Tele-homecare supported by the DITIS collaborative platform

Abstract: Nurses, doctors, physiotherapists, social workers, psychologists and others come together to provide care to home residing patients including elderly people, making continuous assessment, diagnosis and treatment possible beyond the walls of hospitals and specialist treatment centers. 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. DITIS is a web based system that supports this model. It enables the effective management and collaboration of virtual healthcare teams, and provides secure access to medical information from anyplace and anytime via desktop computers (at work) or a variety of mobile devices from anytime and any place. It includes a set of tools for effective scheduling and coordination of team members, with features including automatic notification and alerting. It makes use of supportive tools relevant to home care that improve efficiency and minimises errors of home care monitoring. The paper introduces the DITIS system, and identifies the needs and challenges of co-ordinated teams of multidisciplinary healthcare professionals (HCPs). Then the adopted technology is briefly described. Pilot implementations of the systems as well as an evaluation study of the system are also briefly presented.

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

1. Introduction

The current context of health and health care is characterized by change and transition associated with health care system reform and restructuring [1]. 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 and in the most cost-effective manner. 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 [1,2]. In this paper we will focus on home-based care.

The practice of home-based care is often a collaborative activity, requiring extensive and interactive communication, within and between members of specialized occupational groups to coordinate patient care services. Thus, the provision of as optimum and effective care as possible demands the cooperation, communication and

coordination among all these mobile professionals, and the formation of a 'team of care' around each patient. 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 at home. It is of course obvious, that for home-based care 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.

By maintaining a dynamic collaborative virtual healthcare team, DITIS [3,4] achieves the delivery of better home-care, as well as secure, easy, and timely access, to the unified Electronic Healthcare Record database. 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.

The paper is organised as follows. Chapter 2 discusses the project objectives and provides an illustrative scenario, Chapter 3 addresses the system design and implementation, Chapter 4 briefly describes two pilot implementations and Chapter 5 an evaluation of DITIS. Finally, Chapter 6 offers our conclusions and future directions.

2. Project objectives and Illustrative scenarios

Complex and chronic illnesses demand the use of specialist treatment protocols. According to these:

- The patient care is provided by a team of HCPs, as for example cardio specialists, nurses, physiotherapists, social workers, and so on. 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'*
- Specialist nurses and other mobile HCPs visit patients regularly at home, offer care, which must be provided in co-operation, and often under the direction of the treating doctors of a hospital (e.g. oncologist, cardiologist).

DITIS aims to overcome the above difficulties by maintaining a dynamic collaborative virtual healthcare team, as well as secure, easy, and timely access to the unified Electronic Medical Information database for the continuous home-treatment of patients. The virtual healthcare team is created explicitly to satisfy the needs of each particular patient at a point in time. Access to information is provided by fixed and mobile devices at any point in time and from anywhere. As a result many clinical objectives are addressed, which are thoroughly described in Section

To provide the presence of the (virtual) team by the patient at any given time, irrespective of locality, or cross country movement.

- To improve communication within the dynamic (virtual) home care team and between the home care team and the hospital (locally, or cross country), thus providing enhanced quality of care.
- To provide flexible and secure access and management of healthcare records at any time and from anywhere, to improve continuity of care.
- To improve the collection of statistical data for further audit and research within the home care setting, enhancing knowledge and offering the possibility of evidence-based care.

- Provide continuation of care for chronic illness via Virtual Collaborative Medical Teams, finally leading to a Pan-European scale (for visiting or retiring in a foreign country).
- To aid in making the dependant role of the home-care nurse legally binding (for example, in the home setting when interacting with a hospital doctor for the prescription of a pain drug in the home).

Given the above are satisfied, the quality of life of chronic and severe patients will improve.

2.1 Healthcare Virtual Teams

Interactivity among the key actors in virtual healthcare teams is important [5]. 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 is presented later). These scenarios can identify the communication and collaborative requirements which 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) [6,7]. In DITIS we adopt the Long Distance Healthcare Virtual Teams model [6]. In this model team members work mostly separated in space and are mobile, 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 [6]. 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. Finally, mobile agents [6,8] 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. In DITIS 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.

