Quality of Service consideration for the wireless telemedicine and e-health services

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Abstract—In this article we investigate the application of IEEE 802.11 wireless standard to QoS (Quality of Service) support within wireless e-health/telemedicine services. The stringent requirements and real-time nature of medical application introduce the need for QoS provisioning in wireless medical networks. The quick delivery of a patient's measurements is an extremely important as well as reliability in terms of data delivery in the emergency care. Another important issue for wireless e-health applications is the mobility support. An ambulance, which is moving through different e-health domains, supporting different e-health applications the connectivity between the monitoring applications with the medical data source may be assured by the different wireless technologies. An overview of the e-health technologies and wireless telemedicine systems are presented and some open research problems are identified. A survey on QoS provisioning in wireless e-health, handoff schemes for QoS support in wireless networks, the scheme of priority for telemedicine/e-health services and techniques/methods for IEEE 802.11 to guarantee QoS is also provided. The simple e-health scenario is when the user has the possibility to have 'communication anywhere' within the mobile network. The technology which is in use has to provide services that would reduce patient journeys, hospital visits and hospital admissions, and would save the time of healthcare professionals, as well as would support individuals living at home and improve the quality or effectiveness of the care or treatment that is delivered. The basic requirements for the different types of application are presented spatially for the e-health/telemedicine services. To this end, we present emergency situation scenarios, designed as a possible e-health emergency scenario. Resource allocation for e-health application is inherited in many aspects including the offered services, traffic requirements, propagation's characteristics and network structure. Within medical networks [1] delay is a critical factor, since there are many cases in which a communication should be timely in order to save the life of critical patient. This paper presents architecture and novel scenarios for QoS provisioning in emergency telemedicine. Some performance evaluation results are obtained by simulations.

Keywords-component; Wireless healthcare information networks, QoS, architecture, modeling, performance evaluation, resource allocation, bandwidth control.

I. INTRODUCTION. TECHNOLOGIES AND E-HEALTH

Information technology (IT) plays an important role in e-health [2]. The medical sector is the most important area in which recent technological development in wireless networking has been applied. The use of wireless networks is very important for the information delivery in out-of-hospital incident because healthcare networks are expected to be able to operate at any time, allocating the available resources and ensuring QoS provisioning for the specific healthcare applications. By the use of such applications (medical databases, electronic health records, routing text/audio/video/photo/video medical information) medical services may be supported in underserved locations, such as rural health center, ambulances, ships, aeroplanes as well as home environments [3,4,5,6,7].

In [7] **D.D.Vargos** discuss wireless healthcare information systems in which he proposed several factors that should be taken into account for data delivery in wireless healthcare network:

- Availability;
- Confidentiality and privacy;
- Data delivery latency;
- Reliability, QoS Provision and Mobility Support.

The availability of resources is absolutely imperative in health networks, because the generated traffic may be crucial for the patients' health and life since. To this end, authentication mechanisms are needed in order to preserve the confidentiality and privacy of the patients' data (these mechanisms are beyond the scope of this paper). The quick delivery of a patient's measurements is an extremely important issue (especially in emergency situations) as well as reliability in terms of data delivery in the emergency care. Another important issue for wireless e-health applications is

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the mobility support. An ambulance, which is moving through different e-health domains (areas that include static or mobile type of nodes during the simulation), supporting different e-health applications the connectivity between the monitoring applications with the medical data source may be assured by the different wireless technologies [7].

II. QOS IN WIRELESS E-HEALTH

Mobile communication devices become more and more popular. Wireless Local Area Networks (WLAN/IEEE 802.11) are used in a lot of scenarios today as well as for easy communication between these devices and connection to the Internet. The number of WLANs in public facilities like official buildings and hospitals increases rapidly as well as the entire small private "home" WLANs. The increase in popularity of Wireless LANs led to considerations with respect to multimedia traffic over WLANs. The most sensitive case of multimedia traffic is the Internet telephony (Voice-over-IP) for a sufficient speech quality the mouth-to-ear delay must be kept small and should be released of jitter at the receiver [8].

