Journal of Mobile Multimedia, Vol. 2, No.1 (2006) 023-036


# DITIS: VIRTUAL COLLABORATIVE TEAMS FOR HOME HEALTHCARE

ANDREAS PITSILLIDES[1†], GEORGE SAMARAS[1], BARBARA PITSILLIDES[2], DIMOSTHENIS GEORGIADES[1], PANAYIOTIS ANDREOU[1], ELENI CHRISTODOULOU[1]

[1]*Department of Computer Science, University of Cyprus*

[2] *Cyprus Association of Cancer Patients and Friends (PASYKAF)*

[†]*Andreas.Pitsillides@ucy.ac.cy, Web site: http://www.ditis.cs.ucy.ac.cy*

Received August 31, 2005
Revised February 19, 2006

This paper presents an e-health mobile application, called DITIS, which supports networked collaboration for home healthcare. The system was originally developed with a view to address the difficulties of continuity of care and communication between the members of a home health care multidisciplinary team. The paper introduces the system DITIS, identifies the needs and challenges of co-ordinated teams of multidisciplinary healthcare professionals and discusses relevant computing models for their implementation. The adopted technology as well as the security needs and a multilayer security framework are briefly described. An evaluation study of the system is also briefly presented.

*Key words*: Mobile e-health, virtual collaborative home-healthcare teams, computational model and system implementation, multilayer security framework
*Communicated by*: A Ganz & R Istepanian

## 1. Introduction

E-health, in particular Mobile e-health, is an environment seeing dramatic progress over the last few years. It involves a spectrum of information and telecommunication technologies to provide health care services to patients who are at some distance from the healthcare provider, and supporting tools for the mobile healthcare professional. The benefits of such applications are numerous with the main one being improvements in access to medical resources and care, leading to improved quality of life. Though there have also been cases of mobile workstations being implemented at small medical units to facilitate easier access to specialist medical advice (e.g. [1]), most of the applications have been introduced to support patients at home. These could either be patient-centred, where patients and/or caretakers are given direct access to mobile devices (e.g. biosensors for measuring vital signs and data transfer devices) for communicating with the provider (e.g. nurse, doctor, etc), or healthcare provider-centred, where healthcare professionals who visit and care patients at home have direct access to mobile applications and for communicating with other medical staff. In this paper we will focus on healthcare provider-centred teams for chronic illnesses cared at home.

Complex and chronic illnesses, such as cancer, demand the use of specialised treatment protocols, administered and monitored by a co-ordinated team of multidisciplinary healthcare professionals, focused on the patient needs. Care of chronic illnesses by a dynamic team of health care professionals at home is often necessary due to the protracted length of the illness, the differing medical conditions, as well as the different stages of the chronic illness. Most importantly home care can offer comfort for the patient and their family, in the familiar surrounding of their home, and at the same time being cost effective, as compared to the high cost of hospital beds. Hospital based treatment for chronic patients is limited, often demand based for short periods of time, used mainly for acute incidents.

It follows that the practice of e-health is often a collaborative activity requiring extensive and interactive communication within and between members of specialized occupational groups to coordinate patient care services. This becomes necessary when dealing with patients requiring a multidisciplinary team approach to their care, and who are treated outside the hospital environment. In such a case, the team is mostly geographically dispersed and rarely see the patient together. This requires the creation of virtual multidisciplinary teams of care whose management and coordination can be supported by technology. A principal aim of DITIS (ΔΙΤΗΣ, in Greek, stands for: Network for Medical Collaboration) is to overcome the difficulty of coordination and communication.

DITIS [2] is a system that supports dynamic Virtual Collaborative HealthCare Teams dealing with the home-healthcare. It supports the dynamic creation, management and co-ordination of virtual healthcare teams, for the continuous treatment of the patient. It was initiated in 1999, supporting the activities of the home healthcare service of the Cyprus Association of Cancer Patients and Friends (PASYKAF) in the district of Larnaca, using a healthcare provider-centric philosophy (as an intermediate phase toward a patient-centric philosophy), focused on home-based rather than facility-based care, receiving governmental and industry grants. It is implemented using existing networking and computing components [3, 4, 5]. DITIS is expected to deliver a product that can improve the quality of the citizen's life. Contrary to today's health processing structure, which is in all practical terms facility-based care, this project aims to shift the focus onto home-based care, where everything is moving around the patient. The virtual healthcare team will be able to provide dedicated, personalized and private service to the home residing patient on a need based and timely fashion, under the direction of the treating specialist. Thus it is expected that chronic and severe patients, such as cancer patients, can enjoy 'optimum' health service in the comfort of their home (i.e. a focus on wellness), feeling safe and secure that in case of a change in their condition the health care team will be (virtually) present to support them. A central part of DITIS is therefore the aspect of collaboration. Collaboration and virtual teams refer to the notion that a team of professionals decide to collaborate over the internet and thus create a virtual team that eliminates the need of physical presence [6]. For DITIS, the collaboration requirements are based on identified scenarios of collaboration. Providing top quality care necessitates close collaboration, secure, easy and timely exchange of information, and coordination of the team activities. Creating virtual collaborative teams for the healthcare environment introduces new and more specialized requirements and computational models. The adopted technology for the implementation of the virtual teams as well as the security issues are important factors in a successful design.

In section 2 we analyse the justification and need for the proposed system, and in section 3 we discuss collaboration concepts and supporting computational models for medical virtual teams. In section 4 we present the identification of the healthcare team, their roles and collaboration scenarios. Section 5 describes the system design and implementation and introduces a performance evaluation study. Finally in section 6 we provide some concluding remarks.

## 2. Justification of Needs and Aims

The current context of health and health care is characterized by change and transition associated with health care system reform and restructuring [7]. Restructuring initiatives are intended to develop a more results-oriented, integrated and accountable health system that delivers the right services, to the right people, at the most appropriate time, in the right place, in the most cost-effective manner. The aim has been to enhance the health quality of populations by better balancing health promotion and disease prevention, community-based and institutional services. Further technological advances are enabling a greater shift from institutional services to ambulatory and community-based services, as for example home-care. The pressure to expand and enhance home-based services is expected to grow as a result of demographic shifts in an increasingly ageing population, changing consumer expectations with respect to service and care options, and technological and scientific advancements in the delivery of health services. Many see home care as a more cost-effective alternative to acute care and/or to long-term institutional care [7, 8]. Within the home care context, DITIS aims to provide patient care by a team of healthcare professionals, as for example cancer specialists, general medical doctors, nurses, physiotherapists, psychotherapists, dieticians, social workers, and so on. We believe that a key factor that needs to be kept in mind is that the provider is not a monolithic entity but rather consists of a diverse group of people. Thus, the provision of as optimum and effective care as possible demands the cooperation, communication and coordination among all these professionals, and the formation of a 'team of care'. Providing top quality team care necessitates secure, easy and timely exchange of information, and coordination of the team activities. This should be achieved irrespective of the physical presence of the individual members of the team, or even if different doctors treat the patient, for possibly different symptoms at different hospitals, or visit him at home. It is of course obvious, that the concurrent physical presence at the point of care of all members of the team is rarely possible. This creates serious difficulties for providing the quality care that patients deserve to obtain in a friendly (to them) home environment. Through DITIS a delivery of better home-care is assisted, by maintaining a dynamic collaborative virtual healthcare team, as well as secure, easy, and timely access to the unified Electronic Medical Record database for the continuous home-treatment of patients. The dynamic virtual healthcare team is created explicitly to satisfy the needs of each particular patient at a point in time with each patient having its own virtual medical team. It is worth pointing out that prior to DITIS the team of professionals was (loosely) coordinated by weekly meetings, or in case of some urgent event information was exchanged by telephone calls, or face-to-face meetings. Often the same

