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Throughput efficiency in body sensor networks: A clean-slate approach

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ABSTRACT

In this paper, a flexible role-based architecture for Body Sensor Networks (BSNs) is introduced. The proposed non-layered context-aware architecture is application-oriented and able to incorporate future applications. Particular applications have certain requirements. Functional units (roles) instead of protocol layers are designed to perform the required tasks for applications to work properly. The role data of an application is inserted in the role headers of the container and is available for other applications with the same basic, specific or particular roles. Furthermore, the performance of Automatic Repeat Request (ARQ), Forward Error Correction (FEC) block codes and FEC convolutional codes with respect to the throughput efficiency has also been analyzed for a BSN following the proposed role-based architecture. The numerical results show that the proposed role-based architecture outperforms the traditional layered architecture with respect to the throughput efficiency for all error control schemes. FEC block codes are able to maintain a high throughput efficiency over longer distances because the hop length extension technique is applied.

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1. Introduction

A Body Sensor Network (BSN) is formed by multiple sensors placed at the human body to monitor the vital signs of a person (Omeni, Wong, Burdett, & Toumazou, 2008). The physiological states of the person are being sensed, sampled and processed by specific implant and body surface sensors, as show in Fig. 1. Implant sensors are located inside the human body, whereas body surface sensors are placed at the human skin or at most two centimeters away. The vital signs are sent towards the gateway, which transmits them to a monitoring station. Finally, they are forwarded towards Internet for further analysis.

BSNs support a wide variety of applications. In this paper, different application scenarios for body sensor networks have been identified. We distinguish between the healthcare scenario, the emergency or life-critical scenario, the entertainment scenario, the sports scenario and the military scenario. Furthermore, a flexible role-based architecture for BSNs is introduced. The proposed non-layered context-aware architecture is application-oriented and able to incorporate future applications. Particular applications (e.g. forwarding of vital signs towards a health center as routine or in case of emergency) have certain requirements. Functional units (roles) instead of protocol layers are designed to perform the required tasks for applications to work properly. The different role types have been classified. Packets are built with the data payload and the metadata required for each specific role. The role header fields of the most important common basic roles are described. An application example has been introduced to compare the traditional layered-network model with the proposed architecture. Furthermore, the performance of Automatic Repeat Request (ARQ), Forward Error Correction (FEC) block codes and FEC convolutional codes with respect to the throughput efficiency has also been analyzed for a BSN following the role-based architecture. The numerical results show that the proposed role-based architecture outperforms the traditional layered architecture with respect to the throughput efficiency for all error control schemes. FEC block codes are able to maintain a high throughput efficiency over longer distances because the hop length extension technique is applied.

To the best of our knowledge, this is the first paper that discusses the role-based architecture for BSNs and analyses packet size optimization based on the throughput efficiency for the proposed clean-slate architecture. The paper is structured as follows. In Section 2, we analyze different application scenarios for BSNs. In Section 3, we discuss the related work. In Section 4, we introduce our role-based architecture proposal. In Section 5, the role selection is described. In Section 6, the channel model for BSNs is explained. In Section 7, the optimal packet size for each error control scheme to optimize the throughput is derived. In Section 8, our numerical results are shown. Finally, the paper is concluded in Section 9.

2. Application scenarios for body sensor networks

Next, several application scenarios for BSNs are described.

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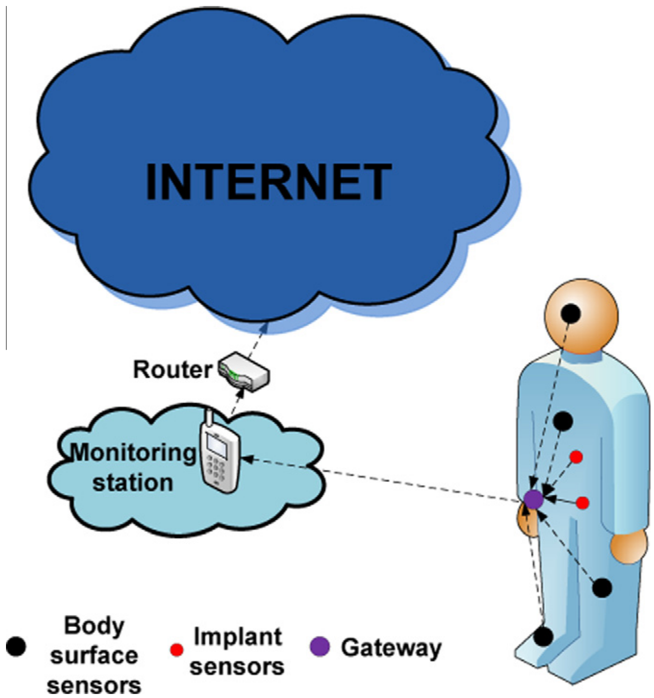

Fig. 1. Architecture for a single-hop body sensor network.

