devices for mobile learning and other application areas. This paper discusses outcomes from a pilot project on voice enablement of m-learning environment. The lessons learned from the pilot study enabled us to define the technical requirements of voice-enabled e-learning services platform from which m-learning applications, like forums and other Web 2.0 tools, could be launched to increase the usage of mobile devices for interactive learning. Before discussing our *VòIS* architecture for e-learning, a brief background on interactive voice recognition technology is provided below, followed by a discussion on our pilot study and proposed architecture design for voice-enablement of e-learning (interaction) tools. The paper concludes by articulating some key issues underlying the usage of voice recognition technology and its impact on m-learning environments.

II. Interactive Voice Recognition Technology

From making airline reservations to confirming postage rates, consumers are increasing their acceptance of applications that utilize synthesized speech or voice recognition. While the public can be unforgiving when it comes to the naturalness of synthesized speech, demand for speech applications has been steadily increasing. According to Forrester Research [10], the speech recognition market has reached an inflection point. After many years of slow growth, the year 2006 showed increased spending on speech technology with a compound annual growth rate of 52% versus 11% for IVR spending over the last five years. The percentage of companies who have deployed speech grew four-fold – from 10% in 2000 to 40% in 2003 – with an additional 32% planning to deploy speech every year. This growth suggests that for most online learning programs, the question is no longer deciding whether to adopt speech, but, rather, determining which applications are most suitable for speech and developing a speech strategy that most effectively complements and integrates with an overall e-learning strategy.

M-learning has not yet fully embraced voice recognition technology to complement its existing learning technologies. Online interaction tools such as discussion forums, blogs, and wikis are often considered good surrogates for classroom interaction [11, 12]. According to a National Center for Education Statistics (NCES) study [8] 90% of institutions offering online Internet courses used one or more communication technologies such as online forums, blogs, wikis, and chat rooms to facilitate classroom interaction among students and instructors to discuss course materials. This demonstrates the value of interaction tools for improving the online pedagogy.

While interactive tools are relatively easy to use for people with full eye-sight, they are incompatible for people without eye-sight (or blind-disabled). Similarly, the American Foundation for Blind (http://www.afb.org) estimates roughly 10 million people in the United States with visually impairments, only 15% use computers and Internet. This leaves 8.5 million without access to the online interaction tools. Speech or voice enabling technologies, such as text-to-speech (TTS) technology and automatic speech recognition (ASR), has the potential of overcoming access and user interface deficiencies for the disabled. Currently, however, speech technology usage is limited to integrating Web browsers with screen readers, zoom text, and alternative media such as audiotapes or audio descriptions [12]. These applications require disabled to be sophisticated with computer usage and have the ability to afford computers and the assistive technology; thus, limiting their full integration into online learning and employment. Therefore, an added benefit of speech technology is that it expands mobile learning to the disabled. Another goal of this project is to develop a voice-enabled platform that works seamlessly with interactive learning tools such as discussion forums, wikis, blogs, instant messaging and others, to increase the access and participation for the disabled population in online and mobile learning environments.

Speech technology has traditionally been an esoteric and expensive technology available only to big businesses and research labs. Combining speech recognition with the simplicity of markup languages like VoiceXML makes it dramatically simpler to develop a Voice User Interface (VUI). Furthermore, the wide proliferation of speech applications, until recently, has been impeded by the fact that it is error-prone and still cannot handle natural language. The Web provides a relatively simpler framework for interaction with a computer or phone. Within this framework, several self-service applications have been developed in customer service and help desk environments accessible from computers or telephones.

Today, interactive voice response (IVR) applications can adequately handle the basic self-service requirements of navigating menus, traversing links, and entering data into forms. Combining recordings with speech synthesis is sufficient to develop intelligible voice interfaces that are hands-free and can be seamlessly integrated with other Web-based systems. The next section discusses our pilot study which was conducted to test the technical feasibility of voice-enable online learning tools like discussion forums and making them voice accessible from mobile phones.

III. Pilot Study On Voice Enablement Of A Discussion Forum

A pilot study was conducted to determine the feasibility of voice-enabled architecture in higher-education learning environment. The goal was to enable us to learn the requirements for a broader voice enabled learning platform discussed later in this paper. The prototype, called Voice-enabled Discussion Forum (VeDF), was tested with 11 blind users to access online discussion forums for over 45 days after which they were surveyed providing both quantitative and qualitative support for our study. The reason for selecting only blind students was that these users would provide us with the best feedback on voice interaction as they have some experience of using voice enabled devices and the best motivation of using this technology as it enables them to participate in online learning. Our plan is to expand to both disabled and non-disabled students in the larger study with the full-scale applications later.

Specifically, the objectives of our study were to:

- setup an online discussion forum on our learning Architecture
- setup and design voice recognition system accessible from a telephone and link it to the online discussion forum
- provide seamless integration between voice-enabled and regular web discussion forums
- implement and test the prototype VeDF system
- create real-world forums for evaluating the prototype
- select a sample group of blind and/or visually impaired users for the evaluation study
- test the IVR system with the sample group
- collect preliminary feedback from sample users on the system and
- determine the potential of VòIS architecture.

In general, users found our application friendly and were able to accomplish their discussions in acceptable time frame. In this pilot study, students used an online discussion forum to exchange text messages from handheld devices [13]. The same forum was accessible from a traditional PC computer and a Smartphone. An earlier study [14] had evaluated the same online (text only) forum with students from several courses in both online and traditional classroom environments. This study found the anytime/anywhere convenience of accessing the forum very useful but the user interface very cumbersome because it required them to type text messages using the phone keypad. The feedback from the students in this study led to the development of a voice-enabled architecture for mobile-and other phone devices [15]. This application used a server-based screen reader which converts all text messages to voice on-demand and also facilitates the storage of voice recorded messages on the server. The project's focus is on using text-to-speech (TTS) technology to convert the text messages to voice format on the web server and make them available to the students through the discussion forum application. These projects shifted our focus on making online learning more accessible by using speech recognition technologies through a hybrid of computer and telephone devices.

A hosted telephone/speech gateway solution from a Voice Service Provider (VSP) company was used to help us quickly develop a prototype and test our architecture with students at our university. This VSP provided us with an environment equivalent to Internet Service Provider (ISP) for accessing the Internet. They provide voice gateway and speech Architecture software which was linked to our host server via a secure hyper-text transfer protocol (HTTPS) connection. We have developed a customized VeDF application using the VoiceXML standard and interfaced it with an existing online learning discussion forum on our server. More details on this are provided in the sections below.

A. Prototype Configuration

Our voice-enabled discussion forum has several unique features that can appeal to the disabled and non-disabled users alike. The success of this technology has the potential to attract a wide variety of applications that can be voice-enabled in the future. Here are some of these features of our application:

- No training requirements – user needs to know how to use phone
- Synchronized phone and web browsing of message boards
- Voice and data integrated discussion board
- One voice command functionality
- Message thread recording and replay
- Cross Architecture (telephone and computer) access
- Caller-ID login: registered users can login only with password
- Customizable voice user interface: your welcome messages
- Scalable (1000's of participants in a single forum)
- Instant messaging with searchable message log
- VoIP or PSTN phone access
- Individual user accounts and passwords
- Superb audio conferencing
- Best in class use speech recognition and TTS technology
- On demand help availability
- Available 24x7 for unlimited use

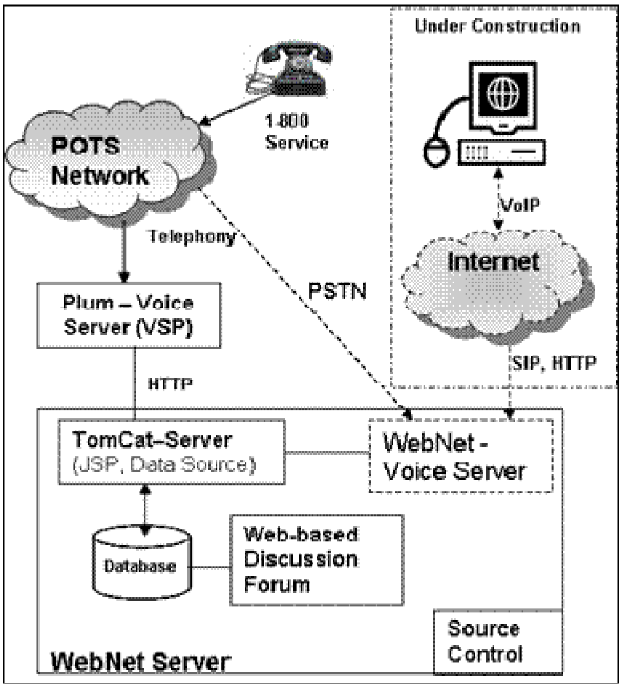

Figure 1: Pilot Prototype Configuration

As mentioned earlier, this project's accomplished its technical goal of developing and testing a voice-enabled discussion forum (VeDF) application by integrating a commercially available speech Architecture with the online discussion forum software. Our IVR application was developed with the *Open Source* software model. The use of Plum hosting services™ as the VSP is a temporary arrangement to let us quickly demonstrate the feasibility of the application. We plan to replace the Plum-VSP Architecture with our own voice server Architecture in the next phase. The WebNet voice server Architecture has been configured and internally tested with the Nuance Voice Architecture™ and NMS Communications™ CG series telephony card for developing IVR system with telephony access via VoIP/SIP and PSTN communications protocols. This Architecture will replace the Plum VSP services for full-scale development and testing environment in next phase. We will use Plum only for the production environment as it provides a better 24x7 support, maintenance and uptime. The overall configuration of our Pilot prototype application, with indication for future changes in dotted-line, is shown in Figure below.

In the above configuration, a user can call a toll-free number provided by the Plum hosting service from any telephone device. This call is processed by Plum and re-directed to our IVR system. Plum provides the voice gateway to the WebNet server, a Dell PowerEdge™ 3.0GH$_z$ RAID-1 server with dual-processor capability. This server hosts our IVR system designed with the VoiceXML standard. Plum provides a text-to-speech engine (TTS) from AT&T Natural Voice™ and automated speech recognition (ASR) software from SpeechWorks™ which are used by our IVR system. Our IVR system is developed on the Java™ Architecture with the Tomcat web server using J2EE software language, JSP scripting language, and JDBC database environment. The IVR system was connected to the web-based discussion forum through the database which provided the content for the IVR application. A source control environment, with Subversion™, has been installed on the WebNet server for multiple programmers to check-in their software and quality control. We plan to replace the Plum service with our own voice server Architecture for the development and staging environment in next phase. This voice server is developed with the Nuance Voice Architecture and will have both SIP (for VoIP phones) and PSTN (analog phones) connectivity with the NMS Communications CG series telephony card installed on our server, as mentioned earlier.

B. Voice Forum Application Architecture

Our IVR system is developed using technology that supports the open public standards and in particular, uses the VoiceXML scripting language. VoiceXML was created to simplify the development of Interactive Voice Response (IVR) applications. Thanks to active support from America's leading technology companies, including AT&T, IBM, Lucent, Microsoft, Motorola, and Sun, the VoiceXML language standard entered the public domain in 2000 as the accepted lingua franca for voice and IVR applications. VoiceXML provides a mature feature set - a superset of traditional IVR features - for handling conventional telephony input, output and call control, including: touch-tone input, automatic speech recognition support, audio recording (e.g., for voice mail), the ability to play recordings (such as .wav files), speech synthesis from plain or annotated text, call transfer, and other advanced call management features.

General benefits of fully standards-compliant VoiceXML IVR system include:

- *Elimination of Vendor Risk* -- VoiceXML applications can be easily ported among VoiceXML IVR machines. This portability

™ Plum Voice Portals (http://www.plumvoiceportals.com/)
™ Nuance, Corp.

™ Dell Computers, Inc.
™ AT&T, Corp.
™ Nuance, Corp.
™ Sun Corp.
™ Subversion, Inc.

eliminates reliance on any one vendor, and Plum has to earn the right for continued business.

- *Standardization of Applications* -- VoiceXML is a well documented and very popular public standard similar to HTML -- avoids reliance on proprietary APIs or marginal solutions.
- *Flexible Deployment Options* -- VoiceXML apps can run within self-contained systems or via hosted gateways.

Our pilot VoiceXML IVR system architecture consists of the Plum *Telephony Gateway* controlled by the Plum *VoiceXML Interpreter;* these components together form the heart of a *VoiceXML IVR Gateway*. The gateway seeks VoiceXML instructions from any *Application Server*, which was hosted on the WebNet server. This application server provided a dynamic *VoiceXML Software Suite* consisting of a *Controller Servlet*, *Voice User Interface (VUI)* server pages and *Data Source* objects which integrated our IVR with the online forums *Database*. Plum's *Admin Tools* enable browser-based configuration of the gateway, application setup, modification, user management, reporting, etc. This modular implementation allows for *Future Plug-ins* of other *ASR* and *TTS* engines into the VoiceXML IVR Gateway and Admin Tools can be expanded to allow for enhanced application control.

For this pilot implementation, as mentioned before, we used Plum Hosting Services™ to provide a quick way to get started while eliminating large capital expenses. Plum provided a per-minute and per-port hosting environment to develop and test this early version of our prototype.

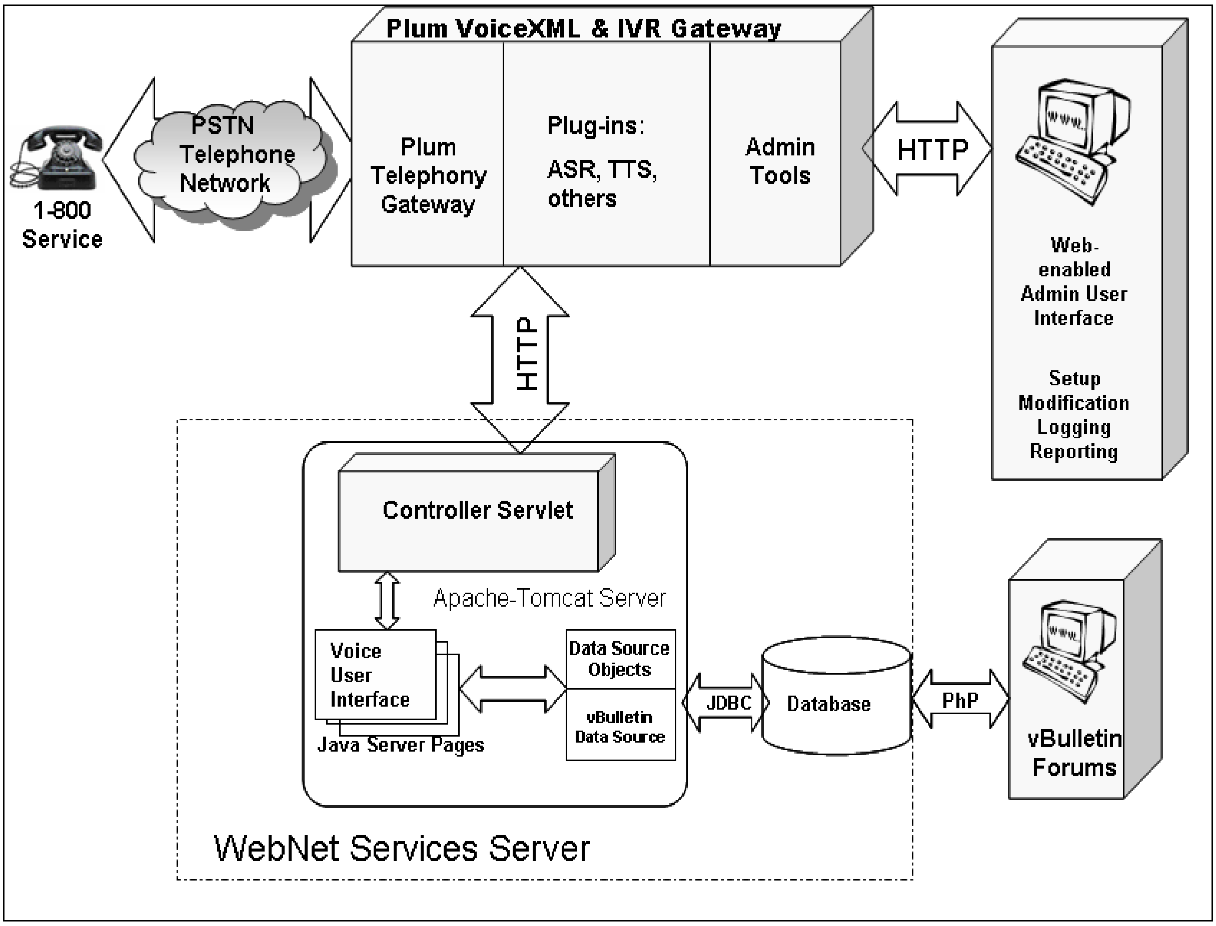

Figure 2: Voice Forum Application Architecture

The VeDF application architecture, shown in Figure 2, was designed using a layered and modular architectural design to support for future enhancements and integration of other application tools, while allowing for quick and dynamic code flow changes, as is required in a typical initial proof of concept application. This prototype application consisted of Java Server Pages (JSP), interacting with java class objects which implemented a simple interface to a given data sources. Interactions with the existing web based software where broken down into distinct steps, such as 'Login', 'Post Message', 'Get Forum List'. After an initial usable prototype, it was decided to also include the use of a controller servlet that dispatched the given state of the application to the associated JSP page. This allowed the controller servlet to dynamically change the applications path at run time, allowing for global user authentication, posting of new threads, and providing greater security to the end users, as security verification was able to take place with every interaction with the system.

