

HOME TELECARE: SYSTEM ARCHITECTURE TO SUPPORT CHRONIC DISEASE MANAGEMENT

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Abstract – A system architecture to support information transfer between hospital, general practitioner and the home is described in the context of a Home Telecare System (HTS). The HTS facilitates the acquisition, review, analysis and archiving of a longitudinal clinical record to support chronic disease management. The system allows the clinician to schedule for his/her patient the regular recording of clinical measurements (weight, temperature, lung function, blood pressure, single lead electro-cardiogram and ambulation). The patient has in their home a PC with a serially-connected clinical workstation. In addition, the HTS allows the scheduling of questionnaires, medication reminders and the monitoring of an emergency alarm button.

The clinician's interface uses standard Web browser technology to connect to a Web and database server. Use cases indicate that this configuration is not suitable for the patient interface in the home. In this case, a separate stand-alone application with a local subset of the database that periodically communicates with a central server is more appropriate to support a highly usable interface that can be easily customised and maintained.

Keywords – Home Telecare, clinical measurements, Web, communications, chronic disease

I. INTRODUCTION

This paper discusses the development of an architecture to support data communication for home telecare. The methodology is described in context of the Home Telecare System (HTS), a system designed to support an emerging model of care in which chronic disease is managed by monitoring patient health status at home [1]. The rationale being that better monitoring leads to tighter control and management of the disease [2].

II. SYSTEM CONFIGURATION

The HTS facilitates the acquisition, review, analysis and archiving of a longitudinal clinical record to support chronic disease management. It provides the patient with a summary of measurements taken within the home, along with additional information to aid in the management of their wellness. Clinicians have access to the patient record

including all measurements taken. In addition, the clinician may schedule the acquisition of various clinical measurements, health questionnaires and configure a medication schedule.

Information acquired from the home to assess patient health status typically comprises: -

- **Physiological measurements:** The system facilitates recording of blood pressure, a single lead electrocardiogram, lung function, weight, temperature and ambulation (using a wireless triaxial accelerometer).
- **Self-assessed patient health status:** Clinical symptoms and functional health status are assessed by answers to electronic questionnaires.
- **Health Diary:** An electronic health diary is available for free-format entries, including recording of visits by carers (community nurses, general practitioners, etc.).
- **Alarms:** The wireless triaxial accelerometer serves a dual function by integrating an emergency alarm button into the belt worn ambulatory device. On activation the system automatically dials a monitoring centre, sends an identification message (along with a short text message to a second mobile phone number) and establishes a voice communications channel with the patient.

As well as data acquisition and monitoring, patients are provided with on-line health education leaflets and links to web sites pertaining to their disease.

Patient health status is collated into a longitudinal record that is updated at regular intervals and made available to health professionals. The clinician is able to view and edit patient details, track health status, change medications and health information provided to the patient, and manage clinical data acquisition from the home.

A 'Measurements Scheduler' manages the protocol for data collection. The doctor can select any combination of physiological parameters they would like to monitor from the available measurements. The frequency at which the measurements are acquired can also be selected. Similarly, the doctor can customise delivery of health status questionnaires, online health education material and web sites for each patient. The Measurements Scheduler alerts the patient via the computer interface to perform a particular measurement or answer a questionnaire. In this way the system allows the doctor to tailor the collection of measurements, and the delivery of questionnaires to their requirements. A 'Medications Reminder' provides timely alerts via the computer interface. This is based on the