Qualities of Service guarantees are important if the network capacity is insufficient. For real-time streaming multimedia applications (such as voice over IP and IP-TV) since these often require fixed bit rate and are delay sensitive, and in networks where the capacity is a limited resource (cellular data communications). QoS is the ability to provide a different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow (a required bit rate, delay, jitter, packet dropping probability and/or bit error rate) may be guaranteed

The model and evaluation of the traffic requirements for telemedicine networks was presented in [1]. **Martinez** et al. [9] proposed a methodology for the technical evaluation of QoS traffic requirements in healthcare services based on telemedicine, which includes the service description, considering both application requirements and network topologies, and the service evaluation, implemented by an automated tool. **Hu** et al. [26] have proposed a mobile sensor network infrastructure to support the third-generation telemedicine applications which uses an energy-efficient query resolution mechanism in large-scale mobile sensor networks and provides the guaranteed mobile QoS for arriving multimedia calls.

III. HANDOFF SCHEMES FOR QOS SUPPORT FOR WIRELESS NETWORKS

In cellular telecommunications, the term **handoff** refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another so it is the process of changing the channel (frequency, time slot, spreading code, or a combination of them) associated with the current connection, while a call is in progress [29]. Handoff is always implemented on the voice channel. The value of implementing handoffs is dependent on the size of the cell. Today the size of cells becomes smaller in order to increase capacity. Also people talk longer. The handoffs are very essential [11].

There are different types of handoff [11] in digital systems:

1) Hard handoff (break-before-make process and handoff between two frequencies.);

2) Soft handoff (make-before-break process). The process needs to secure two code channels during the handoff process;

3) Softer handoff. Handoff occurring between sectors only at the serving cell. It is a make-before break type using combined diversity of two code channels.

There are two decision-making parameters of handoff: (1) based on signal strength and (2) based on carrier-to-interference ratio [11].

The idea of handoff was introduced in order to achieve the uninterrupted communication of an ongoing call. The handoff process is one of the most complex functions in a cellular network since it ensures the continuity of connection and has a direct impact on the QoS perceived by users as well as for the mobility support (which is the important factor of the QoS provisioning in telemedicine/e-health services).

The handoff process is managed by the so-called handoff schemes. Therefore, the level of QoS of wireless mobile networks depends on the handoff strategy. Several handoff schemes, that support different services and different traffic requirements, can be found in the literature [e.g., in 11].

B. Non-Prioritized Schemes

There is no given priority to handoff calls over originating calls for this scheme, the forced termination probability is relatively higher than normally anticipated [12,13]. This scheme does not differentiate handoff and initial calls. An initial or a handoff call will be served, as long as there is a channel available in the cell; otherwise the request is blocked immediately. This (non-prioritized) scheme is able to minimize the call rejection and has the advantage of efficient utilization of the available frequency spectrum but this scheme is not suitable for multi-service environments like healthcare information systems [7].

C. Prioritized Schemes

Handoff prioritizing schemes (PS) provide improved performance at the expense of a reduction in the total admitted traffic and an increase in the blocking probability of new calls [14]. The concept of all handoff prioritization approaches is to give handoff requests precedence over the new session requests [15], but the improvement in performance is related to the way that each scheme gives priorities to handoff calls. Several handoff prioritization schemes, that support different services and different traffic requirements, may be found in the literature [11]. These handoff prioritization schemes may be further classified into channel reservation schemes (offer a method to increase the number of the accepted handoff requests by reserving a number of channels exclusively for handoff requests, in a predictive or non-predictive manner), handoff queuing schemes (give priority to handoff attempts by permitting them to queue instead of denying access, if the potential new base station is busy), channel transferred schemes (in the case that there are no available channels to accommodate a handoff call request, a channel from a neighboring cell may be transferred), subrating schemes (In them, certain channels are allowed to be temporarily divided into two channels at half the original rate to accommodate handoff calls), genetic schemes (Using genetic algorithms to assign the channels by local state-based call admission double-threshold policies), hybrid schemes (are combinations of channel reservation, handoff queuing, channel transferred, genetic and subrating schemes; the key idea is to combine the different prioritization policies in order to further decrease the blocking probabilities or to improve the channel utilization) [7].

IV. The Scheme of Priority for the wireless telemedicine/e-health services

Within the telemedicine environment it is possible to define three types of call based on the level of urgency. First of all call from ambulances and emergency calls; secondly, calls from serious patients (for example with chronic diseases, etc); and finally other calls which don't use real-time applications (request for the some statistical data, etc.).

Fei Hu and **Sunil Kumar** in [10] have presented three types of medical services for the sensor-based telemedicine network:

1) *Real-time calls from Ambulance Patients*. These calls are given the highest priority because the level of urgency is the highest (using the video camera sensors, Global Positioning System (GPS) system, and other advanced medical sensors to establish a rate-guaranteed connection with the medical center). Moving through different cells calls are treated as "handoff-guaranteed" since the wireless bandwidth should be reserved in the next cell to guarantee their on-going connections.

