DITIS: A COLLABORATIVE VIRTUAL MEDICAL TEAM FOR HOME HEALTHCARE OF CANCER PATIENTS

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1. INTRODUCTION

Complex and chronic illnesses, such as cancer, demand the use of specialised treatment protocols, administered and monitored by a patient centric co-ordinated team of multidisciplinary healthcare professionals. Care of chronic illnesses (e.g. cancer patients) by a 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. As it is not possible for the health care team to be physically present by the patient at all times, or at any time physically together, whilst the patient is undergoing treatment at home (or work), a principal aim is to overcome the difficulty of coordination and communication, through DITIS (ΔΙΤΗΣ, in Greek, stands for: Network for *Medical Collaboration*). DITIS 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 medical teams, for the continuous treatment of the patient at home, and if needed for periodic visits to places of specialised treatment and back home.

DITIS 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

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Larnaca, using a **patient centric** philosophy, **focused on home-based rather than facility-based care**, receiving governmental and industry grants. It deploys a novel networked system for Tele-collaboration in the area of patient care at the home by a virtual team of medical and paramedical professionals, implemented using existing networking and computing components, initially addressing cancer patients (A.Pitsillides et al., 1997; Dikaiakos et al., 1998; A.Pitsillides et al., 1999; A.Pitsillides et al., 1999; B.Pitsillides., 1999; B.Pitsillides et al., 2003). DITIS was originally developed with a view to address the difficulties of communication and continuity of care between the home health care multidisciplinary team (PASYKAF) and between the team and the oncologist often located over 100kms away. DITIS has through its database and possibility of access via mobile or wire line (computers) offered much more than improved communication. Its flexibility of communication and access to the patient's history and daily record at all times and from anywhere (e.g. home, outpatients, or even during emergency admission) has offered the team a continuous overall assessment and history of each symptom. DITIS has thus offered improved quality of life to the patient, for example by offering the nurses the possibility of immediate authorisation to change prescription via mobile devices and the oncologist the possibility of assessment and symptom control without necessarily having to see the patient. It has offered the home care service the opportunity to plan future services and lobby for funding by offering audit, statistics, and performance evaluation and also the possibility for research. The pilot initial results indicated the usefulness of the proposed system, as well as highlighted practical, at times frustrating, problems. DITIS is currently being extended to island-wide implementation to support the PASYKAF home care service.

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.

In section 2 we analyse the justification and need for the proposed system, and in section 3 we provide the identification and analysis of the home healthcare professionals roles and collaboration scenarios. In section 4 we present the system design, and section 5 the pilot implementation in PASYKAF Larnaca. Finally in section 6 we provide some concluding remarks on our experiences, and present the benefits derived from the system, as well as future enhancements, and directions.

2. JUSTIFICATION OF NEEDS AND AIMS OF DITIS

The current context of health and health care is characterized by change and transition associated with health care system reform and restructuring (Cherry et al., 2001). 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.

2.1 Home Health Care

No issue embodies more the meaning of "reform" than the **shift from facility-based care to home-based care**. Reform and restructuring of the health system has seen hospitals closed at a faster pace than the planning and organization of the infrastructure for home and community-based care. Cost containment measures in acute care facilities have given rise to shortened lengths of stay and the shifting of care provision from the inpatient setting to the ambulatory care setting. The **need for home-based care is growing but the capacity to manage that need is still being developed**. This has placed a significant burden of care on individuals, their families and volunteer caregivers.

Home care services are an important and growing component of the health service delivery system. The pressure to expand and enhance home-based services is expected to grow as a result of demographic shifts in the 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 (Cherry et al., 2001).

The **definition** of **home care,** that we adopt, is well captured in (Canadian Institute report, Jun 1999):

> *"A range of health-related, social and support services received at home. These services enable clients incapacitated, in whole or in part, to live in their home environment. These services help individuals achieve and maintain optimal health, well being and functional ability through a process of assessment, case co-ordination, and/or the provision of services. Service recipients may have one or more chronic health conditions or recently experienced an acute episode of illness or hospitalization. The range of services provided includes prevention, maintenance, rehabilitation, support and palliation."*

2.2 The need for DITIS:

Although the context of health reform may vary across countries, the major objectives are similar and include:

- a move towards *people-centred* services;
- a commitment to *healthy public policy* and a desire to improve the health status of individuals and communities;
- increased emphasis on *knowledge/evidence-based decision making* and *efficiency and effectiveness* in service delivery;
- a shift from facility-based health services and a focus on illness, to *community-based health services* and a focus on *wellness*;
- the *integration* of agencies, programs and services to achieve a seamless continuum of health and health-related services; and
- greater *community involvement* in priority setting and decision-making.

