MONITORING QoS OVER WIRELESS SENSOR NETWORKS
For Medical Applications

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Abstract: Wireless Sensor Networks (WSNs) for medical purposes enables real-time (RT) acquisition of vital signals. In this context the network reliability, data integrity and RT delivery have extreme importance. The network should guarantee an appropriate level of Quality of Service (QoS). This paper presents the QoS parameters and metrics of standard telemedicine and WSNs based Medical Applications (MA), and a strategy, based on QoS monitoring, to prevent QoS degradation in WSNs for MA.

1 INTRODUCTION

A Biomedical WSN (BWSN) is a small-size WSN for MA. BWSNs have the potential to promote new applications and services in different healthcare scenarios, e.g., mobile telemedicine, emergence response and management, location services and patient monitoring (Varshney, 2009). In the case of patient monitoring scenarios, a BWSN can be used to monitor a wide range of biological and vital signals.

This monitorisation can be done through various situations, e.g., in emergency response providing information about the health condition of patients, monitoring physiological signals in people with chronic illness or measuring the activity level of elderly or disabled people (Gao et al., 2008). In any of these situations, BWSN presents itself as a key technology to the success of many ongoing investigations. They are responsible to transport information, which in MA have to obey to very strict quality criteria (Liang, 2009). As noted in (Liang & Balasingham, 2007), the main function of a BWSN is to ensure that sensed signals are delivered reliably and efficiently. There is a set of QoS requirements that must be fulfilled.

In the rest of this paper we discuss the QoS needs of MA and briefly present the main QoS parameters and metrics in traditional networks and propose a strategy to QoS monitoring in order to improve the performance (prevent the degradation) of BWSNs.

2 QoS REQUIREMENTS OF MEDICAL APPLICATIONS

Currently, most medical procedures are performed based on information obtained from electronic or/and informatics systems. This information, about the health condition of an individual, must have medical quality. According to the (American College of Medical Quality, 2010), medical quality can be defined as “the degree to which health care systems, services and supplies for individuals and populations increase the likelihood for positive health outcomes and are consistent with current professional knowledge”. This definition makes clear that, healthcare systems and its communication networks have a key role in the quality of healthcare services provided to citizens. So, it is extremely important that the communication networks used to transport medical information ensure a service with

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quality. In the context of communication networks, this characteristic is expressed in terms of QoS.

Recommendation E.800 of the International Telecommunication Union (ITU) introduced the following QoS definition: "totality of characteristics of a telecommunication service that bear on its ability to satisfy stated am implied needs of the user of the service". According to the definitions presented above, communication networks used to transport information used by health providers are a keystone to the quality of patient health and care according to its medical condition.

The term QoS is understood and interpreted in various ways by the scientific community; most often it refers to the ability of a network to deliver data efficiently and reliably (Liang, 2009). RFC2386 defines QoS as: "A set of parameters that the network should ensure during the transport of a data stream". Given this definition, it is necessary to specify what parameters should the network ensure, who imposes them and in what situations.

2.1 QoS Support in BWSN

BWSNs can be considered small size WSNs, and therefore they have the same constrains, e.g., limited computational power, limited memory and severe power supply limitations (in implantable nodes this problem worsens) (Khan et al., 2009). However, from the network viewpoint there are some important differences, such as, the number of sensor nodes on the network, its localization and the number of hops between nodes, e.g., compared with normal WSNs, BWSNs contain a reduced number of nodes; nodes localization in BWSNs is well known or restricted to a limited area, on the other hand, in a normal WSN the sensor nodes are randomly deployed in large areas. These differences, although significant, do not invalidate the utilization of the same QoS parameters and metrics. However, if taken into account, they may facilitate the development of more efficient QoS mechanisms. Most of the ongoing investigation in BWSNs takes advantage on these characteristics to implement QoS mechanisms to specific monitoring applications.

There are several published works about BWSNs based monitoring systems that, in most cases, are individual or for a small number of patients (Khan et al., 2009) (Alemdar & Ersoy, 2010). The authors of (Liang & Balasingham, 2007), present a priorities based routing protocol with QoS guaranties on the following parameters, end-to-end delay, delivery ratio and power consumption. This protocol was validated by simulation with 20 sensor nodes. According to scholarly information, this was the first QoS enabled routing protocol to healthcare monitoring applications. In (Ko et al., 2010), the authors present a monitoring system to hospital use where the nodes localization is precise and well known. In this case, the authors conclude that the existence of a backbone of static network nodes improves the network performance.