2) *Handoff-prioritized calls from potentially emergency patients (such as older people or patients with chronic diseases).* The second highest priority (the serious patients may need to perform the direct two-way communication with the medical center) to these calls when they need to handover to a new cell.

3) *Non-real-time calls from Cluster-heads who collect medical data* from wrist-worn super sensors of average patients or normal people. Sensors would "wake up" periodically or when urgent medical conditions are detected by the body sensors. The type of communications is the best-effort for these services.

Some representative types of medical activities may include off-line and on-line applications [7]:

1) Off-line applications: administrative files and electronic patient report (EPR) transfer (from medical data exchange between centers and moving vehicles or specialty sections) clinical routine consults through accesses to databases, queries to medical report warehouse, etc.

2) On-line applications: multimedia connections including audio and video exchange, biomedical signals and vital parameters (such as ECG signal, blood pressure, oxygen saturation, etc.) transmission, etc.

V. Techniques and Methods for IEEE 802.11 to Provide QoS

Different methods and techniques have been used to solve similar questions by others [28,16,17,18]. The QoS requirements of real-time applications like voice and video does not provide any priority and there is no service differentiation between different flows. Generally, the QoS schemes proposed based on IEEE 802.11. There are primarily three ways in which QoS are provided [16]:

1. Most of the techniques use different Inter Frame Space (IFSs) or different Contention Window (CWs) or both [19,20,21] for the *Prioritisation* among different classes of data;
2. By some distributed variant of Weighted Fair Queuing (WFQ) [19,22] will help to achieve the *Resource allocation* of prioritized classes of data: This is achieved.
3. Measurement and model based to provide QoS are used for *Admission control* mechanisms [23, 24, 25].

M.Mishra and A.Sahoo in [16] propose the method that provides priority to real time flows by using contention window based service differentiation method. **Dimitros J. Vergados** in [28] investigates a grand challenge to superiority on the DiffServ (Differentiated Services) wireless networks is that several e-health applications may be supported with different QoS constraints. **Yi Liu** in [17] the emerging IEEE 802.11e standard for Wireless Local Area Networks (WLANs) has been proposed to support quality of service (QoS) by assigning different channel access parameters (CAPs) to different access categories (ACs). **D.Gao and J.Cai** in [18] show that the 802.11e standard provides a very powerful platform for QoS supports in WLANs. They provide an extensive survey of recent advances in admission control algorithms/protocols in IEEE 802.11e WLANs.

VI. Proposed Architecture and Scenarious

The research is particularly concerned about is to give to a user (patient, doctor, etc.) possibility to have 'communications anywhere' within the mobile network (figure 2). The technologies which are in use should be able to provide services that reduces patient journeys, hospital visits and hospital admissions, saves the time of healthcare professionals, supports individuals living at home, and improves the quality or effectiveness of the care or treatment that is delivered [28]. An example of the telemedicine/e-health technology which is presented on figure 1: a patient takes measurements (at home, etc.), then data should be transmitted via wired (phone lines) or wireless connection through the server to the medical centre (stored to the database, etc.).

Table 1 presents the basic requirements for the different types of applications especially for the e-health/telemedicine services.

TABLE I. CLASSIFICATION OF E-HEALTH QOS REQUIREMENTS [27]

Application Type	Required Throughput	Small delay	Small jitter
Teleconsultation	High	Yes	Yes
Telediagnostic	High	Yes	No
Telemonitoring	Low	No	No
Teleeducation	High	No	No
Access to DB	Low/High	No	No

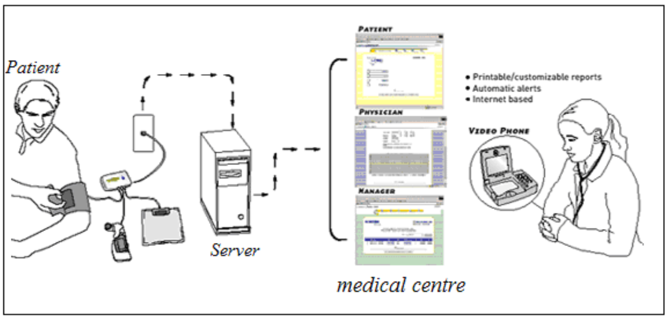

Figure 1. E-Health homecare scenario

The communication signal strength [26] should be the strongest within the hierarchical network (fig.2). A mobile user can use *soft handoff* (where a cell phone is simultaneously connected to two or more cells, or cell sectors, during a call).