DITIS aims to support the above healthcare reform objectives. We focus our analysis on cancer patients, but expect our results to be applicable to home healthcare in general.

For home health care:

- The patient care is provided by a team of more than one healthcare professional, 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'*
- Specialist nurses and other healthcare professionals visit patients regularly at home, offer care, which must be provided in co-operation, and often under the direction by the treating doctors of a hospital (e.g. oncologist).

Providing top quality care necessitates close collaboration, 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 Cancer patients deserve to obtain in a friendly (to them) home environment. Through DITIS we expect to assist in the delivery of better home-care, by offering the health-care team services that are aimed in achieving a seamless continuum of health and health-related services, despite the structural problems of home-care, as compared to facility based care, as for example the geographic proximity and geographic separation between the team members and the patient.

DITIS aims to overcome these difficulties by maintaining a ***dynamic collaborative virtual healthcare team*** (Figure 1), as well as secure, easy, and timely access to the **unified Electronic Medical Record** database (Figure 2) 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.

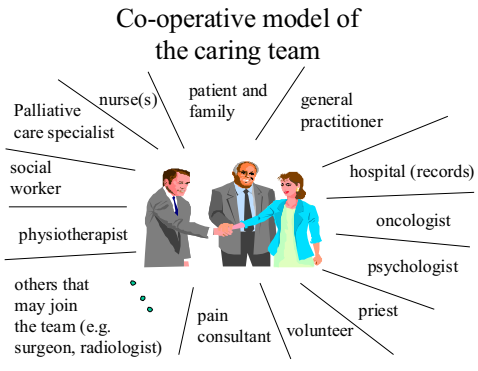

Figure 1. Patient centric home health care

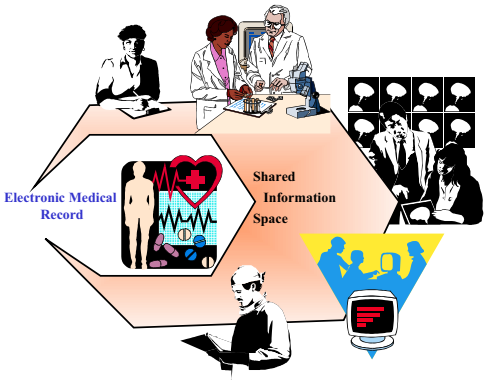

Figure 2. The unified information space of DITIS

As a result the following **clinical objectives** are addressed:

- 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 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 collection of statistical data for further audit and research within home care setting, enhancing knowledge and offering possibility of evidence-based care.
- Provide continuation of care for chronic illness via Virtual Collaborative Medical Teams, finally leading to a Pan-European scale (to cover the needs of visiting or retiring patients or healthcare professionals 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.

2.3 Prior to DITIS

The case of the home-care provision prior to DITIS is described below:

Home care professionals visit the patient at home. Traditionally, 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 is requested from the patient, so as each professional can build their own medical and psychosocial history and treatment notes (handwritten). These handwritten notes were filed at the PASYKAF offices, once the health-care professional returned to the office, often at the end of the day.

If a visit to the patient was scheduled, then the file from the office had to be removed and taken with the health-care professional to the patient home. This was inflexible, as there was no possibility of access by another health-care professional at the same time (say the physiotherapist, unless separate records were kept). Also the health-care professional had to make a visit to the office to collect the patient file (even if there was no other business with the office). Additionally, in case of an emergency, even though a health-care professional (not necessarily belonging to the team) may had been able to respond immediately due to his geographic location with respect to the patient, a visit to the office would had been necessary, just to collect the patient file. Of course, for a patient visit to the hospital, especially in emergency, there was no possibility of immediate access to the patient file by the treating doctors. Therefore there was limited possibility for **continuity of care**.

As with every manual system, there was limited possibility for 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 was aimed to address these problems in the provision of home-care services by a team of professionals.

2.4 Competing Alternatives

The DITIS system integrates a number of state of the art technologies to provide a sophisticated tele-application in the medical domain. To substantiate the importance of such as system one must differentiate it from other related attempts. Indeed a number of related projects and efforts exist; however, no one, as far as we can ascertain, offers the features and innovation of DITIS within a single integrated application. We can classify these systems (and compare them to DITIS) based on their focus activities.

