AN ATTEMT TO DEFINE CONTEXT AWARENESS IN MOBILE EHEALTH ENVIRONMENTS

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Abstract

Nurses, doctors, physiotherapists, psychologists and other professionals or specialists come together to provide care to home residing patients, making continuous assessment, diagnosis and treatment possible beyond the walls of hospitals. Such teams of professionals are focused on each individual patient, and are virtual, i.e. they make decisions without being together physically, dynamically, i.e. professionals come and go as needed, and collaborate, as they combine their knowledge to provide effective care. Our system, coined DITIS, is a web based system that enables the effective management and collaboration of virtual healthcare teams and accessing medical information in a secure manner from a variety of mobile devices from anytime and anyplace, adapting the information according to various parameters like, user role, access right, device capabilities and wireless medium. This paper introduces the DITIS system, and identifies the needs and challenges of co-ordinated teams of multidisciplinary healthcare professionals (HCPs) functioning in a context awareness environment under the wireless environment. Pilot implementations of the systems as well as an evaluation study of the system are also briefly presented.

Keywords: Mobile e-health, Context adaptation, home healthcare, collaboration, virtual teams.

1 INTRODUCTION

In recent years, there has been a major reconstruction on healthcare sector due to the diversification of user needs, demands and expectations, within the structure of a modern society [Georgiadis D., 2002]. eHealth is the discipline that took over in the last years in the health sector, proving the need for providing a dynamic working environment of different actors (medical ones) promoting effective collaboration among the actors, including the patient, at anytime, and any context (place). The needs of mobile users differ significantly from those of desktop users. Getting personalized information "anytime, anywhere and anyhow" is not an easy task. Researchers and practitioners have to take into account new adaptivity axes based on which personalized interface design of mobile Health would be built. Such applications should be characterized by flexibility, accessibility, context awareness, quality and security in a ubiquitous interoperable manner in order to provide the citizens with quality on demand information (services) [Pitsillides A., 2006]. User interfaces must now be friendlier enabling active involvement (information acquisition), giving control to the citizen and provide easier means of navigation supported by the small screens of the mobile devices and enable adaptation of hypermedia, multi-media, and multi-modal intelligent and personalized user interfaces.

Mobile devices usually are small with inefficient input methods, small screen, limited battery life and prone to damage and spoilage [Pitoura E., 1998]. These problems should be denoted and handled due to a development of a system in eHealth sector. In addition, specialists want efficient help from an eHealth system without re-analyzing and restructuring their way of working with the system. After a more thorough examination of these problems, the need for dynamic workflows and the need for time driven events came to the surface.

Supporting context awareness increases the complexity of a system such as the dynamicity (i.e. environmental and syntactic) and information adaptation according to the communication medium and mobile device characteristics. Our study is focused on the needs for collaboration in the health care sector and more specific in the virtual health care teams[1] and the creation of dynamic workflows under the same sector supporting a context awareness environment. In this paper our system is presented that tackles all the pre-mentioned problems of the eHealth sector. All these problems are addressed in more detail in the following sections and a proposed solution, named DITIS, is presented along with a preliminary evaluation of the system using as a case study in a local nonprofit organization that provide palliative homecare. DITIS is a context awareness application that co-ordinate teams of professionals under the wireless environment.

2 BACKGROUND THEORY

2.1 Mobile eHealth

eHealth is a discipline that took over in the last years in the health sector, establishing the need for providing dynamic working environments of different actors (medical professionals) promoting effective collaboration among the actors, including the patient, at anytime, and any context (place). The term eHealth is being used increasingly as a generic expression to refer to any form of IT enabled health system reform. eHealth addresses both changes in the access of healthcare information and services, as well as the wider dissemination of healthcare related skills and specialist expertise into the community, into the home, and ultimately to the individual. This transformation, enabled by eHealth, challenges the traditional roles of hospitals and clinics where healthcare exchange has always taken place in the past. The next phase includes the use of mobile devices to provide a user-friendly interface and a conduit to healthcare providers to bring healthcare services directly into the personal space of the world citizen (Mobile eHealth).

[1] Virtual healthcare teams are teams that consist of healthcare professionals who collaborate and share information on patients through digital equipment.

The progress of telemedicine from desktop platforms to wireless and mobile configurations may have a significant impact on future health care. The new technologies can make the remote medical monitoring, consulting, and health care more flexible and convenient [Tachakra S., 2003].

2.2 Wireless Environment and Mobile Devices

Following the growing user demands and requirements as well as the rapid development of the technological advancements and infrastructure capabilities the development of eServices should not only focus on making the service available on the desktop Internet, but also examine the different mobile Internet delivery platforms. A multi-channel (WAP, MMS, SMS, Web etc.) and a multi-device (PC, mobile phones, PDA, tablet PC etc.) access mix will improve the access of the services offered, since will be available anytime, anywhere and anyhow through a single point of access entry. Indisputably, this is the vision of an interoperable, transparent and secure Internet environment whereby multi-channel service delivery integration is considered fundamental.

Moreover, the growth of mobile communications has had a profound economic and social impact in Europe and beyond. The mobile phone is now pervasive and is used in every human activity, private, business and governmental. While penetration levels are likely to continue to increase, the most significant future development will be the growth of mobile broadband services, as the potential provided by third generation mobile (3G) and its enhancements, as well by other wireless technologies, including RLAN, satellite and others, is realized. The dissemination of these technologies represents a paradigm shift that will enable the emergence of new data services, combining the benefits of broadband with mobility (COM, 2004). Over the past year, European 3G mobile operators have launched commercial services in ten Member States, and more networks are expected in the following months. Looking forward, the convergence of telecommunications, broadcasting and internet will result in the proliferation of high speed multimedia services delivered over mobile networks. The 2.5G / 3G and R-LANs will co-exist by giving a broader technology base from which new innovative services could develop to the benefit of all. Hence, users can benefit from the high-speed wireless access when near a hot-spot, and receive 3G services over a wider area.