2.1. Healthcare scenario emergency or life-critical scenario

This scenario refers to the monitoring of the physiological signals of a patient to control his/her health. We highlight the following applications:

2.1.1. Monitoring of physiological signals of patients

A wide range of sensors can be deployed to monitor the vital signs of the human body (see Fig. 2), such as the blood pressure, the blood flow, the glucose level, the body temperature, the brain electrical activity (Electroencephalograph (EEG)), the heart activity (Electrocardiogram (ECG)) and the blood oxygen (pulse oximeter). BSNs can also be very useful for the management of chronic diseases such as asthma or Alzheimer. In Seto et al. (2009), a BSN is designed to monitor the activities, geographic location and air pollution around children with asthma with the purpose of improving their conditions and prevent asthma attacks. In Avvenuti, Baker, Light, Tulpan, and Vecchio (2009), a BSN is designed to monitor the brain activity and body movements of Alzheimer patients with the purpose of identifying the signal elements that trigger a crisis, managing the patient during these critical periods and preventing possible falls. In Patel et al. (2009), a BSN is designed to estimate the severity of symptoms and motor complications of the Parkinson's disease such as tremor, bradykinesia (slowness of movement) and dyskinesia (involuntary and sometimes violent writhing movements).

2.1.2. Obstetrics

Fetal health assessment in pregnancies is very important to prevent death and to avoid or at least minimize perinatal morbidity (Gribbin & James, 2005), which is defined as a disorder in the neonate as a result of adverse influences or treatments acting on the fetus during pregnancy. Monitoring of fetal movements is useful in identifying fetuses at increased risk of fetal death. Auscultation of the fetal heart sounds is also important. Therefore, BSNs for the monitoring of the fetal health should be designed. In Borges, Barroca, Velez, and Lebres (2009), an application consisting of several flex sensors attached to a wearable monitoring belt has been proposed to monitor the fetal movements of a pregnant woman.

2.2. Emergency or life-critical scenario

This scenario refers to the monitoring of people exposed to critical environments or life-critical situations. In this scenario, the data is usually very sensitive and disseminating it to a number of interested parties (emergency services, physicians, family

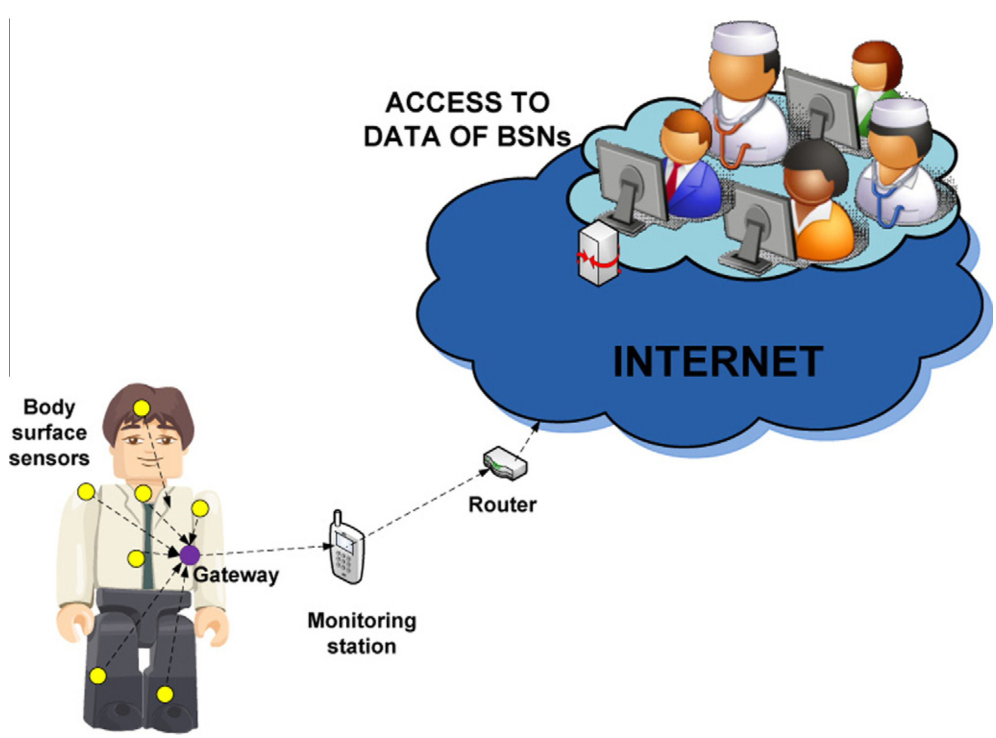

Fig. 2. Monitoring of physiological signs in the healthcare scenario.

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