There are various **projects** covering accurate **diagnosis** and treatment until a patient gets to the hospital or in a home care center. Among them are: Ambulances Health Telematics HC 1001, Emergency-112 Health telematics HC 4027, Vital-Home ISIS 98 502085) that have already developed such telemedicine services over GSM. However these have not addressed the notion of virtual collaborative medical teams for the home care sector. The projects that deal with **home care** can be divided in two types: The first type is closer to research projects concerned with delivery of home care developing new generation of bio-sensors and transmitters (e.g. CHS, CHRONIC, EPIDEMICS, M2DM, TELEMEDICARE, E-REMEDY). The second type improves collaboration between health professionals for better home care delivery (e.g. D-LAB, PHARMA, MTM, MOEBIUS). None of these projects consider mobile technologies to support health-care team collaboration in home care applications.

Similarly a number of European projects are actively focusing on the use of **handheld devices** for health care provision. WARD IN HAND (IST-1999-10479) allows the management of key clinical information while providing decision support to mobile medical staff of a hospital ward, MOBIDEV (IST-2000-26402) promises to provide mobile users with secure access to the Hospital Information System in and outside the hospital, using web interfaces based on Bluetooth technology and GPRS/UMTS networks and also improve user friendliness via voice commands, DOCMEM (IST-2000-25318) and MOMEDA (HC 4015) aim to offer web access to electronic patients records (EMR) via multimedia terminal and possibilities of remote consultation, SMARTIE (IST-2000-25429) aims to develop web tools for multi-platform EMR access and support for

medical error prevention, MTM (IST-1999-11100) provides via a local wireless network multimedia medical support to the mobile hospital personnel. These projects are based on a variety of technologies (e.g., GSM, GPRS or local wireless networks) and face the mobile health care problem from a variety of angles. As far as the authors know, none considers collaboration and virtual healthcare teams using commonly available GSM/GPRS based communication channels and handheld devices (e.g. Smart Phones). It is worth mentioning that DITIS, along with some of the above projects, has been invited to participate in a cluster proposal dealing with "Mobile Medical Devices (MEMO)" due to its unique approach in facing home health care provision (i.e., patient-centric virtual collaborative medical teams), and was also invited to demonstrate in the High Level Ministerial Conference: "*e*Health 2003: ICT for Health", Brussels, 22-23 May 2003.

3. IDENTIFICATION OF THE HEALTHCARE TEAM, THEIR ROLES AND COLLABORATION SCENARIOS

The healthcare team includes oncologists who are based in the oncology centre, treating doctors who are usually located in the community, 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 (see Figure 1). 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.

3.1 DITIS functionality

With the following plausible scenario we illustrate aspects of DITIS functionality.

*Nurse Mary wakes up early in the morning. After showering and a quick breakfast she connects (**with her Mobile Computing Unit, MCU**, such as a Smart Phone, Pocket PC etc…) to the central office web server to check in and acquire her day's visit schedule (the nurse does not have to physically check in). Her schedule includes a number of visits. For each patient to visit, Mary downloads on her MCU (**via her personalized agent**) the needed information, plans her route, and updates the Web server of her schedule. At first she visits Mr. P., a nice sweet old man who while enjoying the comfort and love of his home he regularly requires (and receives) attention due to the seriousness of his situation. Arriving at his house and examining Mr P nurse Mary realises an extreme change in his condition. She immediately (**via GSM/GPRS**) connects with the web server and via the MCU's application interface reports the incident. The system records (**into the electronic medical record of the patient in the database**) the new data, and based on the identified/pre-wired scenario triggers and transmits messages (**via the mobile agents**) to the other members of the team alerting them and requesting their services. [Future implementations may include intelligent host interfaces and intelligent event identifiers which identify the implications of such events, and adapt/learn and modify the scenarios dynamically].For each member of the team DITIS extracts (**via the personalized agents**) from the EMR only the needed (and authorised) parts of the information, prepares it and then forwards to them. That is the MCU device of every team member is receiving not only the data of the triggering incident (i.e., patient P. experiences extreme pain in the lower back) but also relevant patient history. (**The virtual team around patient P. has now been set in motion in seconds defying distance***