The new advances on wireless technologies (3G, 3,5G, 4G, etc), Personal Digital Assistance Devices (PDAs) and sensor networks, make the m-Health sector a thriving new domain that may have a significant impact on healthcare provision. Nevertheless, there are limitations that have to be tackled in order to provide effective and efficient services.

2.2.1 Wireless Environment Limitations

Mobile wireless computing brings about a new paradigm of distributed computing in which communications may be achieved through wireless networks and users can continue computing even as they relocate from one support environment to another. The impact of wireless computing on system design goes beyond the networking level and directly affects data management and data computational paradigms. Infrastructure research on communication and networking is essential for realizing wireless and mobile systems. Equally important, however, is the design and implementation of data management applications for these systems (e.g., wireless virtual teams) a task directly affected by the characteristics of the wireless medium, the limitations of mobile computing devices, and the resulting mobility of resources and computation.

These limitations require a more flexible computational model than the one supporting wireline communications. This is because most of the assumptions that influence the definition and evolution of the traditional client/server model for distributed computing (Gray 1993) are no longer valid. These assumptions include: (a) fast, reliable and cheap communications, (b) robust and resource rich devices, and finally (c) stationary and fixed locations of the participating devices.

Wireless networks, however, are more expensive, offer less bandwidth, and are less reliable than wireline networks. Consequently, network connectivity is weak and often intermittent. Moreover, mobile elements must be light and small to be easily carried around and thus in general have less resources than static elements, including memory, screen size and disk capacity. These results in an

asymmetry in mobile computing systems: fixed hosts have sufficient resources, while mobile elements are resource poor. Furthermore, since mobile elements must rely for their operation on the finite energy provided by batteries, energy consumption is a major concern. Mobile elements are also easier to be accidentally damaged, stolen or lost. Finally, having mobile hosts roaming around, changing their location and therefore their point of attachment to the fixed network places new requirements on system design. The center of activity, the system load and the notion of locality changes dynamically. The search cost to locate mobile elements is added to the cost of each communication involving them. Moreover, as mobile elements enter regions in which communication is provided by different means, connectivity becomes highly variable in performance and reliability.

These limitations of mobility and wireless communications result in a form of distributed computing with drastically different connectivity assumptions than in traditional distributed systems. Thus, it is necessary to employ new computational paradigms to achieve a usable system. These new software models must cope with the special characteristics and limitations of the mobile/wireless environment. They should also provide efficient access to both existing and new applications which is a key requirement for the wide acceptance of mobile computing. In summary, the appropriate mobile computing models must efficiently deal with:

- disconnections, to allow the mobile unit to operate even when disconnected
- weak connectivity, to alleviate the effect of low bandwidth
- both light-weight and heavy-weight mobile clients, i.e., clients with different resource capacities
- dynamic adjustment of the mobile host functionality, i.e., the type and degree of functionality assign to mobile hosts
- the variability of the wireless environment
- multiple types and application models, including: current, and future TCP/IP applications, and emerging mobile application paradigms.

To this end, a number of models have been introduced recently including the client/agent/server [Badrinath B.R., 1993 - Fox, 1996 – Oracle, 1997 – Zenel B., 1997 – Tennenhouse D.L., 1996], the client/intercept [Samaras G., 1997 – Housel B.C., 1996], the peer-to-peer [Reiher P., 1996 – Athan A., 1993], and the mobile agent [Chess D., 1995 – White J.E., 1996 – IBM Aglets, 2001] models.

Through this work, we identified the shortcomings of the wire-line client/server model and its inability to support mobile computing. The requirements pertaining to wireless/mobile software models are clearly stated and the positive and negative aspects of the various models are presented in relation to these requirements. Defining a taxonomy of models and providing a methodology for building software for mobile computing is critical, since it provides the framework for the development of future applications and a yardstick to measure their effectiveness in addressing the challenges of mobile/wireless computing.

2.2.2 Mobile Devices Limitations

Mobile devices were a necessity since most team members are mobile workers, visiting the patients at home, or need to be accessible from anywhere at anytime. On the other hand, mobile devices usually are small with inefficient input methods, small screen, limited battery life and prone to damage and spoilage. These problems should be handled efficiently during the development of a system in the eHealth sector. In addition, specialists require efficient help from an eHealth system without the need for re-analyzing and restructuring their way of working with the system. After a more thorough examination of these problems, the need for virtual teams, dynamic workflows and the need for time driven events came to the surface, providing a context awareness environment.

Our implementation uses existing mobile devices such as the Smartphones, Pocket PCs, Palm PCs and Handheld PCs using state of the art mobile technologies so as to be used by the vast majority of mobile devices. A common, light, user friendly interface is provided which is automatically fine tuned to meet each mobile device's requirements.

We consider the limitations of the wireless environment like frequent disconnections, weak connectivity, variety of bandwidth and also the limitations of the mobile devices through our system, named DITIS.