2.2 Illustrative scenarios

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: A) Referral of a new patient to home-care, referral to other professionals, and first home-care-visit, B) Home-care virtual team creation / addition of members and communication with the virtual team members, C) Service provided in the homecare, requiring collaboration with the treating doctor such as: change of prescription and blood analysis, D) 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 Figure 1 and Figure 2 respectively. This same scenario shows aspects of virtual team interaction for the accomplishment of specific tasks.

Illustrative scenario:

1. A diagnosed cardio patient, Athina, is referred to LITO Home Care by Dr Miltiades, the resident cardiologist at LITO Polyclinic.
2. For this purpose, Dr Miltiades completes the Referral Form. Upon submission of the Referral Form for Ms Athina, needed information is transmitted to DITIS database and a patient record is created in the DITIS System.
3. Dr John, the Home Care Doctor, after reading the referral form and patient record, assigns nurse Barbara to be the nurse that delivers and oversees the home nursing care for patient Ms Athina. Dr John adds himself and Nurse Barbara to the virtual medical team for patient Ms Athina (Dr Miltiades was already added as Cardiologist). He telephones and assesses the immediate needs of the patient and schedules a first visit to Ms Athina.
4. On the day of the scheduled visit Dr John checks the patient record and visits Ms Athina together with Home Care Nurse Barbara. He introduces himself and Barbara and takes a history both medical and psychosocial as well as an assessment of symptoms and patient requirements. He then enters the patient findings in the system (continuation). Dr Miltiades is informed that the patient has been seen by Home Care, and the findings of the initial assessment are now on DITIS.
5. Nurse Barbara then schedules the next appointment in 6 days time (there is no immediate need for the Home Care Doctor), salutes Ms Athina and leaves.
6. She is now aware of patient requirements and refers her to other members of the team, as required.
7. Nurse Barbara decides to add a social worker, Ms Andri, to the virtual team as Ms Athina needs to apply for a pension since she will be unable to resume work in the near future.
8. Nurse Barbara also adds a physiotherapist, Ms Viktoria to the team to teach Ms Athina deep breathing and coughing techniques.
9. A message is sent to the social worker and physiotherapist informing them that they have become part of the health care team. This message is stored in the DITIS messaging service. An SMS is also sent.