***and geographical barriers**.) The responsible doctor, Dr. A., studies the information submitted to her and prescribes the health care protocol which nurse Mary and other team members (e.g. a prescribed physiotherapy) should administer. Also a new appointment is scheduled for patient P. with the oncologist. Nurse Mary performs her tasks and Mr P. returns back to his smiley and happy self; the virtual medical team made the 'miracle'. His family are thanking nurse Mary who is headed to her next appointment. She is checking her schedule when a message (**via her agent**) comes in informing her that Mrs. D., her next patient, has suffered an extreme crisis and she has been taken to the hospital. Nurse Mary, while sorry for Mrs. D., is headed to the next patient in her list, Mr. X. On route she is informed of a new admission that she can schedule right now. Nurse Mary visits the patient Mr Y. for the first time. DITIS already has his EMR (sent by the treating doctor) to the PASYKAF Web server, and has forwarded **(via her personal agent)** the relevant information to the MCU of Nurse Mary. Nurse Mary examines patient Y. and updates the Web database by performing **on the spot data entry** through the user friendly interface of her MCU. And so the day goes on.*

Efficient and effective nursing care has been provided. All this is made possible by DITIS which provides a **distributed web based database with direct wireless connectivity and mobile agents linking all members of the virtual medical team**.

3.2 DITIS Modelling

Several scenarios were identified and analysed (see Figure 3) in order to implement the collaboration system.

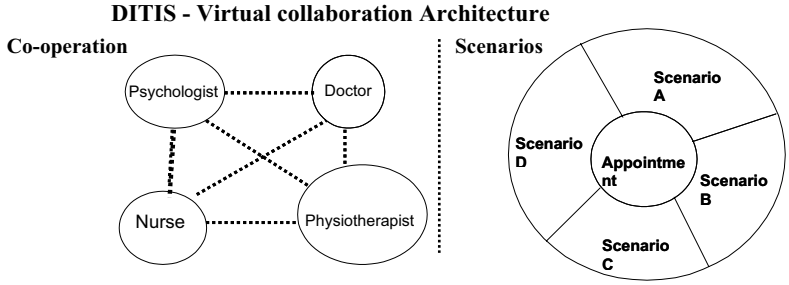

Figure 3. Scenarios for virtual-collaboration.

The UML (Unified Modeling Language) (Lipnack and Stamps, 1997; Kraut et al., 1998) 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
- Change of prescription in the community, Bloods taken in community, and Chemotherapy in the community
- 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 process we present a simplified UML class diagram (Figure 4) which identifies a collaborative healthcare team and possible interactions.

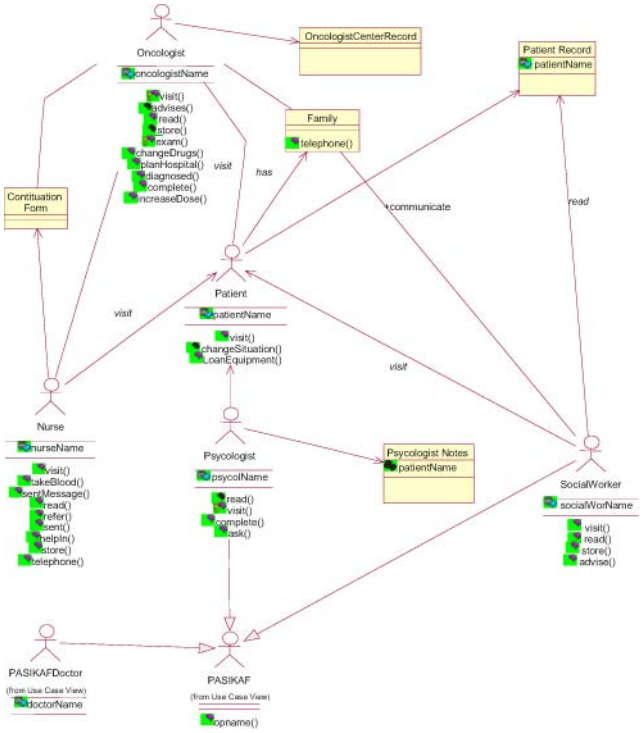

Figure 4. UML Class Diagram identifying a simple collaborative healthcare team and possible interactions.

Note that UML standardises a number of structural, behavioral, and model management diagrams.

3.3 Virtual team creation and management

In this part we discuss virtual teams and the dynamic virtual healthcare team creation for DITIS.

Even though interactivity is often presented as a key characteristic of a computer-mediated communication system, the emphasis is often on the computer-human interaction rather than on human-to-human computer-mediated interaction and trust[9]. The latter is particularly important 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. In particular, we focus on interactivity

among the key actors in medical virtual teams. 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. During the last few years is increasing volume of literature on virtual organisations and virtual teams (Panteli and Dibben, 2001; Jarvenpaa and Leidner, 1998; Lipnack and Stamps, 1997; Kraut et al., 1998; Lewicki and Buncker, 1996). 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.