3 PROPOSED EHEALTH CONTEXT ADAPTATION APPROACH

Given the complexity and diversity of the provision of healthcare, in association with critical factors such as quality of care, adaptability, availability, flexibility, confidentiality, security (due to the medical record singularity), expandability and ease of information sharing, made the eHealth a solid solution for the provision of effective and efficient healthcare, within a more distributed and technically related context (e.g. wireless networks and mobile collaboration).

Combining the complexity of eHealth, along with the well-known problems faced in mobile computing (e.g. wireless environment/medium constrains and mobile devices capabilities such as battery, screen, etc), result in a working environment that had not been appropriately addressed till now.

In addition, the context-awareness provision increases the complexity of the system. Users need to retrieve information, related to their role (i.e. nurse, doctor, etc), according to the mobile device that they are using and the wireless medium that they are accessing the system. In order to surpass these challenges, we propose a system, named DITIS that supports home healthcare provision.

3.1 Proposed System

Given the analysis of eHealth applications (e.g. HUMAN, C-CARE, HealthService24, MPower, COCOON, PIPS, MobiHealth, TOPCARE, etc), and the imminent weaknesses indentified, we hereafter propose an extended collaboration model enhancing the existing one with vital modules that could support multi/cross organization collaboration [Georgiadis D. 2010].

During the user requirements analysis for the development of our proposed system (described below), one fundamental necessity was the support for cross-organization medical teams [Georgiadis D. 2010]. A clear classification of the various types and forms of medical teams based on the dimensions of time, place and organization was spawned, identifying eight types of collaboration. Four cases of groups have their members working in the same organization, four cases of groups sharing same labor space and another four cases of groups working simultaneously (Figure 1).

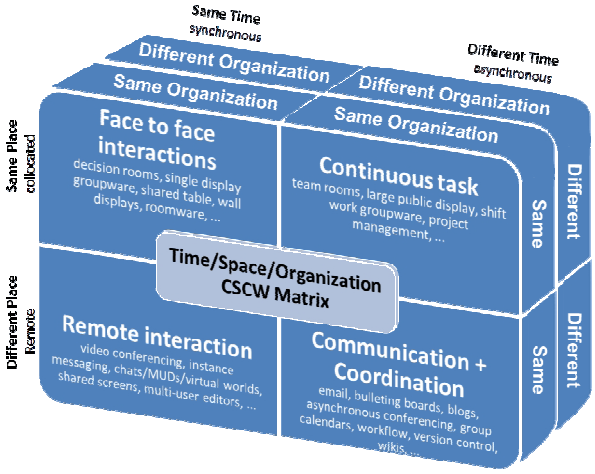

Figure 1. Extended Collaboration Model

Furthermore, during the same phase of the analysis, a set of features were also identified (Figure 2). These features provide the new dimension of our extended model and a more effective and efficient way of collaborating within the eHealth context. These include: (i) Medical Virtual Teams, (ii) Dynamic Workflows, (iii) Events, (iv) Actions, (v) Timeouts, (vi) Triggers, (vii) Responsibilities, (viii) Questionnaires, (ix) Medical Diaries and (x) Pro-activeness. In the following section we present these features in more detail.

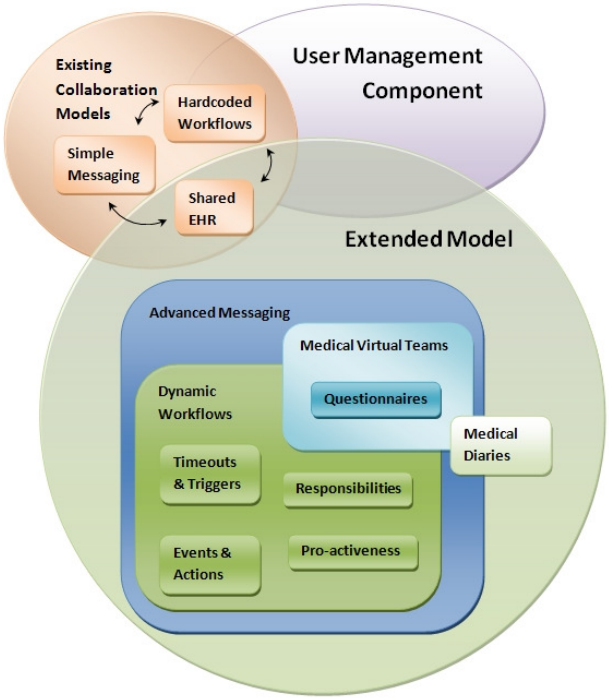

Figure 2. Extended System Model

3.2 Features

The basic features of our system are:

- **Medical Virtual Teams:** Users can form teams under a certain role for a patient. For example, a patient can have a virtual team of professionals, such as a Doctor, a Nurse and a Pathologist, constantly monitoring him remotely, providing better healthcare services.
- **Dynamic Questionnaires:** Questionnaires can be described as a collection of questions. The questionnaires can be sent to individuals in order to be completed. The results are sent back to the sender and gathered in one place, so we can review the results one by one or just have an overall result (voting). In eHealth, nurses can get an advice from multiple doctors on how they must react in a critical situation.
- **Actions:** An action is what a person can do. It could be just sending a message or a more complicated act. These messages are predefined and created by the system administrator. The more complicated act is a calling of a stored procedure.
- **Dynamic Workflows (Interactive Message):** Workflows are defined as a set of actions connected with users or roles or virtual teams or virtual teams and roles together and with another workflow. For example, we can have the action "Visit Patient" and send it to one user of the system or to every doctor of the system or to the virtual team of the patient or to the doctors of the virtual team.
- **Events:** Under the notion of workflows and actions the idea of the events is spawned. Events are the elements e that triggers a workflow. Such events are the decision making of a user (complete an action) of it can be a timeout (predefined time expiration of a task).
- **Timeouts & Triggers:** Under the scope of the medical virtual teams, we have assignments of roles to patients. There are times though that certain tasks are of vital significance (urgent tasks) and thus the need for the dimension of time is spawned. We can set a timeout on such crucial action. When the time that we set passes, another action or workflow is trigged. For example, we can have a nurse asking for a doctor's help. Nurse will initially ask help from the doctor of the patient's virtual team. After the timeout occurs, another action will be triggered. The new action will be about asking help from any doctor of the system.
- **Responsibilities:** Some actions are set to be performed by only one user of a certain role. We can notify all users of this role and send them an action to be performed. The first user that will get the action can take the responsibility of completing this task. All other users will be notified that this task is handled by another person. This way we avoid duplication of work. For instance, we can have the scenario that one nurse is asking for a drug prescription from all doctors. We don't want to have more than one doctor to prescribe the same drug. The Responsibility feature solves this problem.
- **Medical Diaries:** Medical diaries are an easy self monitoring method, used by patients from any mobile device. During this procedure, patients keep a daily record of their symptoms or pain control ranking the symptom on a scale. It's a very simple procedure, using only clicks and predefined text answers due to the mobile devices limitations.

- **Pro-activeness:** The activity motivation services include services that will motivate and encourage persons with chronic conditions to undertake physical and mental exercises and activities, change life style, socialize etc. Daily tasks assistance will provide to patients with direction indications, explanations on how to perform some tasks, or even instructions on how to call for human assistance for example through the use of the socialization services. Additionally, the system can assist patients by providing them with a type of memory help (reminders, directions indications to a place, memory assistance etc).

During the following sections, I will present the implementation of the system. For this implementation, we used all the abovementioned notions. The system was implemented into two different applications. The windows-based application, that it's used from the administrator, in order to setup the collaboration rules and the web-based application that is customized to work on every mobile device and give the ability to the users of using the system 24/7 everywhere and by any means.

3.3 Implementation

For the system's implementation, we used all the notions and components that are mentioned and presented in the previous sections. The system was implemented as two different but also interrelated applications. The windows-based application, that it's used from the administrator, in order to setup the collaboration rules and the dynamic workflows and the web-based application that is customized to work on every mobile device and give the ability to users of using the system 24/7 everywhere and by any means.

3.3.1 Windows-based Application (Administration)

As mentioned before, this application is designed to be used by the administrator to coordinate the whole system. The administrator can choose from creating new Action, Workflows, Users, Roles and Virtual Teams, or manage the existing ones. Finally, the administrator can manage the workflow timeouts. The administrator can also view the timeouts, in order to start/stop the existing timeouts monitoring process. Additionally, the administrator can populate lists (that will be used by the end users) manually (List of all possible selections – '|' separated or from database query. e.g. Yes | No | Maybe or 'Select Name, Value From Users') or with the use of plain SQL commands.

3.3.2 Web-based Application (Users)

Web-based application is used by users in a 24/7 basis through any device. Users have access in their data, and can collaborate in innovative ways, using dynamic interactive messages (workflows), questionnaires and virtual teams.

Users in the healthcare sector have limited knowledge of mobile devices and ability to use state-of-the-art technologies such as PDAs and smartphones. Thus, we adopted screens that are easy to understand and no need much effort on accessing information by using as much as possible key buttons and minimizing the "clicks" and consequently we speed up the process.

3.4 System Architecture

In our research, several elements were illustrated and choreographed to produce the desired result. The outcome of this research was implemented in the system called, DITIS. In order to better understand the model that DITIS is based upon we introduce in the following sections these features with their definition.

The system architecture is basically divided into 5 layers. These layers are the Application/User, the Workflows, the Services, the Sensors and the Database having the last two as parallel (Figure 3).

The Application/Users layer is the layer that hosts our GUI that provides all the necessary functionality for a flexible, efficient and effective collaboration, covering all the pre-mentioned requirements. This layer can be altered according to the hosting organization's needs maximizing the added value of the system.

The Workflows layer is the layer that hosts the dynamic workflows as described earlier. It resembles the business processes layer in the SOA architecture, having an orchestration and coordination of the basic system services, but in a more dynamic and ad-hoc manner.

The services layer hosts the basic services that provide all the functionality of the system such as security, messaging, database access, sensors data access, etc. These services can be called directly from the application or from a workflow, and even more from another workflow.

Finally, the last two layers are the Sensor that hosts all the available sensors of the system (such as: temperature, sound, light, vital signals, etc) and the Database layer that hosts the DBMS of the system. This DBMS can store reading from the sensors for future use by the application, all the data for the user management, collaboration features, virtual teams, dynamic workflows, actions, questionnaires, etc.