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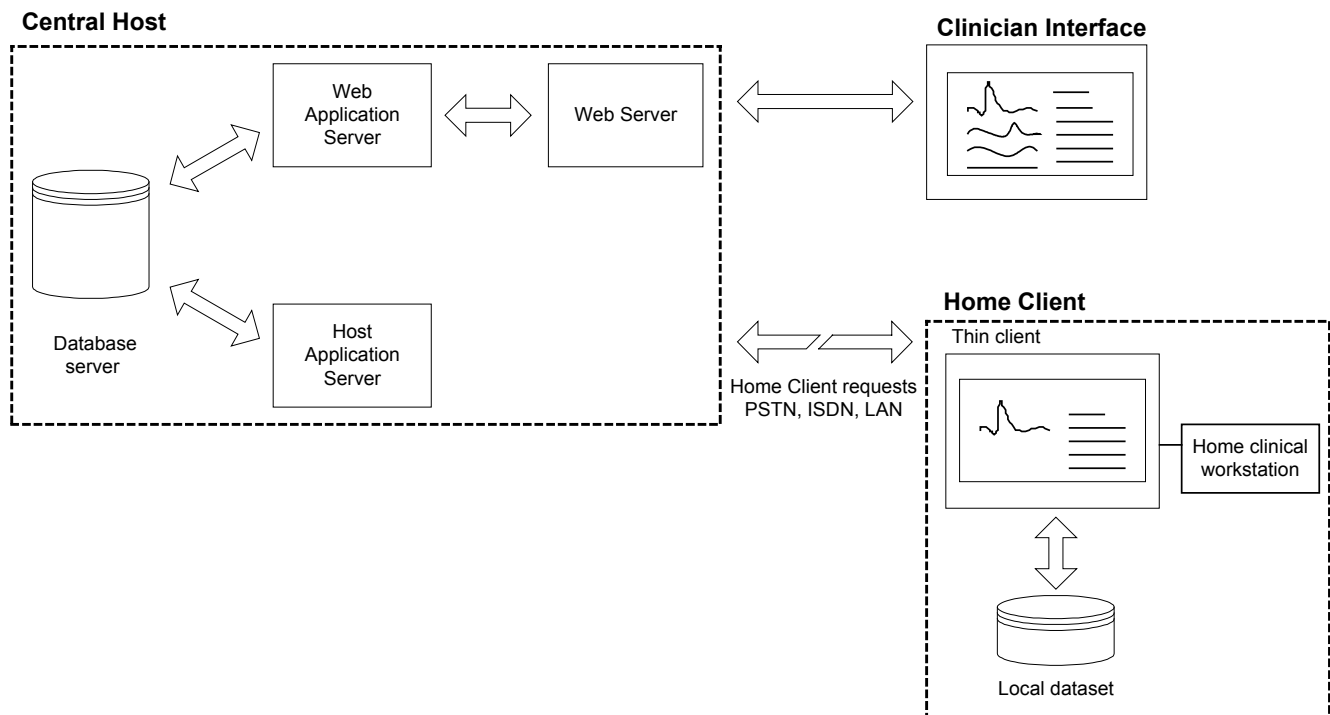


Figure 1: Architecture of the Home Telecare System

patient's daily routine and aids in compliance with medications therapy. Patients also have access to their own clinical record.

III. IMPLEMENTATION

The HTS is a PC-based client-server system that uses Internet communications. An overall architecture of the system is shown in figure 1. It has been implemented as two main sub-systems; the Home Client and the Clinician Interface; which integrate to collate and provide access to patient health status information.

Data collection is managed by the Home Client, a Windows application that is the patient interface to the HTS. Physiological measurements are collected via a data acquisition device interfaced to the RS232 serial port. The Home Client manages acquisition of clinical measurements, the delivery of questionnaires, medication reminders and online health education material via the Measurements Scheduler. This program also handles data communication between the Home Client and remote server.

Data is transferred to the remote server; which acts as a centralised repository for patient information; via the Internet using TCP/IP. Depending on the availability of a network connection, data is either sent directly to the server or stored locally until a network connection is available. The frequency at which data is synchronised with the server can be set according to the requirements of the doctor. A server-side application manages the collection and storage of the patient data. The database for the HTS has been implemented in MS-SQL server and contains patient details, clinical

measurements, and also all the supporting data including questionnaires and scheduling information, that is required to manage a patient's program. Doctors access the system from the Clinicians Interface which is a standard Web application.

