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Fast track article

# Link quality aware channel allocation for multichannel body sensor networks

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ABSTRACT

Body Sensor Network (BSN) is a typical Internet-of-Things (IoT) application for personalized health care. It consists of economically powered, wireless and implanted medical monitoring sensor nodes, which are designed to continually collect the medical information of the target patients. Multichannel is often used in BSNs to reduce the spectrum competition of the tremendous sensor nodes and the problem of channel assignment has attracted much research attention. The health sensing data in BSNs is often required to be delivered to a sink node (or server) before a certain deadline for real time monitoring or health emergency alarm. Therefore, deadline is of significant importance for multichannel allocation and scheduling. The existing works, though designed to meet the deadline, often overlook the impact of the unreliable wireless links. As a result, the health sensing data can still be overdue because of the scheduled lossy links. Besides, potential collisions in the schedules also incur considerable delay in delivering the sensing data. In this paper, we propose a novel deadline-driven *L*ink quality *A*ware *C*hannel *A*ssignment scheme (LACA), where link quality, deadlines and collisions are jointly considered. LACA prioritizes links with urgent deadlines and heavy collisions. Besides, LACA allows the exploitation of the spare slots for retransmissions on lossy links, which can further reduce the retransmission delay. Extensive simulation experiments show that compared to the existing approaches, LACA can better utilize the wireless spectrum and achieve higher packet delivery ratio before the deadline.



## 1. Introduction

Internet of things (IoT) enabled healthcare is a promising research direction in recent years [1,2]. Body sensor network (BSN) is a novel IoT enabled healthcare application specified for personalized health care and has attracted much research attention in recent years [3–6]. A BSN often consists of a number of sensor nodes attached to or implanted in the target patients, which continually collects the health information and transmit it to the data sink for personal health analysis [7]. As the microelectronic technology develops, more and more types of wearable sensor nodes are designed and applied in BSNs [8–11]. For example, the smart wrist rings [12] can be used to measure the physiological parameters such as

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heart rate, blood pressure, skin temperature. The smart shirt [10] can be used to measure the electrocardiogram (ECG), photoplethysmograph (PPG), heart rate, blood pressure, body temperature.

These devices, while collecting more comprehensive human health information, have intensified the wireless spectrum competition as most of them work in the same frequency. Therefore, multi-channel is employed as an important means to reduce the collisions and better utilize the wireless spectrum resources [13].

In typical multi-channel BSNs, each node works in a duty cycle and the network operates as the duty cycle repeats. Channel allocation is a fundamental and significant problem. Each link is assigned a slot in the duty cycle and a corresponding communication channel in the slot. Some channel allocation schemes have been proposed in recent studies. Jun et al. [14] exploit the capture effect to reuse the good channels in channel allocation, which can improve the transmission efficiency. Wang et al. [15] propose a decentralized scheduling algorithm to allocate the channels and time slots in order to jointly reduce control overhead, packet transmission delay and duty cycle. Bui et al. [16] provide soft real-time and bandwidth guarantees by avoiding collisions with multiple channels using real-time chain. Saifullah et al. [17] aim at establishing real-time channel scheduling in Wireless HART network.

Since health data is important for real time monitoring [10] and health emergency alarm [12], the health data is often required to be delivered to the sink before given deadlines. However, most of the existing works cannot well support the deadline-driven data routing and transmissions in BSNs. The reason is two-fold. First, the lossy nature of wireless links is not carefully considered in the channel assignment and scheduling. The existing works often assume a packet can be successfully delivered in one single slot. However, this is not true for real world scenarios where wireless links can be easily interfered [18,19]. As a result, the arrival delay of the data packets are often under-estimated and the resulting schedules may lead to data overdue problem. Second, retransmissions are not considered in the existing works, while there are often a number of slots are left unused. In the existing works, the retransmission is typically postponed by an entire duty cycle [20,21], which adds large delay to the end-to-end delivery time.

To address the above limitations, we propose a novel deadline-driven *L*ink quality *A*ware, deadline-driven *C*hannel *A*llocation scheme (LACA) aiming to maximize the packet delivery ratio (PDR) before deadline as well as minimize the wireless collisions. Compared with the existing works, LACA has two salient features: *First*, LACA jointly considers link quality, wireless collisions and deadlines in the scheduling. A novel metric that takes both deadline and collisions is proposed to prioritize the paths with more urgent deadlines and heavier collisions. For assigning links for a specific path, channels with better link quality and less collisions are preferred. The links that have more collisions are more likely to be assigned with better channels/slots. *Second*, instead of trying to minimize the assigned slots, we further assign "backup" channels/slots to the lossy links. With these "backup" slots, the lost packets can be intermediately transmitted and the delay can be significantly reduced. It is worth noting that these "backup" slots do not incur extra energy overhead since they are activated only when packet losses happen.

We implement LACA in simulation experiments and compare its performance with the existing works extensively. The evaluation results show that LACA greatly improves the PDR before deadline in multichannel BSNs and does not incur extra energy overhead.

The major contributions of this paper are listed as follows.

1. A novel metric for channel allocation is proposed, which prioritizes the paths with more urgent deadlines and heavier inter-path collisions.
2. A novel link quality aware channel allocation mechanism (LACA) is proposed, which jointly considers link quality, collisions and possible retransmissions.
3. We evaluate LACA's performance by extensive simulation experiments and the results show that LACA significantly improves the packet delivery ratio (PDR) before deadline than the existing works.

The rest of this paper is organized as follows. Section 2 presents the related works and the motivation of our work with illustrative examples. Section 3 presents the design details of LACA. Section 4 evaluates LACA with simulation experiments. Section 5 concludes this work.

## 2. Related work and motivation

The health data in BSNs is often required to be delivered to the sink before a given deadline in order to achieve real-time patients monitoring or health alarms. Therefore, deadline is a more critical issue in BSNs than that in general sensor networks.

Several studies have been working on the problem of deadline guaranteed channel scheduling. These works could be divided into two categories according to the channel diversity: (1) works using single channel scheduling. (2) works using multichannel allocation and scheduling.

### 2.1. Works using single channel scheduling

Works on single channel mainly include [22–26]. These works focus on scheduling the links to guarantee the deadline in single-channel networks. Kumar et al. [22] try to decrease the distance among the source and destination by using multiple short-distance hops instead of long-distance hops. Li et al. [23] prove that providing deadline guarantee for message transmissions in wireless sensor networks is NP-hard. They propose a scheduling scheme with MAC layer back-offs and the