Role of 5G in Medical Health

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2 authors:

Ali Hassan Sodhro
Linkoping University

Madad Ali Shah
BBS University of Technology and Skill Development Khairpur Mirs

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Ali Hassan Sodhro
Electrical Engineering Department
Sukkur Institute of Business Administration
Sukkur, Sindh, Pakistan
ali.hassan@iba-suk.edu.pk

Madad Ali Shah
Electrical Engineering Department
Sukkur Institute of Business Administration
Sukkur, Sindh, Pakistan
madad@iba-suk.edu.pk

Abstract— In this paper, Channel State Estimation is designed based on Transmission Power Control (CSE-TPC) algorithm for QoE (Quality of Experience) optimization in terms of modulation level and duty cycle. CSE-TPC enables the transceiver to adjust the transmission power level and target the received signal strength indicator (RSSI) threshold for satisfying the requirement of energy saving over 5G networks for medical health applications such as, Wireless Body Area Networks (WBANs). A log-normal shadowing channel model is considered to minimize energy consumption in WBANs. Through simulation results in MATLAB it has been observed that energy consumption can be minimized in medical applications.

Keywords—5G; Medical Health; CSE-TPC; WBAN; RSSI

I. Introduction

While much of this work is underway today, very big strides will appear soon in the coming years i.e. 2018 onwards. The mobile operators are entertaining the Internet services at ultra-fast rates of 20Gbps. Besides, it has also been planned and expected to offer commercial 5G networks by 2020. With the dramatic improvements in the number of digital devices, much of the world will be connected round the clock through these 5G networks. This research presents how 5G differs from previous generations of cellular communication (i.e. 3G and 4G) and discusses emerging applications in health care. This research also demonstrates how these developments will enable new systems of cost-effective medical care delivery.

The rapid development of wireless body sensor networks (WBSNs) and wireless communication, remote diagnoses and monitoring of patients gain interest in Telemedicine [1-3]. The idea is to monitor various biological parameters by multiple sensors placed on the body surface or even by implanted sensors and those all signals are collected by a receiver (i.e. mobile phone or PC) to transmit the recordings to a doctor[4-6]. If the patients are monitored and diagnosed consistently, many lives could be saved well in time. Thus, the real-time communication between patients' WBSNs and remote servers will become a very important challenge [7,8]. Despite the intensive research efforts [9,10], such solutions are not commonly used in routine medical investigations today. The technology is still not mature, and there exists several constraints limiting the clinical possibilities. Some new improved functionality might possibly be implemented within a future 5G infrastructure, which will open for higher communication bandwidth, improved addressing solutions and improved security [11,12]. Hence, the integration of 5G along with WBSNs can be best possible solution for remote healthcare aplications. The purpose of the 5G network is not only to connect people but also to provide connectivity to any device or application that benefits from network access. Mobile technology evolution is a key component for the comprehensive development of M2M communications and the Internet of Things (IoT). Future 5G capabilities could generate significant improvements in many health scenarios, including the management and tracking of hospital assets, robotics-assisted tele-surgery, assisted living and remote monitoring of health or wellness data, and remote applications of medication [13]. 5G is based on paradigm shift that includes very high carrier frequencies with massive bandwidths, extreme base station (BS) and device densities, and unprecedented numbers of antennas [14,15]. As a key technology of 5G, massive multiple input multiple output (MIMO) technology can tremendously improve the performance of wireless networks. Massive MIMO BSs are equipped with a very large number of antennas, possibly tens to hundreds of antennas, and simultaneously communicate with multiple users on the same frequency band [16,17]. 5G technologies possess following key capabilities for mobile health monitoring including very low latency, long battery time, security, bandwidth scalability, network Capacity, and massive numbers of devices as shown in Fig.1. These all capabilities formulate 5G technologies as more useful approach for real-time health monitoring.