Security of data on the Internet is a major issue, hence special features have been included for the safe handling of patient details and clinical data. Confidentiality of medical records is maintained by implementing separate access levels. An authentication system is used to restrict access to patient records. For added security, this data can be encrypted as it is stored and decrypted when it is retrieved. A secure communications channel can also be used as Internet traffic in its basic form is not encrypted.

IV. DEVELOPMENT STAGES

The HTS is a third generation development, that uses the Internet as a communications medium, and seamlessly facilitates the acquisition, review, analysis and archiving of a longitudinal clinical record to support management of chronic disease. The concept is based on providing network connectivity to low cost, easy to use, PC-based clinical measurement devices that can be used in a home setting, and the resulting clinical record is made available to health professionals.

The initial development was based on longitudinal monitoring of ECG, the system was entirely web-based, and a desktop database was used to archive patient records [3]. The patient interface utilised ActiveX technologies and FTP for web-enabling a PC-based ECG acquisition device and access to the patient records was also from a browser interface. An

intrinsic problem with this methodology, particularly for the home user, was the requirement of a network connection for both the viewing and acquisition of clinical measurements. Use of a Web interface made it necessary to have a valid connection for reviewing records and for database updates during the acquisition of clinical measurements.

Although the system is designed for longitudinal monitoring, where a store and forward method is much more suitable than real-time updates, the frequency of synchronisation is primarily determined by the monitoring protocol for a given disease condition. Hence from a design point of view it was more apt to include an offline acquisition facility with the ability to vary synchronisation according to requirements of the user.

The patient interface was then modified to use database replication for an offline review and acquisition facility and ActiveX was used to manage synchronization with the server at regular intervals [4, 5]. Replication of the database also allows the utilization of flexible, low-cost, off-peak communication links. Periodic synchronization of the database with the server provides sufficient updates without the expense and vulnerability of a connection every time the patient reviews an existing measurement or acquires a new measurement. In both these designs ActiveX controls were used to coordinate the viewing and acquisition of clinical measurements using a client side reviewing and recording program as a "Helper Application" that is called as a secondary window outside the browser. Although ActiveX provides the functionality to present the patient interface from a browser environment it is not a very efficient solution. Moreover HTML has a limited interface capability to support additional features in the patient interface.

The HTS was designed to extend the features offered to the home user beyond the viewing and acquisition of clinical measurements to include a Measurements Scheduler, Questionnaire Delivery System, Medication Reminders and online health education material. Moreover the data acquisition is not limited to a single physiological measurement but can possibly include up to a maximum of five measurements. Although ActiveX controls could be successfully used to extend the functionality of the browser environment, a stand-alone Windows application that can be customised to the requirements of the user is more suitable. The Home Client was thus designed to manage the recording and reviewing of clinical measurements from a local subset of the database, handle data communication to the remote server and provide functionality to support any additional services offered to the home user. The patient database was transferred to a database server, and an application server is used to manage the TCP/IP communication with the Home Client. A web application with connectivity to the patient database is used for doctors to access the clinical records.

V. DESIGN ISSUES

1) *Modular architecture*

The HTS provides a generic framework to support management of chronic disease. The system's modular architecture allows personal customisation of the Home Client for each patient to suit any disease specific monitoring protocol. The doctor is able to select any combination of physiological measurements, questionnaires, health education material, and schedule measurement collection and medication reminders according to a patient's daily regime. Although physiological measurements are restricted to blood pressure, heart rate, lung function, weight and temperature, the questionnaire system can deliver any disease specific or validated health status instrument via the computer interface. Similarly any electronic health education material and external web sites can be registered with the system. The system has been developed in a generic manner. Data can be collected using a variety of hardware interface methods including data acquisition cards inserted into the PC bus, hardwired interfaces (RS232, USB etc) or wireless connections to the PC.