information was requested from the patient, so as each professional can build their own medical and psychosocial history and treatment notes (handwritten). Therefore there was limited possibility for continuity of care, audits, and statistics. Research was difficult, evidence-based medicine was not supported, dynamic coordination of the team was almost impossible, and communication overheads were very high and costly in human and monetary terms.

## 3. Collaboration Concepts and Computational Model

Human-to-human computer-mediated interaction and trust is particularly important [9] since virtual teams are effective not only because of technological advancements but also and most importantly because individuals are able to interact and thus constructively engage in knowledge sharing and creation in the increasingly emergent virtual work environments. During the last few years the volume of literature on virtual organisations and virtual teams is increasing [9, 10, 6, 11, 12]. This body of research generally agrees that virtual teams consist of a collection of geographically dispersed individuals who work on a joint project or common tasks and communicate electronically [10]. In particular, interactivity among the key actors in virtual medical teams is important [13]. In such virtual teams, where effective and quality patient management care are the expected outcomes, high levels of interactivity often need to be developed quickly and it is important that they last throughout the short duration of the interaction. This necessitates care in the design of team collaboration tools. The collaboration requirements in our application are based on identified scenarios of collaboration analysed using UML (an illustrative example will be presented later). These scenarios can identify the communication and collaborative requirements the computational model must support. Virtual teams can be classified according to the location (short or long distance), time (same or different) and according to the organisation (same or different) [5, 14]. In this study we adopt the Long Distance Healthcare Virtual Teams model [5]. In this model team members work mostly separated in space. In this case most team members are mobile and thus collaborate wirelessly (via a mobile network). Due to the limitations of the wireless link this model requires an asynchronous model which in essence guarantees the continuous running of the team. If a team member is unavailable, the system will record the request and when the team member becomes available, the request will be served. The computational needs of such a model will be discussed next.

To deal with the characteristics of mobile computing, especially with wireless connectivity and small devices, various extensions of the client/server model have been proposed [5]. Such extensions advocate the use of proxies or middleware components. Proxies of the mobile host residing at the fixed network, called server-side proxies, perform various optimizations to alleviate the effects of wireless connectivity such as message compression and re-ordering. Server-side proxies may also perform computations and collaborative tasks in lieu of their mobile client. Proxies at the mobile client undertake the part of the client protocol that relates to mobile computing thus providing transparent adaptation to mobility. They also support client caching and communication optimizations for the messages sent from the client to the fixed server. Finally, mobile agents [5, 15] have been used with client/server models and their extensions. Such agents are initiated at the mobile host, launched at the fixed network to perform a specified task, and return, if necessary, to the mobile host with the results.

These software models are presented and studied in [5] within the context of collaboration, virtual teams, and healthcare requirements. The computational model adopted for the DITIS "collaborative healthcare environment" is the Client/Agent/Server, with the user agent residing on the server side. Each user is assigned explicitly one agent. This agent will not only exist for sustaining the user's existence in the network, but also for sustaining the user's existence in the virtual medical team at all times (see Fig.1). The user's agent is always online and connected with the other members of his virtual team. Users can communicate with each other through their agents. The agent receives the message from the senders' agent and forwards it to his user for advising. If the user isn't connected, the agent waits for the user to connect or responds by himself depending on his responsibilities [16].

To illustrate the agent personalisation we present the following example for accessing a list of drugs. The agent can be customized to retrieve info on the common drugs that are being used by its user (e.g. pain specialist) and therefore lower unnecessary access to the database and presentation problems in a small device. This scenario promotes the use of mobile agents in terms of network usage reduction. An additional benefit is to also use intelligence, which can be downloaded into the agent helping him become a better assistant for any user. The majority of DITIS users are mainly busy health care professionals, e.g. home-care nurses, oncologists and psychologists. Such users need fast access to medical information, for example, concerning the side effects of drugs. The combination of two drugs may lead to an unfortunate situation for the patient. This is classified as a standard human error, but the

built in intelligence of the agents can minimise this problem. The agent can retrieve information about the two drugs which are about to be combined from the database and deliver it to the user when it "feels" there is a need to do so. An additional equally important feature is the ability of the user agent to adapt its interfaces to any format the user device supports. In this case the agent can work as a proxy for transforming the output into the appropriate desired format. For example, in the case of mobile devices that support WML, the agent will reformat the output for the WML browser. In the case of desktop computers the agent will reformat the output for the HTML browser. In this way, it is expected that the system will handle multi-modal devices and provide a better experience to the busy user.

In DITIS I the Client/Agent/Server application model is used implemented using a number of technologies, including mobile agents running on the Voyager platform. Every user is represented by a mobile agent. Thus the virtual medical team exists anytime. In DITIS II we strive to use a computational model that has Client/Agent/Server functionality, but using technologies that possess robustness properties appropriate for the application environment. This will be elaborated later in the implementation section.

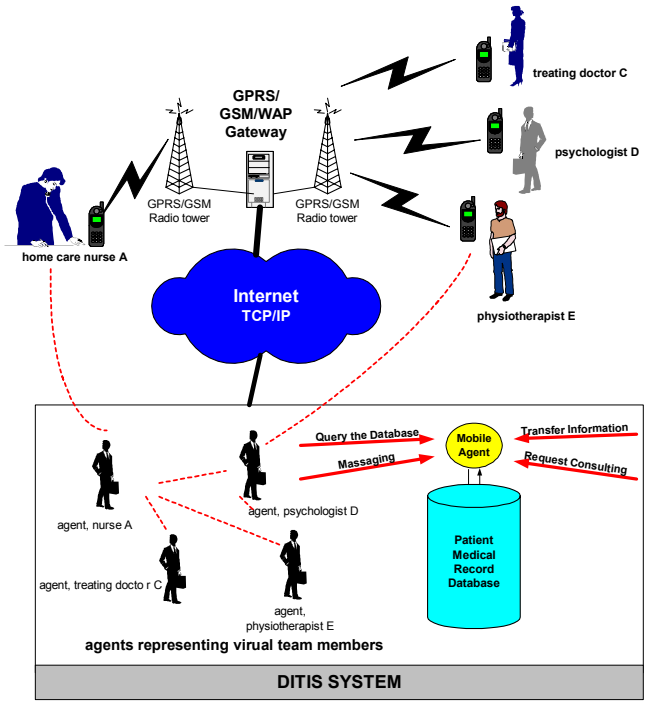



Figure 1. The Client/Agent/Server application model used in DITIS, showing every user represented by a mobile agent.