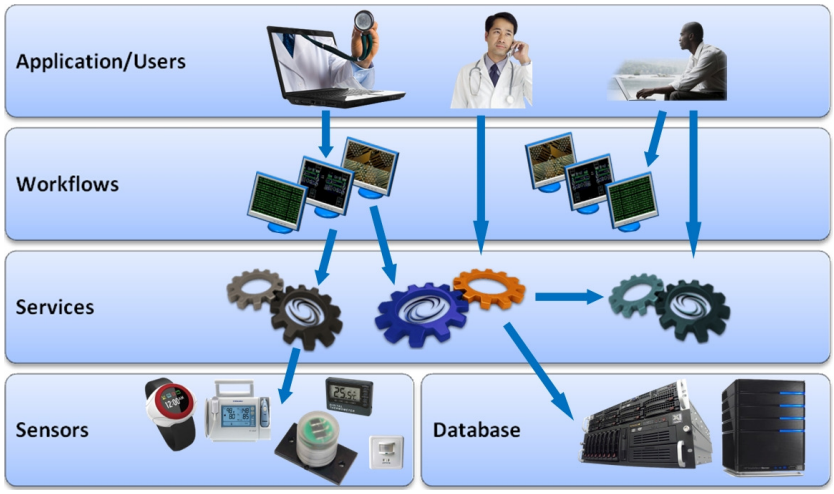

Figure 3. System Architecture

3.5 Defining the context in eHealth context-aware applications

The notion of context in context-aware applications is not merely an issue of external situational circumstances or device/channel properties, but it could also refer to a wide array of user characteristics that have an effect throughout users' interactions with a system [Tsianos N., 2009].
In eHealth context-aware applications, the context is affected by variables like, role of the user (i.e. personalization), environment (i.e. virtual teams and patients status) and communication medium (i.e. wireless and mobile devices).
Existing eHealth applications have rules and processes hardcoded and predefined. In case users have new requirements, organization change rules or the context changes, the whole processes have to be analyzed, coded, recompiled, redistributed and finally retrain the end-users if needed. In other words we notice a lack of dynamicity, syntactic and contextual.
By syntactic dynamicity (i.e configurable), we mean the ability of the information to change on demand during a task's execution (according to new requirements), without the whole software application development process to take place, as mentioned above.
A simple scenario that illustrates a syntactic change on a workflow it would be to alter the involving actions in a workflow. Instead of alerting the doctor and presents only the two options (Yes and No), we add an extra option of the one that doubles the dose (Figure 4 – Green/Doted Circle). This change could be realized by the system administrator through our interface without the need of any programming skills.

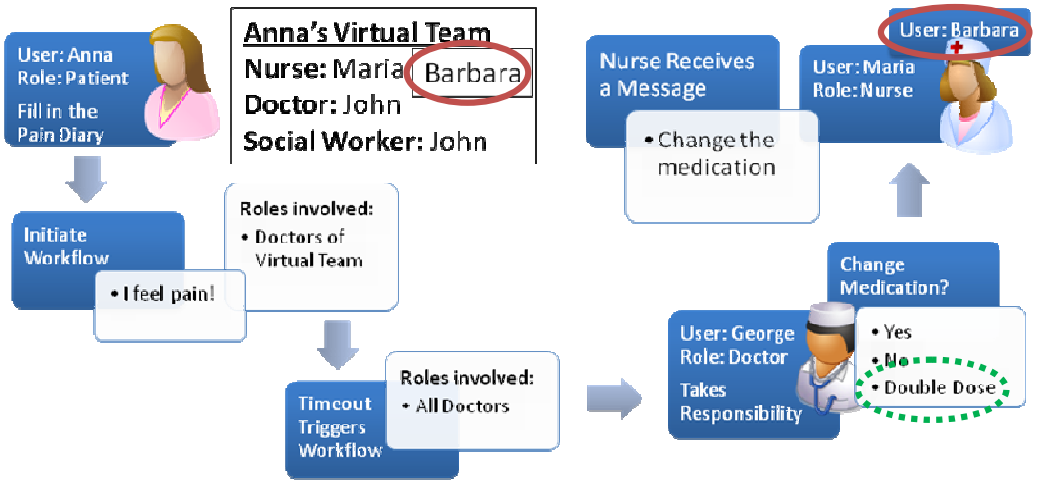

Figure 4. Context Dynamicity Examples

Contextual dynamicity (i.e self-adapting) is the ability of the workflow to detect and adjust on environmental changes like the medical virtual team members. For example, given the previous case (Figure 4 – Red/Continuous Circle), the nurse of patient "Anna" changes from "Maria" to "Barbara". The new execution of the same workflow, results on alerting the newly assigned nurse Barbara. This dynamicity provides users with a high level of awareness. In addition, the error avoidance is increased due to the fact that users do not need to know all possible changes that may occur, consequently enhancing the transparency level.

Additionally, information can be adapted according to user's role, the wireless medium and the mobile device that is accessing the system. Doctors can access patient records only for their patients. In that case we have a filtering of the information in a row level of a database. Nurses, on the other hand, have access to the demographics information of the patient and some basic information of the medical record. This is a case of table filtering in a medical system's database. In addition, users may want to choose a more personalized representation on the services that want to view from the system. Finally,

the information that is presented should be transformed for best viewing, according to the device capabilities and trimmed down for fast and economic transport through the wireless medium that is in use.

3.6 The case of DITIS system

To get the right information at the right time and the right place in an easy and comprehensive manner isn't so easy for eHealth application's users. The system supports an active involvement of the users, giving them the control over the information through their ways of understanding. Furthermore, the system provides easy means for navigation and orientation of the information having in mind the limitation of the accessing device (mobile phone, PDA, laptop, etc) and the connectivity medium (wireless network, GSM, GPRS, etc) in order to support alternative interaction methods.

Having in mind the abovementioned, in system DITIS, we adopted fully customizable screens according to the accessing device handled by the server. The server inquires the device's capabilities (screen size, media capability, supported input methods, etc) and restructures the screens in order to meet these capabilities and serves the result. In addition, we minimized the "clicks" for getting the right information, al-ways considering the users' preferences. Furthermore, menus are customizable per user in order to meet his demands. This resulted in serious reduction of time to access a service and the requested information.