2) *User interface*

The Home Client has a very simple easy to use interface that is suitable for users with no prior computer experience. The Windows interface allows for customisation to user requirements. The system is built in such a way as to ease pressure on the patients. The Measurement Scheduler and Medication Reminder provide assistance in complying with the monitoring protocol and medication therapy. The system operates in an offline mode with local data storage capability. Synchronisation with the server at regular time intervals is automated.

3) *Data synchronisation and network connectivity*

The system is highly automated, with minimal user intervention required; the synchronisation process is completely transparent to the user. Although the system has been built to support longitudinal monitoring and adopts a store and forward strategy to update the patient database, the Home Client can be set to synchronise on any event such as recording a new measurement or at regular timed intervals as specified by the doctor. The Home Client uses a dial-up connection and synchronises by pushing data onto the server and pulling any new data from the server. Any changes to the patients' measurement protocol, medications, and health information can only be updated when the Home Client makes a connection to the server. Thus in addition to updating the longitudinal clinical record on the server, the synchronisation also updates changes made by the doctor to the patient's monitoring protocol, the most critical of which is the medications reminder, which must be updated almost immediately. A server initiated push; in which the Home Client would have to permit connection by another computer; is required to reflect any changes in real-time. This method is

not suitable as it could threaten security of data on the Home Client. A user-initiated synchronisation is a possible solution to update medications before the next scheduled connection from the Home Client when using a dial-up connection.

VI. CONCLUSIONS AND FUTURE DEVELOPMENTS

This article has described the development of the HTS with particular attention to the design issues when communicating with a remote server via the Internet, the features required to support a home monitoring protocol have also been discussed.

The HTS is an integrated approach to support the management of chronic disease through home monitoring and patient self-management. Health status is monitored by means of physiological measurements, clinical symptoms, self-assessed functional health and a health diary. In addition to health education the system has facilities for supporting a customised home monitoring protocol, and provision of medications reminders. It has a simple easy to use interface, it is highly automated with minimal user intervention required, and communication with the remote server is completely transparent to the user. Doctors access patient records through a browser interface.

The system in its present configuration facilitates data collection from the home and makes it available to the doctor. It will be evaluated in a field trial to assess user acceptance of the technology. Doctors have access to the basic clinical parameters tracked over time. The evaluation will also be used to further refine data collection and the presentation of relevant parameters. The exact format and frequency of reporting will also be investigated. Once the information requirements, that is the data gathering protocol and presentation format have been established, features such as automated processing and reporting of patient health status will be included.

A web architecture is not suitable for the functionality required by the client application in a home telecare system [6]. Features such as a medications reminder and a measurements scheduler that require local intelligence cannot be supported by a web interface. A stand-alone application running on a home PC provides the required device interfaces to support physiological monitoring and more importantly, enables the definition a simpler user interface than a web browser. A local subset of the database with periodic synchronisation allows for flexibility in the communications link with the central host and provides patients with access to their data. Thus a configuration consisting of a separate stand alone application with a local subset of the database that periodically communicates with a central server is more appropriate to support a highly usable interface that can be easily customised and maintained.

The web interface is sufficient for present requirements of doctors where they only need to have read access to the clinical data, however Java or ActiveX tools will be required to support any complex data processing that may be provided

in future versions of the system. Smaller easily downloaded objects and platform independence which will ensure ubiquitous and secure access to the Clinician Interface, make Java Applets a more viable option than ActiveX Controls.

Although the potential of technological advancements to improve the management of chronic disease by monitoring patients at home is now widely recognised, the feasibility of adopting new models into mainstream health delivery systems needs to be studied through carefully designed trials for a given chronic disease [7]. The technology described is basically an enabler for this process and it is the ability of a system to cater for user requirements that will ultimately determine its success or failure. A modular architecture and ability to customise the Home Client for different monitoring protocols make the Home Telecare System an ideal research tool for investigation of the role of home monitoring in management of chronic disease.

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