## 4. Identification of the Healthcare Team, their Roles and Collaboration Scenarios

In this section we identify the team's members, their roles and collaboration scenarios. This analysis allows the creation and management of virtual teams addressing the requirements of their work environment better.

The healthcare team includes oncologists who are based in the oncology centre, treating doctors who are usually located in the community (e.g. General Practitioners), home care nurses who visit the patient regularly at home, and a number of other professionals called in as the demand arises, typically physiotherapists, psychologists, and social workers. The home care nurses spend most of the time with the patient, and thus the analysis has initially focused on them and their interactions with the rest of the healthcare team. Firstly, nurses become the most frequent users of the system. They use it to access patient records and communicate with each other, for example, through nursing care plans, symptom diaries, or to arrange appointments and reschedule visits and to set up a virtual team for teleconsultation on the spot. Secondly, they are the ones who maintain and keep the system up to date with the latest patients' information, e.g. state of health, medicine taken etc. Thirdly, as they are the ones who visit the patient at home most often, they are also able to assess the domestic situation of the patient and the psychological state that exist among members of the family and therefore are able to report a more coherent picture about patients' conditions and to consult with other professionals to join the team, as needed.

### *4.1 Modelling of collaborative scenarios*

Several scenarios were identified and analysed (see Fig.2) in order to implement the collaboration system. The various scenarios are built around "appointment" which in essence represents the patient. The different scenarios involve the various members of the virtual health care team.

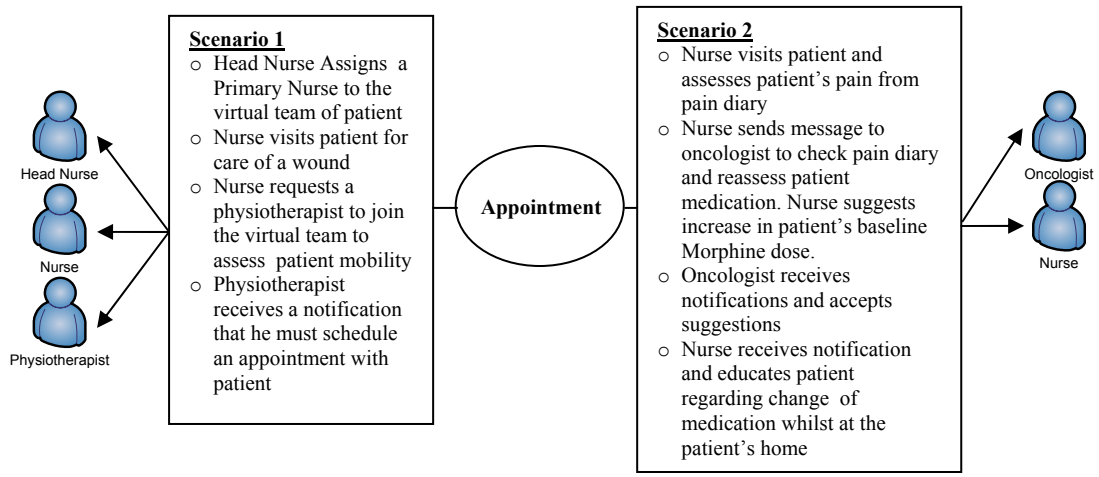



Figure 2. Representative scenarios for virtual-collaboration.

The Unified Modelling Language (UML) has been used to identify roles and analyse and formalise collaboration scenario between virtual healthcare team members. Using results of the analysis the collaborative system software is developed. Some common scenarios include:

- Referral of a new patient to home-care, Referral to other professionals, and First home-care-visit.
- Home-care virtual team creation / addition of members and communication with the virtual team members.
- Service provided in the homecare, requiring collaboration with the treating doctor such as: Change of prescription, Blood analysis, and Chemotherapy.
- Continuity of care in outpatients, Continuity of care for patients admitted to a hospital, and Continuity of care for staff members on call.

To illustrate the modelling process we present the submission and handling of a new patient referral and discuss the creation and management of a virtual team. For the referral scenario, we present a sequence and collaboration diagram in Fig.3 and Fig.4 respectively. This same scenario shows aspects of virtual team interaction for the accomplishment of specific tasks.

Illustrative Scenario for new patient referral to Home Care

A new patient gets referred to DITIS for home care services and first visit by nurse:

1. A diagnosed lung cancer patient is referred to PASYKAF Home Care by the oncologist at the Oncology Center. For this purpose, the oncologist completes the electronic Referral Form.
2. Upon submission of the Referral Form a patient record gets created in the DITIS System and based on the predefined workflow for the first visit certain actions are initiated by the system, as for example the creation of the core virtual team (includes Oncologist) and alerts. The head nurse for that Home Care Unit receives an SMS alerting her to the new admission.
3. The head nurse assigns nurse P to be the nurse that delivers and oversees the home care for the patient. The workflow module initiates further actions including the addition of the Nurse to the virtual team and alerts (including SMS) to inform her of her new admission. Nurse P looks at the patient record. She telephones and assesses the immediate needs of the patient and schedules a first visit to the patient (by entering an appointment).
4. On the day of the scheduled visit (which is included in her calendar), nurse P checks the patient referral and visits the patient. She introduces herself and takes a history both medical and psychosocial as well as an assessment of symptoms and patient requirements. She then enters the

patient findings in the system (continuation). This automatically informs the oncologist that the patient had been seen by Home Care, and the findings of the initial assessment are now on DITIS.

5. Nurse P then schedules the next appointment in 6 days time, salutes the patient and leaves.

6. She is now aware of patient requirements and refers him to other members of the team, as required.

7. Nurse P decides to add a social worker to the virtual team as the patient needs to apply for a pension since he will be unable to resume work in the near future.

8. Nurse P also adds a physiotherapist to the team to teach the patient deep breathing and coughing techniques.

9. An SMS is sent to social worker and physiotherapist that they have been selected to be part of the health care team (upon confirmation they are added to the virtual team and authorised access to the patient record, according to their role, is given to them).