Generally, this environment allowed us strict call flow control within the application, while still allowing dynamic code deployment and execution utilizing JSP pages. These JSP pages could change dynamically at run-time; give us much greater flexibility, while still maintaining security and control. The technical goal of this pilot study was to develop a prototype tool for students to access online discussion forums; this can potentially reduce access barriers that prevent them from fully integrating, participating and excelling in online education programs.

C. *VeDF - Voice User Interface*

1) The user connects through a phone and the public switched telephony network (PSTN) to the VoiceXML Interpreter through the Plum telephony gateway.
2) The VoiceXML Interpreter conducts the call interaction with a caller based on the instructions of a VoiceXML script supplied by the application server. The Interpreter natively detects touchtone input and can manage pre-recorded audio prompts or files. The Interpreter also calls the TTS (text-to-speech) and ASR (automatic speech recognition) for enhanced voice functionality.
3) The VoiceXML Interpreter communicates via web protocols (HTTP) to our remote VoiceXML application server.
4) The VoiceXML application server delivers the application, including VoiceXML text pages and binary audio files. The application server receives spoken, touchtone, and recorded input from the VoiceXML Interpreter.
5) The VoiceXML application server queries the database via the data source objects to dynamically drive VoiceXML to the interpreter (hence "speak" with the caller).
6) Both Human and Machine Personas were used to provide the audio prompts to the end-users. The human persona was professionally developed through the recording studio using a local radio station.

In sum, the key variation from the originally proposed architecture was that the speech recognition functionality was accessed from the voice service provider (VSP) host, Plum Voice Portals, Inc. and integrated with our server which provided the IVR functionality through VoiceXML scripts. These scripts then used the Java™ Architecture to access the discussion forum messages and served them to the user with the VoiceXML gateway of Plum Voice Portal. This architecture is designed to be scalable for growth and flexible to be integrated with other forums at the back-end and voice Architectures at the front-end. The Voice User Interface (VUI) was developed with the VXML 2.1 standard from W3C organization. This standard permits the use of voice Architecture from any vendor that supports the VXML standard. The data from the discussion forum were extracted using the Java Data Base Coding (JDBC) without making any modifications to the vBulletin™ discussion forum application or the DF database. This permits quick flexibility to integrate our voice forum application with other discussion forums software vendors that support the JDBC standard.

D. *Pilot Study Results*

The pilot study has allowed us to investigate the feasibility for a voice-enabled discussion forum application, as well as design, develop and evaluate a prototype application with blind and visually impaired learners from different organizations. The prototype provides the basis for the architecture for developing a commercial voice-enabling services Architecture that can be extended to other communication and interaction tools such as blogs, wikis, pod casting, and instant messaging services current available for use on over the Internet with minimal effort. End-users were an integral part of the design and prototype development effort; this user involvement allowed us to discover new requirements to change application functionality and system components. Changes to the application architecture where required, as the initial request for a feature was often found to be an indicator of an additional requirement. Because this prototype was primarily created for research and feasibility studies, these changes were made fairly quickly. Some of these ideas and methods will be helpful in developing the VòIS architecture.

Before development of prototype, two blind users were interviewed and observed as they used commercial IVR/Call center applications. As the prototype was being developed it was tested with the core group of ten users from higher education programs. Users were shown a demo and provided an instruction sheet on how to use the application and were given tasks like software training, joining a social club and course material discussion. Case scenarios were developed for each organization to provide a realistic testing environment. Problems

™ vBulletin, Inc (www.vbulletin.com)

encountered were recorded and fixed within 48-72 hours time period. This process continued for over 45 days, after which users were surveyed on various aspects, including system performance and user satisfaction, with a standardized questionnaire. There were some technical problems initially with the system and breakdowns. But after the initial learning curve, users liked accessing information from the phone, and were generally satisfied with the systems performance and interface.

An empirically validated survey instrument [16] for measuring learner satisfaction for e-learning systems was customized for our pilot study. The students were given written instructions on how to access the voice forum through a handout which listed the steps on how to use the phone to login, access the website, and participate in the discussion board and chat. A fixed chat time and day to participate in the chat and discussion questions were posted on the bulletin board. Students were given the incentive to participate in form of class participation grade for graduate students and extra-credit for undergraduate students.

Of the ten users who participated in our prototype evaluation study, two users did not respond to the survey and therefore, the results are based on sample of eight users. The survey was divided into two parts: 1) 12 survey questions on the Voice-enabled discussion forum (VeDF) system which required users to circle their answer on a five-point Likert scale with 5=Strongly Agree, 3=Neutral, 1=Strongly Disagree). 2) 12 questions on users' background. The users were provided with a help to fill-out the survey either by the researcher or through the Blind center where they visited. Surveys were e-mailed or faxed along with an Informed Consent Form. **Error! Reference source not found.Error! Reference source not found.** below presents an analysis of the feedback received from the users on the survey conducted at the end of the evaluation period.

TABLE 1: RESULTS FROM ALL END USER SURVEY

Survey Questions	AVG	STD DEV	VAR
VeDF did a good job in providing access	4.00	1.10	1.20
VeDF met all my expectations	3.50	1.38	1.90
VeDF user interface was easy	3.33	1.21	1.47
VeDF prompts were easy to understand	4.33	0.52	0.27
Average time it took to accomplish a task was acceptable	3.67	1.03	1.07
VeDF is useful for disabled students to access online learning	4.00	1.26	1.60
VeDF can be useful tool to access the other online materials	4.33	0.82	0.67
VeDF makes the process of discussing with other student easier	4.00	0.00	0.00
I prefer using VeDF instead of screen readers like JAWs	3.00	1.10	1.20
I prefer using VeDF instead of BRAILLE to access online forums	4.00	1.22	1.50
I foresee a good demand for this technology from the blind	4.33	0.82	0.67
I'm willing to use phones with IVR technology instead of computers	4.17	0.41	0.17

The survey on VeDF prototype indicates a general satisfaction on the use of this system for accessing online materials from the users. Users were neutral on some survey items like substituting VeDF for JAWs. On questioning the users later we found that they misunderstood the question. Our survey did not include the "to access online forums" in this question which resulted in general comparison of the two systems. They were also more familiar with JAWs having used it for a longer time and it can be used with many other programs. Secondly, we found that they were unhappy with the system audio prompts because we used the machine personas available from AT&T Natural Voice system. To fix this problem, we contacted a local radio station and asked them to record the system's audio prompts. These human prompts were much clearer and as you can see from the results, the VeDF prompts received a score of 4.13 out of 5.

TABLE 2: RESULTS FROM SURVEY WITHOUT THE TWO USERS

Survey Questions	AVG	STD DEV	VAR
VeDF did a good job in providing access	3.75	1.49	2.21
VeDF met all my expectations	3.50	1.41	2.00
VeDF user interface was easy	3.25	1.49	2.21
VeDF prompts were easy to understand	4.13	0.99	0.98
Average time it took to accomplish a task was acceptable	3.63	1.19	1.41
VeDF is useful for disabled students to access online learning	3.88	1.36	1.84
VeDF can be useful tool to access the other online materials	4.25	0.89	0.79
VeDF makes the process of discussing with other student easier	3.75	1.16	1.36
I prefer using VeDF instead of screen readers like JAWs	3.13	1.25	1.55
I prefer using VeDF instead of BRAILLE to access online forums	4.14	1.07	1.14
I foresee a good demand for this technology from the blind	4.13	1.13	1.27
I'm willing to use phones with IVR technology instead of computers	4.13	0.64	0.41

The reason for lower averages on other items was because of some of the technical issues with the Plum voice portal gateway which we did not have any control. Plum's ASR and TTS engines were inconsistent in their performance. For example, their ASR was very sensitive to speech barge-ins and when we tried to adjust the sensitivity of this barge-in the system did not respond to these functions. Another problem was clarity with their TTS personas often produced *slurry* speech and some of the VoiceXML parameters used to speed-up or slow-down the TTS conversation speed the system did not respond to these functions.

Nonetheless, the survey results were very encouraging; especially, if you consider the last question which asked the user whether they were willing to use phones instead of computers to access online information. This question got a score of 4.13. The standard deviation and variance were normal, except we found two users had answered all the questions with *one* value (5 for one user and 1 or 2 for the other). This looked suspicious to us. So, when we removed their responses from the survey analysis, the results looked as follows:

Comparing the average scores with Table 1, you will notice average support for the system was even better. In addition to the questions on the VeDF application, users were asked a few background questions. Table below provides a glimpse on the users who participated in this study. Please note all the scores are not an average; some are just simple counts of user responses.

All users were blind-disabled and one also had mobility impairment. The average duration of their disability was around 25 years with most users being blind for over 12 years. In term of their technological sophistication, users in our sample have used computers for almost 14 years and Internet for 9 years and four of the users have taken online course or course with hybrid (in-class and online) components. In terms of their experience with IVR systems, seven out of eight have used an IVR system before with 3 users having used too many times, 3 users greater than 25 times and 2 users have used IVR less than 25 times. The average number of times the users used the VeDF application before the survey was 12.25. This is satisfactory in terms of exposure of the application to the users to make a critical analysis of our application.

TABLE 3: USER BACKGROUND INFORMATION

Background Questions	**AVG**
User Disability	
Disabled (1=Yes, 2=No)	8/0
Disability (1=Blind, 2=Deaf, 3=Mobility Impaired, 4=other)	8/0/0/0
Disability Duration (Years)	***24.38***
Level of Disability (1=Total, 2=Partial)	8/0
User Experience with Computer Technology	
Computer Usage (Years)	***13.75***
Internet Usage (Years)	***8.88***
Online Education Participation (1=Yes, 2=No)	4/4
User Experience with IVR Technology	
Used IVR Before (1=Yes, 2=No)	7/1
IVR Usage (1= <+ 25 times; 2= >25 times; 3=too many)	3/3/2
Use of VeDF for study	***12.25***

A deeper analysis of the results from our study reveals that even though the users were quite familiar with computer and Internet usage; yet, they were still willing to switch to a telephone-based application. The users preferred using our application instead of other assistive technologies like JAWs and BRAILLE which are also very expensive. Another look at the user background also reveals that although the users have considerable experience with computers and Internet they are also regular users of commercial IVR applications (7 out of 8) – this suggests that they may prefer to use the online forums from both computers and telephone depending on their convenience. Finally, most of users in our sample indicated very little exposure to online education participation; four of the users have never participated in online education course and of the remaining two users had participated only in one hybrid online course; only two users indicated some experience with online education courses. These results support the results of earlier research studies which indicated that online education is, generally speaking, not very user friendly to blind and disabled populations. Although the survey only measures learner satisfaction, we plan to develop other measures to determine the answers for our research questions in the next phase of our project.

The results from this study cannot be generalized to the larger disabled population at this time. The sample size was small and population was self-selected. However, in next phase, we plan to develop and test our application in a diverse setting with a much larger population. This will provide a better external validity for the study and allow us to generalize our results to the larger population. Nonetheless, this study makes a useful contribution to the knowledge of how voice-enabled applications would be received by the blind user population. The informal user feedback was crucial for next phase. We found the application was just as easily usable by technically sophisticated and novice computer users. Also, users with partial and total disability were able to use the system comfortably with minimal training. The results from this study, however, cannot be generalized to the large disabled population with multiple types of disabilities. Our sample size was small and type of disability was limited to make a full-scale commercialization decision yet. More research and development is necessary -- both on the technical side and testing on the human side with a bigger and more diversified sample population before making a final decision. However, results from this phase, users liked being part of an online system where they could share their discussions with other students (disabled and non-disabled). This was a promising development and gave us confidence in proposing Voice-enabled Interactive Service (VòIS) architecture for e-learning environment.

IV. PROPOSING A VOICE-ENABLED INTERACTIVE SERVICE (VÒIS) FOR E-LEARNING

The goal of a VòIS platform for an e-learning system is to better meet the needs of students and mobile learning communities via speech recognition technology.

Our pilot study explored this goal by demonstrating how an interaction tools like discussion forums can be voice-enabled. However, enabling voice interaction in one online tool is not enough to increase usage of mobile devices. After voice enabling all interaction tools, our project long-term goal is to explore the use of these tools from mobile devices and measure its' impact on learning pedagogies.

The online education programs and e-learning software markets are experimenting with, or currently utilizing, a wide variety of communication and interaction tools ranging from live chats, blogs, wikis, instant messaging, pod-casting and others. One suggestion from our pilot study user group was to have the voice/audio messages searchable from the mobile devices by user or topic, have immediate access to the new messages, and others. These user requirements are embedded in the VòIS architecture to extend this functionality to all communication and interaction learning tools such as blogs, wikis, e-mail, and instant messaging services.

A. VòIS Design Specification

Our design will include a Voice Services Core (VSC) component which will support:

- *A configurable and dynamic Call Flow*. The call flow in our pilot study prototype is currently fixed following standardized login path and menu navigation. However, many commercial applications may have different protocols for login, navigation, user input, etc. This service will allow easy integration with the existing login, navigation and other flows of the application.
- *A logging environment* that will capture all the call flows, configuration services and message logging. Provide audit log capabilities.
- *A data environment* which will provide connectivity via JDBC data sources to a wide variety of databases supporting the communication protocols.
- *An audio searching capability* that allows voice message searching through meta-tags assigned to messages by users. This service will utilize technologies such as Active Speech Recognition (ASR) and pre-parsed extracted meta-data.
- *A voice API* environment that can be easily deployed as a web package by IT staff in organizations to voice-enable their communication and interaction tools on their existing Intranet/Extranet Architectures. This allows our service to be integrations with existing applications with minimal cost and tight integration with any existing in-house applications an end customer may currently utilize.