2.2 QoS Support in WSN

WSNs differ from “traditional” networks in several aspects, e.g., WSN nodes have strong constrains in power consumption and consequently in the power of RF signal emitted which limits its communication range and transmission rate (Zhang et al., 2010); they have strong computational and memory limitations, so that the algorithms used must be lightweight and efficient; the dynamic nature of WSNs and the lack of centralized control present additional challenges in the development of efficient QoS solutions (Ben-Othman & Yahya, 2010).

Due to its specificities, in WSNs, the QoS must be ensured in all layers of the protocol stack in use, starting at physical and ending in application layer. The authors of (Wang et al., 2006), present an analysis of the QoS requirements at each layer based on the Open System Interconnection (OSI) model. Here, our concern is to discover how a WSN can guarantee QoS to applications that depend on it. Thus, in order to obtain some independence from the network technology used we will focus on the mechanisms to guarantee QoS at the network layer.

In (Asokan, 2010) the author analyses the most relevant routing protocols in mobile Ad Hoc networks (WSN can be regarded as an Ad Hoc network). In his analysis he highlights that the studied protocols take into account only a small set of the total QoS parameters. Finally, he concludes by saying that routing protocols are needed, namely, those that take into account more ample QoS parameters. Also among the authors of (Asokan, 2010) it’s consensual that there are still many unsolved issues regarding routing protocols with QoS guarantees.

3 QoS PARAMETERS AND METRICS

QoS requirements are imposed to network by applications that use it. They don't depend only on the intrinsic characteristics of data to be transmitted but also on its use, in other words, on its application.

3.1 QoS Parameters Concerning the Application Viewpoint

In (Ruiz, 2006) the author identifies the following parameters, as the most important at this level: Peak Data Rate (PDR), Sustainable Data Rate (SDR) and Maximum Burst Size (MBS). Drawing upon these parameters one can define traffic classes which can be applied to different data flows and applications.

Different network technologies have adopted different QoS classes. However, there is a common feature among them, the distinction between classes for applications with and without RT requirements. Being the most widely used network technology, in Table 1 we present the traffic classes defined for IP networks as defined in (Marchese, 2007).

Table 1: IP QoS Classes.

QoS class	Characteristics
0	RT, jitter sensitive, highly interactive.
1	RT, jitter sensitive, interactive.
2	Transaction data, highly interactive.
3	Transaction data, interactive.
4	Low loss only (short transactions, bulk data, video streaming).
5	Traditional applications of IP networks.

Other technologies have defined different classes. However, in essence, they have the same division taking into account the application characteristics.

3.2 QoS Parameters Concerning the Network Viewpoint

According to (Marchese, 2007) and (Ruiz, 2006), from the communication network viewpoint, the most important metrics used to measure and ensure that the QoS required for a given application is guaranteed, are: Packet Transfer Delay (PTD), Packet Delay Variation (PDV), Packet Loss Ratio (PLR), Packet Error Ratio (PER) and Bandwidth (BW). There are no unique values to these metrics. Rather, they depend on the network characteristics and particular requirements of each application.

3.3 QoS Parameters in WSN

In the context of WSNs, due to its specificities, the QoS metrics presented earlier are insufficient. In (Chen & Varshney, 2004) the authors identify new QoS metrics that reflect the collective effort of all network nodes to perform a given task. They are: collective delay or latency, collective packet loss rate, collective bandwidth, collective data rate and information throughput. WSNs routing protocols with QoS requirements have to take into account these metrics in order to provide more efficient QoS mechanisms.

3.4 Telemedicine QoS Metrics

QoS requirements depend on the application characteristics and network technology in use. Since we are interested in the development of mechanisms for QoS support in BWSNs, a good starting point is to study how 'traditional' networks are used in medicine. There are countless applications and services using information systems and communications networks in medicine. However, in this work, the focus is on applications and services that allow remote monitoring of biological and vital signals, such as, ECG, EEG, BP and T. According (Ruiz, 2006) and (Varshney, 2009), taking into account the characteristics of each one of these signals and the requirements of the application at stake, the following metrics, Table 2, are sufficient to telemedicine and telemonitoring applications and services in "traditional" IP networks.

Table 2: QoS Metrics to Telemedicine.

PTD	Application or service characteristics
50ms	Audio transmission with interaction.
100ms	Interactive application.
150ms	Video transmission with interaction.
400ms	Default value to real-time applications.
PLR	
3%	Tx of medical images and signals.
10%	Tx of radiology images with compression ratios of 10:1 and 20:1.
15%	Interactive video and audio transmission.
20%	Default to real-time applications.
BW	
15Kb/s	Tx of medical images and signals.
60Kb/s	Tx of radiology images with compression ratios of 10:1 and 20:1.
100Kb/s	Interactive video and audio transmission.
200Kb/s	Default value to real-time applications.