A.Mishra et al [18], propose a new architecture for continuously sending physiological data with low resource consumption. Moreover, they assumed that 5G technologies will enable a considerable increase in transmission rates and must provide dedicated channels for processing and delivering relevant biomedical data. Thus, these resources allow service continuity in cases of network congestion. The authors declare that by offering these features, 24-7 remote patient monitoring solutions could soon become a reality [18]. S. Nunna et al [19], discuss how 5G technologies can be combined with mobile edge computing (MEC) to provide an ad-hoc system of collaboration in real time. They showed a use case related to remote tele-surgery, which has stringent requirements for latency and application criticality. Besides that, their research points out that 5G technologies and MEC are still in the preliminary development stages, but they will be able to evolve to become revolutionary in boosting the e-health and m-health fields [19]. B.Arunsundar et al [20] proposed a new architecture based on ubiquitous 5G for telemedicine that uses

Electrical Engineering Department, Sukkur Institute of Business Administration.

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cognitive networks and multiple-input/ multiple-output technology. In the proposed architecture, indoor and outdoor scenarios are differentiated to increase the efficiency of data transmission according to the environment [20]. In [7], a new architecture for the emergency healthcare system based on mobile cloud computation (MCC) and 5G wireless link is proposed. Based on the processing speed of MCC and the communication rate of 5G scheme, this system can monitor and locate patients in real time. Multiple base stations of the massive MIMO cooperate with each other to locate the patients using cross-location method. In [21], the design of a heterogeneous communications network is proposed with M2M communications and MTC for interconnection between intelligent devices without the need of human intervention.

The contribution of this paper is twofold: First, CSE-TPC Algorithm is designed to save energy in WBANs. Second, transmission power and energy are evaluated in terms of network metrics, such as; modulation level, duty cycle, pulse shaping filter-roll off factor, symbol error rate, distance, and Peak-to-average ratio (PAR).

Remaining of the paper is organized as follows. Section II presents the design the CSE-TPC Algorithms, Section III, presents experimental results and conclusion is discussed in Section IV.

II. CHANNEL STATE ESTIMATION-BASED TRANSMISSION POWER CONTROL ALGORITHM

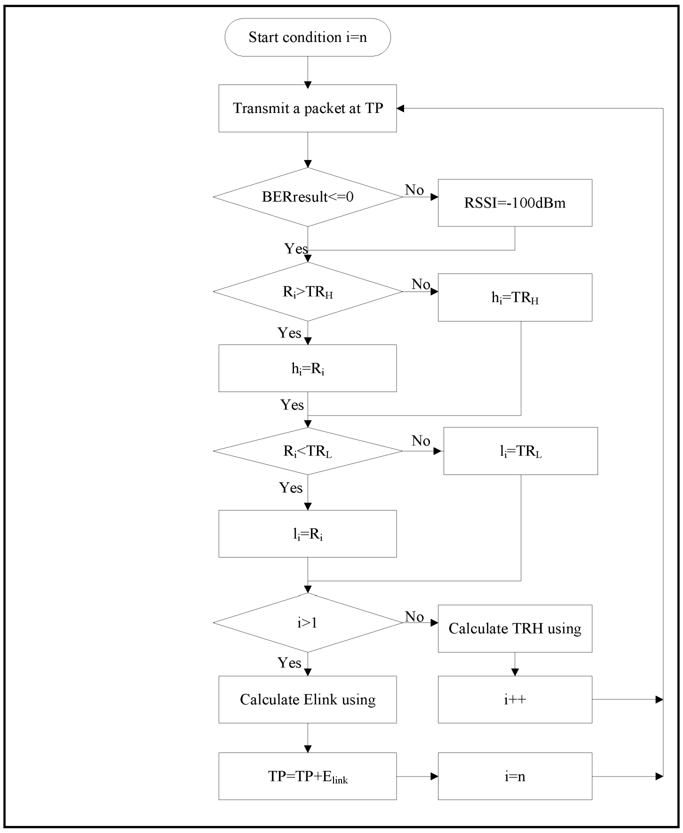

Fig. 1 Channel State Estimation based TPC Algorithm [22,24]

The channel state can vary greatly or frequently with the body posture or motion. When the channel state deviates significantly, the transceiver should quickly adapt the transmission power to the shift. If the channel fluctuates frequently, the transmission power control protocol should reflect its transition pattern rather than the momentary channel state. To satisfy these requirements, a CSE-TPC algorithm is designed and discussed in cited research [22,24], that simultaneously estimates the channel state in short and long terms.