This VSC can be utilized to develop the following VòIS functionality:

- *Integrated message searching capability*; namely, allow telephone users to search for textual and audio information by a variety of criteria, including user, thread topic, date, content, or other meta data.
- *Branding or content syndication capability* within our service to allow for easy to implement customization of the Voice User Interface, providing end users a transparent method of customizing all visible interfaces to the application.
- *Integration* with specific applications like vBulletin forums, Wikipedia, blogs, and other interaction tools, using add on 'modules' to extend the VSC capabilities.

To accomplish these goals, we will use the Java Enterprise Edition application environment. An inferred requirement of the objectives requires an application environment that can provide a phased and modular environment, while allowing dynamic changes to the run-time environment of the services provided. This modular design also allows for easy plug-in front ends (Voice Architectures, VoIP, TTY, etc) and easy component plug-in at the back ends with practically any database driven web applications without requiring any major coding effort.

Although it is technically feasible to apply voice-enabling technology to web-based interaction tools, this project's broader goal is to determine whether this voice-enabling technology:

1. Will increase the access and usage rate of the learners in e-learning programs?
2. Can be seamlessly integrated with existing software applications on enterprise Architectures with minimal modifications?

B. VòIS Usability

The pilot study provided us with the knowledge and data to extend the application in short and long-term future directions. However, the prototype is tightly integrated to the functionality of a discussion forum. While this allowed us to determine the feasibility of voice-enabling technology and test its usage with the disabled, its impact was limited to users and organizations using these architectures. Therefore, the challenge of VòIS architecture is to create application services and middleware tools that will make our voice Architecture modular and *plug-n-play* software, independent of any interaction tools and voice software. Our goal is to enable voice access via telephones to interactive learning tools, as shown in Figure 3 below.

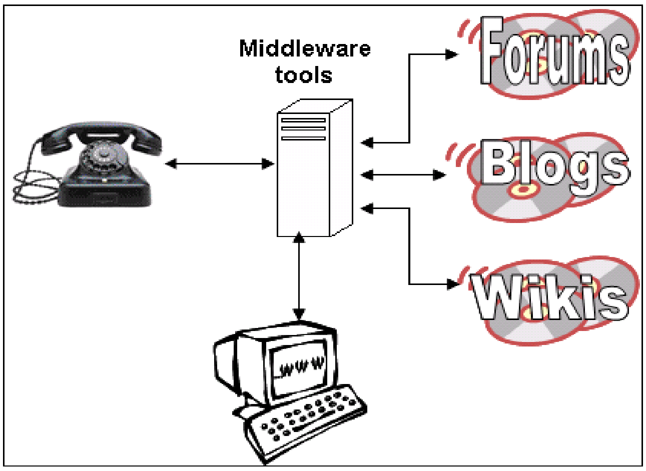

Figure 3: VòIS Middleware Tools

V. VÒIS ARCHITECTURE

This architecture's goal is to support a *plug-n-play* environment with interactive learning tools and other commercial software. The software selected for integration will be leading software in their areas and work on a variety of operating systems such as Microsoft Windows™, Sun Solaris and Linux™. Universal programs design principles will be followed to integrate these applications. The Nuance Voice Architecture™ supports VoiceXML 2.1 the open, industry standard for speech applications and services developed through broad industry participation in an open forum managed by the W3 Consortium. Because VoiceXML leverages the Web infrastructure, such as application servers and databases, our application will be able to leverage the existing investment in online educational infrastructure such as e-learning servers, pedagogical tools, and discussion forum databases. Most notably, this allows our VòIS Architecture to interface with a wide range of existing systems.

This architecture (shown in *Figure 4*), referred to as 'VòIS' (Voice-enabled Interaction Service), will be separated into three primary components, all of which together, provide the voice interaction services. For the purposes of this document, '*Core*' refers to the basic services and components which provide the base operating capabilities of the system. This includes services such as logging, system management, application flow management, etc. '*Components*' refers to system resources that are used, primarily by services, to provide access to resources that the system requires. Examples of core components include database access, file access, telephony card access, VoIP access, etc.

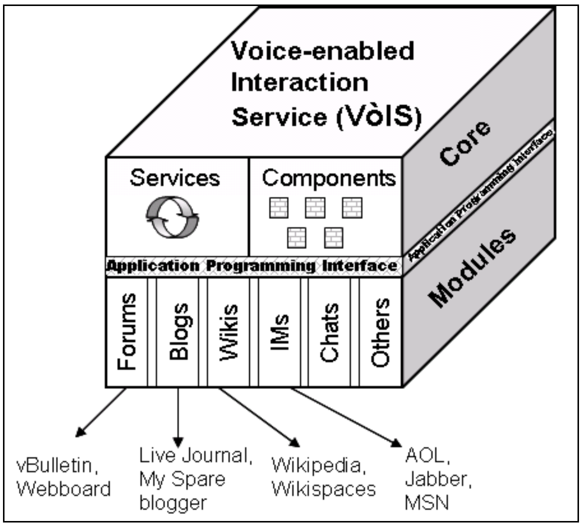

Figure 4: VòIS Architecture

A. Core

1. *Services:* provide the basic functionality of the system. Examples of these core services include
   - Logging
   - Call Flow
   - Configuration
   - Deployment

The services are implemented as tasks that are constantly running within an application server, performing the basic work that is required by the VòIS. These services may operate based on configured parameters that allow them to interoperate with whatever given environment they are current deployed in. Examples of the above services configuration options may include:

- Logging to Database vs. Files.
- Call flow of Voice application vs. TTY application vs. Web Application. Different server may define different call flows based on the way they are configured.
- Services that provide special interfaces to a given J2EE run-time environment, such as connectors for Apache Tomcat, WebSphere, Nuance Voice Architecture, etc.

2. *Components: allow the application environment to interact with services that the server will utilize. These components can provide all access to resources that the system requires, such as:*
   - File Access
   - Database Access

- VoIP (SIP)Access
- PSTN Telephony access
- Web Access
- Messaging Access

Many of these components would simply be capabilities that are provided by the J2EE environment that the voice core services (VSC) will execute. These servers often provide custom capabilities depending on the provider of the environment. Components would allow the server access to these specialized capabilities in an abstract manner, without requiring modification of the VSC. As a simple example, WebSphere Application Server, a J2EE compliant environment, may provide its own file storage methods. A File Access module could provide access to this capability to any of the Services running, without the services being aware that the file is being treated different then if it was simply a file on the local hard drive.

B. Application Interface

While the VSC itself provides everything required functionally, an application programming interface (API) is useful to allow modules to interact with the system as a whole. An API is a set of shared libraries, similar to DLL's in a Windows environment, or shared libraries under a Unix-based system. There are several methods and technologies for this, and we plan to provide to applications several different techniques to provide access to the VòIS. A local library that can be directly loaded by applications running on the same server will allow applications running on the same physical machine to interact with the server. Additionally, a SOAP or Web Services API will allow for applications to run remotely, and access the server by utilizing such web technologies as SOAP and Microsoft.NET.

This API will expose many of the capabilities of the VòIS Components to external applications. For example, a module (documented below), may require database access to a MySQL database. By utilizing the data access portions of the VCS API, these modules could have managed access to a given database, without the need for the module to manage this particular data connection.

C. Modules

Modules are the logical organization of any '*external*' interaction tools software. Modules will translate other applications concepts into those understood by the Voice Interaction Server. These modules may utilize any of the available APIs proposed earlier, as well as potentially utilize the same or similar components as the Core Services.

All of these interactions provide an abstraction of the concept of messaging. During initial research, it was found that nearly all sources of communications that we are targeting use the same or similar concepts when dealing with interactions and messaging. Forum users post messages, and response to messages, and these strings of communications are known as threads. An instant messaging application has a single thread between two individuals. The assumed reasoning behind these similarities is that they are basic concepts that humans have developed for dealing with any electronic medium. Any sort of message is generally a single piece of information. This is sent as one piece to an intended target. Sometimes, these interactions are shared with multiple individuals. Other times, they may be private and personal, from one person to another.

VI. CONCLUSION

This paper has proposed voice-enabled interactive services architecture for e-learning systems that can be used from mobile phone devices. In general, this project has been a very useful exercise in understanding the role of speech recognition in mobile and e-learning. While the current device limitations reduce the usefulness of these devices, they are useful tools to complement existing computing and Internet environments. Speech-enabled interface can certainly enhance the usage of these devices as they minimize the negative impact of interacting with these small devices.

Voice enabled technology for user interactions is steadily growing. More than two-thirds of phone callers commonly use automated speech in their business interactions. Although early deployments for speech were relatively basic and resided on proprietary interactive voice response (IVR) Architectures, the introduction of new speech software standards has spawned new applications in improving the user interface. The relatively straightforward ROI for speech applications makes them an attractive investment opportunity. The inherent limitations of using the telephone keypad restrict the type of information that is collected because it only supports basic numeric commands. Speech applications provide a much greater range of options, eliminate menu trees, and allow callers to quickly go to their destination or information source. Many early adopters attest to the positive payback from speech applications by progressively adding more speech applications to support multiple aspects of their business operations. According to Harris Interactive report [10], sixty-one percent of customers were satisfied with their most recent speech encounter. This project has provided an application design to take advantage of this consumer sentiment and leverage the speech recognition and mobile networking technologies for electronic learning.

One problem with mobile computing is that most users in the U.S. have access to the Internet via PCs but a much lower percent of the learners in Asia, Africa and Europe have on-demand access to Internet from everywhere and anytime. On the other hand, mobile device penetration with access to data services and Internet is much higher globally than in the US. Therefore a mobile learning has much higher scope in Asian, African, and European countries than in US. This does not mean that US education institutions can ignore this form of learning. Learning, like other industries, is highly global and therefore, many of the e-learning programs in the US have students from countries around the globe. Voice-enablement can increase the access of higher education institutions to students who do not have unlimited access to Internet or PCs and disabled students who are disadvantaged by e-learning pedagogy. The success of VòIS architecture has the potential of increasing the usage of mobile devices in e-learning.

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A Knowledge Founded Model Embracing Leadership Change within Virtual Work Environments

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Abstract

This document posits an approach for leaders to gain advantage through knowledge facilitation within virtual work environments and presents a leadership model, the Knowledge Founded Virtual Self-Management Model (KFVSM). The model addresses the leadership of virtual teams as self-management founded, to operate within a soft systems structure, and oftentimes are project based. A proactive leadership structure incorporating environmental scanning founded on a dynamic fulcrum provides the superstructure of the model. The model was developed in reaction to increasing virtual work environments incorporating high levels of information technology within dynamic markets demanding quick change and the broad application of a project perspective to organizational endeavors.

The model operates from a knowledge facilitation platitude and incorporates some considerations such as crowdsourcing, Software-as-a-Service, etc. Multiple contextual factors from the organization and follower perspective are incorporated along with information on technology advances facilitating social networking. The model is meant to propagate organization paradigm shifts rather than just providing a method to react to them. Lastly, the KFVSM embraces leadership learning, change, and growth and views leadership as a skill to be developed over time and in reaction to change, knowledge, and need.

***Index Terms*— leadership, virtual, memetics, project management model**

1. Introduction

The list of success stories for our specie, nations, individuals, business organizations, etc. who have advanced, found victory, and profit based on the application of newly discovered knowledge, innovative facilitations of archived knowledge, and the hybridization of new knowledge with old is extensive and goes back to the start of recorded history. In fact, the processes used to facilitate and manipulate knowledge for success is knowledge in, and of itself. It is possible to relate this knowledge concept directly to the establishment and successful application of leadership. Successful leadership and knowledge facilitation run parallel to one another within organizations. Leaders can gain advantage through knowledge facilitation within virtual work environments realized through openness to change and needed information technology and it is this perspective which provides rationale for the development of the KFVSM. (Please see model diagram – p. 9)

2. Leadership / Memetic Foundation

From an historical view, a look to a possible scenario for knowledge succession of early man provides a glimpse into a perspective on knowledge discovery and application relative to the establishment of leadership within a group. This rudimentary example provides foundation to an understanding of modern day leadership, for the driving factors are equivalent. Early humans served as scavengers within their biomes and protein acquisition would have been greatly needed but limited in opportunity.

A member of the group may have noticed through trial and error in conjunction with low level critical thinking, that the edge of a rock might become sharp during concussion with other rocks. Creative thinking matriculates the thought that to concussion the sharp rock on a newly scavenged bone might reveal what is inside, for this bone marrow has been exposed through the action of the carnivores from time to time and consumed by the group. The group moves to a carcass as advised by their partner who had previously demonstrated to the food needing cohort the use of this possible bone opening tool.

All members gain advantage and nourishment through reproduction of their partner's actions and newly acquired knowledge. The critical and creative thinker's status rises within the group as the establishment of respect takes place and the member gains advantage through accepting the risk of sharing the information with the group, taking a leadership role. The knowledge fragment or meme disperses throughout the group and other groups while eliciting a foundation for the development of other applications involving stone tools, scavenging, etc. Change offers leadership opportunity.

New knowledge is combined with old and some knowledge processes used in the past may never return. According to Holtz: "…the human brain is a constantly changing constellation of relationships among billions of cells. Complex networks of neurons are linked by pathways forged, then continually revised, in response to experience" [2]. This is the natural process of cerebral knowledge succession.

An atmosphere of leader trust materializes which creates fertile ground for the advancement of this new knowledge and leadership. Leadership legacy germinates, as partners will now come to their colleague for advice and help on a problem, a need for change, and a chance to spread knowledge. The new leader, as well as the group looks to new methods to apply the newfound tool and exploitation of the new knowledge to aid in their survival. Much as a spark to a dry forest, this birth of knowledge creates multiple pathways for its propagation, application, and growth. It was put forth by Locke ". . . that the mind, though possessing natural abilities and manners of operation, is initially like a tabula rasa, a blank tablet which not have yet been written" [3].

3. Memetics

The Memetics approach to epistemology and knowledge development, transition, and perpetuation provides a logical and observable process to study knowledge and Memetics is displayed in the previous example. Memetics was first referenced by Richard Dawkins in 1976 and treats knowledge as bits or fragments of information and processes advanced through our species much as a genotype or phenotype might be and is a foothold from which to observe knowledge creation and change. The fragments of knowledge are referred to as memes. According to Heylighen, a meme is a bit of knowledge or cognitive meaning which can be transmitted from one individual to another. This is actually a duplication of the meme within another individual who then also might go on and spread it to others [4].

The propagation of the meme throughout a populace emulates advancement of a genetic compliment through a population. Information technology driven virtuality puts the advancement into hyper-warp and allows for transmission of a meme from a single source to 1,000's in a matter of seconds. Memes though differ in that they are transferred between any two individuals, group to group, group to individual, through whatever media might be available, and are not bound to the parent-offspring genetic recombination process. Memes take fragments of time in many cases to transmit and not generations as in genetics.

When a meme is no longer applicable, when it is passed in ever decreasing numbers, it is experiencing a decrease in its level of fitness for application within the time period and will move from practical existence to the realm of archiving. The meme may become extinct in direct application and be replaced in a knowledge niche with other memes, but these replaced memes add to the foundation of knowledge much as an individual coral's body structure adds to the base upon which active coral survive. Practical application determines the current presence and validity of knowledge in the epistemological succession process.

4. Cloud Computing

The way computing is done worldwide is advancing through a change of direction and perspective. While the actual definitions may vary, this development is broadly called 'cloud computing'. Cloud computing is a method of computing where scalable and elastic IT-enabled capabilities are provided 'as a service' to external customers using Internet technologies. In the future, if you are exercising memory or applications which are housed on your PC, you will not be on the cloud. The cloud enables storage, application housing, memory, etc. at remote server sites. This equates to your computing device basically being an access device to the cloud where all applications and memory will reside. This configuration will further facilitate virtual teaming and virtual project management teams through easy and quick data access, application, and communication on multiple levels.