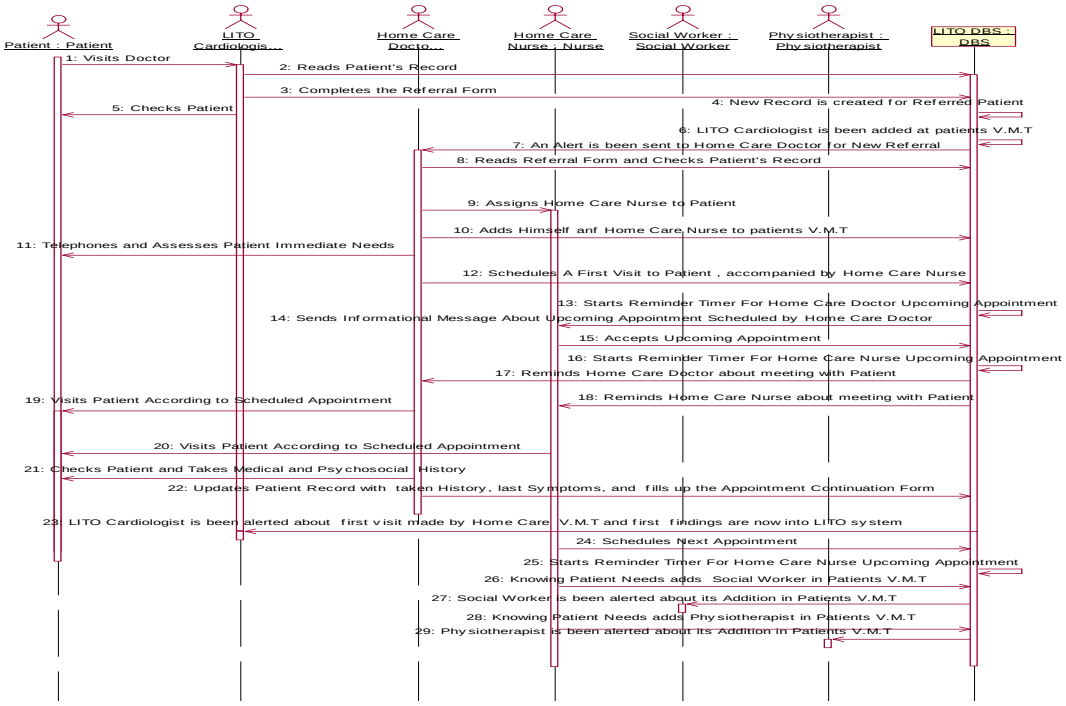

Figure 1. Sequence diagram

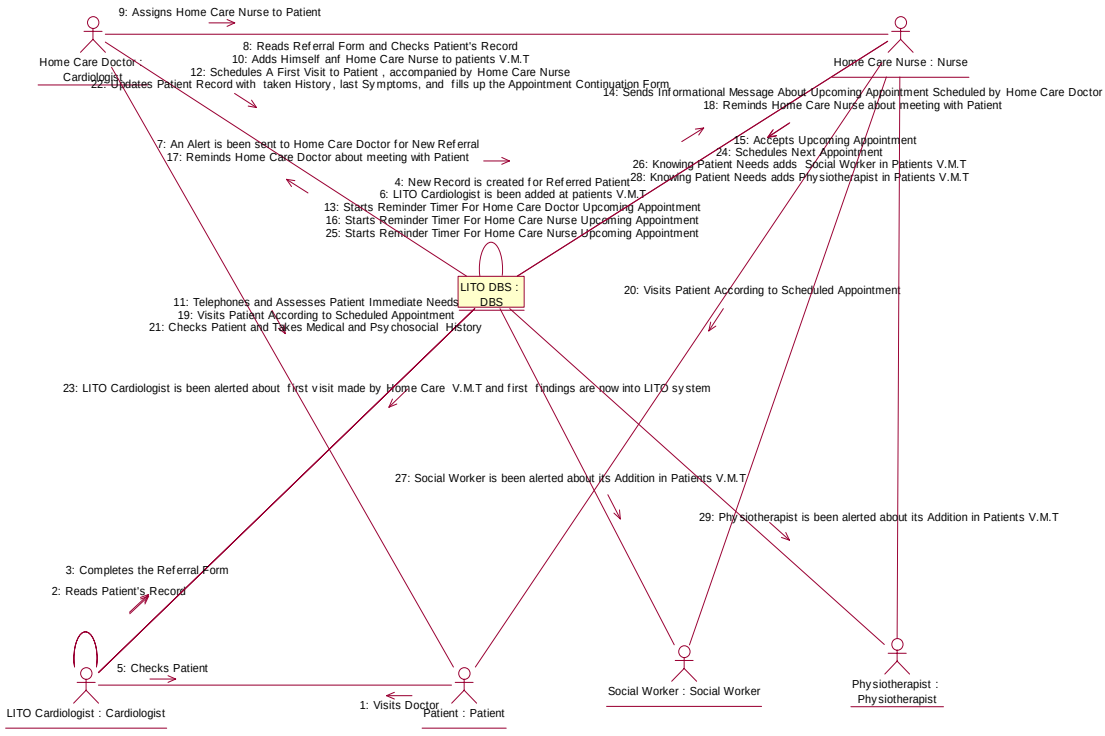

Figure 2. Collaboration diagram

3. System Design and implementation

DITIS is an Internet (web) based Group Collaboration system with secure fixed and mobile connectivity. Figure 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 towards an open Healthcare Information Infrastructure [9]. DITIS is designed to be open to the other services, in order to retrieve information from any medical facility such as hospitals. In order to achieve this, the system supports an HL7 parser for sending and receiving HL7v2.5 messages. Of course, the project team is continuously monitoring relevant international standards so as to ensure interoperability with emerging platforms.

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, etc) as well as decision support tools (drug interaction, assessment tools, etc).