Similarly, other scenarios for work flow and collaboration are identified and implemented in the system.

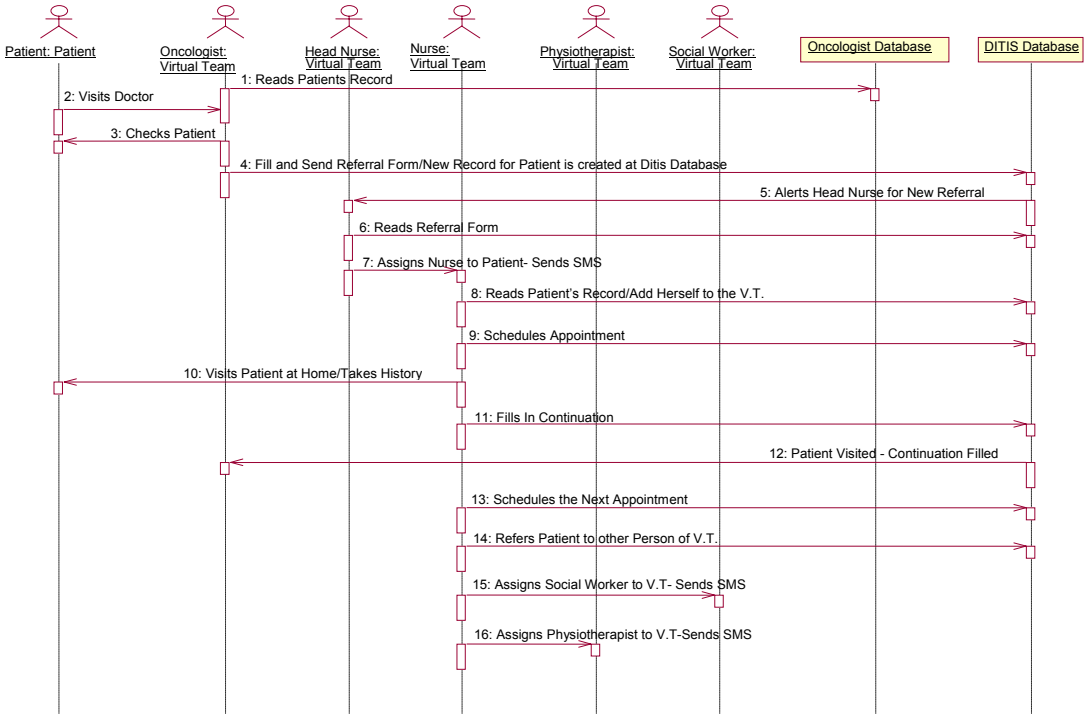



Figure 3. Sequence Diagram for new patient referral to home care - First visit by nurse

It is worth noting that the notifications via SMS are automatically sent through the messaging module. This is configured from the start in software according to the workflow and collaboration, as identified in the analysis. The system also provides SMS as an option each time the user composes a new message by selecting that an SMS notification must be included in the message. To provide flexibility and easier customisation for other organisations, we are currently investigating the implementation of the work flow in accordance with a more flexible approach so that administrators of the system can modify workflows dynamically (i.e. during 'run time').

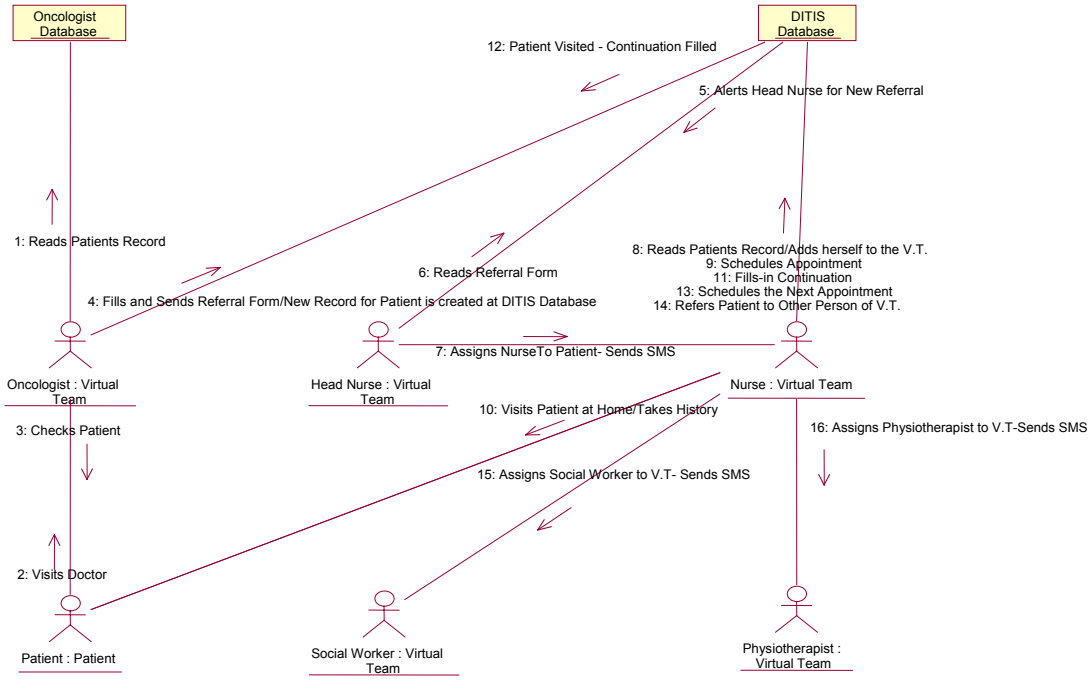



Figure 4. Collaboration Diagram for new patient referral to home care - First visit by nurse

## 5. System Design, Implementation, and Evaluation

DITIS provides secure access to e-records from any place and anytime via desktop computers (at work) or a variety of mobile devices (when on the go). It includes a set of integrated procedures for effective scheduling and coordination of team members, with features including messaging, automatic notification, and alerting. It also makes use of supportive tools relevant to home care that improve efficiency and minimize errors (e.g. messaging, calendar, symptom and pain diaries, medication charts, wound care assessment, drug interaction, etc…) [2]. The collaboration platform is based on identified roles and scenarios of collaboration, analysed using the Unified Modelling Language (UML). It is an Internet (web) based Group Collaboration system with secure fixed and mobile connectivity. Fig.5 presents an overview of the deployed system. The development of DITIS is based on the HL7, ICD-0 and ICD-10 standards, with a view toward an open Healthcare Information Infrastructure [17]. DITIS is designed to be open to the other services, in order to retrieve information from any medical facility such as hospitals. HL7 is tightly bound to UML, because it uses its methodology to help design messages, from use-cases to message definition. The 3rd version of HL7 is now currently under development, and has many concerns about respecting privacy in the storage and transmission of medical data. Another standard that was used was the ICD-10. This stands for International Classification of Diseases. This allows exchange of messages either in electronic health records (EHR) or in HL7, to clearly identify diseases using standard codes. DITIS mainly used its subpart called ICD-0, which deals with Cancer-related diseases, however there are plans to migrate to ICD-10, as the Oncology Centre it is collaborating is migrating to ICD-10. Note that continuous monitoring of international standards is necessary. In particular we monitor, as a high priority electronic records, messaging, e-prescriptions, and protecting personal information (PKI and health cards) [18]. The use of the following standards is reviewed: the electronic patient record, e.g. CEN standard EN 13606, ISO PKI Technical Specification, multipart ISO standard on health cards, CEN standard for electronic prescriptions, and for messaging HL7 Version 3 and use of XML.