Cloud computing is founded on the concept of the globe reaching a point where the network, Internet, intranets, massive hardware configurations, in tandem represent a giant supercomputer of their own. This amalgamated supercomputer allows a computational arena where users might center all of their computer software, connectivity, and hardware within the cloud and not on their individual PC's or systems. Various vendors will facilitate the cloud configuration. This results in the users being able to access there applications, memory, servers, etc. in the cloud and only use, or rent those computer services they need at anyone point in time (scalability), and ensure that whatever is applied is the most up to date version of the application. These configurations allow for SaaS (Software-as-a-Service), HaaS (Hardware-as-a-Service), IaaS (Infrastructure-as-a-Service), PaaS (Platform-as-a-Service), VIaaS (Virtual-infrastructure-as-a-Service), etc.

There are number of concerns for the clients of cloud computing suppliers and the cloud facilitators and these are offered from a Berkeley University study in February of 2009 and include:

1. Availability of service
2. Data lock-in
3. Data confidentiality and auditability
4. Data transfer bottlenecks
5. Performance unpredictability
6. Scalable storage
7. Bugs in large distributed systems
8. Scaling quickly
9. Reputation fate sharing
10. Software licensing [5]

The primary way to avoid these pitfalls is to understand the triggers, include them in your risk control plan, and be sure to use effective environmental scanning to check for issues and address them quickly and effectively as well as monitor the development and maturation of the cloud and adjust as needed. It is important for organizations to understand the possible deltas so they might follow strategies to mitigate them as much as possible as we facilitate, sell, and operate within the cloud to decrease cost and increase revenue through virtual work and virtual project application.

5. Crowdsourcing

Definitions may vary, but the basic concept of crowdsourcing is to leverage the collective intelligence of people at large to complete business tasks that a company would either perform itself or outsource to a provider. Crowdsourcing has been around since early man, but the virtual world puts the concept into hyper-warp in application. Although it looks like a simple form of benefiting from collective intelligence, the term is more often used in the context of organizations making focused efforts to achieve a specific task by soliciting contributions from a large, loosely defined community using collaborative technologies as the facilitator and this applies well to virtual project teaming configurations since the endeavor is temporary and virtuality allows the members to function as a displaced, asynchronous, transitory team. Contributors are often prescreened for their knowledge and skill level and this would be the case with virtual project team members.

Crowdsourcing benefits include access to a large talent pool, reduced expenses and time spent for tasks, and utilizing the Internet for collecting data and feedback which offers time and cost benefits for research and development functions. It is a means for management to keep control ever rising staffing costs and staffing risks associated with marketplace and demand fluctuation. When combined with the scalability of using the cloud for memory and application access, a very flexible business model emerges which can run on the fly. Crowdsourcing improves creativity access and provides the exciting prospect of leveraging new resources with experience and skills that may not already be apparent within the organization as well as enhanced flexibility. Crowdsourcing is another tool to apply to get the most out of virtual human resources options and bringing the best participants to the virtual project team.

6. Consumerization of Information Technology

Technology has become more embedded in peoples' lives, and is used virtually in all aspects of daily life – on and off the job. It is important that IT organizations understand how to harness the new paradigms that consumerization creates and that this be facilitated to advance the advantages of virtual working teams. Consumerization recognizes the overwhelming commonality of information technology application and attempts to exercise that fact to the organization's benefit.

The key to understanding is to look at consumerization as an attitude toward the use of technology. Members of organizations need to draw from the fact that they are consumers of technology and are thereby better equipped to apply it in virtual working arrangements since they use it in all facets of their lives on a daily basis. Social networking, blogging, etc. can provide an advantage to an organization and overcome some of the issues with virtual project teaming such as trust. Catering to the consumerization acknowledgement needs of employees will create new opportunities for organizations to gain economic advantage.

This consumerization trend presents a conundrum to the traditional corporate IT organization. Although there is general agreement that there may be gains in use of consumer technology, security remains the deal breaker. The challenge for enterprises is to manage the trend in such a way that does not limit the usefulness of technologies and not result in any loss of information, value and time in the virtual workspace. This security issue is major with distributed virtual teams and must be dealt with as with any risk. IT and security organizations should assess value and security pressures in determining appropriate policies and controls to apply in the control and monitoring of virtual work teams.

7. Transition to a Business Foundation

This same succession image we find in naturally occurring memetic knowledge advancement might be applied to the business environment as organizations and products come and go on a plane of competition and survival. The spread of knowledge and application relative to IT consumerization, crowdsourcing, cloud computing, etc. in meeting organization needs can provide an advantage in the knowledge niche.

The customer has limited resources to trade for unlimited desires in the retail realm. This fact naturally creates competition between the businesses attempting to have those limited resources traded for their products. As is noted by Argyris, "The key activity in the universe called managing is creating and bringing about intended outcomes…" and those intended outcomes are survival, growth, and profit for a business organization [6]. An environment is realized in which succession of business processes and products naturally takes place in an effort to gain the trading of the customer. Those methods and products, which work the best, will perpetuate and go through succession along with the knowledge or memes, which might support them and this phenomenon, is observable in multiple industries.

Knowledge or meme creation, application, and succession within work environments entered a realm unlike any previously observed in recorded time with the birth of information technology driven virtual business environments. Information technology allows for meme communication and applicability rates never observed in the past enabling world markets to explode. These meme succession and development rates now facilitate high speed paradigm shifts bound in a virtual business environment and leadership must adjust to the needs of this knowledge and IT driven environment.

Ammeter and Dukerich's research concluded that leader behavior is the only predictor of team performance and suggested that the interaction between leader methodology and team member performance provides a fruitful opportunity for an organization to gain an advantage [7]. Leader application of an understanding of knowledge hybridization and use, advancement within the business niche, and a realization of the needed leadership methodologies within the dynamic virtual realm results in great opportunity and risk within ever expanding world markets. Proper hybridization of leadership and knowledge management reduce risk and perpetuate opportunity.

8. Project Management Proliferation

Project management has moved more to the hub of management processes than any other management design in the past quarter of a century [8]. Project management became a major organizational concern in the 1960's, although its foundation goes back to early history and it became scientifically based in the 19th Century [9]. The real need for project management links to when business came to the realization that organizing work around projects provided benefits [10]. More work is oriented today with a beginning, a center, and an end. The perpetuation of project management has grown in business directly along with virtual teaming (Gray & Larson).

Project management encompasses an endeavor which is temporary, bringing together a group of individuals, many of whom might work for differing factions of the parent organization, to complete a change founded unit of work to advance the organization on some level. Projects are typically divided into two different types of endeavors which include "Greenfield" type projects that encompass some type of construction endeavor and IT (information technology) / business based projects which involve some type IT based application development or change. The IT / business type projects oftentimes do not result in a tangible product created somewhere geographically, but rather an IT founded creation which is housed in virtual space on IT devices and this type of project is the focus of this writing. Virtual project teams involve collections of individuals who function together while being physically separated [11].

IT / Business projects are very applicable to virtual project team configurations on account of the product itself tending to be virtual in composition and the majority of the participants on the project having access to a variety of virtual worker tools including e-mail, web conference, instant message, white boards, blogs, mash-ups, webnars, cloud bound applications and storage, Microsoft applications or type applications, etc. Virtual project teaming provides low cost, high quality, rapid resolutions through the collection, blending, and application of knowledge via collective networking [12]. This allows for the application of crowdsourcing where the project is able to access participants from the world via participation solicitation. Thus, the best individuals can be brought to the temporary endeavor, and other project endeavors simultaneously, and then members move onto other undertakings upon project completion. It is this fact which equates to the virtual project participants as being transitory in make-up.

When troubles occur within the project team, the organization oftentimes finds no comprehensible leadership, individuals working in silos, and the level of social unrest increases [13]. Hefner and Malcolm, in a survey of 175,000 IT projects, determined that 16% were completed within budget and time objectives. They also determined that close to one-third (32%), were cancelled before completion and that fewer than half (42%), ever met the initial requirements and objectives [14].

9. Virtual Work

Virtual work has transitioned from an occasional occurrence in the early 1990's to a norm in the present Century. Roebuck and Britt view the networking virtual process as replacing the pyramid hierarchy of the workplace [15]. As of 2004, there were over 24 million people working at remote locations [16]. Talukder determined that 81% of business-based respondents indicated virtual environments would increase in the next three to five years [17]. According to Krantz 1990, and referenced by Humphreys, "Organizations must now contend with vastly different conditions in which former approaches no longer apply, and which require that they develop capacity to change, learn, and adapt quickly and decisively" [18]. This fact lies at the crux of change and growth for organizations wishing to apply the appropriate paradigms for success in this global environment.

The application of virtual technology requires managers and leaders change methods to meet the demands and opportunity of the environment [19]. Relationships, or lack there of between dependencies pertaining to virtual work groups has the potential of providing knowledge for virtual organization operations [20]. The importance of high levels of performance in virtual environments will continue to expand as organizations increase virtual operations and the use of teams that work partially or completely virtually [21].

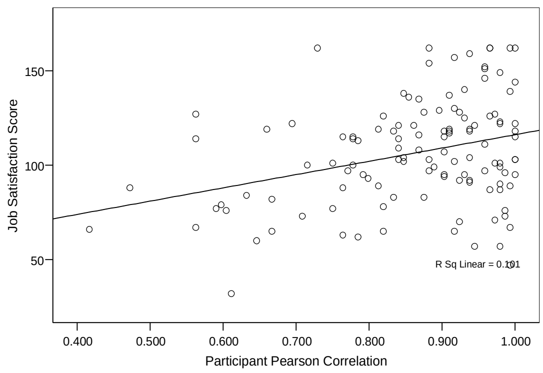
The proliferation of virtual work equates to managers being required to provide leadership within the new environment and the fine-tuning of methods to rally the demands put on themselves and the team. Virtual team members have special concerns with trust, multitasking, current technology use, culture, member burnout, member development and education, and facilitating self-leadership and management, and may never meet face-to-face. It is incumbent upon the virtual leader to take into account these considerations and how to address them to ensure success. Virtual project team communication should be monitored based upon:

- Do we have agreement on our team ground rules?
- Turn around time on emails, phone calls, etc.
- How we share information
- Willingness (and method) to give & receive direct feedback
- How we make decisions
- How will we effectively use media?
- Conference Calls (Whole and/or part of team)
- Email
- A meeting/interaction platform (i.e., NetMeeting, others)
- Document/Information
- Sharing/Knowledge Management
- Face-to-face Opportunities (Whole and/or part of team)
- Other tools?
- How will this team handle disagreements and/or conflict?
- How will we remain connected to our stakeholders or customers? [22]

A quantitative, correlational study by Hitson, based on data collected from virtual workers in 23 nations indicated virtual workers find the greatest levels of job satisfaction when lead via a Self-Management style of leadership [23]. Comfort with a Self-Management style tends to increase as the virtual team member increases their tenure in the virtual workplace. The Self-Management style is characterized by the actions of leaders who exhibit minor responsibility for team methodology or results. Leaders who display this style provide negligible structure, methodology leadership, transformational leadership, assistance toward objective acquisition, and team limit management [24]. With this style, the actual team members have little responsibility for the leadership of the team as well. The followers tend to lead and manage themselves individually and depend extensively on information technology to do so.

Self-managed teams tend to not need much in the form of leadership or receive much leadership [24]. With this style, the designated leader or the followers handle leadership behaviors on an as needed basis. An example of this type of team leadership scheme would include project teams and quality improvement teams and project use within organizations as increased in parallel with the advancement of IT.

According to Hackman, teams lacking rigid leadership structure within the virtual environment show better performance [25]. This realization lends credence to the result that virtual team workers would find a self-management leadership methodology desirable since they would tend to be acting on their own much of the time. Literature indicates that comfort with self-management leadership grows with exposure to the virtual work environment. Effective and continuous leader communication in combination with knowledge acquisition, distribution, and rapid application has become paramount. Please note the following scatter plot which displays the correlation between follower job satisfaction relative to the level of agreement between what the follower desires in their leader and what they are provided.



Virtual workers' level of job satisfaction is directly affected by the leadership style they are exposed to and certain leadership styles function better than others do within the virtual teaming environment [23]. This finding runs in tandem with studies completed on face-to-face teaming operations. The greater the agreement between what the follower desires from their leader and what they receive, the greater the level of job satisfaction [23]. The leadership needs may vary from follower to follower and team to team, but meeting those needs leads to higher levels of performance and follower job satisfaction.

10. Model Rationale

Project driven, rapidly expanding virtual work environments, the business advantage of knowledge development, application, and hybridization, the advantage of the Self-Management style in virtual work environments combine to precipitate a tripod of rationale for the development and facilitation of the KFVSM. The model works from the perspective that leadership ability and process is a diagnosable, teachable dynamic function of our specie. Consideration of the ever increasing dynamic nature of world business markets as driven by information technology is facilitated within the model allowing for reactive, expedient change. This empowerment, change, knowledge based leadership development and application serves as the fulcrum for the balanced advancement of the organization where the needs of the organization and the business environment are held in balance with the needs of the organization members / followers thus allowing market change to be quickly turned into an advantage for the whole organization.

Leadership is a group of activities carried out by organizational members that centers on accomplishing the tasks of setting direction, building commitment, and creating alignment [16]. Virtual work environments put great stress on the alignment factor as the target of success is constantly shifting. Evaluating leadership outcomes requires a multi-disciplinary approach in order to be successful and this can be achieved by referencing the meeting of organization environments relative to the fulfillment of contextual factors of all stakeholders.

While there are many different mechanisms to parse the various aspects of leadership, the virtual environment demands eight key aspects of leadership ability. Those aspects are advocacy and inquiry, re-definition of leadership, emerging environments, evaluations, strategy and tactics, organizational vision, innovation, and normative foundations. These aspects are perpetuated through intelligence, responsibility, task competency, motivation, courage, resolution, trustworthiness, decisiveness, self-confidence, assertiveness, and adaptability which form the center of the leadership pillar of the model. This suggestion rests on evidence that a prescriptive and systematic approach to leadership and performance evaluation is more effective than sporadic or ad-hoc evaluation and increases the chance of high levels of leadership and organization performance.

The primary task of leadership in today's virtual organization environment is to lead change, quick change. The change environment creates a leadership dilemma for today's leaders, but this can be mitigated through innovation, knowledge development, and using the memetic process to the advantage of the organization. The memetic process functions in unison with information technology to facilitate knowledge use through self-managed team members. To lead effectively requires an advocacy and inquiry personal philosophy in which the leader displays a concrete and rationale approach to the process of leadership and knowledge development, management, and distribution. This approach must be shifted to meet environment needs. The leadership dilemma stems from decline related issues such as increased global competition, restructuring downsizing, increasing virtual markets, and business failures in the organizational environment, which present many complex challenges to the organizational leader should a systematic approach to leadership not be facilitated [25].

11. Scanning and Predictive Process

According to Kouzes and Posner, people learn to be leaders by emulating behaviors observed by leaders they view as role models [27]. This involves the transfer of leadership knowledge or a leadership memetic bound process. Understanding leadership requires the evaluation of leadership behaviors as they work together to influence the outcome of leadership practices [28]. Evaluating leadership is driven in a large part by leadership's ability to divine what the future has in hold. Breadth of experience, span of knowledge control and knowledge feedback mechanisms, understanding organizational and community values, follower needs all contribute to improving the accuracy of forward-looking predictions. By contrast, attributes of pride, perceptions of having to stand alone and power issues all serve to cloud the vision to be communicated.

Prior to a vision being communicated to followers, reflection must give way to an analysis of where the organization needs to go and this involves continuous scanning and predicting actions. As an organizational guide, leadership must develop a strategy that defines the moral, ethics, and values of where the organization needs to be while at the same time being cognizant of the foundations of change and knowledge application which stakeholders will relate to in the here and now. In other words, the context of change in congruence with knowledge development and proliferation is as important as the end result. Scanning and predictive behavior are integral parts of the KFVSM and encompass both the needs of the followers, the organization, and all stakeholders.