3.1 Technology Description

The DITIS Framework is a collection of health care services that supports the collaborative patient management via a multi-modal interface. The DITIS architecture is a five-layer architecture. Figure 3 illustrates the relationship between each of the DITIS layers.

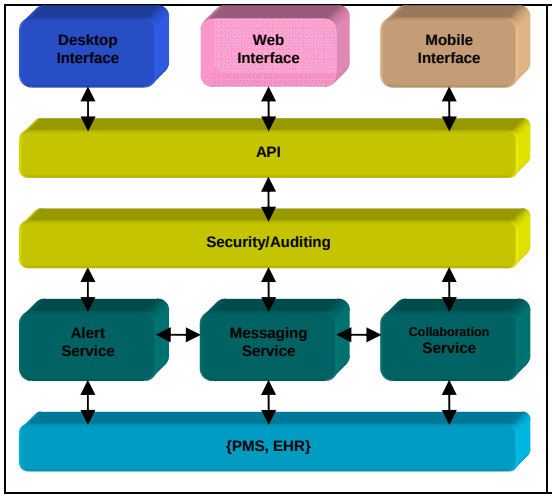

Figure 3: DITIS layered architecture

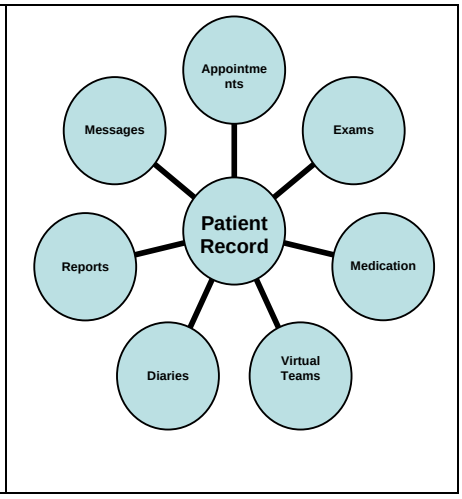

Figure 4: DITIS services

The patient record (PMS, EHR) is the foundation of the DITIS Framework. As it can be seen in Figure 4, it is composed of various modules that support the recording and processing of different information concerning the patient. This information includes the patient's demographics, medication, exams, diaries and more.

The main services that access directly the patient record layer are the Collaboration, the Messaging and the Alert Service. The Collaboration Service is responsible for the Virtual Healthcare Team management, and implementation of

organization specific requirements and policies. In order to achieve this, the Collaboration Service maintains a collaboration engine which conserves the rules and policies implemented in the system. The Alert Service is responsible for alerting both health care professionals and patients about future appointments, medication alerts, and other. Both the collaboration and alert service are linked to the messaging service as they require messages in order to inform the user or the system about the status and actions that may be required for certain events. The Messaging Service is responsible for delivering messages to the users of DITIS. Messages are structured data stored in the system. In some cases SMS notifications are used in conjunction with messages routed by the system DITIS to increase the chance of alerting the user to specific events or actions, dependant on the importance of the event or action. Note that all SMSs are generated and sent by the system therefore a log is always kept, for example to generate new actions or for audits.

Next, in the DITIS architecture comes the Security and Auditing layer. DITIS implements a security strategy based on the OCTAVE methodology (Operationally Critical Threat, Asset, and Vulnerability Evaluation) [10,11,12] which is briefly described in section 3.2.

Finally the API layer includes a list of all commands for accessing the system. The API is used by all implemented interfaces (desktop, web and mobile) and acts as the bridge to the DITIS system. These interfaces are implemented with state of the art technologies in order to provide accessibility to DITIS by any device and enhance the functionality.

3.2 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 methodology. The OCTAVE methodology dictates the hardening of each security component, replicating the primary infrastructure as the main fail-safe plan and employing a certificate authority mechanism to ensure that all data channels are secured. 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 [11,12]. DITIS also employees an application level auditing mechanism which enables system administrators to navigate through the history of each individual record without being obliged to go through complex log files.