### *5.1 System design*

Initially, DITIS, employed Mobile Agent technologies, Web Databases with Java Database Connectivity, and Web based database for storage and processing of information. Due to the commercialization plans of DITIS and the need for solid, fast and robust system, we have moved to more commercially proven technologies. We adopted the following technologies: Internet Information

Services (IIS), ASP.NET, SQL Server and the Microsoft Mobile Internet Toolkit (MMIT or simply .NET Mobile), which uses the Client-Server model.

To allow similar functionality to the Client-Agent-Server model the mobile agents are replaced by Mobile ASP .NET applications that handle all users' needs. In particular the collaboration features are managed for now from the ASP.NET pages (thus providing server side agent like functionality). In parallel, during the design phase we have initiated research on mobile agent platforms that are created under .NET for future embodiment. Some examples are currently under study (see, e.g. [19]).

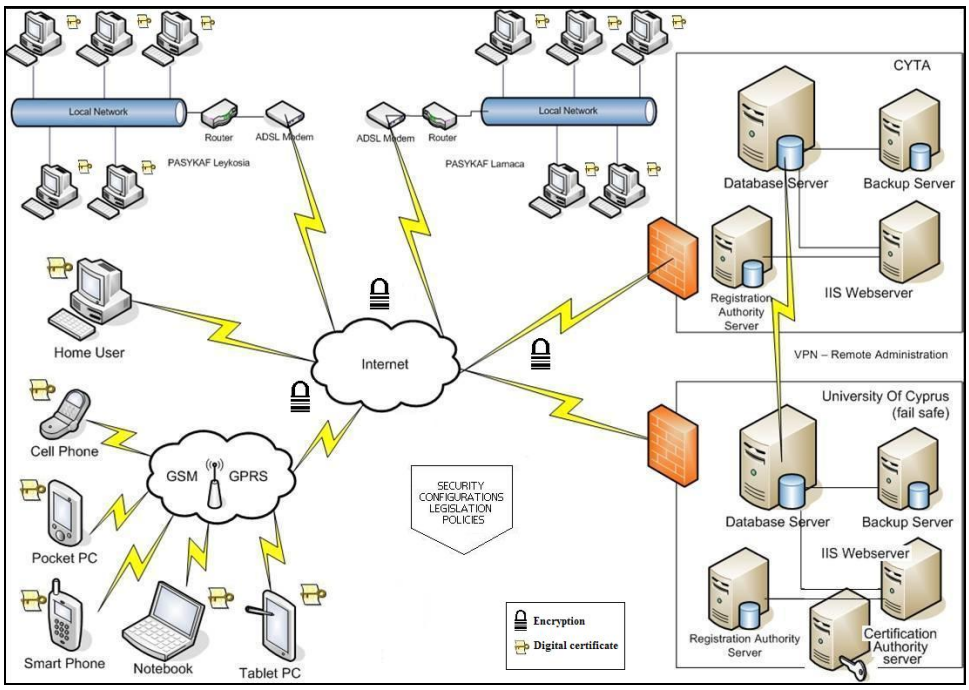
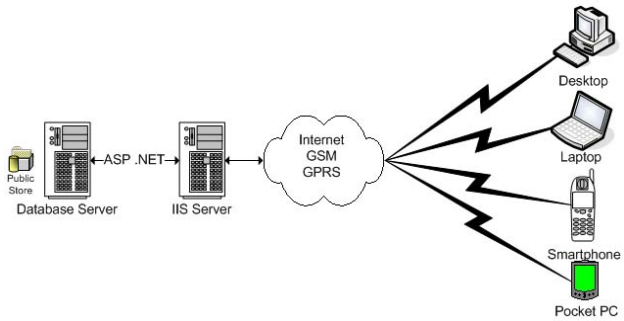
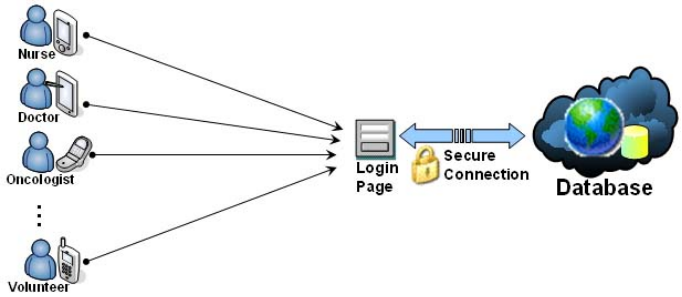


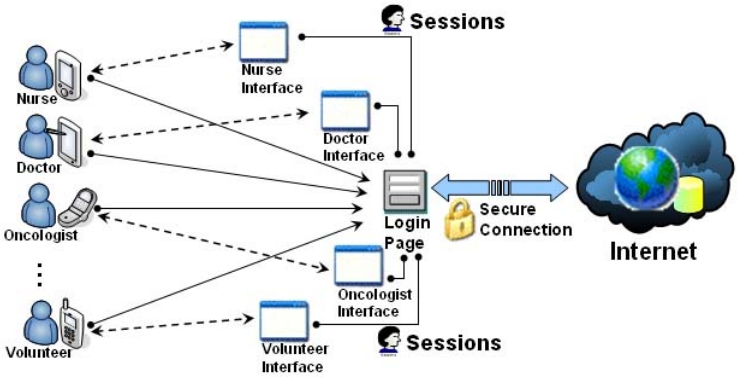

Figure 5. DITIS overview of deployed system



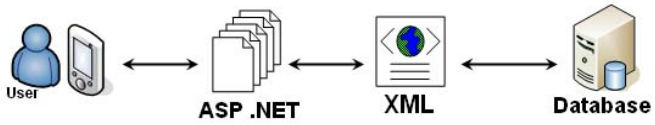

(a) User initiated action: ASP communicates with database




(b) Role based authentication of users




(c) Personalised user interface according to the user type (role)




(d) ASP.NET page collects the data in XML and formats them according to the user's device

Figure 6.Agent like functionality provision by current DITIS system implementation

The current functionality, especially as it relates to mobile agent functionality, is as follows. The user communicates with the ASP requesting some action. The ASP accesses the database (SQL Server 2000), collects the requested data, forms the response (HTML or WML) and forwards it back to user (see Fig.6.a). All users have to login under the same login page. The system, through the database, authenticates the user and understands the type of user according to their predefined role (e.g. Nurse, Doctor, Oncologist, Volunteer, etc…) (see Fig.6.b). After the successful login, the user is forwarded to the personalised interface according to the user type (role) that he/she is. Nurses, for example, have different interface than Doctors (see Fig.6.c). All the data are in XML format. Users access the ASP.NET pages. The ASP.NET page collects the data from the database in XML format and formats them according to the user's device (see Fig.6.d).

