
Mobile communications for using in telemedicine

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Abstract: Telemedicine the use of telecommunication and information technologies in order to provide clinical health care at a distance helps eliminate distance barriers and can improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations. Although there were distant precursors to telemedicine, it is essentially a product of 20th century telecommunication and information technologies. These technologies permit communications between patient and medical staff with both convenience and fidelity, as well as the transmission of medical, imaging and health informatics data from one site to another. Early forms of telemedicine achieved with telephone and radio have been supplemented with video telephony, advanced diagnostic methods supported by distributed client/server applications, and additionally with telemedical devices to support in-home care. There is a growing trend in the health domain to incorporate Smartphone's and other wireless technologies to provide more efficient, cost effective, and higher quality healthcare. With newer more sophisticated mobile devices for example, Smart phones this is an escalating practice. To date the use of mobile phone technology in the healthcare domain (m-Health) has been limited to uses such as disseminating information. However, m-Health is beginning to include software and data applications based on mobile devices and technologies. This movement is largely due to the advent of newer technologies associated with Smart phones. Some Smart phones can now be considered to be intelligent sensors with sensing capabilities such as GPS¹ location, proximity and accelerometers. This paper examines the use of such technology in providing seamless mobile communications for telemedicine.

Keywords: M-health, Telemedicine, Smartphone, Mobile Wireless Sensor

1. Introduction

As technology evolves everyday devices like mobile phones and in particular Smart phones develop more novel and innovative uses in the area of m-Health [1]. This trend has experienced a movement due to the advent of newer technologies largely associated with Smart phones [2]. Some Smart phones can now be considered to be intelligent sensors with sensing capabilities such as GPS¹ location, proximity and accelerometers [3].

Along with the availability of "super" powered processors [4] these Smart phones also possess the ability to aggregate and utilize the sensed data in a novel manner. A crucial area that m-Health must address is the optimization of data transfer over disparate networks. In

this paper the authors describe how the FP7 PERIMETER project [5] makes use of such a mobile wireless sensor network (MWSN) [6] to ensure sensitive health related information can be transferred in a seamless and timely fashion across different selected high quality network connections. This paper is broken down into seven sections. This introduction serves as the first. Section two the architecture section, examines the underlying architectural components developed and deployed. The third section details the m-Health Mobile Wireless Sensor Network concept. Section four, examines the technological choices made with regard to algorithms to support the system. The fifth section focuses on describing PERIMETER's Health use case to validate the system. The sixth and concluding section also examines the Future Work to be carried out.

¹ Global Positioning System

2. Perimeter Middleware Architecture

The PERIMETER middleware provides a new paradigm for seamless mobility across network connections. This model considers the user, and their needs, as being of utmost importance when using a service or application on their mobile device, and provides them with the network connection that best meets with their specific needs. If their current network does not meet their expectations, they are seamlessly transferred to another, without any interruption to their service or manual interaction from their side. The m-Health MWSN system architecture is established around the PERIMETER middleware architecture which is based on the traditional layered architecture approach. There are two types of PERIMETER hardware nodes, the PERIMETER Terminal which is a mobile handheld device with certain resource restrictions for example, storage space and a Support Node which has no resource restrictions for example, a server or laptop.

The architecture depicted permits users to experience seamless connectivity while on the move. The PERIMETER components include;

1. The Application Layer consisting of the Graphical User Interface (GUI) and Application Manager which provides the user with an intuitive interface to the entire PERIMETER system.
2. The Context Inference Engine (CIE), further detailed in Section IV, collects raw source data, such as geographical location and network information, and infers high level context information from this.
3. The Data Network Processor (DNP) processes information relevant for making a decision about how satisfactory the current connection is for the user based on their context (from the CIE) and other contributing factors, as will be discussed Section IV.
4. The Decision Maker component decides whether a network switch is required based on information from the DNP and CIE. It also decides which network should be connected to.
5. The Privacy Preserving Authentication, Authorization, Accounting and Reputation (PPA3R) provides identity management, anonymization and pseudonimization
6. The Trust Engine (TE) performs computations on data processed in the PERIMETER system, assigning trust and reputation values as appropriate.
7. Vertical Handover Abstraction Layer (VHOAL) and Measurements are charged with the task of seamless switching of networks.
8. The Storage Layer takes care of storing and retrieving local and historical information using a peer-to-peer approach.