Each element of a virtual organization strategy needs to be regularly checked against what leaders think they saw as part of their managerial crystal ball. In order to do this, a small but meaningful sample of measurable checks and balances need to be taken to ensure that what a leader thought was the future is in fact what transpired. It is here that the crux of evaluation, scanning, and predicting are especially important because without measurement, leaders cannot reflect; without reflection leaders cannot analyze; and without analysis, knowledge implementation and self-management within virtual work environments are scattered at best.

12. KFVSM Application

A leadership model for information technology driven virtual work groups and project teams should provide a methodology to visualize a process able to deal with the dynamic parameters and primary variables impacting the environment under review. The model must rest on the assumption that leadership is a trait which is trainable and changeable and that this factor will allow for continuous leader, follower, and organization success. The memetic process lies at the development and dissemination of applicable, malleable, combinable knowledge, which fosters continuous change, self-management, and growth for the virtual organization. For the memetic process and the leadership process to function at their highest levels, quality information technology must be facilitated, properly trained, and continuously updated.

According to Ha and Stoele, information technology accounts for more than 50% of capital equipment investments within today's organizations [29]. Given such promise, organizations invest significant portions of their resources on technology acquisition and implementation only to achieve returns from these investments a minor 10% of the time [30]. The degree of compatibility between people and technology correlates to the degree of organizational leadership, strategic culture application, and applied employee reward system in place [31]. The goal of the KFVSM is to increase return on these organizational investments in virtual IT facilitation and team leadership and functionality.

Leadership forward vision is both figuratively and literally demanded by KFVSM if the greatest levels of virtual team leadership success are to be realized. The leader must literally, through scanning and predictive processes founded in metrics, evaluate the position of the organization relative to its objectives and the meeting of the needs of the followers to ensure that balance and forward progress are being maintained within both realms of the fulcrum of leadership resting in the center of the model. The leader must figuratively scan the organization playing field, the competition, markets, conditions, just as the captain of ship from the bridge, and make long-term decisions as to the course to be charted to enable the greatest levels of success. It is from this leadership position of vision, at the foundational pivot point of the model, that stability of all stakeholders, organization, and follower needs and processes are maintained while allowing for growth.

The virtual leader, just as with the traditional leadership role, must strive for the proper blend of supporting, coaching, advising, and delegating to members of the follower group. This can vary from follower to follower and project to project. Oftentimes virtual team members are transitory in that they quickly move from project to project and may participate on multiple virtual teams simultaneously. This moves the team leader from captaining a team ship to a team fleet where each member is an independent stand-alone vessel in the virtual realm. This factor also has impact on proper blend of supporting, coaching, communicating, rewarding, advising, and delegation to be applied by the leader.

Contextual factors pertain to certain circumstances and variables associated with a specific environment [32]. The primary contextual factors impacting the movement toward pre-set organization objectives for virtually operating organizations include metrics, processes, accountability, creating change, governance, internal communication, external communication, organization culture, gaining support, networking, and diversity. The primary contextual variables for virtual followers include training, counseling, listening, rewarding, communicating, multi-tasking, job satisfaction, analyzing, follow-up, evaluating, and planning. These contextual factors must be balanced by the leader in conjunction with organization objectives, knowledge application, and dynamic markets through reactive adjustment of the KFVSM at the point of the fulcrum.

Leadership behaviors that will lead to effective change implementation and build sustained change capability include focusing on building the capability of organizational members to turn continuing change into an advantage and inspiring shared vision by engaging others with a vision of things which can be accomplished. Other essential behaviors include enabling followers to act by believing in their fellow members' potential and establishing conditions in which their potentials can be realized. This process encompasses acting as a role model and displaying integrity via coordination of words and actions while gaining a perspective of the needs and personalities of each follower [33]. Leadership behaviors which advance the objectives of the organization, stakeholders, and executive leadership allow for success and leader advancement within the organization. The KFVSM encompasses this advancement within an environment driven by contextual variables, guided through strategy driven business environment scanning, founded on time tested and new leadership practices, and facilitated via knowledge bound information technology based virtual work.

The model provides a soft system approach to virtual team leadership which serves as a qualitative methodology specifically to this soft system where advantage can be gained through the application of systems thinking to non-systematic scenarios [34]. As espoused by Couprie, Goodbrand, Li, and Zhu, "Soft problems . . . . are difficult to define. They will have a large social and political component. When we think of soft problems, we don't think of problems but of problem situations" [35]. Soft systems specifically refer to systems, which can be very difficult to quantify such as those involving human beings or human beings interaction with other systems such as virtual team operations and this is the case with virtual teams and virtual team leadership. Quantified information and data can be coupled with soft systems thinking and a path to understanding motivations, viewpoints, and interactions among virtual organizations is facilitated [35].

A soft systems approach to virtual work leadership recognizes that the system is unstructured and the leader gains vision through expressing any problem situation through rich visuals. The KFVSM provides the ability to view the situation and produce root contextual definitions and allows the leader to decide from what rich visual perspectives to look at the virtual leadership environment. The result is the leader building conceptual models of what the system must do for each root consideration and compares the conceptual models with the real world while identifying feasible and desirable changes in developing recommendations for taking action to improve the virtual teaming leadership environment from both sides of the model; a soft-systems self-audit.

13. Conclusion

When leaders construct a new vision and communicate new meanings to followers, a common theme is facilitated and this provides strategy to the interaction of the team within, and with other teams. Bolman and Deal asserted, "Vision turns an organization's core ideology or sense of purpose, into an image of what the future might become" [36]. Virtual working individuals make up the fastest growing segment of the workforce and this is combined with the advancement of virtual project teams [37]. Because of these facts, importance is generated to gain a greater understanding of the dimensions of distance between virtual employees and leaders because of the impact the relationship between these two parties has on the function and performance of the organization.

Amalgamation of virtual follower readiness, transcendent leadership parameters, understanding of power and influence, application of project management concepts, knowledge and application of dynamic leadership styles provide a playing field where the greatest chance of success exists. Virtual team leadership enabling trust, project management skills, effective communication, a transitory perspective, expanding information technology, and proper team personnel through facilitation of an understanding of soft systems allows for virtual team members to experience elf-management, leadership, power, growth, and success simultaneously. The KFVSM allows for a strategic approach to virtual team leadership and the flexibility to meet quickly changing operating environments. Multiple and changing variables involved within the virtual leadership equation might be managed effectively and increase leader performance.

Leaders that spend time exhibiting these behaviors may find that they have a more proactive workforce, with motivated and satisfied employees [38, 30]. Additionally, the shared knowledge and the ability to identify with the leader bring an increased level of confidence in both the leader and in themselves [40]. These outcomes are excellent foundations to make the organization more resilient for the long term within virtual work environments and reach greater levels of success.

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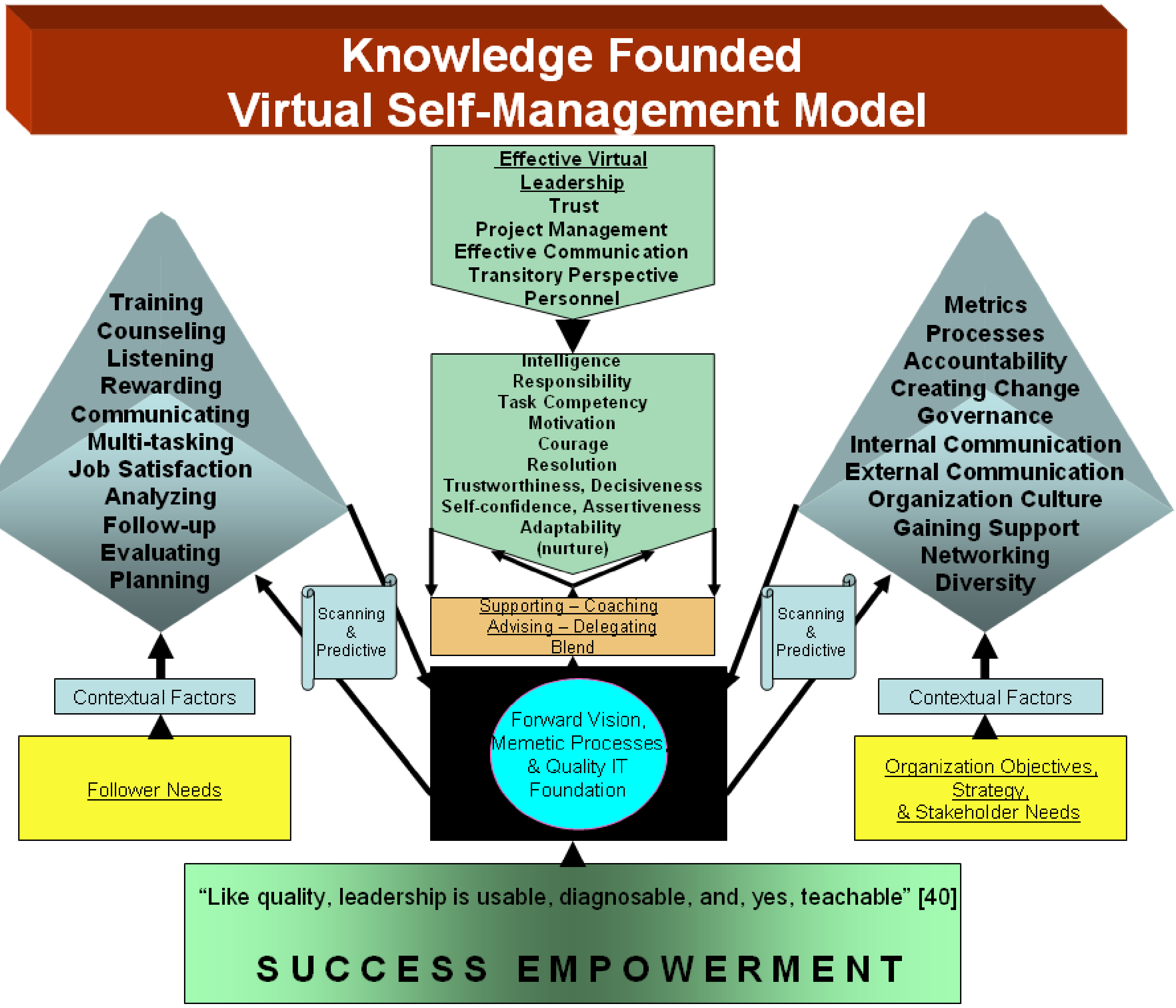
Knowledge Founded
Virtual Self-Management Model
Effective Virtual Leadership
Trust
Project Management
Effective Communication
Transitory Perspective
Personnel
Training
Counseling
Listening
Rewarding
Communicating
Multi-tasking
Job Satisfaction
Analyzing
Follow-up
Evaluating
Planning
Metrics
Processes
Accountability
Creating Change
Governance
Internal Communication
External Communication
Organization Culture
Gaining Support
Networking
Diversity
Intelligence
Responsibility
Task Competency
Motivation
Courage
Resolution
Trustworthiness, Decisiveness
Self-confidence, Assertiveness
Adaptability
(nurture)
Supporting – Coaching
Advising – Delegating
Blend
Scanning & Predictive
Scanning & Predictive
Contextual Factors
Contextual Factors
Follower Needs
Forward Vision, Memetic Processes, & Quality IT Foundation
Organization Objectives, Strategy, & Stakeholder Needs
"Like quality, leadership is usable, diagnosable, and, yes, teachable" [40]
SUCCESS EMPOWERMENT

Real World Evaluation of a New Environment Adaptive Localization System

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***Abstract*— In order to assist the responders during disaster management a self-organizing, scalable, heterogeneous and location aware WSN architecture called Disaster Aid Network (DAN) was proposed in our previous work. One of the main aspects of DAN is the localization aspect which deals with the development of a subsystem for patient localization at the disaster site. The patient localization is split into ranging and position estimation tasks. In this paper a new environment and mobility adaptive signal strength based ranging technique for range estimation is proposed and is tested using both close-to-reality simulations and empirical analysis. These range information is given as input to a particle filter based position estimation algorithm previously proposed by us to provide the location estimate of the patient. In this paper a new localization system is setup by implementing this ranging and position estimation technique in a ZigBee network. A real world evaluation of this localization system is undergone and its localization performance is analyzed.**

Keywords- Emergency response; ZigBee; Ranging; position estimation; Localization system, Real world evaluation.

1. Introduction

In Wireless Sensor Networks (WSN) researchers are dealing with challenges like heterogeneous networks, scalability, self-organisation, self-sufficient operation, multi-hop communication, ad-hoc networks and localization. Some of the short range wireless communication standard based technologies that can be considered for WSN are Bluetooth, ZigBee [3], RFID, etc.

The potential problems faced in the aftermaths of a disaster are: response capabilities of the local jurisdiction may be insufficient, large-scale evacuations from the disaster site, complications in implementing evacuation management strategy, disruption of critical infrastructure, large number of casualties, long duration to obtain an initial common operating picture [23].

We proposed a new emergency response system based on the Disaster Aid Network (DAN) architecture to improve emergency response at the disaster site in [2]. DAN is a self-organizing, scalable, heterogeneous sensor network (see figure 1) of 30-200 nodes comprising of:

- Patient nodes with electronic triage tag and optional continuous vital sign monitoring. They are also called blind nodes [16] because their positions are unknown and have to be estimated.
- Pseudo anchor nodes are patient nodes whose positions are already estimated.
- Doctor nodes (mobile anchor nodes) are mobile nodes (Tablet PC) whose locations are known.
- The monitor station is a collector node which collects the patients' locations and visualizes them for the organization chief.
- Static anchor nodes are nodes placed at fixed positions whose locations are already known.
- Server: A server running a database for data collection and aggregation is placed at the management centre.

Based on the functionalities and operational setup, the design and development of DAN system can be classified into four aspects as follows: communication, localization, data aggregation and visualization, and sensor-actuator. This paper focuses on the localization aspect of DAN which is critical for the DAN system.

2. DAN Localization Aspect

The localization aspect deals with the development of a subsystem for localization of patients at the disaster site. Each patient node localizes itself on the occurrence of an event and communicates its location along with other relevant patient information to the server. The monitor station runs a visualization software that receives a patient's location from the database of the server and displays it on a disaster sitemap. The real time patient location information among others has two main use cases.

- The responders can track each patient in real time. This avoids the time consuming search for missing patients at the site (ex: minor injury patients can run away from the site without informing the responders)

- The patient location helps to provide the responders with the number of patients belonging to each disaster site zone and patient flow rate between these zones leading to efficient resource (distribution of doctors, ambulances, etc.) planning.

This can improve situation awareness of the responders and assist in efficient resource planning and distribution. The organization of supply and service or logistics can be improved and the patients' do not need to wait before being evacuated to the hospitals.

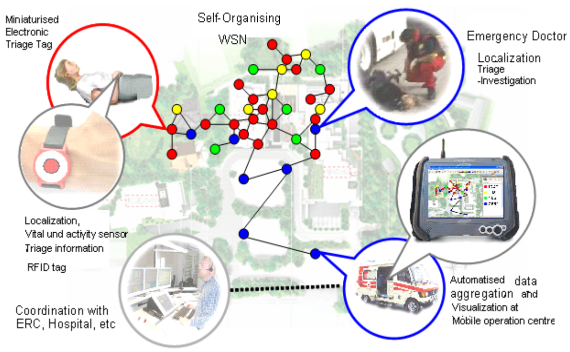


Fig. 1. DAN System

In this paper, the specifications for the localization aspect are formulated and a patient localization methodology is proposed. A new environment and mobility adaptive ranging technique (to estimate the distance between a blind node and its neighbouring nodes) that suits our localization specification is developed and analyzed using both simulation and empirical analysis. This distance information is given to the position estimation algorithm of the patient node which estimates the actual location of the patient in two dimensions. A new position estimation technique that is already developed and tested via close-to-reality simulations is briefed in this paper. Furthermore, these range and position estimation techniques are implemented and its real world evaluation in an outdoor environment is performed.