*5.2 Mobile devices*

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. The current implementation uses existing mobile devices such as the Smart-Phones, Pocket PC, Palm PC and Handheld PC. As a result, DITIS mobile device interface was built as simple as possible to support such devices.

Two modes of 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 similar functionality, but limited data stored in a local database on the mobile device (see Fig.7). The local database 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). As a result 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 [20]. As mobile device technology evolves so is the opportunity to include more sophisticated functionality on the mobile device itself.

An example interface is shown in Fig.8 for two commonly available mobile devices, which show a number of menu selections for the home-nurses.

[†] The standalone implementation is a custom build program. It runs on any mobile device which the AppForge booster framework supports.

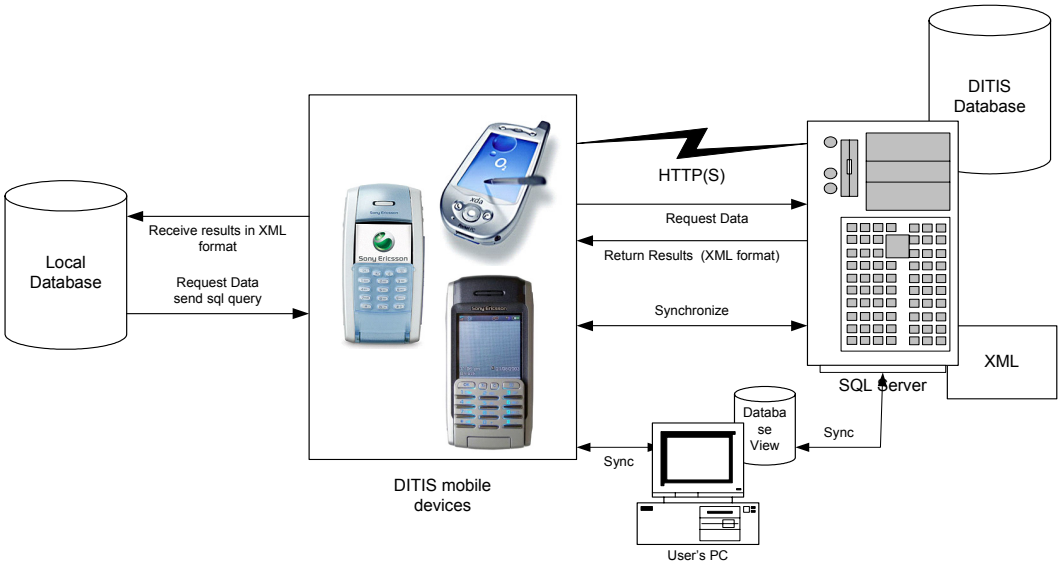



Figure 7. DITIS mobile system architecture

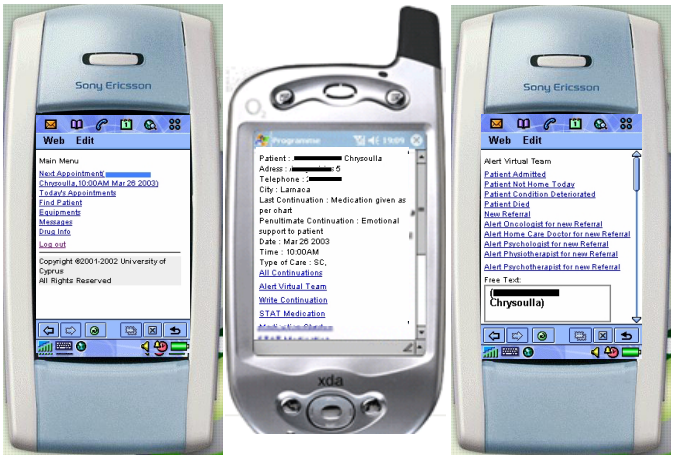



Figure 8. Example collaborative system screen on mobile devices

*5.3 DITIS Security Framework*

The DITIS system was implemented with the goal of providing end-to-end security, addressing the security needs of the health care team down to the activity level, with ease of use. The security objective includes: Retain the privacy and integrity of medical and personal information; Authentication / Authorization; Achieve non-repudiation (Digital Signatures); Secure the local storage of information; Availability - Failover plan; and Ease of use – Considerations on how security mechanisms may affect operation of work. We adopted the OCTAVE (Operationally Critical Threat, Asset, and Vulnerability Evaluation) methodology [21,22,23]. By using OCTAVE, the DITIS development team determined areas of focus that were addressed in the security strategy:

* Security awareness. The study revealed lack of adoption of security practices such as using strong passwords. Many times ignorance could cause the same damage as an intentional illegal action. Before trying to secure the organization from outsiders, appropriate measures should be taken to safeguard assets from security unaware employees.

* Access control. The healthcare team of DITIS includes a number of professionals, who are not necessarily co-located, or even may belong to different organisations, thus appropriate access control needs to be provided. Also each group of users handles different data about a patient related to their job function. There is the need to assign different permissions to each group of users (roles based) providing an appropriate view of the patient record.

* Ethics & Legislation. The healthcare team is bound by the medical confidentiality and its first priority is to respect the patient's right for privacy. However, not all people involved in the

organization are bound by the medical confidentiality i.e. a secretary. Mechanisms should be implemented to prevent people outside the medical confidentiality to access confidential information. Furthermore, health professionals are accountable for their actions. Therefore, mechanisms should be in place to track users' actions. Generally, if anyone is found compromising confidentiality he/she must face appropriate penalties set by the organization and the law.

* Transparency. The patients have the right to be informed when their personal data is stored and processed electronically as defined by the law. The healthcare team is obligated to inform the patients that they use their personal information to provide services and also ensure that the patient can access his information. In addition, the healthcare team feels that it is important to have the written consent of the patients to store and process their personal data so that they are legally covered in a case of a lawsuit.