The building of a virtual team around a patient will normally commence with the arrival of a referral form for a new patient. Once the primary home-care is assigned, the virtual team can be progressive and dynamically created, following the evolving needs. A simple illustrative UML sequence diagram of the virtual team creation is presented in Figure 5. This simplistic scenario can be expanded to handle various collaboration scenarios

The communication aspects can be illustrated with the following simplified scenario involving a home-care nurse using a wireless (laptop, MCU, or mobile phone) device to connect to the network of a mobile telecom operator and from there to the DITIS system server running at the premises of the home-care organization. The information could be in HTML or WML format, depending on the type of the connection device. A visual representation of the scenario can be illustrated in UML. The scenario while simple can be used to depict the flow of communication among the various partners. In a more complex scenario the mobile agent will communicate, in addition to the database, with other mobile agents that represent other members of the virtual medical team.

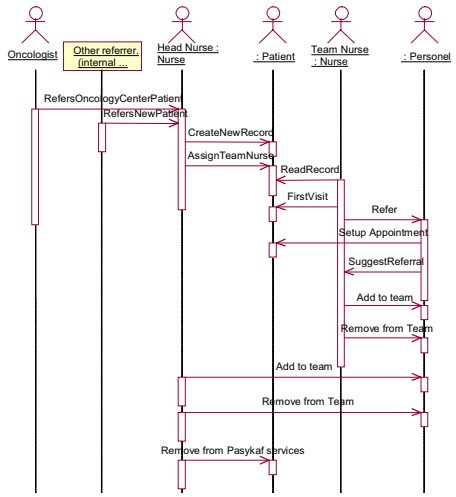

Figure 5. A simple UML sequence diagram for the virtual health-care team creation once a referral for a new patient is received.

4. SYSTEM DESIGN AND IMPLEMENTATION

DITIS is an Internet (web) based Group Collaboration system with fixed and GSM/GPRS mobile connectivity. It employs Mobile Agents, Web Databases with Java Database Connectivity, and web based database for storage and processing of information, including Electronic Medical Record (EMR) pertinent to cancer patients, in accordance with National and International standards (e.g. WHO ICD-10, ICD-O, HL7) (see reference ICD-10, Health Level Seven), software for collaborative work, intelligent interface for uniform access to the common database and the Group Collaboration software from both fixed and mobile computing units. DITIS also supports the integration of new technologies in Telemedicine and the home care service for cancer patients through the use of Mobile Computing Units (e.g. Tablet PC, Pocket PC 2002, Handheld PCs, Smart Phones, PDAs).

In the context of DITIS, a number of research and development issues have been addressed, including: Requirements analysis, Infrastructure development, Design of Electronic Medical Record, Design of collaborative platform, Design of wireless e-services, Design of collaborative software agents, Design and implementation of prototypes, Design of user interface, and Studies of system functionality.

The details of the system architecture are presented below, together with some aspects of the design criteria. These include:

Standards

The development of DITIS was based on the HL7, ICD-0 and ICD-10 standards, with a view toward an open Healthcare Information Infrastructure (Blobel, 2002). In the ISO telecommunication stack model, the 7th layer is the Application layer. HL7 stands for ´Health Level Seven´, which is an application-level protocol dedicated to health services. It is meant to be an international communication standard between all digital health services, much like a health-care middleware. It sets 120 standard classes distributed in 22 domains to allow different systems to have a common vocabulary. DITIS is and must 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 is migrating to ICD-10. Note that continuous monitoring of international standards is necessary. In particular, in the light of the high priority for electronic records, messaging (e-prescriptions), protecting personal information (PKI and health cards) (Rogers et al., 2002) 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.

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. At the time of development high power mobile devices such as Pocket PC 2002 or Tablet PC were not available. Therefore the team turned to existing mobile devices such as the Smart-Phones, Pocket PC, Palm PC and Handheld PC. As a result, DITIS interface was built as simple as possible to support such devices. WAP and HTML technologies were used to address the problems of platform independence and portability. If the device supported a WML or HTML browser then it was supported as a candidate host for the application. An example interface is shown in

Figure 6 for two commonly available mobile devices, which show a number of menu selections for the home-nurses.

Mobile agents and computational model

Mobile agents are a special category of agent that can migrate on any node of a heterogeneous wireless or wire-line network of computers, in order to perform errands that were assigned by the user of whom the agent is dedicated (Samaras et al., 2003; White, 1996; Harrison et al., 1994). The mobile agent can travel from a node to another using the resources on each node it visits. The advantages of using resources on each node that the mobile agent visits include a reduction of the network bandwidth, and use and distribution of processing.