2.1 Patient Localization Specification

The specifications for patient localization at the disaster site are: handle the different environments (both outdoor and indoor); use minimum or no special infrastructure (static anchor nodes) due to lack of deployment time; track 30-200 patient nodes moving with varying speed (0 to 3 m/s); attain an accuracy of around 10m; be scalable and robust. Even though accuracy is important the main challenge here is to handle the varying mobility and different environment with adverse RF conditions and also use minimum or no infrastructure.

2.2 Patient Localization Methodology

At the beginning of the emergency response, the portable monitor station (typically a notebook is setup. The static reference nodes are deployed manually in such a way that the network coverage is provided to the entire disaster site. Each emergency doctor is typically equipped with a doctor node which acts as mobile reference node. Once a patient is found, the doctor provides a wearable patient node, which is a blind node in terms of localization and needs to be localized over time. Therefore each patient node runs a decentralized localization algorithm. The patient localization methodology is divided into two parts called ranging and position estimation. Each part is addressed separately before combining them to yield the final patient location estimate. The ranging part estimates the distance (range) between the blind node (node whose location has to be estimated) to its neighboring reference nodes (nodes whose locations are already known). These range estimates are input to a position estimation algorithm running on the blind node which provides two dimensional real time location estimations of the blind node (patient).

2.2.1 Ranging Methodology

Range free techniques perform well when reference nodes are deployed uniformly throughout the site. As the nodes are deployed randomly and move randomly at the disaster site, range-based technique can be expected to offer a better accuracy compared to its range-free alternative [21]. In the range-based technique we selected RSSI based ranging technique as it needs less infrastructure compared to its counterparts like TOA (Time of Arrival), TDOA (Time Difference of Arrival) or Angle-of-arrival. Since offline (finger printing) based RSSI ranging techniques are time consuming, needs prior knowledge of the deployment site and repetition of finger printing for minor environmental changes, we use an online based RSSI ranging technique. Comparing with other signal sources (Infrared, ultrasound, etc) a radio frequency (RF) signal source is preferable because it is cost effective and provides a suitable transmission range indoor and outdoor. Therefore, we have selected an online RSSI-based ranging technique using the RF signal for distance estimation during patient localization [1].

Having selected an RSSI range-based technique for the distance estimation, a SOA analysis of RSSI based ranging algorithms has to be done. A new ranging technique for the patient localization has to be developed. A real world offline ranging database has to be built and given as input to the simulation model of the new ranging technique to obtain the distance estimates and their ranging performance has to be analyzed. The ranging technique developed has to be improved to exceed the limitations of the first stage of development.

2.2.2 Position Estimation Methodology

The ranging methodology proposed in the previous section will provide the distance estimates to the position estimation part whose methodology is explained in this section.

The DAN system consists of anchor and patient nodes that are either static or mobile. The patient nodes can move (actively or passive) in an undefined manner (patients moving from one zone to another, patients running away from site, etc.) or be static (red or yellow triaged patients lying down, etc.). Thus, DAN is seen as a dynamic and mobile WSN whose topology changes during its operation time. Mobility makes a WSN delay intolerant i.e. information gathering and localization is done in real time, depending on the speed of the nodes [6]. Besides, a localization algorithm for mobile WSN should cope up with temporary loss of anchors. So position estimates based on simple techniques (ex: trilateration) is unsuitable for our scenario. Mobility should be directly taken into account when designing localization algorithms for mobile WSN and Monte Carlo Localization (particle filter) based algorithms are suitable [6].

Our new system to localize patients at the disaster site can be characterised as a non linear and non Gaussian system with multimodal densities. Linear filters might even give good results for nonlinear, non-Gaussian systems if the system can be approximated by a linear, Gaussian system but in general nonlinear filter techniques are required. A particle filter approximates the posterior with a finite set of samples drawn from the posterior thereby allowing the representation of a broad class of densities including multimodal distributions. In general, a particle filter has superior accuracy over the EKF (Extended Kalman Filter) and the UKF (Unscented Kalman Filter) but this comes at the cost of higher computational effort. Due to the above stated reasons a particle filter based solution is chosen for our position estimation. A new particle filter based patient position estimation algorithm that suits our localization specification has already been developed by us and its performance is analyzed using close-to-reality simulations [22]. In this paper this algorithm will be briefed.

The ranging and position estimation techniques have to be implemented in a ZigBee network and real world evaluated in an outdoor environment. This demonstrator is considered as a first release of the patient localization sub system for DAN.

3. State of the Art Analysis of Localization in WSN

The state of the art (SOA) localization system and RSSI based ranging algorithms related to our work are analyzed in this section

3.1 Localization Systems

Systems like Active Badge [8], Cricket [9], RADAR [10] required a lot of infrastructure. GPS [11] is not suitable for Indoor. In order to obtain a good GPS accuracy the following conditions have to be satisfied: proximity of GPS to buildings should be greater than 3 meters, device should not be brought under dense trees, antenna should be held firmly above shoulder height (approximately 2 meter), and point to the open sky. It is impossible to follow the conditions mentioned above for localizing patients at a disaster site which is an unknown environment with adverse RF conditions. RFID based solutions like SpotON [20] are not suitable for us since they demand high anchor node density, works in short range and needs a fixed infrastructure. We did a primitive analysis of the CC2431 localization solution [13, 4] from Texas Instruments (TI) and it revealed that the blind node location estimation is unstable and needs large number of reference nodes for considerable performance. So this system is also not suitable for our scenario. Therefore we started developing a new localization solution for our scenario.

3.2 RSSI Range-based Techniques

The works in [15], [17], [18], [19] discuss about RSSI based ranging techniques. It is difficult to compare the results of different SOA works due to different preconditions and lack of generally agreed test beds and testing protocols for such networks being available yet. Besides most of the SOA results have been obtained via simulation and real life evaluation are rarely used. We therefore limit the analysis in this subsection only to those algorithms that might have usability for our patient localization.

In [7], Kamin Whitehouse et. al. mentions that RSSI localization in unknown or changing environments needs to adjust system parameters such as signal strength and calibration coefficients automatically. In

[12] Erin-Ee-Lin Lau et. al. proposes a centralized ranging technique using RSSI smoothing and a position estimation technique. The CC2431 ranging technique [13] from CC2431 localization solution (from Texas Instruments) estimates the range between a blind node and a reference node by measuring the average RSSI value between them which is used directly for the distance estimation.

4. New Ranging Technique

In this section a new method named Ranging using Environment and Mobility Adaptive RSSI method (REMA) for patient localization during disaster management is proposed [1]. Based on the simulation results of REMA this technique is further improved to propose "Improved REMA" technique. The localization specifications (see section 2.1) imply that the blind node movement is arbitrary, blind node velocity changes over time, the environment conditions change over time, and an approximate node density of around 300 m² /reference node.

4.1 Ranging using Environment and Mobility Adaptive RSSI method (REMA)

To combat both the static and mobile variations of RSSI during range measurements effectively, we propose REMA which divides the problem space into two and address them separately before combining them to yield the final distance estimation.

- Static variations compensation: by applying online path loss estimation
- Mobile variations compensation: by applying smoothing algorithm on the static variations compensated distance

The key takeaways from SOA algorithms that act as a base for REMA are as follows. We have used the smoothing algorithm from Erin-Ee-Lin Lau et. al. [12] as an initial step. From our experiments and the experimental results of Kamin Whitehouse et. al. [7] we have understood the need for calibration of path loss coefficients to reflect environmental changes. Along with these key takeaways, we have introduced the following main new features in the REMA:

- A range estimation concept that combines calibration of path loss coefficient technique and distance (or range) smoothing.
- Online path loss estimation: The path loss co-efficient estimation is carried out throughout the life of the network, to closely track the environment changes around the reference node. The existing reference node setup is used to estimate the path loss coefficient for each reference node.
- An offline RSSI database built through indoor and outdoor real world experimentations is used to analyze the algorithm's performance.

Each blind node runs the REMA for estimating its distance to each of its one hop anchor nodes. This estimated distance is fed as input to a position estimation algorithm running on the same blind node. Figure 2 shows the steps carried out in REMA method which are explained as follows.

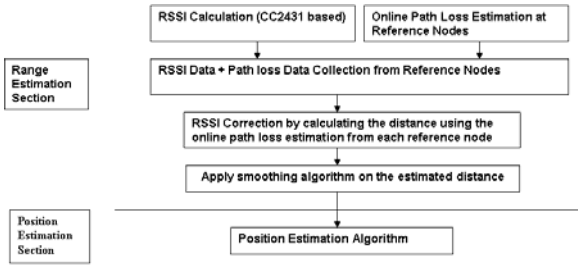


Fig. 2. REMA Flow Diagram

4.1.1 RSSI Calculation

Each blind node broadcasts a burst of packets to its one hop reference nodes and requests the reference nodes to compute the average RSSI value. When the reference node receives a packet it will automatically add an RSSI value to the received packet. The RSSI value is always averaged over the 8 first symbol periods (128 μs) [13]. The reference node computes the average RSSI value by simply averaging the RSSI of all the received burst of packets (from the blind node). In addition to the RSSI value, each reference node is also requested to send its latest online path loss coefficient value estimated at that point of time.

4.1.2 Online Pathloss Estimation

Using a single offline static path loss coefficient for all the reference nodes during range estimation does not reflect the changes in environment over time. So we propose an online position estimation technique where each reference node calculates the path loss coefficients online and periodically updates them. Now, each reference node repeats this pathloss estimation procedure in a time interval of say 'Tn' time units. A low value of 'Tn' results in more accurate distance estimation, for the cases of varying environment conditions. On the other hand, a low value of 'Tn' slightly increases the communication overhead. So a trade-off between the reference node communication overhead (battery lifetime and available communication bandwidth) and distance estimation accuracy has to be achieved. When the path loss coefficients of all such reference nodes are combined over a given period of time, it represents the online path loss modelling of the entire environment (disaster site). Hence, our path loss estimation can be visualized as a discrete online path loss modelling. We consider it to be environment adaptive as it quickly updates the path loss model for the environment changes.

We propose an online path loss estimation technique called 'averaging path loss' for REMA. A reference node i broadcasts a burst of packets to its one hop reference nodes. A one hop reference node j computes the average RSSI value ($avg.RSSI_{ij}$), and the pathloss coefficient n_{ij} between the reference node i and its one hope neighbour j. The n_{ij} is calculated by substituting the actual distance (d_{ij}), $avg.RSSI_{ij}$, and the RSSI at one meter distance from a reference node (A) in equation 1. Similarly the pathloss coefficients between i and all its one hop reference nodes are calculated and averaged (periodically) to obtain the averaged path loss coefficient n_i that reflects the environment around i.

$$n_{ij} = \left(\frac{avg.RSSI_{ij} - A}{10 \log_{10} d_{ij}} \right) \quad (1)$$

4.1.3 RSSI Correction

RSSI correction is a two step process which transforms the RSSI into a estimated distance between a reference node and a blind node. These steps are as follows:

Step I: The blind node requests and collects the RSSI and averaged path loss co-efficient n from each of its one-hop reference nodes.

Step II: The blind node computes its distance estimate d_{est} to each of its one-hop reference node using equation 2.

$$d_{est} = 10^{((RSSI - A)/(10 \times n))} \quad (2)$$

4.1.4 Smoothing Filter

After RSSI correction phase, the smoothing filter of Erin-Ee-Lin Lau et. al. is adapted for our scenario and applied on the estimated distance to get the final smoothened distance. These point to point distance estimation values are fed as input to the position estimation algorithm. This distance smoothing algorithm assumes:

- The blind node does not move arbitrarily in the test bed
- The blind node moves with a constant velocity

The distance (range) smoothing algorithm is a four step process as explained below:

Step 1: The estimated range for the i^{th} update is given by equation 3.

$$\hat{R}_{est(i)} = \hat{R}_{pred(i)} + a\left(R_{prev(i)} - \hat{R}_{pred(i)}\right) \quad (3)$$

Where, $\hat{R}_{est(i)}$ = the ith smoothed estimate range,

$\hat{R}_{pred(i)}$ = the ith predicted range,

$R_{prev(i)}$ = the ith measured range,

The filter constant 'a' attenuates the large deviations or ignores the large deviations between the measured and predicted range values.

Step 2: The estimated range rate for the i^{th} update is given by equation 4 where, b is a filter constant. Range rate estimation works identical to the range estimation explained in Step 1.

$$\hat{V}_{est(i)} = \hat{V}_{pred(i)} + \frac{b}{T_s}\left(R_{prev(i)} - \hat{R}_{pred(i)}\right) \quad (4)$$

Where, $\hat{V}_{est(i)}$ = the ith smoothed estimate range rate,

$\hat{V}_{pred(i)}$ = the ith predicted range rate,

T_s = time segment upon the i^{th} update.

Step 3: The predicted range $\hat{R}_{pred(i+1)}$ for the $i+1^{th}$ update is given by the equation 5.

$$\hat{R}_{pred(i+1)} = \hat{R}_{est(i)} + \hat{V}_{est(i)} T_s \quad (5)$$

Step 4: The predicted range rate $\hat{V}_{pred(i+1)}$ for the $i+1^{th}$ update is given by the equation 6.

$$\hat{V}_{pred(i+1)} = \hat{V}_{est(i)} \quad (6)$$

One of the main limitations in this smoothing filter is the selection of filter gain constants 'a' and 'b'. The filter gain constants are configured as a = 0.0625 and b = 0.0625 for both indoor and outdoor environments by performing offline data analysis using a sample dataset.

4.2 REMA Ranging Simulation

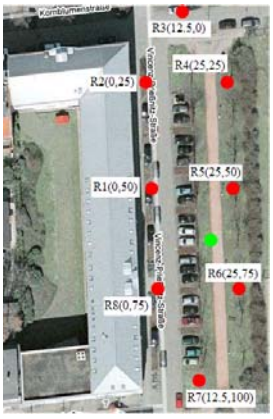
The REMA model that uses 'averaging path loss' technique for online path loss estimation and Erin's smoothing filter for distance smoothing is simulated (via Matlab) in an outdoor and indoor test bed ranging database and the results are presented in this section. For simplicity the 'average path loss' technique estimates the path loss coefficient for each reference node only at the beginning of the data collection in the test beds i.e. a one time static path loss value is estimated for each reference node individually. The simulation results of REMA are compared with that of the SOA range estimation technique 'CC2431-Ranging' (see section 3.2). The 'CC2431-Ranging' uses a single static offline path loss value for all reference nodes which is selected as 3.25 (optimal) empirically.

4.2.1 Offline Ranging Database

This subsection explains the formation of a metadata based offline database by collecting ranging data at outdoor and indoor NLOS test beds. A ZigBee-compliant TI CC2430 node (see [5]) is used either as static reference nodes elevated at 1.5m height or a single mobile RSSI collector node. Reference localization systems are used to capture the actual path traced by a single mobile RSSI-collector node during experimentation. A test person carries a reference localization system and a single collector node and walks around (approximately 1m/s) in the test bed. At any time during our experiment duration of 50 minutes, the actual position of the collector node (from the reference localization system) and the RSSI from the static reference nodes are collected to form the ranging database.