* Quality of Services (QoS). Considerations are raised towards a number of security requirements related to QoS. For example, nurses fear situations where a patient may need immediate care and they could not access his medical record in order to find his medical treatment and act accordingly. Loss of integrity is unacceptable since it would affect the provided care services. Furthermore, quality of healthcare services is depended on an effective security management. A structured administration is needed to immediately respond to problems. The team must feel the presence of a person that will help them with the system if they have a problem. Transferring confidence to the system is not an easy task to do as some members of the team have until recently been working with the traditional paper workflow.

Based on the outcomes of OCTAVE's evaluation, DITIS development team adopted and designed a multi-layer security architecture to provide strong protection to the system, data and people involved [21].

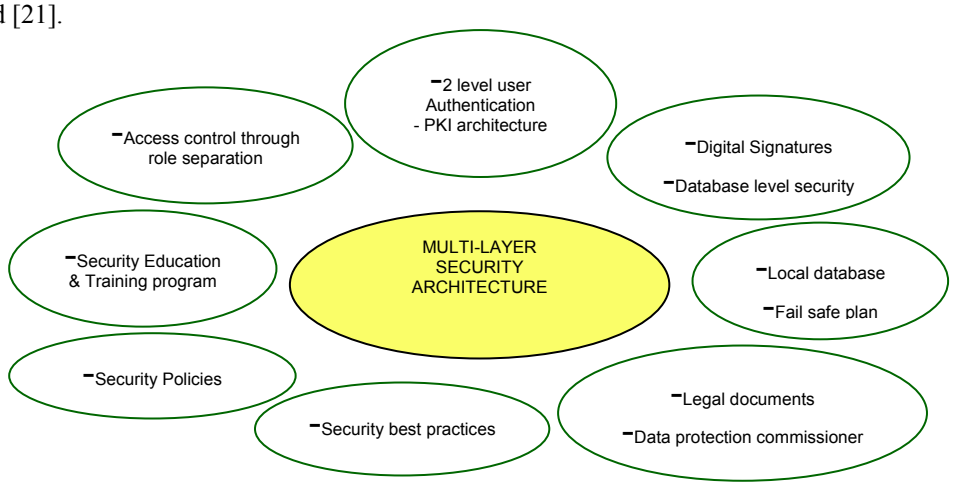



Figure 9. DITIS Multilayer Security Framework

As the security was role based, a necessary task was to define the access control level through role separation. In this way, each group of users i.e. nurses, social workers, has access to a certain view of the patient record and retrieves information for which they have a legitimate need to know. The various access control levels were identified by the development team after interviewing each professional and gathering the needs and requirements associated with each role. A detailed analysis and study of each role in the system followed resulting in the implementation of a specialized profile for each group of professionals in the database. In this way, each user accessing the system belongs to a specific group and inherits the characteristics and access permissions of the associated role profile.

User authentication is achieved in two levels. The first level of authentication is between the user and the device and is achieved by providing a strong PIN number / password to the wireless device. The second level of authentication is between the user and the healthcare application and is achieved by using a digital certificate and a strong password. An appropriate PKI (Public Key Infrastructure) system is implemented and managed by the Computer Science Department of the University of Cyprus to provide certification services to DITIS [24]. By using digital certificates three things are achieved: user authentication; encryption of all confidential medical information that is transmitted over the Internet; and integrity control on the information exchanged over the Internet as any alterations are recognized and the user is aware that the information is not in its original context. In addition, through the usage of digital signatures non-repudiation is achieved and every individual is

accountable for his/ her actions, leading to such activities as e-prescription, which is essential for effective management of drug administration in the home.

Confidentiality and privacy are achieved by implementing appropriate ethical documents that are signed by the intended individuals recognising the importance of keeping information safe and processing patient data for improved quality care. These documents are developed with adherence to local and European laws of data protection.

Further security actions taken are the design of a set of security policies regarding: patch management, auditing, password generation, backups, and system security assessment; implementation of security tools such as antivirus, monitoring tools and firewalls; replication of the Electronic Medical Record as part of a fail safe plan (Fig.5); evaluation of each component (wireless devices, servers etc) and enforcement of appropriate practices to eliminate well known vulnerabilities associated with these components; and design of a security education and training program to inform about the proper usage of the system regarding the security aspects.

Security is an on-going process, meaning that the security architecture must be reviewed regularly and updated as needed, according to the technological advances and new security requirements that may arise.

*5.4 Evaluation*

A recent study was carried out at PASYKAF for evaluating several aspects of DITIS. The findings are reported in [25, 13]. 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.

The paper in [13] 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 recognised 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 [26] 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. However, even though this is a novel application and despite the fact that it has been introduced five years ago, the implementation has remained slow and the system has not yet been able to secure its place and its future in the health sector; though it has been making an impact on the health care support provided by the PASYKAF nurses and medical staff[#]. Speedy commercialisation of the system seems to be the solution for its long term survivability, and this is currently pursued, but as with any new ideas and products there is considerable risk involved. In the meantime, DITIS is at present also being deployed, for its healthcare collaboration and patient management aspects, in the context of two EU funded e-TEN market validation projects (HealthService24 and LinkCare), involving trials for cardiac patient monitoring.

On the Clinical side the following objectives were addressed by DITIS:

* The presence of the (Virtual) Collaborative Medical Team by the patient at any given time, irrespective of locality or movement. Continuity of care is supported.

* Improved communication within home care team and between home-care team and hospital, thus providing capability to consult within a team of experts (e.g. home nurse with treating doctor or oncologist), 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.

* Improved and secure, timely access to patient information, in accordance with their authorisation levels, through unified information space centred around the patient. As an added benefit, the patient need not provide the same history to multiple professionals.

---

[#] It is worth noting that through the use of DITIS PASYKAF has moved to a paperless mode of operation since August 2003.

* Improved and flexible collection of statistical data for further audit and research within the home care setting.

* Improved evaluation through the capability to offer audit and research.

* Improved cost effectiveness through improved communications and better planning of services.

* Improved health practices (shift toward evidence-based) and reduction of bureaucratic overhead.

* Assists in promoting the dependant role of the home-nurse legally binding (for example, in the home setting when interacting with a hospital doctor for the prescription of drugs in the home).

As a consequence of meeting the above clinical objectives the *system improves the provision of health care to Cancer patients*, thereby achieving better quality of life, in the warmth of their own home.

## 6. Conclusions

In this paper we motivated virtual collaborative teams for home healthcare and discussed their implementation issues through the project DITIS.