Figure 6. Example collaborative system screen on mobile devices

A simple scenario illustrating the benefits of the migration of the mobile agent is the following:

The application initiates a complex query on a Database server which resides on a different network. The networks are connected using a slow, unreliable, Internet link.

According to the mobile agent paradigm, an agent can move to the node that the Database Server resides, perform the query, filter the results according to the application server preferences and then forward them to the application, which may initiate further queries to the database. Thus, for network reduction concerns, it is cheaper to transport a simple agent on the server that the database resides than retrieve the entire results of a complex query, especially if the device that launches the application is a less powerful device, as for example a Pocket PC or a Smart-Phone. Pocket devices, as mentioned above, lack bandwidth, memory resources and in many cases persistence in connection. These problems led the development team to adopt the use of persistent mobile agents. Each user is assigned explicitly one mobile agent who is personalized to suit his needs, and ensure his/her continuous presence as a member of the virtual team (see Figure 7). To illustrate the personalisation we present the following example for accessing a list of drugs. As the database complies with certain standards such as ICD-10 and HL7, a vast list of drugs is represented covering every medical situation.

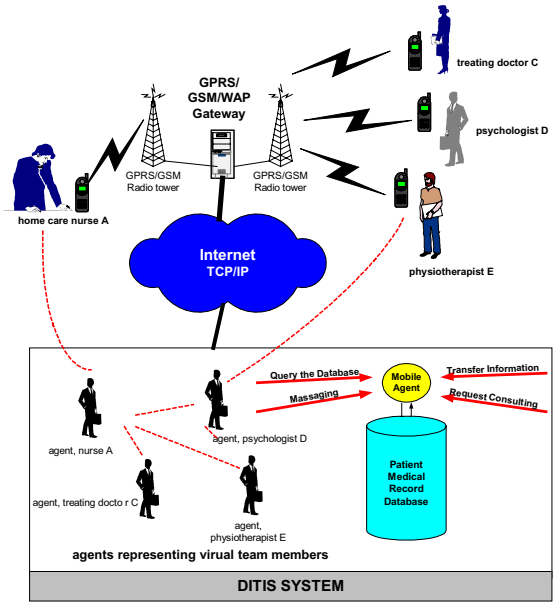

Figure 7. The Client/Agent/Server application model used in DITIS, showing every user represented by a mobile agent.

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 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. These features of mobile agents are currently being investigated (Samaras et al., 2003) and planned for implementation. 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 intelligent 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.

Communication model

Since the team cannot be physically present at the point-of-care at all times, the system creates a virtual team based on communication network solution. The philosophy adopted for modeling the networked solution incorporates the paradigm shift in computing toward network centric, based on the observations that:

1. The Internet offers global connectivity, and the World Wide Web offers access to distributed information (Berners-Lee et al., 1994). The system employs this capability in conjunction with today's wireless connectivity (Samaras and Pitoura, 1998) for the realization of the virtual "always" present medical team. The Internet provides the fixed network infrastructure while the various wireless networks (namely GSM/GPRS) the mobile/nomadic network. These two technologies are enhanced efficiently, intelligently, cooperatively and in a light portable manner (Samaras and Pitsillides, 1997; Housel et al., 1999). The system takes advantage of the evolution of information and communication technologies, and emerging protocols and standards.
2. The fixed network hosts servers containing the data of the patients. Around it an application layer is built which handles cooperation and system intelligence. The virtual team is equipped with small, portable and light handheld PCs or devices (MCU's) that are capable of wireless connectivity. Networked handheld PCs or MCUs are able to seamlessly synchronize, communicate and exchange information with servers. They offer standard communication support, enabling access to the Internet for email and Web browsing. Emerging protocols and standards at that time were investigated, as for example the Wireless Application Protocol, WAP (see reference Wireless Application Protocol).
3. Mobility and Tele-presence come however, with certain cost. This cost is the limitations of wireless link; expensive, low bandwidth, high latency and low reliability (e.g pockets of poor mobile network coverage). The cumulative effect of these limitations can be frequent disconnection and weak connectivity. The use of mobile agents minimises this problem. In general, mobile agents offer autonomy and asynchronous connectivity and can be easily enhanced with intelligence.