The channel state is determined by fading, path loss, and shadowing in the WBANs. The WBAN propagation paths can experience fading due to several reasons: energy absorption, reflection, diffraction, shadowing by the human body, body posture, antenna orientation, and multipath. The path loss depends on the distance and frequency. The path loss model in free space is based on the Friis formula, which can be shown in decibels between a sender and a receiver as follows:

$$PL_{dB}(d) = PL_{dB}(d_0) + 10 \times n \times \log 10(d / d_0) + S \quad (1)$$

Whereby, $PL_{dB}(d_0)$ is the path loss at a reference distance and n is the path-loss exponent.

$$PL_{dB}(d_0) = -20 \times \log 10(\lambda / 4\pi d_0) \quad (2)$$

$\lambda = \frac{c}{f}$, where c=3x10^8 m/sec and f=2.4GHz, and S shows shadowing.

To select the optimal transmission power, identifying the channel state between the hub and the sensor node is significant.

A. *Short-Term Channel State Estimation*

The purpose of the CSE-TPC algorithm is to maintain the RSSI within a target RSSI threshold range (TRL, TRH) at the receiver. The traditional TPC methods [23],[25],[26] use the preceding or average RSSI to estimate the channel state. The preceding RSSI indicates the latest momentary channel state. However, if the RSSIs frequently deviate, the preceding RSSI can not precisely present the current channel state because it changes rapidly. The average RSSI includes several RSSI samples during a dedicated period, which reflect the channel state for that period. Nevertheless, the average RSSI can not indicate the accurate channel state because averaging offsets the RSSIs out of the target RSSI threshold range when the channel state that frequently fluctuates. To remedy that challenge, the CSE-TPC algorithm is designed based on [22],[24] to estimate the channel state by taking into-account only the RSSIs out of the target RSSI threshold range. The RSSIs above TRH are related to the redundant energy consumption, which can be decreased by reducing the transmission power. In this study, it has been referred as h_i, where i denote the sequence number of a received packet. A smaller i represents a more recently received value. h_i can be calculated in eq. (3) as

$$h_i = \begin{cases} R_i & if\ R_i > TR_H \\ TR_H & if\ R_i \leq TR_H \end{cases} \tag{3}$$

whereby, R_i indicates the RSSI at sequence i. If the RSSI is less than or equal to TR_H, TR_H is inserted into h_i to calculate only the RSSIs that exceed TR_H.

The RSSI value below TR_L is associated with a poor channel state. Thus, this value is symbolized as l_i in eq. (4)

$$l_i = \begin{cases} R_i & if\ R_i > TR_L \\ TRL & if\ R_i \leq TR_L \end{cases} \tag{4}$$

Using h_i and l_i, it can be verified whether the transmission power is overestimated or underestimated. To evaluate more accurately the channel state including h_i and l_i, eq. (5) is helpful.

$$E_{link} = \frac{\sum_{i=1}^{n}(TR_H - h_i) + \sum_{i=1}^{n}(TR_L - l_i)}{n} \tag{5}$$

Eq.(5) shows the short-term channel state estimation parameter E_{link}, where n is the number of RSSI samples for calculating E_{link}. The left-hand-side summation in eq.(5) indicates the average RSSI deviation from TR_H, which represents the amount of redundant energy consumption that can be reduced by decreasing the transmission power. The right-hand-side summation denotes the average deviation from TR_L. This value is related to the channel reliability, which can be enhanced by increasing the transmission power. With this equation, the necessary RSSI can be estimated for a good channel state. If E_{link} is negative, the transmission power is excessive rather than insufficient. In this case, the node should decrease the transmission power by a factor of $|E_{link}|$. On the other hand, a positive E_{link} implies poor channel reliability; thus, the transceiver should increase the transmission power by a factor of $|E_{link}|$. The short-term channel-state estimation is a more precise solution than the ordinary channel state estimation that uses the average RSSIs. Moreover, the required transmission power level can be identified by means of E_{link}. Therefore, the CSE-TPC can adjust the transmission power more precisely and quickly.