Two modes of mobile operation were implemented. One offers access to the DITIS database through the mobile network using web services, and the other is a standalone implementation† with richer functionality which also supports a miniature database system. The local database system holds vital information about a subset of the entire database. It includes recent patient records, appointments, medication and other (this data is organised by the DITIS system and pushed to the device in accordance with the user's schedule and current patients). This introduces an additional benefit, as the user can have continuity of service even during periods of no connectivity with the network. As soon as the user connects to the mobile network (GSM/GPRS/UMTS) or cradle the device synchronizes with the backend server. The synchronisation aspects were analysed for a number of scenarios and the synchronisation strategy was implemented [Pitoura E., 1998 – Andreou P., 2006]. As mobile device technology evolves so is the opportunity to include more sophisticated functionality on the mobile device itself.

An example interface for the web is shown in Figure 5 for two commonly available mobile devices, which show a number of menu selections for the home-nurses. For the standalone system example interfaces are shown in Figure 6.

† The standalone implementation is a custom build program. It runs on any mobile device that supports the Windows Mobile framework.

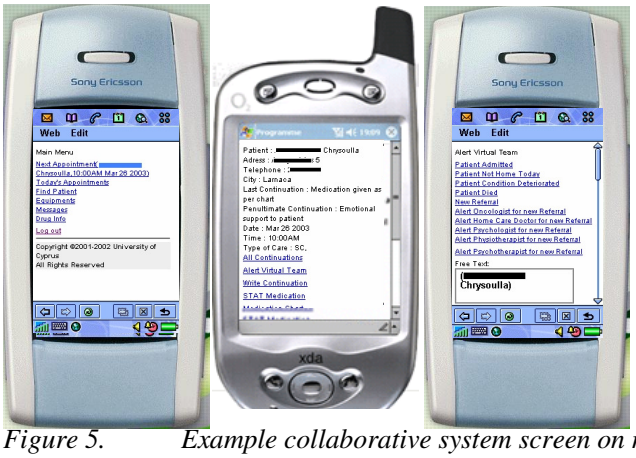

Figure 5. Example collaborative system screen on mobile devices (web interface)

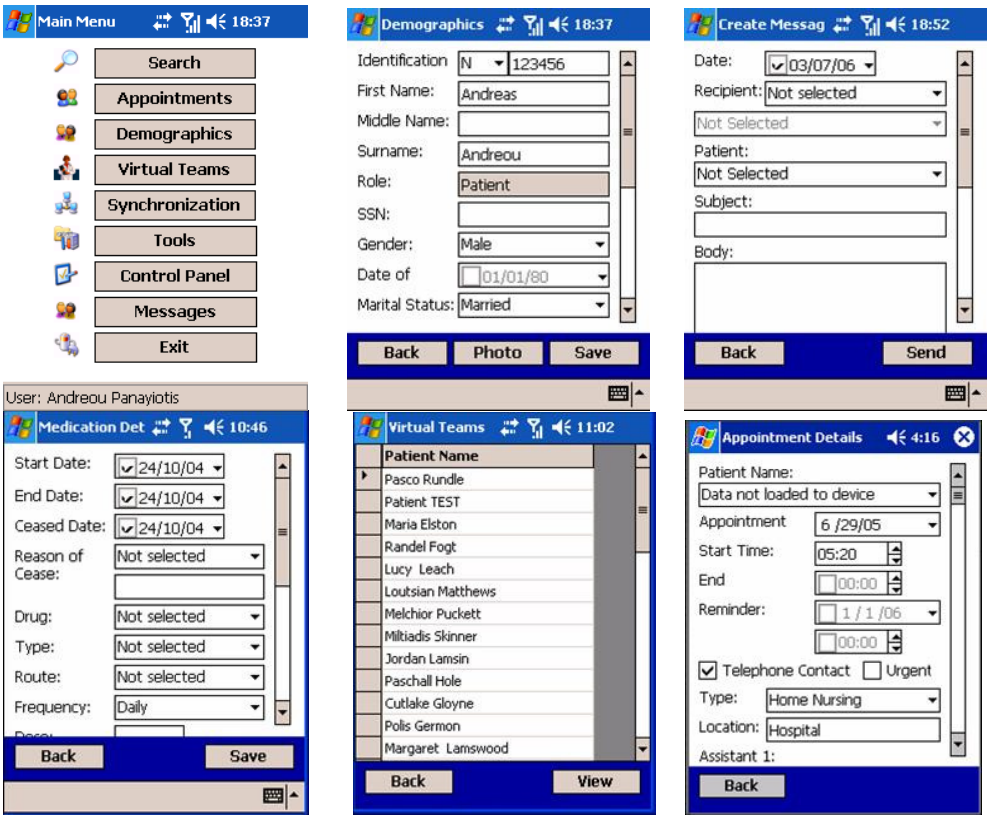

Figure 6. Example screens on mobile devices (standalone interface)

Users will access the system from any mobile device that uses a simple HTML browser. All users have to login under the same login page. The system, through the database, authenticates the user and understands the type of user (Nurse, Doctor, Oncologist, Volunteer, etc…).