The interaction of these components provides a comprehensive architecture upon which the premise of the PERIMETER mobile wireless sensor network is built. The next sections describe the functionalities of this system.

3. M-health Mobile Wireless Sensor Network

The promise of an omnipresent, seamless and reliable connection requires that the same set of services should be available at home, in the office or on the move, on a wide range of terminals including Smart phones, PDAs² and laptops. As the number of wireless access networks and technologies that users can connect to grow, their effective management becomes increasingly important. From the user perspective, this includes the need for protocols and algorithms that make the best use of multiple operators and multiple accesses, to attain consistent connections of adequate quality at the lowest cost. Of course this must be achieved without compromising privacy, quality or security.

The PERIMETER MWSN system currently runs on platforms with the Google Android operating system [7] installed, users run the middleware on mobile devices such as the Nexus one Smartphone [4]. Using data sensed from the Smartphone regarding geographical location, available networks and preceding user's feedback, the PERIMETER middleware uses complex aggregation algorithms described in section IV to quantify context and the quality of the users' mobile session on a particular network. Several mobile devices running PERIMETER send and receive information and in parallel the system executes algorithms on the gathered data. Two factors, Quality of Service (QoS) and Quality of Experience (QoE) are extremely important for PERIMETER to attain its objective of seamless mobility across network connections.

QoS is a measurable technical concept which can be understood in terms of networks and networks metrics [8]. It is a quantification of performance from the network perspective, including factors such as congestion, packet loss, jitter and delay peaks. QoE, on the other hand, is the overall performance of a system from the point of view of the users. QoE relates to the end-to-end performance of a service and how this service meets with the expectations of its users [9]. From the point of view of the user, QoE is the only measure that actually counts to the user of a service.

QoE can be regarded as a concept which comprises all the elements of a user's perception of a network and its performance. In reality, though QoS is well defined [10], it is only a subset of what comprises QoE for the user. A major cause of a user's dissatisfaction with a service is due to issues related to QoE. Service providers must be proactive, and devise strategies to model, measure and ultimately improve QoE for their users.

To provide good QoE, the objectives of QoS have to be met and linked to the measure of QoE. However, other factors need to be taken into account to model and ultimately measure the QoE of a service.

QoE is extremely important where a service or application must attain certain standards such as those used by medical personnel, for the optimal transfer and integrity

² Personal Digital Assistants

of medical records over disparate Networks.

The next section details how PERIMETER addresses the challenging QoE thematic research and the algorithms used by PERIMETER's framework to determine QoE

4. Algorithm Calculations

This section describes PERIMETER's QoE framework and measurement of QoE.

PERIMETER determines QoE on a per service, or application, basis. This is due to the fact that different services have different QoS factors associated with them, and have different user perceptions of quality. Thus, PERIMETER defines QoE per Classes of Services (COS) [11].

QoS factors are measured in PERIMETER using the Measurements component. This component provides quantifiable QoS information (such as packet-loss and one-way delay-jitter, which have a significant impact on QoE [12]) to the DNP component, responsible for QoE determination.

In order to quantify the subjective factors related to QoE, PERIMETER uses the Absolute Category Rating (ACR) system [13]. With ACR, different scores, ranging from 1-5 are used as follows: Excellent = 5; Good = 4; Fair = 3; Poor = 2; Bad = 1. These scores are used to measure less quantifiable aspects of QoE, and by assigning different weighting factors to these aspects, a Mean Opinion Score (MOS) can be computed.