3.3 Deployed system technologies

DITIS adopts state of the art technologies like ASP.NET, XML, Microsoft Mobile Internet Toolkit (MMIT or simply .NET Mobile) and SQL Server and Internet Information Services (IIS). The deployed system at PASYKAF home based cancer care and LITO polyclinic is depicted in Figure 5.

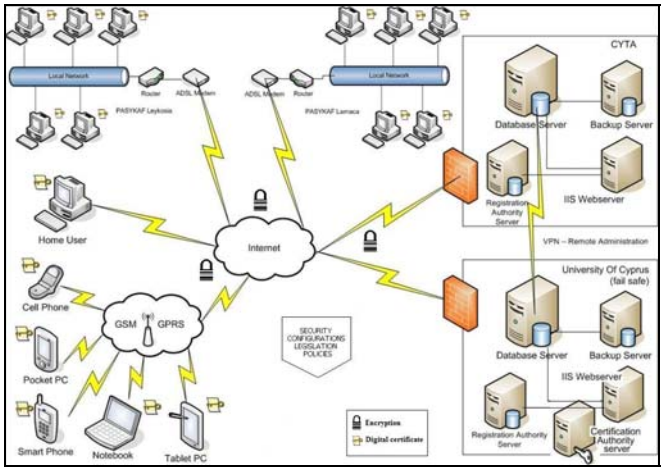

Figure 5. DITIS overview of deployed system at PASYKAF home based cancer care and LITO polyclinic

3.4 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 Smartphones, Pocket PCs, Palm PCs and Handheld PCs. DITIS mobile interface was built using state of the art mobile technologies so as to be ready for deployment 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. Note that graphics for the web implementation was kept at a minimum so as to keep the telecommunication costs low, whereas for the standalone device a richer graphics based interface is adopted (see Figure 6 and Figure 7).

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 [13,14]. 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 6 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 7.

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

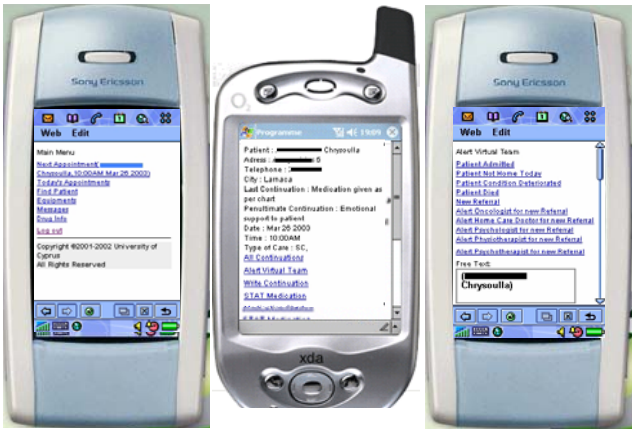

Figure 6. Example collaborative system screen on mobile devices (web interface)

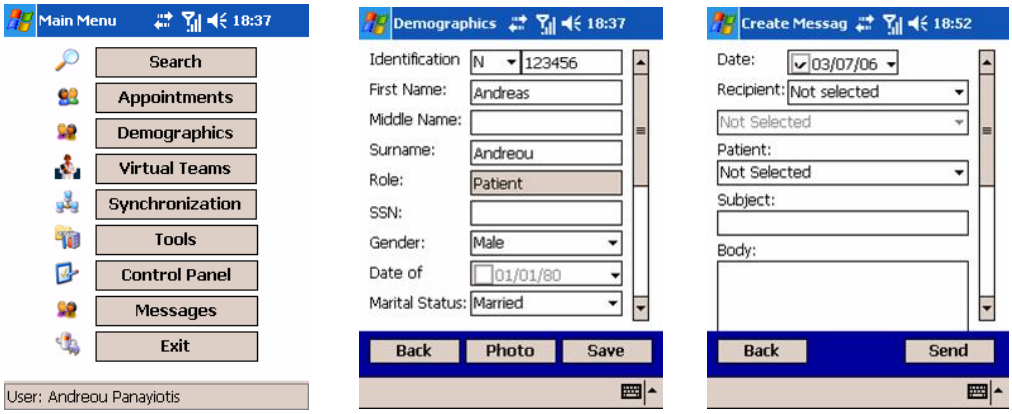

Figure 7. Example screens on mobile devices (standalone interface)