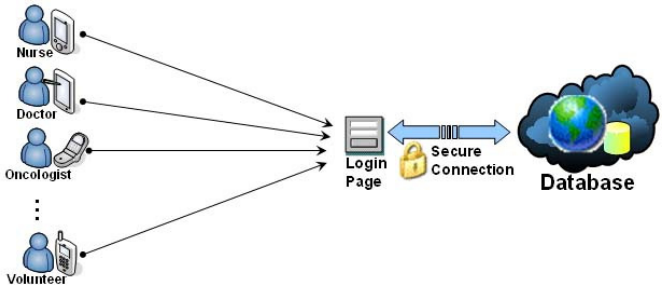

Figure 7. Single Access from any mobile device

After the successful login, the user is forwarded to the proper interface according to the user type that he/she is. Nurses, for example, have different interface than Doctors.

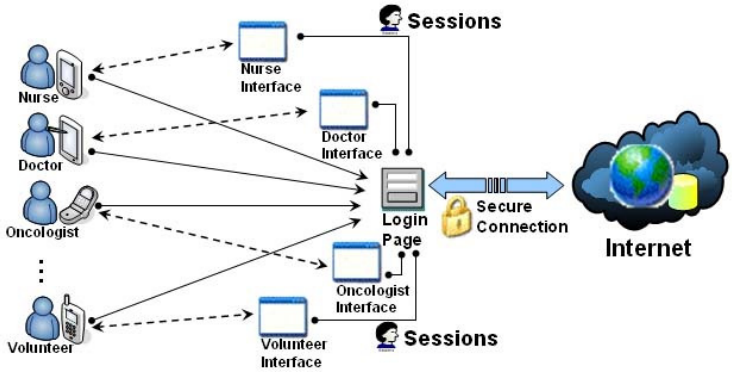

Figure 8. Multiple Role interfaces

A preliminary evaluation follows in order to demonstrate the viability of the system and present the key advantages of long term usage of DITIS as the main tool for supporting palliative care services.

4 PRELIMINARY EVALUATION

A study was carried out at PASYKAF for evaluating several aspects of DITIS. The findings are reported in [Panteli N., 2003] and [Panteli N., 2006]. The study reveals that DITIS offers innumerable opportunities for palliative care nurses and other cancer-care practitioners. Nurses, psychologists and doctors acknowledge that DITIS has numerous advantages and that they are willing to incorporate it in their work activities. DITIS can improve communication, coordination and collaboration among members. Due to the huge amount of data regarding new and old patient records that need to be handled on a daily basis, DITIS enables users to access data quickly either from their office or remotely. Furthermore, it can be used as a statistical tool, for producing internal reports for the district offices and the head office as well as external reports required by the Ministry of Health and other government departments.

In [Panteli N., 2006] presents a longitudinal study on DITIS. The study has found that users' support has gradually improved over the last years as they have been increasingly exposed to the system capabilities and have recognized the advantages of the system in their day to day work for both administrative and consultation purposes. Another reason for this is that the nurses have gained participation in the project team with periodical meetings with the project manager and developers. The study in [Mitchell R., 1997] had adopted the stakeholders' analysis. It found that there are different relationship characteristics among the key stakeholders showing diversity in interests, expectations and level of involvement in the implementation of the system. DITIS has appeared to act

as a useful fuel for improving patient-records and promoting an integrated approach that has a direct impact on the quality of treatment and health care support to home-based cancer patients.

The evaluation of the system yielded some very interesting results. The main outcome was that the system proved to decrease the use of resources when compared to conventional approach. The other important benefits identified were:

- Improved communication within healthcare team (nurses and other professionals both hospital and not hospital based) and between healthcare team and hospital, thus providing capability to consult within a team of experts, without need to move patient from his home to each one of them. This results in reduction of number of visits to health professionals and reduces burden not only on patient, but also his relatives, and makes better use of the scarce and expensive medical professionals and scarce hospital beds.
- Provision of continuity of care through the presence of a healthcare team by the patient at any given time, irrespective of locality or movement.
- Improved and secure timely access to patient information, in accordance with their authorization levels, through unified information space centred on the patient. As an added benefit, all the professionals treating the patient have access to the same set of data.
- Improved cost effectiveness through improved communications and better planning of resources and services.
- Improved health practices (shift toward evidence-based) and reduction of bureaucratic overhead.
- Business potential is great due to a number of reasons: 1) patients' preferences to stay in their homes rather than being institutionalised, as long as they feel secure, 2) decrease in the need for hospital beds and 3) better allocation of the professionals' time.

The economic outcomes of the use of the DITIS system are quite promising. It is expected that remote monitoring provided by linked collaborative medical teams should yield cost savings because of the expense of hospital stays together with costs for transportation.

5 CONCLUSIONS

In this work we have studied the requirements of eHealth services and more specifically mobile eHealth services related to homecare provision and we have identified the main limitations of current solutions. Our study revealed that current solutions feature limited collaboration messaging methods, inadequate support for communication under a wireless medium and do not support dynamic content adaptation based on the "environment" of the patient. To address these problems we present an extended collaboration model which enables cross-organizational communication, advanced messaging system and dynamic workflows.

In order to assess the efficacy of our proposed approach, we have implemented the ideas presented in this work in a prototype homecare system, coined DITIS. We evaluated DITIS in a real setting involving a non-profit organization that provides palliative care to cancer patients. Our experimental series evaluate the proposed system both from the organization as well as the patient perspective using a number of quality metrics. We have shown that DITIS presents significant time and cost savings to the organization as well as increases the quality of life of the patient. Particularly, DITIS showed 52% reduction in time and 17% in cost saving, calculated on travelling, briefing, collaboration and reporting procedures.