Outdoor test bed: A 100x25m (approximately) outdoor parking space (see google image of outdoor test bed in figure 3) is setup with 8 reference nodes dispersed by 25m NLOS. The test bed comprises of static or mobile obstacles like people, cars, bikes, tree, trucks, bicycles, metal containers and rods. A differential GPS device acts as a reference localization system and is benchmarked at the test bed to obtain an average accuracy error of less than 2m.

Indoor test bed: A 23m x 12m (approximately) indoor area covering seven rooms and a corridor in the second floor of an office building (see figure 4) is setup with 7 reference nodes (one node in each room). The test bed comprises of static or mobile obstacles like people, computers, coffee machines, printers, walls, etc. The CC2431 location engine solution from TI [4,13] acts as a reference localization system (due to its availability with us, though not an optimal reference system) and is benchmarked at the test bed to obtain an average error of 3.1m, maximum error value of 4.8m and minimum error value of 1.5m.



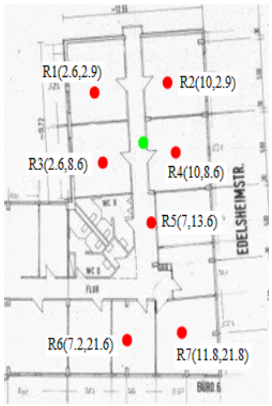


Fig. 3. Outdoor test bed Fig. 4. Indoor test bed

4.2.2 Results using Outdoor Database

The average ranging error (in terms of % of error in distance estimations) obtained using 'CC2431-ranging' and REMA method, during the distance estimation over time between the mobile node and each of the reference nodes R1 to R4, are as follows:

- R1, 'CC2431-ranging': 59.80% and REMA filter: 21.81%
- R2, 'CC2431-ranging': 80.05% and REMA filter: 42.04%
- R3, 'CC2431-ranging': 85.93% and REMA filter: 38.18%
- R4, 'CC2431-ranging': 74.39% and REMA filter: 38.69%

In all above cases (R1 to R4) REMA outperforms 'CC2431-ranging' in the outdoor environment.

Figure 5 plots the frequency distribution of distance estimation error in outdoor environment of all reference nodes combined together over the error intervals (in meters). Comparing the frequency distribution of error of CC2431 ranging and REMA filter, it is found that the REMA filter shows high probability of getting low error values and low probability of getting high error values. This indicates that the distance estimation of REMA filter is more accurate than that of the CC2431 ranging in the outdoor environment.

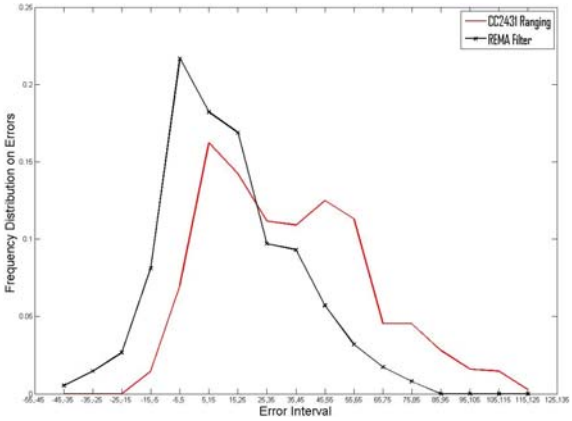


Fig. 5. Frequency distribution of error

4.2.3 Results using Indoor Database

The average ranging error (in %) obtained using 'CC2431-ranging' and REMA, during the distance estimation between the mobile node and each of the reference nodes R4 to R7, are as follows:

- With respect to R5, 'CC243-ranging': 73.5% and REMA filter: 40.89%
- R4, 'CC243-ranging': 59.05% and REMA filter: 40.89%
- R6, 'CC2431-ranging': 65.05% and REMA filter: 36.84%
- R7, 'CC2431-ranging': 82.30% and REMA filter: 66.84%

In the above cases (R4 to R7) REMA filter outperforms 'CC2431-ranging' in the indoor environment as well. The distance estimation error for indoor setup is worse than that of the outdoor approximately by a factor of two.

4.2.4 Summary

The REMA ranging method (with 'averaging path loss' and Lau et. Al. smoothing algorithm) is simulated using an offline ranging database and the results are that REMA reduces the overall average range estimation error by about 31% when compared to the SOA 'CC2431-ranging' [1]. The results indicate that RSSI based ranging is a feasible solution for the patient localization at least in outdoor environments even though considerable estimation errors at certain areas remain, while in indoor the performance is severely affected. The REMA method is a suitable base for patient localization even though further improvements have to be done towards achieving the targeted final accuracy.

4.3 Improved REMA Method

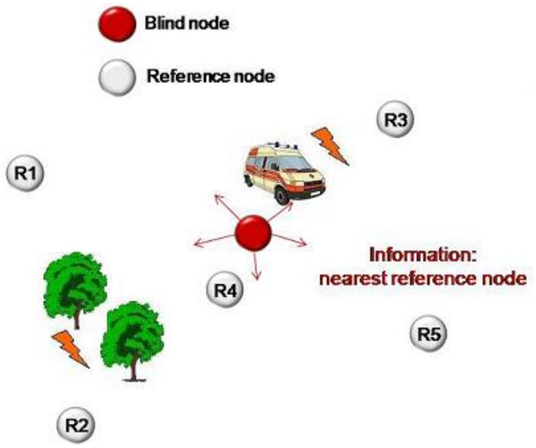
In this section the REMA method that uses 'averaging path loss' and Lau et. Al. smoothing algorithm is discussed and a concept to improve the online path loss estimation and smoothing filter is proposed leading to "Improved REMA".

4.3.1 Online Path loss Technique Improvement

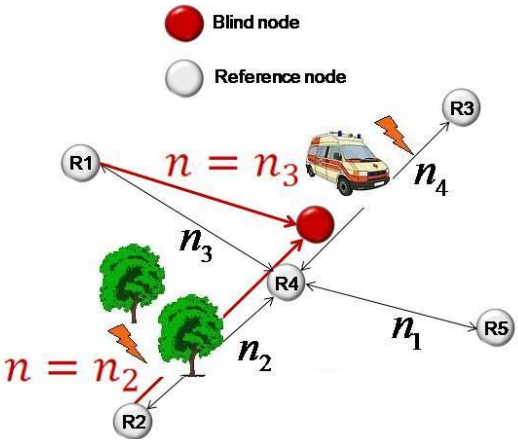
The 'averaging path loss' technique proposed for online estimation in REMA method (see section 3.1.2) is only a simple approach. We have an exponential correlation between the path loss coefficient n and the distance d (see equation 1). So small changes in the path loss coefficient accounts for large changes in the distance. We therefore consider the accuracy of the path loss coefficient to be a critical issue for distance estimation and only a simple approximation by averaging is not sufficient for our purpose. So in this section we introduce a new online path loss estimation strategy to represent the real path loss value between blind node and reference node, which we call dynamic path loss estimation strategy (DYPES). The idea is to estimate an individual path loss for each blind node, depending on the area it is in. This strategy can be divided into 3 phases as follows:

- Each reference node collects signal strength and location from all other reference nodes with known location
- A blind node broadcasts the location of the reference node from which it receives the highest RSSI value (see Fig. 6 (a)), assuming that the distance is minimal.
- Each reference node sends an individual path loss to the blind node which is the path loss between itself and the reference node closest to the blind node (see Fig. 6 (b)).

Assuming the blind node is at the same position as a reference node the path loss calculation is optimal, the farer away from any reference node the worse the path loss estimation. We consider the accuracy of the path loss coefficient to be a function of the distance between blind node and nearest reference node. Figure 6 illustrates the new path loss estimation strategy.



a) Phase two



b) Phase three

Fig. 6. DYPES method

4.3.2 Smoothing Filter Improvement

Erin Lau et. Al. smoothing algorithm is unsuitable with arbitrary movement, changes in directions and velocity of the blind node. Another critical issue is the parameter (filter gain constant) tuning as it is difficult to configure a generalized value that is versatile. Therefore in this section we check the three candidate filters to meet our requirements: handle arbitrary movement, handle different velocities, handle outliers and fluctuations of RSSI, and generalized parameters without further adaption. These three candidate filters are as follows:

- best-of-k filter, which uses the best obtained RSSI measurement from the previous k measurements as shown in figure 7.
- Erin's smoothing algorithm as described in section 4.1.4
- combination of best-of-k and Erin's smoothing filter

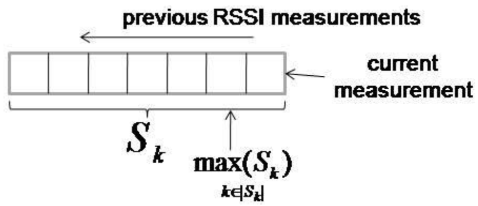


Fig. 7. Best-of-k filter scheme

We consider the best-of-k filter to be theoretically best-suited for our requirements as it attenuates fluctuations by ignoring up to k−1 outliers. We assume that a radio signal cannot be strengthened passively. Let α be the upper bound for the received signal strength between 2 nodes, separated by a distance d and n be the path loss coefficient. Assuming a good estimation of n (an optimal estimation of n would naturally lead to the exact distance estimation if using α), the critical issue is to receive k RSSI measurements where at least one measurement is close to α. The value of k is chosen such that it is large enough and doesn't impose too much delay to the system.

In the evaluation section, the three filters mentioned above will be evaluated using a real world RSSI database to select the best-suited filter. Even though distance smoothing is used in REMA, the Improved REMA (best-of-k and DYPES) uses RSSI smoothing. The method of Improved REMA is as shown in figure 8.

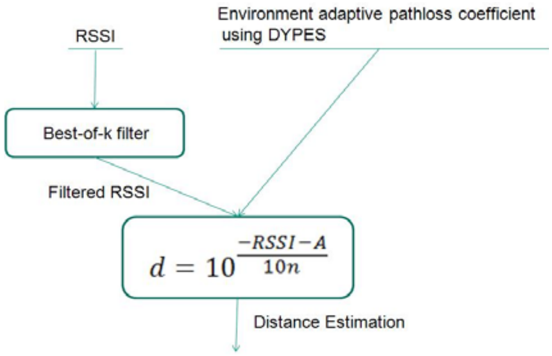


Fig. 8. Improved REMA method

5. Position Estimation Technique

In this section a new particle filter based position estimation algorithm for patient localization called Improved Range-Based Monte Carlo Patient Localization (IMPL) that was already proposed by us in [22] is briefed. The distance estimates obtained by Improved REMA that works on a blind node is given as input to the IMPL which provides the patient position estimate. IMPL maintains a weighted sample set in order to estimate the patient node's position. IMPL undergoes three main steps: Prediction, weighting and resampling which are explained below.

Prediction: The prediction step depends on whether there's already an established sample set (after initialization) or not (during initialization).

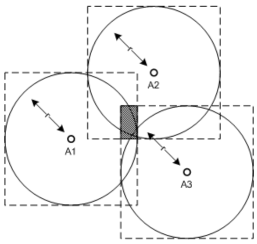


Fig.9. Forming the anchor box

In prediction during initialization, first the area to be sampled from is constrained to an anchor box. The region covered by the transmission range r of each one-hop anchor is approximated to a box as shown in figure 9. The overlapping area of all the boxes (shaded area in figure 9) forms the anchor box. Then a sample set of 40 uniformly distributed samples are drawn from the anchor box. In prediction after initialization, we take each sample from the previous time step and form a circle of radius $v_{\max} + addition$ centered at that sample's position. From every circle one new sample is drawn.

Weighting: A weight is calculated (based on the range measurements) for each sample in the sample set, to know if they are good or bad representations of the actual location of a blind node. In order to weigh a sample i of a blind node, all the range measurements of this blind node to its one-hop anchors are selected. Consider a range measurement rm_j between a blind node with a sample i and its one-hop neighbor j, then a partial weight wp_i^j is computed as shown in equation 7. Here the range measurement rm_j is projected onto a Gaussian distribution (see Fig. 10) of mean $\mu = d + \mu_v$ (where d is the distance between the sample and the one-hop neighbor) and standard deviation σ_v. The σ_v and μ_v of a Gaussian random variable v are the systematic and random error of the range measurement error model (of the environment). Their values are deduced from the environment i.e. all anchor nodes within the transmission range of each other compute the error between their actual distance and their estimated distance. All these values are collected in a single node to calculate the σ_v and μ_v.

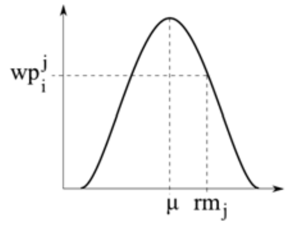


Fig. 10. Calculating the partial weight

The total weight w_i for sample i is the product of all partial weights.

$$wp_i^j = \left(1/\sigma_v\sqrt{2\pi}\right)\cdot e^{-0.5\cdot\left(rm_j-\mu\right)^2/\sigma_v^2} \qquad (7)$$

Resampling: After normalizing the weights of the sample set to one, samples are redrawn from the normalized sample set with a probability proportional to their weights. The size of the new sample set remains the same.

The position estimate (x, y) of the blind node is calculated as the weighted mean of the sample set. The closeness value for blind node p with N samples is computed as in equation (7).

$$closeness_p = \sum_{i=1}^{N} w_i \sqrt{(x_i - x)^2 + (y_i - y)^2} \,/\, N \qquad (8)$$

where (x_i, y_i) denotes the position of sample i, w_i denotes the weight of the sample i and (x, y) is the current location estimate of node p. The closeness of an anchor node is set to 0.

IMPL has to be initialized with a set of parameters:

- Systematic and random error (σ_v and μ_v) of the range measurement error model.
- the transmission range r of the nodes
- the maximum velocity of the mobile node and additional factor which increases the circle to draw the samples ($v_{\max} + addition$)
- the upper and lower bounds for the coordinate system

These parameters have to be found heuristically or can be set in an initialization phase automatically.

6. Real World Evaluation

In this section our new ranging and position estimation techniques for patient localization are implemented and the position estimation performance is evaluated in a realistic scenario. We compare the obtained results with a state-of-art localization system from Texas Instrument in section 7.

6.1 Test Bed

For evaluating our system we implement our ranging and position estimation algorithm on a ZigBee-ready hardware node of the CC2520ZDK development kit from TI. This ZigBee-ready node comprises of a MSP430F2618 16-bit ultra-low power micro controller connected to a 2.4 GHz IEEE 802.15.4 RF transceiver, SMA antenna. Each device is either used as reference node or blind node in our experiment. Each reference node is placed in a transparent plastic box mounted on a tripod at a height of 1.5m and are distributed on the experiment site. The SX2 Hemisphere DGPS is used as a reference. A person carries a DGPS mounted on top of a rucksack and also a single blind node mounted next to the DGPS antenna in a transparent plastic box and walks randomly in the experiment site. At any time during the experiment, the actual position of DGPS and the estimated position of the blind node are recorded. Accuracy error is plotted as Euclidean distance between the recorded DGPS position and the estimated position of our system.

We define two experimental test beds. A line-of-sight area (LOS) and a non-line-of sight area (NLOS). The LOS area is a football field of around 80m x 45m with a reference node density of around 450m²/node and is an obstacle free area with line of sight between all nodes as shown in the google image in Fig. 11. The NLOS area is around 60m x 30m with a reference node density of around 225m²/node. This area includes a parking lot and a walking pathway with trees. It has obstacles such as metal containers, cars, fences and trees as shown in the google image in Fig. 12. The black dots within the experiment area represent the positions of the localized reference nodes. All our experiments explained in this chapter are done in these test areas unless otherwise stated. In order to compare the data of LOS and NLOS areas, experiments are done with exactly the same setup and the data is recorded in the same session.