4. Pilot implementations

4.1 Homecare treatment of cancer patients

The system was initially installed in 1999 and has been supporting the activities of the the Cyprus Association of Cancer Patients and Friends (PA.SY.KA.F.) who offers home-care services to more than 500 cancer patients per year in Cyprus. One of the district offices has gone paperless with DITIS since 2003. PA.SY.KA.F. personnel received extensive training to use DITIS [15], and virtual collaborative healthcare teams are carrying out home care services using mobile devices. At the same time DITIS is being extended to collaborate with other cancer health care entities. 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. DITIS had offered a solution to these problems, as shown by the DITIS evaluation [16].

4.2 Integration in a home care monitoring platform for cardiac patients

Since 2005 DITIS has been successfully integrated in a health care monitoring platform developed under the Healthservice24 (HS24) and LinkCare e-Ten projects [17,21] aimed at providing a viable mobile health care service, permitting healthcare professionals to remotely and interactively diagnose, collaborate with each other and treat patients whilst the patients are free to continue their normal daily life activities.

Ongoing monitoring is especially important in case of chronic and high-risk patients, e.g. cardio patients discharged early from hospital after a surgery and high-risk cardio patients that require almost constant monitoring. Today these patients are often hospitalised for long periods, resulting in high hospital costs and moral degradation.

The integrated system is in pilot use in the Cyprus LITO clinical centre providing home care monitoring to chronic and high risk cardio patients. In the HS24 project a patient/user is equipped with diverse vital signs sensors, like blood pressure, pulse rate and ECG interconnected under a wireless Body Area Network managed by a PDA or mobile telephone and worn on the body, and thus moving around with the person. This way, patients can stay mobile but be continuously monitored and receive advice when needed. In the LinkCare project specialist are collaborating though DITIS to improve the healthcare provision.

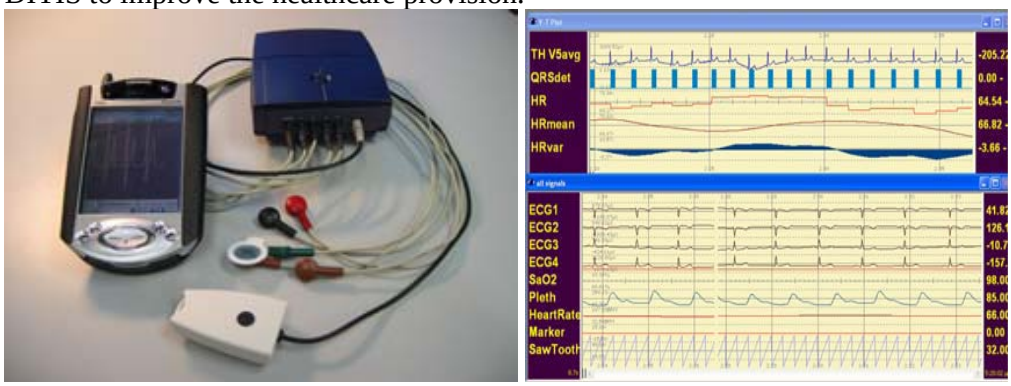

Figure 8: HealthService24 Body Area Network and example doctor interface

In the HS24 setup, vital signals are transmitted to an intermediate data center, with streaming functionality, that enables users to download and view the data on any of the supported devices. HCPs, to whom the patients' data is transferred, can remotely assess, diagnose and treat patients whilst the patients stay fully mobile and continue with their daily life activities. The integrated home care monitoring platform is then incorporated into the DITIS platform which supports additional functionality as described in Section 2.

The integrated DITIS and monitoring system can decrease hospital time for chronic and high-risk patients, but also for elderly people at home, while their feeling of safety remains intact by allowing them to obtain health advice by experts at any moment and place. Consequently, the system reduces health care costs resulting from the occupation of hospital beds significantly. The cost reduction aspect makes the service potentially interesting for health insurances and governmental institutions paying for medical services [17].