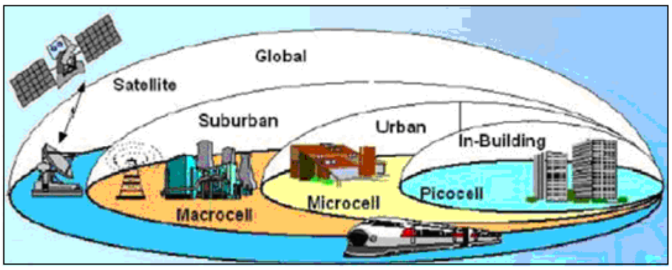

Figure 2. A multi-layer hierarchical network structure that includes the following cell-sizes: pico-cell, micro-cell and macro-sell.

Within a wireless Telemedicine Environment [27] the limitation of wireless interface (in conjunction with the increased throughput requirement) are very important and lead to consider source management, because it is a key feature in QoS provisioning. There are many different scenarios for the e-health/telemedicine services that can exist within the multi-layer hierarchical mobile network structure.

VII. SCENARIOS AND REQUIREMENTS

Every recorded biomedical parameter has its own bandwidth requirements. Some of them are presented in table 2 such as respiratory rate and heart rate.

TABLE II. THE TYPICAL BIOSIGNAL BANDWIDTH REQUIREMENTS [27]

Biomedical Measurements	Voltage range (V)	Number of users = K (sensors)	Bandwidth (Hz)	Sample rate (samples/s) = Hz	Resolution (b/sample)	Information rate (b/s)
ECG	0.4-5m	5-9	0.01-250	1250	12	15000
Heart sound	Extremely small	2-4	5-2000	10000	12	120000
Heart rate	0.5-4m	2	0.4-5	25	24	600
EEG	2-200µ	20	0.5-70	350	12	4200
EMG	0.1-5m	2+	0-10000	50000	12	600000
Respiratory rate	Small	1	0.1-10	50	16	800
Temperature of body	0-100m	1+	0-1	5	16	80

A. *Simulation Parameters and Performance Evaluation*

The location of the patient (and supported ambulances during the emergency situation) can vary rapidly. Figure 3 gives an overview of possible scenarios when patients need emergency help form the hospital:

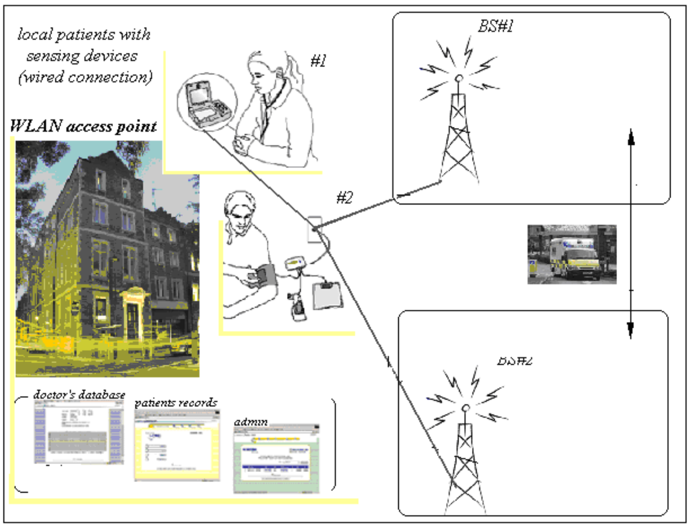

Figure 3. Simulation scenario with the moving ambulance (node)

Two base stations are connected to the hospital by wired connection. When emergency situation happens the remote services are in use: such as the information inquiry systems (IIS), sensing devices, etc. but databases physically can be located in two different ways within telemedicine/e-health services (figure 3). First of all into the "Hospital" or in a medical centre interested in data, secondly, into an organization with the permission to view, a statistic committee, etc. The scenario includes the local patients with sensing devices (wireless or wired connection), information can be collected and store as patients' records within the doctors' database. It can be later reviewed by the third part (admin) anonymously or with patients' permission.