DITIS supports home-care by offering wireless health care services for chronic illnesses. The main service is the dynamic creation, management and co-ordination of virtual collaborative healthcare teams for the continuous treatment of patients at home, independently of physical location of the team's members, or the patient. For each patient a flexible (dynamic) virtual medical team is provided, made up from visiting home-care nurses, doctors, and other health care professionals, responsible for each case. This virtual team is able to provide dedicated, personalized and private service to home residing patients on a need based and timely fashion, under the direction of the treating specialist, thus minimising the necessity to move the patient from his home. This results in the provision of better care and a reduction of number of visits to health professionals or hospitals away from patient's home.

The collaboration and virtual team requirements, both in terms of interactions and computing model were analysed in the paper. The implementation of the system is also described highlighting the implementation aspects of the identified virtual team computing model requirements within the limitations of the adopted technologies. The security needs are also analysed using the OCTAVE methodology and a multilevel security framework is presented to address the needs of DITIS.

Future extensions will include further evaluation of the system benefits, including a cost benefit analysis, and a formal study of the interactions between team members to be undertaken with a view to the provision of adaptability in the virtual team interactions and work flow. These interactions and work flow are currently hardwired into the system (software coded at system implementation phase), as derived from user requirements analysis using UML diagrams. In the future the aim is to make these more dynamic.

## Acknowledgement

The DITIS project was funded by the Cyprus Research Promotion Foundation (RPF) (1999-2001 and 2004-2006) and Microsoft Cambridge Research Labs (2003-2004). The total support of the Cyprus Telecommunications Authority (CYTA) with telecommunications infrastructure, NetU as a partner in RPF grant (1989-2001), WinMob Technologies Ltd for wireless technologies, Ericsson (through S.A. Petrides Ltd) for the provision of handsets, Microsoft for the .net framework and XDA devices, and the Cyprus Development Bank (CDB) for financial support are gratefully acknowledged.

## References

1 S. Salmon, G. Brnt., D. Marshall, A. Bradley, Telemedicine use in two-nurse-led injuries units, Journal of Telemedicine and Telecare, 6, Suppl. 1, 43-45, 2000.

2 DITIS. Web Site: www.ditis.ucy.ac.cy (last accessed August 2005).

3 B. Pitsillides, A. Pitsillides, G. Samaras, E. Christodoulou, N. Panteli, P. Andeou, D. Georgiades, User Perspective of Ditis: Virtual Collaborative Teams For Home-Healthcare, IOS press book series "Studies on Health Technology and Informatics", 100th "Golden" volume, Current Situation and Examples of Implemented and Beneficial E-Health Applications, hardcover ISBN: 1 58603 448 0, p. 205-216, 2004.

4 A. Pitsillides, B. Pitsillides, G. Samaras, M. Dikaiakos, E. Christodoulou, P. Andreou, and D. Georgiades, A Collaborative Virtual Medical Team for Home Healthcare of Cancer Patients,

Book Chapter, M-Health: Emerging Mobile Health Systems, (R. H. Istepanian, S. Laxminarayan, C. S. Pattichis, Editors), Kluwer Academic/Plenum Publishers, pp. 247-266, 2005.

5 G. Samaras, D. Georgiades, and A. Pitsillides, Computational and Wireless Modeling for Collaborative Virtual Medical Teams, Book Chapter, M-Health: Emerging Mobile Health Systems, (R. H. Istepanian, S. Laxminarayan, C. S. Pattichis, Editors), Kluwer Academic/Plenum Publishers, pp. 107-132, 2005.

6 J. Lipnack, J. Stamps, Virtual Teams: Reaching Across Space, Time, and organizations with Technology, John Wiley & Sons, Inc. NY, 1997.

7 M. Cherry, L. Ogilvie, D. Paquette, Evaluation of Information Standards for Home Care Health Transition Fund Final Project Report, Canadian Institute for Health Information, Canada, March 2001.

8 Canadian Institute for Health Information. National Consensus Conference on Population Health Indicators Final Report. Ottawa:CIHI, 1999.

9 N. Panteli, M. R. Dibben, Reflections on Mobile communication systems, Futures, 33/5, 379-391, 2001.

10 S. L. Jarvenpaa, D. E. Leidner, Communication and Trust in Global Virtual Teams, Journal of Computer-Mediated Communication, 3, 4, June 1998.

11 R. Kraut, C. Steinfeld, B. Butler and A. Hoag, Coordination and Virtualization: The Role of Electronic Networks and personal Relationships, Journal of Computer Mediated Communication, 3, 4, 1998.

12 R. J. Lewicki, B. B. Buncker, Developing and Maintaining Trust in Working Relationships, in R. M. Kramer and T. R. Tyler (eds) Trust in Organizations: Frontiers of Theory and Research, Sage Publications, Thousand Oaks, CA, 1996.

13 N. Panteli, B. Pitsillides, A. Pitsillides, G. Samaras, 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, accepted for publication 2006.

14 A. Tiwana , From Intuition to Institution: Supporting Collaborative Diagnoses in Telemedicine Teams, Proceedings of the 33rd Hawaii International Conference on System Sciences, 2000.

15 J. E. White, Mobile Agents, General Magic White Paper, www.genmagic.com/agents, Mobile Agents, www.agent.org/ and www.cs.umbc.edu/agents, 1996.

16 D. T. Georgiades, Dynamic Creation of Collaborating System and Database Management, Using Mobile Agents, Masters Thesis, Computer Science Department, University of Cyprus, June 2002.

17 B. Blobel, Analysis, Design and Implementation for Secure and Interoperable Distributed Health Information Systems, Volume 89: Studies in Health Technology and Informatics, 352 pp, ISBN 1-58603-277-1, IOS Press, Amsterdam, 2002.

18 R. Rogers, J. Sembritzki, P. Village, CEN/TC 251 Health Informatics, Priorities for application of ICT Standards–A project report for Ethel Thematic working group T1, CEN/TC 251/N02-073, Dec 2002.

19 Mobile Agents Platform Under .NET. National University of Computer & Emerging Sciences. (FAST – Foundation for Advancement of Science & Technology), Personal Communication, Karachi, Pakistan, 2005.

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

21 C. Alberts, A. Dorofee, "Managing Information Security Risks: The OCTAVE approach", Addison Wesley Publisher, 2002.

22 E. Stavrou, A. Pitsillides, e-healthcare Security Framework: DITIS Case Study, ISHIMR, 10th International Symposium for Health Information Management Research Thesalloniki, Sept 22-24, 2005.

23 E. Stavrou, A. Pitsillides, Security Challenges in a Mobile Healthcare Environment, IWWST '05, 3rd International Workshop in Wireless Security Technologies, 4-5 April 2005, London, UK

24 M. Pieris, Policies in the Health Care to Support Public Key Infrastructure, Masters Thesis, Department of Computer Science, University of Cyprus, June 2003.

25 N. Panteli, 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

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