5. Evaluation

5.1 Longitudinal study

A longitudinal study on DITIS in the home-care of cancer patients can be found in [5]. The study adopts the stakeholders' analysis [18] to explore the various groups that have directly or indirectly supported the system during its implementation. It aims to understand these challenges and the results of the study point to a diversity of interests and different degrees of support. The role of stakeholders in information society implementations has long been recognized in the literature, though it has only been during the last few years that the identification of different stakeholders as well as the roles and interrelationships between them was found to be important for uncovering some of the complexity in system implementation ([19]). The adopted research was interpretive, as our aim is to capture stakeholders' interpretations of the system itself and their use of the system. To this end, our research method is qualitative in nature, examining "humans within their social settings" ([20]). The fieldwork has taken place in various district sites in Cyprus. Each site is served by a number of palliative-care nurses who visit patients regularly in their house. Data on DITIS were collected on different stages of the implementation process.

Overall, the data reveal that DITIS offers innumerable opportunities for palliative-care nurses and other cancer-care practitioners. DITIS is currently widely accepted as an invaluable tool in palliative care. Nurses, psychologists, and doctors acknowledge that DITIS has numerous advantages and that they are willing to incorporate it in their work activities. However, the study also revealed implementation problems. During the first three phases of the study, there was a general feeling that DITIS had not yet been sufficiently incorporated in the daily work activities of the healthcare workers and that this would be a slow process. The main problems identified were with regard to the implementation process. It has been widely recognized that the effectiveness of the system implementation was jeopardized due to financial resources being constrained or at times becoming unavailable.

Based on the results of the longitudinal assessment, corrective measures were taken, including the creation of a more stable team due to the commitment of all relevant actors and availability of funding. These corrective actions were acknowledged by all the users interviewed in final phase of the study. During this phase, there was a general feeling of satisfaction about the use of DITIS in the day-to-day work practices as users have by now begun seeing the benefits of the system. Accordingly, the stakeholders derive from diverse sectors, and even though they all want DITIS to succeed, their expectations are different. From our data, it was found that all stakeholders agree on the important role that the system could have in cancer support.

5.2 Clinical

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. In this way **continuity of care** is supported.
- 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).

- **Improved communication** by providing capability to consult within and between home care teams. 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**, through a unified information space centred around the patient.
- 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, better planning of services, and emphasis on prevention.
- Improved **health practices** (**shift toward evidence-based**) and reduction of bureaucratic overhead.
- **Improved quality of life for chronic and high risk patients** who can remain in their home environment and feel safe that in case of a change in their condition the healthcare team will be (virtually) present to support them.
- **Provision of multiple types of home care services** offering a **promising solution for the Ageing problem,** including integration with a continuous wireless vital signal monitoring
- A**ccommodation of multiple types of collaborative virtual team home care models**

As a consequence of meeting the above clinical objectives the system improves the provision of health care to home care 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. Also in case of need for hospitalisation better planning can be achieved, so as to minimise expensive hospital stays, as well as better manage scarce resources, by coordinating the admission and discharge with the cooperation of the home-care team. 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.

DITIS delivers 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 shifts the focus onto home-based care, where everything is moving around the patient. Thus chronic patients, such as the cancer or cardiac patients, can now enjoy 'optimum' health service, with improved quality of life, in the warmth of their own friendly environment, without a degradation in the quality of

care provided to them, feeling safe and secure that in case of a change in their condition the health care team will be (virtually) present to support them.

DITIS is at present being deployed for its healthcare collaboration and patient-management aspects in the context of two EU- (European Union) funded e-TEN market validation projects (HS24 [17] and LinkCare [21]) involving trials for cardiac-patient monitoring. Furthermore, an OEM is currently being signed with a major telecommunication equipment manufacturer, which aims to market DITIS worldwide.

Future extensions to DITIS 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. Furthermore, through the involvement in a European Commission funded project (MPOWER [22]) we are planning to integrate DITIS with Smart Homes and Sensor Networks, with a focus on the cognitively impaired and the elderly.

Acknowledgement

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