The less quantifiable aspects of QoE for PERIMETER include the following:

- **User Preferences:** The PERIMETER GUI allows the user to specify preferences for different applications on their mobile device. These preferences include: Cost, Battery Life, Security and Quality Level. PERIMETER users have the option to utilize a default preference set if they prefer, which assigns the same (configurable) preferences to all the users' applications.
- **User Feedback:** The PERIMETER user is enabled to provide feedback to the system as to what they perceive their quality to be. The Rate Experience screen in the GUI, allows the user to rate their experience following the ACR scoring structure. To make the GUI as intuitive as possible, the user is presented with a smiley metaphor for each ACR score.
- **Feedback from other PERIMETER users:** The past experiences and QoE calculations of other PERIMETER users on various network connections is also factored into the calculation of the QoE on PERIMETER. The IQX hypothesis model [14] is used to correlate the QoS factors with the MOS value in PERIMETER. This model, shown in (1), defines QoE as a MOS metric and Plus as the QoS. The parameters α , β and γ are equation parameters and are unique to each user. The QoE estimation algorithm is a training algorithm. Therefore, parameters are tuned by

extensive testing (usability and Living Labs [15] as the system matures and more feedback is gathered from the current, and other, PERIMETER users.

$$\frac{\partial QoE}{\partial p_{ios}} = -\beta \cdot (QoE - \gamma) \Rightarrow QoE = \alpha \cdot e^{-\beta_{ios}} + \gamma$$

The computation of the QoEDs is triggered by a number of events in PERIMETER including the degradation of the current network, feedback from the user, changes to the running application's state and the discovery of a network that better meets the user's preferences and ultimately QoE.

The QoEDs are passed to the Decision Maker (DM) in PERIMETER. The DM component decides whether a network switch is required. The DM receives contextual information from the CIE to aid this decision.

The CIE gathers raw source data, using sensors on the user's mobile device. Context is any information that can be used to characterize the situation of an entity [16], where an entity is any person, place, or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves. The CIE gathers information related to the user's geographical information, current and accessible network connections and application in use. Context inference is applied to the gathered data, and concluding useful intelligent information is derived from this [17]. For example, inference and formulae are applied to the geographical information to determine the current location of the user, their speed of movement, their localization and expected direction of movement.

The DM uses the QoED and inferred context information to analyze if a network switch should be initiated. If a decision is made to switch, the VHOAL component provides fast inter technology handover while minimally affecting the performance of the application under use.

The next section provides an overview of the way in which the technology of PERIMETER's QoE framework is applied to an m-Health situation.

5. Perimeters Health Scenario

To demonstrate the operational aspects of the PERIMETER mobile wireless sensor network, it was agreed within the project to adopt a user centric scenario based approach. The following health related scenario, was defined and modified to convey the QoE and wireless mobile sensor network innovations arising from PERIMETER.

Sara is a nurse and she witnesses a man having a motorbike accident. Sara immediately calls 911 from her mobile device. Since the injured man is conscious, the emergency control centre gives the advice that a PERIMETER aware video conference between Sara's Smartphone and the emergency service will be established in order to get an initial diagnosis.

Sara receives a SMS from the hospital with a direct link

that allows her to establish a video conference call with the emergency team. PERIMETER uses the Smartphone's location based sensors to identify Sara's location and scans for connections which provide a secure and fast connection for the video call (Preferences already defined by Sara).

PERIMETER chooses to use an available WLAN hotspot close by that has good connection properties as reported by previous PERIMETER users. While the ambulance is on route to the hospital, high resolution X-ray images can be sent to the hospital, through the secure connection that has been established. When the ambulance is nearing the hospital, PERIMETER discovers a Wi-Fi signal coming from the hospital Wi-Fi base station. PERIMETER performs a handover for the video conference system to the Hospital Wi-Fi connection with no interruption to the video conference.

As described above in the health scenario PERIMETER devises multi-operator multi-access end-to-end solutions that are transparent to the user and easy to manage. This is ensured by extensive usability testing and code refactoring aspect of the project where end users were heavily involved in the layout and design of the PERIMETER GUI.

6. Future Work & Conclusion

The authors have demonstrated how the innovative aspects of PERIMETER are applied to scenarios involving m-Health, telemedicine and in particular emergency situations such as traffic accidents to provide seamless mobile communications.

The PERIMETER project is entering Phase 2 of their development – in their iterative cyclic approach more Living Labs involvement is planned. This will see the maturation and tuning of the QoE algorithms as further testing is carried out. Scenarios such as the emergency one described in section V will be further investigated where users will have the ability to over-ride default preferences to ensure the highest quality of service in emergency situations is attained.

Another area of future work is the further exploitation of the information gathered through the MWSN and processed by the CIE in the determination of best emergency routes, with regard to the maximum connections, for ambulances will be examined.

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