4 QoS MONITORING

As mentioned in (Asokan, 2010), QoS provision over low-rate Wireless Personal Area Networks (LoWPANs) can be done over different layers on the communication protocol stack. However, by themselves, these mechanisms do not provide QoS in all situations, e.g., in individual monitoring applications it is necessary to know how many signals we can transmit without degrading the network QoS, if we need to monitor multiple patients then we also need to know how many patients may be on the network. In a more complex scenario, the patients are distributed in a given area: in this case, it is necessary to determine if and where the QoS can be guaranteed.

It is necessary to develop management and supervision tools to manage and control the network. These management and supervision tools must provide sufficient information to add new monitoring services or applications to network without degrading the existing QoS.

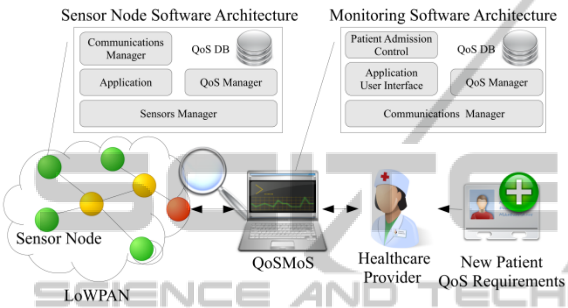

Figure 1: QoS Monitoring System.

Figure 1 presents, in terms of high level blocks, the QoS monitoring system architecture and principal components. Each sensor node has, stored in a QoS Database (QoS DB), information about its QoS requirements. This information can be accessed by the QoS Manager (QoSM) and transmitted through the LoWPAN to the QoS Monitoring Software (QoSMoS). To add a new patient to the network, the healthcare provider must insert the patient QoS needs on the QoSMoS. Then, taking into account the network QoS status (based on information collected from the sensor nodes in the network) and new patient QoS needs the Patient Admission and Control (PAC), decides if and where the patient can be inserted in the network.

5 CONCLUSIONS

This paper provides a review of the state-of-the-art in QoS for telemedicine and BWSNs, presenting the principal QoS parameters and metrics. Finally, we have argued that existing QoS mechanisms do not guarantee QoS in all utilization scenarios and a different approach to increase QoS or prevent its degradation has been proposed. Due limited capacity of WSNs it's necessary to develop monitoring tool to allow QoS management and supervision.

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REFERENCES

Alemdar, H. & Ersoy, C., 2010. Wireless sensor networks for healthcare: A survey. *Computer Networks*.

American College of Medical Quality, 2010. *Index of Policies*. [Online] Available at: http://www.acmq.org/policies/policyindex.cfm [Accessed 17 July 2010].

Asokan, R., 2010. A review of Quality of Service (QoS) routing protocols for mobile Ad hoc networks., 2010.

Ben-Othman, J. & Yahya, B., 2010. Energy efficient and QoS based routing protocol for wireless sensor networks. *Journal of Parallel and Distributed Computing*, 70(8), pp.849-57.

Chen, D. & Varshney, P. K., 2004. QoS Support in Wireless Sensor Networks A Survey., 2004.

Gao, T. et al., 2008. Wireless Medical Sensor Networks in Emergency Response Implementation and Pilot Results., 2008.

Khan, P., Hussain, M. A. & Kwak, K. S., 2009. Medical Applications of Wireless Body Area Networks. *JDCTA: International Journal of Digital Content Technology and its Applications*, 3(3), p.185 ~ 193.

Ko, J., Gao, T., Rothman, R. & Terzis, A., 2010. Wireless Sensing Systems in Clinical Environments: Improving the Efficiency of the Patient Monitoring Process. *Engineering in Medicine and Biology Magazine, IEEE*, 29(2), pp.103-09.

Liang, X., 2009. *QoS Provisioning for Wireless Sensor Networks: Algorithms, Protocols and Modeling*.

Liang, X. & Balasingham, I., 2007. A QoS-aware Routing Service Framework for Biomedical Sensor Networks., 2007.

Marchese, M., 2007. *QoS Over Heterogeneous Networks*. John Wiley \& Sons Ltd.

Ruiz, I.M., 2006. *Contribuciones a Modelos de Tráfico y Control de QoS en los Nuevos Servicios Sanitarios Basados en Telemedicina*.

Varshney, U., 2009. *Pervasive Healthcare Computing: EMR/EHR, Wireless and Health Monitoring*. 1st ed. Springer.

Wang, Y., Liu, X. & Yin, J., 2006. Requirements of Quality of Service in Wireless Sensor Network., 2006.

Zhang, X. et al., 2010. An Energy-Efficient ASIC for Wireless Body Sensor Networks in Medical Applications. *Biomedical Circuits and Systems, IEEE Transactions on*, 4(1), pp.11-18.