Since DGPS is used as reference system its accuracy is benchmarked at our experiment site and an average accuracy error of less than two metres is obtained. We therefore conclude that DGPS is a suitable reference system in this area. The reference node localization and placement are topics of concern. In our experiment the reference nodes are localized using DGPS. The reference nodes are localized by first setting DGPS to zero on a certain reference node (origin) and programming the remaining reference nodes locations with respect to the origin. For each chosen reference node it is checked that the DGPS position does not fluctuate more than 2m by observing the DGPS position for 60 seconds at a specific position. The reference nodes are placed near the edges and within our experiment area, without any special placement strategy.

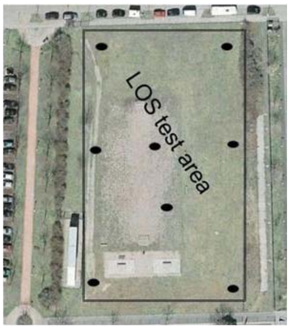


Fig. 11. LOS test bed with reference node positions

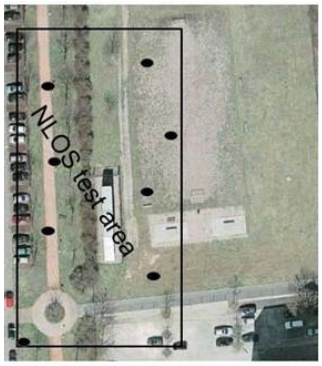


Fig. 12. NLOS test bed with reference node positions

6.2 Evaluation Results

In this section we present the results of different intermediate evaluation steps, leading to the testing of our final localization system in a NLOS test area. In the first subsection we test different RSSI smoothing filters in simulation to determine their performance. In the second subsection we test our ranging technique by combining a smoothing filter and DYPES. In the third subsection we test our position estimation performance.

6.2.1 RSSI Smoothing Filter

An RSSI database is given as input to a simulation model to test filters such as best-of-k, REMA using Erin’s smoothing algorithm, ‘REMA using Erin’s smoothing algorithm and best-of-k combined’ (see section 4.3.2). The ranging error is evaluated as Euclidean distance of the DGPS position to a reference node and the estimated distance.

Offline Outdoor RSSI Database

An offline database is collected by recording RSSI values each second with a blind node which moves randomly in the LOS test area as described in section 6.1 and figure 11). The data for each time step consists of the actual position of the blind node recorded by DGPS and accordingly the recorded RSSI value. In total the database consists of 10,251 such tuples divided into 8 subsets, each containing the collected data received from one reference node.

Simulation of RSSI Smoothing Filters

For determining the free filter parameter values (to be defined later in this section) we use a cross-validation with up to 5 randomly chosen subsets for training, and 3 randomly chosen subsets, excluding the training data, for evaluating the quality of an obtained set of filter parameters. An exhaustive search over possible values is performed.

This search also leads to an evaluation of the influence of these parameters as well as their robustness in a LOS environment. The values of the following parameters have to be estimated:

- A : the parameter which describes the signal strength at 1m distance (in dBm)
- k : the number of past RSSI values used for the best-of-k filter
- a : filter gain constants (distance) for Lau et. Al. smoothing algorithm
- b : filter gain constants (speed) for for Lau et. Al. smoothing algorithm
- path loss : the path loss coefficient suited best for the data obtained data

Figure 13 shows the mean ranging error of the three filters, obtained by varying the number of training sets used to estimate the parameters. With an increasing number of training sets the average range error decreases for each of the tested filters, as the parameter estimation is more general with each added set of data. However, at the right end of the plot, we see an increasing error for all filters except the best-of-k filter. We consider this effect as a result of over fitting; the parameters have been adapted too much to the training set, such that its power to generalize to unseen data decreases. With an increasing number of estimated parameters, over fitting becomes a critical issue. The filter with the highest number of parameters (‘REMA using Erin’s smoothing algorithm and best-of-k combined’: 5 parameters) performs significantly worse after reaching a certain amount of training data. REMA using Erin’s smoothing algorithm (4 parameters) performs better, but as well we can see the same tendency. The best-of-k (3 parameters) is almost unaffected by the amount of training data.

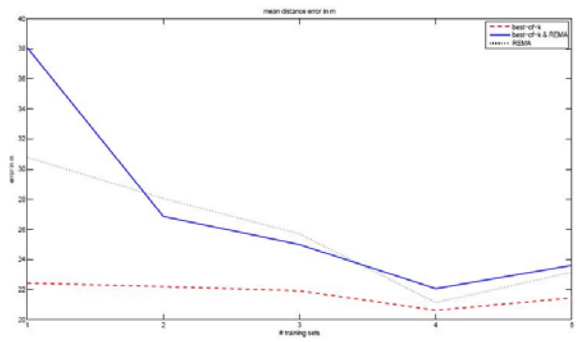


Fig. 13. Mean ranging error for different filters

Conclusion

Filters with a small number of free parameters need less time to converge and are more robust in terms of the amount of training data for LOS environments. Therefore we select the best-of-k filter for RSSI smoothing for Improved REMA Ranging.

6.2.2 Ranging using Improved REMA

We implement an Improved REMA that comprises a best-of-k filter for RSSI smoothing in the blind node and DYPES for online path loss estimation (see section 4.3.1) and evaluate its performance in our LOS and NLOS test area as described in section 6.1. The parameter 'A' should be determined by measurement but due to the fluctuating signal strength it cannot be defined clearly. We therefore use A = 48dBm as this showed best performance and k = 3 for the best-of-k filter for all evaluations further on, as this is a good trade-off between latency of the system and for discarding outliers. The range and path loss is updated every second. However, we are aware of the fact that this setting comes along with a large amount of traffic in the network but consider it as a good benchmark setting to achieve maximum accuracy.

In the LOS test area the mean ranging error obtained is 12.21m, in the NLOS area the mean ranging error is 10.93m. We call the Improved REMA’s performance out-of-the-box as there is no parameter tuning necessary before deploying the system. Table 1 shows the results obtained in the ranging experiments. Against our expectations the ranging error in the NLOS area is smaller than in the LOS area. We believe that this is due to the deployment area for both experiments. The node coverage in the NLOS area is twice as high (225m²/reference node) compared to the LOS area (500m²/reference node).

Test area	Area	RN	Mean error
LOS	80m×45m	8	12.21m
NLOS	60m×30m	8	10.93m

Table 1. Ranging performance summary

6.2.3 Localization using Improved REMA and IMPL

We implement an Improved REMA consisting of a best-of-k filter for RSSI smoothing and DYPES for online path loss estimation. For position estimation we use IMPL (see section 5). The performance of the system is evaluated in our LOS and NLOS test area as described in section 6.1. The experiments as described in section 6.2.2 and 6.2.3 are done in the same session for each test area (LOS and NLOS) so that we can compare the ranging and position estimation error for similar environmental conditions. Figure 14 shows a complete scheme of the localization process.

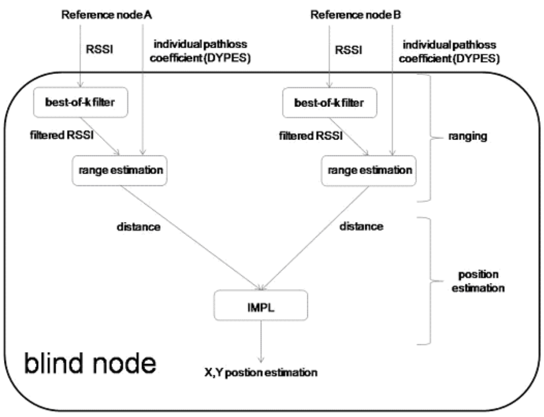


Fig.14. Complete scheme for localization with two reference inputs

We use the following parameters for all experiments if not explicitly stated different. The Improved REMA parameters are signal strength at 1m distance: A = 48dBm, number of past RSSI measurements for the best-of-k filter: k = 3, sample set size for localization is set to 40 particles. The IMPL parameters (obtained heuristically) are measurement error mean: 1m, measurement error standard deviation: 20m, the maximum nodes speed is given as 2m/s plus an additional uncertainty factor of 1m. The localization and path loss updates are done each second. We refer to this system as a first version of our patient localization system (PLoc- V1).

LOS Test Area

We obtain a mean position estimation (localization) error of 13.93m. The average number of visible reference nodes during localization is around 6. It is observed that mean position estimation error is higher than the mean ranging error (12.21m, see table1). We believe this is due to the sensitivity of IMPL if fed with wrong ranging information. One wrong distance severely affects the position estimation of the system, whereas the mean ranging error is less affected by one wrong distance.

NLOS Test Area

In this experiment we test our localization system (PLoc-V1) in a realistic test area that reflects the attributes of a disaster site. The accuracy error plot is shown in figure 15. The blue dots show the number of visible nodes for each time step. For clarity reasons the number of visible nodes is multiplied by 10 to be shown in the same graph as the position error.

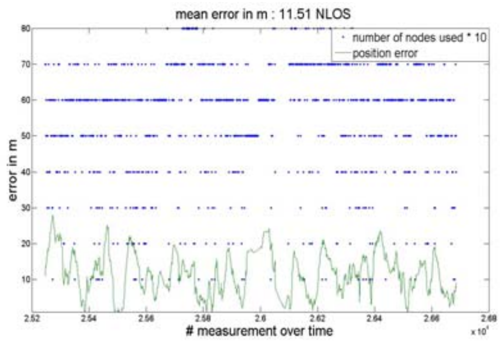


Fig. 15. NLOS test area position estimation error

The mean position error is 11.51m and the average number of visible reference nodes per time step is 5. The corresponding mean ranging error is 10.93 as in table 1. We can see that the accuracy is not severely affected by receiving less reference nodes inputs over certain time instances. The surface plot in figure 16 shows the mobility path of the blind node in NLOS test area and the corresponding position estimation error (difference between actual position obtained from DGPS and the estimated position from PLoc) in different colours at each location of this mobility path. The surface plot plots locations with error less than approximately 20m in green colour.

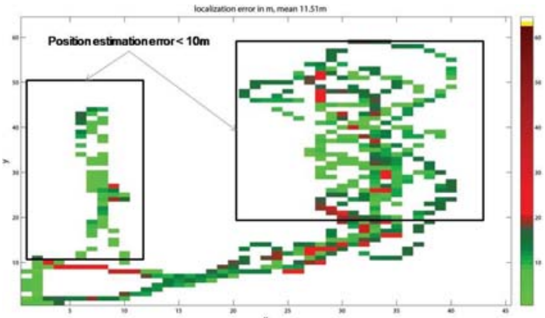


Fig. 16. NLOS test area position estimation error- surface plot

PLoc-V1 Localization Results Summary

Table 2 shows the localization results of Ploc-V1. We state that an average node visibility of 5 reference nodes per position estimation is sufficient for not affecting the position estimation accuracy significantly.

Test area	Area	RN	Mean error	Comment
LOS	80m×45m	8	13.93m	out-of-the-box
NLOS	60m×30m	8	11.51m	out-of-the-box

Table 2. PLoc-v1 Localization performance

7 Comparison of PLoc-V1 and CC2431 Location System

In this section the performance of PLoc-V1 is compared with the state-of-the-art localization system CC2431 from TI. The google image with reference node positions in figure 17 shows the experiment setup in a non line of sight environment with an area of 61 x 55m with 8 reference nodes deployed over the whole area. The area includes a parking lot, a walking pathway and has obstacles such as metal container, cars, fences and trees. We lowered the height of the reference nodes to 1m and placed a couple of nodes behind cars or other obstacles to simulate changing signal conditions. Compared to the test area used in the previous experiments (see figure 12) the non line of sight effect in this experiment area is larger and also includes additional lowering of the reference node height, to reflect adverse RF conditions. Two ZigBee networks (one for PLoc-V1 and other for CC2431 system) operating in different channels are setup and a test person carrying the DGPS (actual position), the PLoc-V1 blind node and CC2431 blind node walks randomly in the test area with different speed and records the data. A static path loss coefficient has to be programmed upfront for the CC2431 system. It took around half an hour to select an optimized path loss coefficient (3.375) by testing the accuracy of this solution at different locations of the test area.

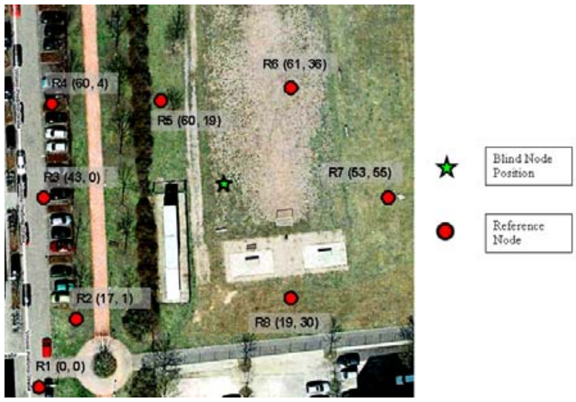


Fig. 17. Test bed for comparison of PLoc-v1 and CC2431

From the comparison of CC2431 and PLoc localization error in figure 18, it can be clearly seen that PLoc performs better in terms of average position error and outliers.

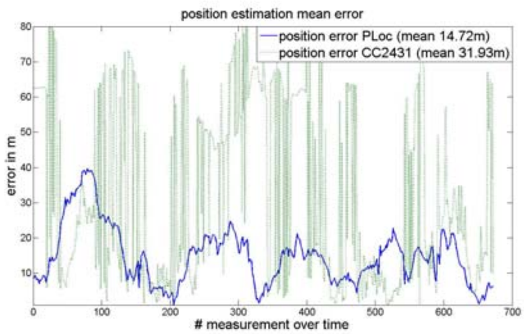


Fig. 18. PLoc vs. CC2431 localization error

It is observed in figure 18 that CC2431 error has frequent peaks with harsh error values which corrupt the range estimation. On the contrary PLoc error peaks are of lower values. This shows that CC2431 does not adapt to environmental changes leading to high distance variances. The localization error results are summarized as shown in table 3.

System	Path loss	Area(m)	Mean error
CC2431	3.375	61×55	31.93m
PLoc	Dynamic	61×55	14.72m

Table 3. PLoc-v1 vs. CC2431 Localization performance

The mean localization error for PLoc-v1 is higher in these experiments compared to the NLOS experiment mentioned in table2 due to the larger test area and lowering the reference node height which introduces additional signal fluctuations. The mean localization error of PLoc-v1 is 53% better than that of CC2431.

8. Conclusion and Future Works

In this paper a new algorithm called Ranging using Environment and Mobility Adaptive RSSI (REMA) is proposed. From the ranging experimentations in indoor and outdoor environments, we found that RSSI based ranging is a feasible solution for the localization in our scenario. With our proposed REMA, we are able to reduce the overall average range estimation error by about 31% when compared to that of the state of the art 'CC2431-Ranging'. This REMA acts as a suitable base and is further improved to propose the Improved REMA method for range estimation during patient localization at the disaster site.

A new RSSI based localization system (first release of PLoc-V1) is evaluated using a demonstrator. The mean localization error of PLoc-v1 that uses Improved REMA (best-of-k and DYPES) for ranging and IMPL for position estimation in a realistic test bed that reflects the attributes of a disaster site is 11-14m, which is closer to the accuracy specification for patient localization. Comparing the performance of PLoc-v1 with state of the art RSSI based localization system CC2431 in a realistic environment shows that the accuracy of PLoc is 53% better than the CC2431 system. Moreover, PLoc-v1 is an out-of-the-box system as it can dynamically calculate the path loss coefficient and adapt to environmental changes while CC2431 uses a static path loss and requires high installation time.

Further improvement of PLoc first release (ranging and position estimation techniques in terms of accuracy, scalability) for outdoor environment and testing of this system at indoor environment will be part of future work.

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