B. *Long-Term Channel State Estimation*

The conventional transmission power control methods in [23],[25],[26] use a fixed-target RSSI threshold range, which is enough to guarantee high reliability. However, high reliability cannot be guaranteed if the channel state varies frequently and abruptly, because the RSSI oscillation scale is larger than the target RSSI threshold range. In this case, the transmission power is repeatedly overestimated or underestimated. For instance, if the RSSI exceeds the target RSSI threshold range, the transceiver decreases the transmission power. However, when the channel state suddenly worsens, decreasing the transmission power results an insufficient RSSI below TR_L ,which causes the transceiver to increase the transmission power to improve the channel reliability. This process is repeated during the body movements, i.e., the channel state fluctuates and consequently worsens both the energy efficiency and channel reliability [22].

If the target RSSI threshold range is larger than the RSSI variation range, no problems arises. Although a large target RSSI threshold range gives robust channel reliability, it causes the transceiver to use unnecessarily high transmission power, particularly when the variation of the channel is small. In other words, the target RSSI threshold range involves a trade-off between the energy efficiency and channel reliability. The conventional transmission power control protocols use a fixed-target RSSI threshold range regardless of the channel state, which implies sacrificing either the energy efficiency or the channel reliability. The target RSSI threshold range can be adaptively adjusted according to the RSSI variation range of the channel. Therefore the target RSSI threshold range can be configured according to a standard deviation of $5 \times n$ RSSI samples. The $5 \times n$ RSSI samples were used to reflect the long-term channel state to the target RSSI threshold range. CSE-TPC increases or decreases TR_H depending on the long-term channel state [22],[24].

$$TRH_{var} = TRL + \sigma \tag{6}$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R_i - \overline{R}\right)} \quad , \ i = 1, 2, \ldots\ldots\ldots, n \tag{7}$$

The 3-dBm value for a minimum target RSSI threshold range was enough because the variation range was from 1 to 2 dBm, even in the stationary scenario. This variable TR_H enabled the channel reliability to increase at the expense of a little energy wastage. Therefore, the transceiver can maintain higher channel reliability by considering its state. Fig.1 shows the flow chart for the CSE-TPC algorithm. The process of deciding the transmission power (TP), is summarized in this flow chart [22],[24].

III. RESULTS AND DISCUSSION

The CSE-TPC algorithm is designed in MATLAB for saving energy in WBANs. Besides, trade-off between transmission power and 5G network metrics e.g., duty-cycle and modulation level is established. It is observed that more energy is saved with CSE-TPC.