Implementation technologies

The current technical architecture of DITIS is shown in Figure 8. The design and development of DITIS, is based on commonly available technology, Internet and GSM/ GPRS connectivity, and includes and integrates (Figure 9).

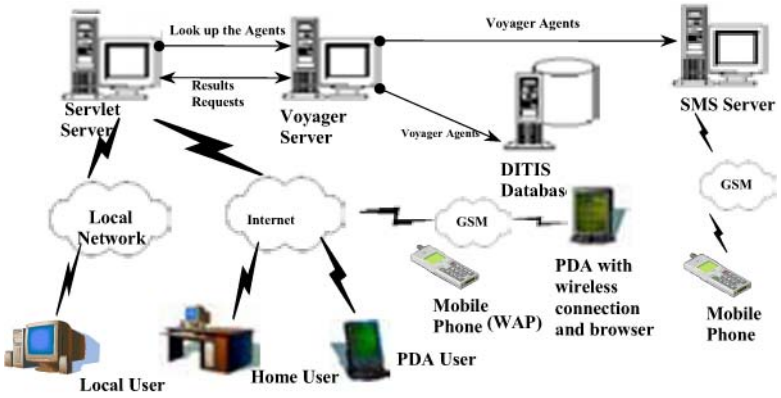

Figure 8. Schematic of DITIS system infrastructure

- Mobile Agents (White, 1996; Harrison et al., 1994) running on the Voyager platform (see reference ObjectSpace Voyager), for the implementation of flexible communication infrastructure (Pitoura and Samaras; 1998) for the support of mobile users.
- Relational Database with Java Database Connectivity (JDBC) (Anuff, 1996; Jepson, 1997; Bradley et al., 1997; Papastavrou et al., 1999) for information storage and processing of Electronic Medical Records and Agents.
- Tele-cooperation system for sharing of information, team communication, coordination of team activities**.**
- Adaptive intelligent interface (Chess et al., Oct 1993; Beyer and Holtzblatt, 1998) for database access from a variety of access units, such as MCUs with GSM/GPRS Internet connectivity, and Fixed units with Internet Access supporting Tele-cooperation.
- GSM Short Message Service (SMS) to enable push and pull of data and alerts, for example, whenever an agent updates information that affects the virtual medical team. MMS the emerging messaging system is under review.

5. EXPERIENCE, EVALUATION AND FUTURE DIRECTIONS

DITIS, supports the activities of PASYKAF (Cypriot Association of Cancer Patients and Friends), who run a national home-based healthcare service for cancer patients living in the community. It is currently installed in all Cyprus counties with the collaboration system currently operating fully in Larnaca (due to the limited availability of MCUs).

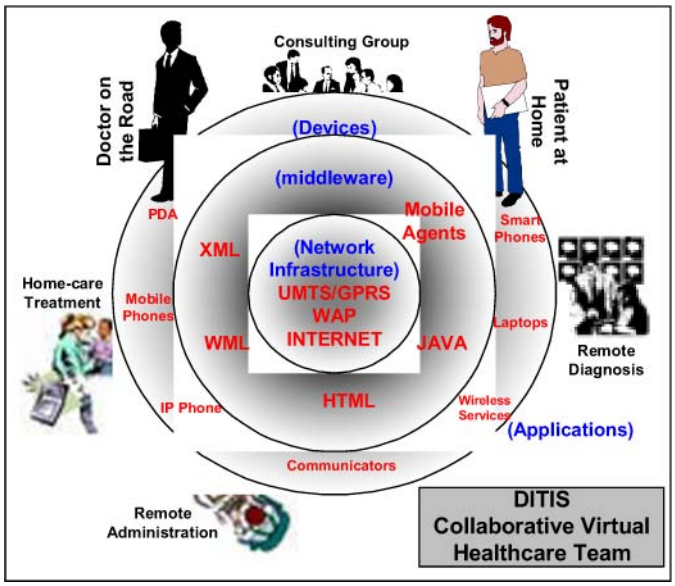

Figure 9. Overview of technologies adopted by DITIS system

Clinical objectives:

The Clinical Objectives addressed include:

- The presence of (Virtual) Collaborative Medical Team by patient at any given time, irrespective of locality, or cross country movement. Continuity of care is supported.
- Improved communication within (virtual) 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 away from patient's home, as well as duration of stay, and reduces burden not only on patient but also his relatives. It further reduces cost of treatment by a reduction in transport costs and time saved by his/hers working relatives. This capability also makes better use of the scarce and expensive medical professionals and scarce hospital beds, irrespective of geographic or organisational barriers.
- Improved and secure, timely access to patient information, in accordance with their authorisation levels, through unified information space centred around patient. As an added benefit, patient need not provide the same history to multiple professionals.
- 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** in Cyprus, thereby achieving better quality of life, in the warmth of their own home.