Future research directions, involve the effective and efficient integration of Vital Signal Monitoring (VSM) devices and sensors networks. Research will have to be conducted on new algorithms that will be integrated with the VSM devices and sensors for prevention and prediction of possible medical

incidents. Due to the criticality and importance of the information in eHealth, the margin for errors must be zero. You have to bear in mind that a mistake here may result in the loss of a human's life and this is not acceptable by anyone, especially by the medical personnel.

References

Aglets Workbench (2001), by IBM Japan Research Group. Web site: http:// aglets.trl.ibm.co.jp

Andreou P. (2006), A secure XML based synchronization scheme for mobile devices, Masters Thesis, Dept of Computer Science, University of Cyprus, June 2006

Athan A. and Duchamp D. (1993), Agent-Mediated Message Passing for Constrained Environments, Proceedings USENIX Symposium on Mobile and Location-Independent Computing, pp. 103--1070, Cambridge, Massachusetts, August 1993.

Badrinath B. R., Bakre A., Imielinski T. and Marantz R. (1993), Handling Mobile Clients: A Case for Indirect Interaction, Proceedings of the 4th Workshop on Workstation Operating Systems, Aigen, Austria, October 1993

Chess D., Grosof B., Harrison C., Levine D., Parris C. and G. Tsudik (1995), Itinerant Agents for Mobile Computing, Journal IEEE Personal Communications, Vol. 2, No. 5, October 1995.

COM. (2004). *Mobile Broadband Services*. Communication from the Commission, COM(2004), 447.

Fox A., Gribble S. D., Brewer E. A. and Amir E. (1996), Adapting to Network and Client Variability via On-Demand Dynamic Distillation, Proceedings of the ASPLOS-VII, Cambridge, MA, October 1996.

Georgiadis T. D. (2002), Dynamic Creation of Collaborating System and Database Management, Using Mobile Agents, M.Sc. thesis, Computer Science Department, University of Cyprus, June 2002

Georgiadis T. D. (2010), Dynamic Workflows in the Home eHealthCare Provision, Ph.D. thesis, Computer Science Department, University of Cyprus, June 2010

Gray, J., and Reuter A. (1993), Transaction Processing: Concepts and Techniques. Morgan Kaufman Publishers, Inc.

Housel B C., Samaras G. and Lindquist D. B. (1996), WebExpress: A Client/Intercept Based System for Optimizing Web Browsing in a Wireless Environment, Journal ACM/Baltzer Mobile Networking and Applications (MONET), Special Issue on Mobile Networking on the Internet. To appear. Also, University of Cyprus, CS-TR 96-18, December 1996.

Ioakim G. (2007), Dynamic Wofkflows in Wireless Enviroment, M.Sc., Computer Science Department, University of Cyprus, May

Pitsillides A., Samaras G., Pitsillides B., Georgiades D., Andreou P., Christodoulou E. (2006), Virtual Collaborative Healthcare Teams for Home Healthcare, Journal of Mobile Multimedia (JMM), special issue on Advanced Mobile Technologies for Health Care Applications, Vol.2, No.1, pp023-036

Mitchell R., Agle B. and Wood D. (1997), Towards a theory of stakeholder identification and salience, Academy of Management Review, 22, 4, 853-887

Oracle (1997), Oracle Mobile Agents Technical Product Summary, www.oracle.com/products/ networking/mobile/agents/html/, June 1997.

Panteli N. (2003), DITIS: An eHealth Mobile Application in Cyprus. A user's Perspective. May 2003, Internal DITIS report, accessible via http://www.ditis.ucy.ac.cy/publications/internalreports.htm

Panteli N. (2006), Pitsillides B., Pitsillides A., Samaras G., An E-healthcare Mobile application: A Stakeholders' analysis, in Web Mobile-Based Applications for Healthcare Management (Editor Dr L. Al-Hakim), Book chapter, Idea Group

Pitoura E. and Samaras G. (1998), Data Management for Mobile Computing, Kluwer Academic Publishers, ISBN 0-7923-8053-3

Reiher P., Popek J., Gunter M., Salomone J. and Ratner D. (1996), Peer-to-Peer Reconciliation Based Replication for Mobile Computers, Proceedings of the European Conference on Object Oriented Programming 2nd Workshop on Mobility and Replication, June 1996.

Samaras G. and Pitsillides A. (1997), Client/Intercept: a Computational Model for Wireless Environments, Proceedings of the 4th International Conference on Telecommunications (ICT'97), Melbourne, Australia, April 1997.

Tachakra S., X. H. Wang, Robert S. H. Istepanian and Y. H. Song (2003), Mobile e-Health: The Unwired Evolution of Telemedicine, Telemedicine Journal and e-Health, Volume 9, Number 3, 2003

Tennenhouse D. L., Smith J. M., Sincoskie W. D. and Minden G. J. (1996), A Survey of Active Network Research, Journal IEEE Communication Magazine, Vol. 35, No. 1, pp. 80--86, January 1996.

Tsianos N., Germanakos P., Lekkas Z., Mourlas C., & Samaras G. (2009). "Incorporating Human Factors in the Development of Context-Aware Personalized Applications: The Next Generation of Intelligent User Interfaces ", A chapter in: Context-Aware Mobile and Ubiquitous Computing for Enhanced Usability: Adaptive Technologies and Applications. D. Stojanovic (Ed.), IGI Global (former Idea Group, Inc.), Hershey, USA, pp. 362-382.

White J. E. (1996), Mobile Agents, General Magic White Paper, Web site: http:// www.genmagic.com/agents.

Zenel B. and Duchamp D. (1997), General Purpose Proxies: Solved and Unsolved Problems, Proceedings of the Hot-OS VI