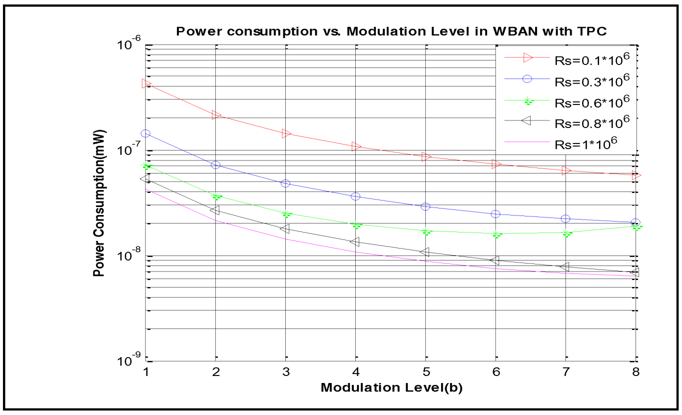

Fig.2 Relationship between power consumption and Modulation Level

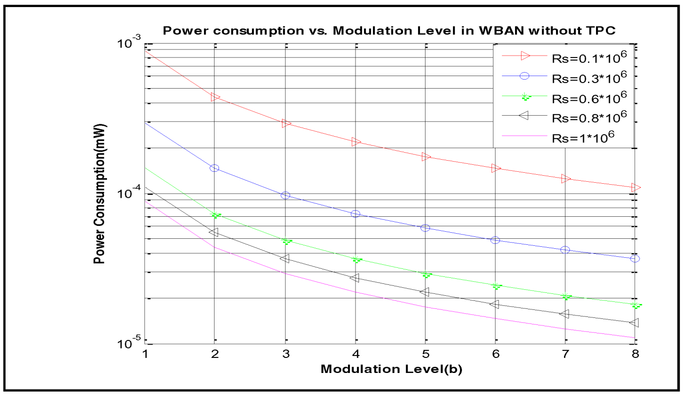

Fig.3 Relationship between power consumption and Modulation Level without

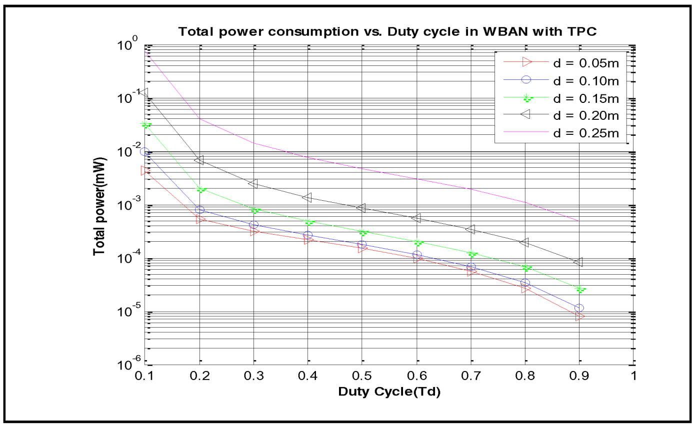

Fig.4 Relationship between power consumption and duty cycle with TPC

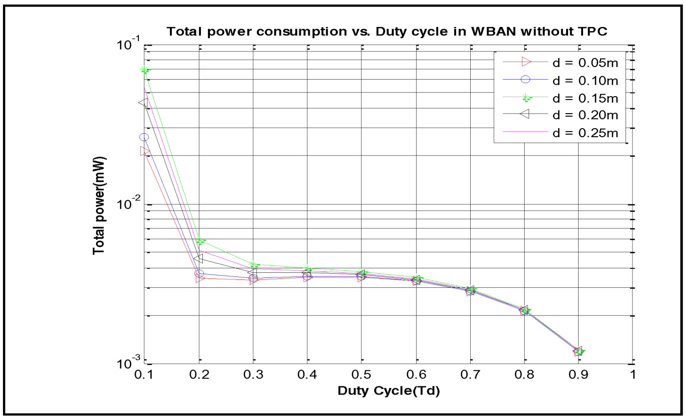

Fig.5 Relationship between power consumption and duty cycle without TPC

Fig.2 and Fig.3, shows the relationship between modulation level and power consumption at different symbol error rate values with and without CSE-TPC algorithm respectively. It is analyzed and observed that more power is consumed when TPC is not used as in Fig.2, and less power drain is achieved with the use of CSE-TPC algorithm as in Fig1. In addition, it has been examined that increase of symbol error rate (SER) value minimizes power consumption in both Fig.2 and Fig.3.

Fig.4 and Fig.5, reveals the trade-off between duty-cycle and total power consumption at different distance values with and without CSE-TPC algorithm respectively. It has been examined that more power is consumed without using CSE-TPC algorithm, while less is used by adopting that algorithm. Moreover, it is analyzed that when distance increases more power is drained as depicted in both Fig.4 and Fig.5.

IV. CONCLUSIONS AND FUTURE RESEARCH

This paper designs Channel State Estimation- based Transmission Power Control (CSE-TPC) algorithm for QoE optimization in terms of modulation level and duty cycle over 5G networks. CSE-TPC adapts the transmission power level according the dynamic nature of wireless channel. A log-normal channel model is considered to minimize energy consumption in Wireless Body Area Networks (WBANs). Through simulation results in MATLAB it has been observed that energy is saved with CSE-TPC algorithm, therefore this algorithm is considered to be suitable for medical applications.

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