The technical scenario: The moving wireless nodes are equipped with sensing/medical devices. An ambulance (the node) may generate different types of telemedicine traffic. Possible types of transmitted information for the emergency scenario: voice, video, picture, files, etc. This traffic will use on-line applications: multimedia connections for audio and video exchange, biomedical signals and vital parameters (such as electrocardiogram (ECG) signal, blood pressure, oxygen saturation, etc.) transmission. Also, this traffic is classified as urgent, according to the critical nature of the information that should be transmitted. For the first scenario, non congested network will be simulated: only one moving node (an ambulance) and base stations will be simulated in the hierarchical mobile network structure. In the first simulation scenario the network operated in non-congestion condition.

After running the simulation I have got 97% confident interval. The IEEE 802.11 protocol is in use. The Basic Rate is 1 Mb, Data Rate is 11 Mb. For an ambulance, the type of transmitted information is considered voice, video, file. The duration of the simulation is 150 second.

1) *Experiment 1:*

To be sure that ambulances will have the priority to establish [29] connections the blocking probability should be zero. It can be controlled by a Threshold parameter. The performance was explored according different threshold (fig. 4), which is used to reserve the bandwidth. So, connections will be admitted as long as the sum of the total allocated bandwidth is less than Threshold. The number of (it is similar in real-life scenario to the number of follow-up patients, ambulances) is a variable as well as the Threshold parameter. The blocking probability of follow-up patients was measured for different thresholds.

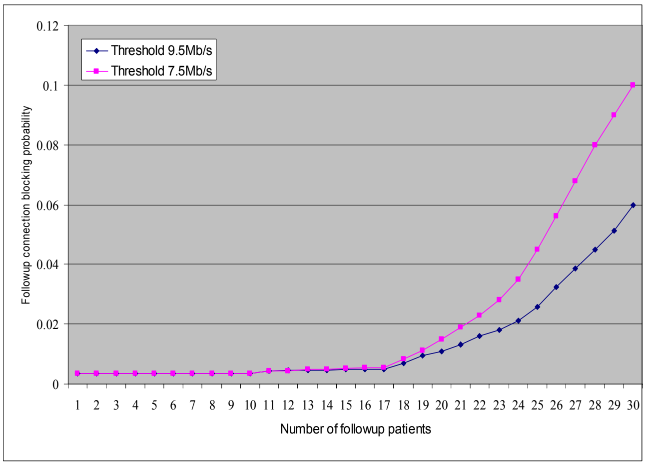

Figure 4. Number of Follow-up patients vs. Blocking Probability

As expected, the threshold has an impact on blocking probability. In particular the larger is the Threshold (in number of follow-up connections) the higher the blocking probability of follow up connections is.

2) *Experiment 2:*

The number clinics were fixed to 2 (and then 3) and observe the variation in average delay with the number of connections from clinics and ambulances (fig. 6.11). The impact of the average delay on the image transfer (size of image file size is 5Mb, which requires 100 seconds for transmission at the rate of 200 kb/s) from ambulance was studied. On the figure 5 the dependences of the number of clinics (the variable parameter) on the number of follow-up patients that were involved in simulation are presented.

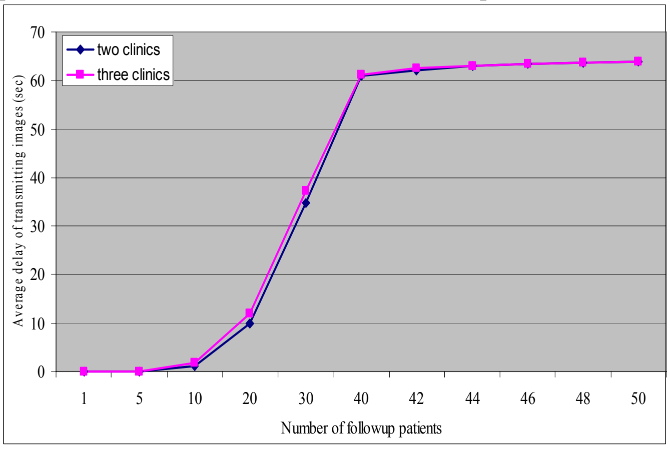

Figure 5. Average delay of image transfer from ambulance to clinic

As expected, the transmission delay increases with increasing the number of clinics that are involved in simulation

VIII. Conclusion

For the medical networks [1] delay is a critical factor, since there are many cases in which a communication should be timely in order to save the life of critical patients.

Scenarios when the prioritizing scheme is applied, the average delay is more that without priority, because of the waiting time for a free channel in order to transmit urgent data. Experiment when the priority is analyzed using the Threshold parameter show that the more bandwidth is reserved the more the average delay, than without prioritization. The more bandwidth is available, the less is Threshold.

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