Technological objectives:
In addition to the clinical objectives some technological objectives were also met.

- As all the technologies are Internet, GSM/GPRS, and JAVA based there is platform independence. The components collaborate seamlessly to implement the system. The DITIS architecture can be adapted also for other systems, such as a cardiac patients system, insurance agents and any type of collaborative environment requiring only minor adjustments on the customized database and the cooperative scenarios.
- DITIS has developed novelty in the integration of new technologies, in home-care, and the support of home healthcare service through the use of Mobile Computing Units (e.g. Handheld PCs, Smart-Phones).

Efficient and effective nursing care has been supported by DITIS, which provides a centralised web, **based database with direct wireless connectivity linking all members of the virtual medical team**.

Identified difficulties:
Several difficulties, some non-technical, were also reported during the development and deployment phase, including:

- Long delays – often beyond partner's control, research funding limitations, and research associates high initial turnover caused some frustration and mistrust.
- Mismatch between users high expectations and inability of technical team to enlighten users about the complexity and time it would take for development.
- Initial health-care professional's phobia of technology.
- Underestimation of the initial workload to initially populate database, and generally to switch to a new system, which was still being developed.
- Current technology limitations (e.g. WAP over GSM). The migration to new technologies (GPRS and ADSL) is resolving many of the original technical problems i.e. service is always on and bandwidth is much higher.

The Research Program DITIS was successful in attaining the initial goals promised.

Some of the new goals and open issues include:

- The improvement of the secure transaction, process and data archiving with the users able to access only the levels that they are authorized, in a dependable, secure, legal, and trustworthy way.
- Improve TRUST, not only between the (virtual) team members, but also between the team members and the technology.
- Improving robustness of system (to commercial levels suitable for application), whilst ensuring that the open design of DITIS is interoperable and compatible with other European systems, for data exchange.
- The expansion of the system, to be used from all healthcare providers that work on cancer, including the connection with the cancer archive (Cancer Registry).
- Assess fully the national and European legal framework with e-health records, as well as prescription.
- Study on spot entry, as e.g. whether in front of patient data entry is acceptable.
- Minimise system management costs.
- Investigate viability of mobile agent paradigm and also of intelligent mobile agents and intelligent interfaces, able to identify the implications of triggering events and send the right information to the members of the virtual team, or new members.
- Study 3G (UMTS) and new wireless handheld devices and their effect on the computing and networking model selected for DITIS.
- Adapt, customize and validate a sound clinical model and a service delivery model which is financially viable, secure, and legally acceptable, at a Pan-European basis.
- The expansion of the collaborative system for usage in other fields (e.g. cardiac home-care, insurance sales, etc…) and its eventual commercialisation.
- Disseminate/promote at government and national policy-making level.

6. CONCLUSIONS

DITIS uses a number of state of the art technologies which are seamlessly put together, such as collaboration and personalization via mobile agents, access to medical data from anywhere and any time via a variety of mobile devices and a variety of protocols (i.e., WAP, HTML) and continuous connectivity via new communication technologies such as GPRS and soon UMTS. The mobile access technologies are JAVA based therefore there is access device independence.

DITIS, supports home-care by offering wireless health care services for chronic illnesses with emphasis on prevention, assessment and diagnosis. The main service is the dynamic creation, management and co-ordination of virtual collaborative healthcare teams for the continuous treatment of patient 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 patient on a need based and

timely fashion, under the direction of the treating specialist, without 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 a reduction of number of visits to health professionals away from patient's home, as well as shorter duration of stay in case of hospitalisation. This decreases burden not only on patient but also his relatives. It further reduces cost of treatment by a reduction in transport costs and time saved by his/hers working relatives. This capability also makes better use of scarce and expensive medical professionals and scarce hospital beds, irrespective of geographic or organisational barriers. The system provides secure and improved, timely, access to patient information, in accordance with each user's authorisation level, through a unified information space centred around the patient. Thus, as an added benefit, patient does not have to provide the same history to multiple professionals. With improved and flexible collection of statistical data further audit and research within the home care setting is made possible, which improves evaluation, and better cost effectiveness through improved communications and better planning of services. Thus improved health practices (shift toward **evidence-based**) and reduction of bureaucratic overhead is offered. Furthermore, system 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).

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 patient, 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.

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