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A Channel-Aware Duty Cycle Optimization for Node-to-Node Communications in the Internet of Medical Things

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Abstract
Energy optimization during node-to-node communication in most of the sensor-enabled networks plays the major role to understand the entire mechanism of any system. With their rapid and emerging role has emphasized the researchers and academicians to focus at the wireless channel and its imperative role in the short-range transmission networks. As wireless channel plays the vital role in achieving the efficient and timely communication between transmitter and receiver in internet of medical things (IoMT) environment. Based on the quality of the channel IoMT system is classified as an energy-efficient or not. To remedy this issue, this paper contributes in two ways. First, the novel energy-efficient framework and channel-aware energy-efficient algorithm (CEA) for the IoMT system in medical healthcare domain are proposed. Second, channel quality analysis indicators such as, received signal strength indicator and transmission power levels are adopted. Besides, main open systems interconnections layers, for example, network, MAC and Physical with crucial energy optimization attributes, i.e., route discovery, duty-cycle, and modulation level or data rate during node-to-node communication in IoMT are adopted to see the effect with and without using CEA in the IoMT system. Experimental results reveal that proposed CEA outperforms by saving more energy in comparison to the Baseline technique.

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Keywords Channel-aware · Node-to-node communication · Duty-cycle · Internet of medical things

1 Introduction

Wireless Communication is considered as the backbone of several emerging systems to get a timely response and stay connected with everyone throughout the world. In this connection, dynamic channel or wireless link is the most essential ingredient to decide about the key status of the entire platform. Emerging role of the Internet of Medical Things (IoMT) is the paradigm shift in every domain especially the healthcare where the access of sensitive information from physicians to patients and vice versa is very vital. While the communication (i.e., transmission) playing the major role in successfully transmitting the data at the desired destination but due to the dynamic nature of the channel most of the power is dissipated in sensor nodes of IoMT as shown in Fig. 1. Stable channel modeling is the way to allocate the resources efficiently. The node-to-node communication in IoMT is entirely changing the map of the academic and research domains by classifying the technological activities into new directions such, deep learning, artificial intelligence, sensor-based smart devices, smart medical homes, intelligent ambulances, etc. [3]. Emerging boom and flexible nature of IoMT based fields one can expect the smarter, user-friendly and greener platforms with a longer lifetime of the system.

The usage of the IoMT and inter-dependent technologies with greater deployment capabilities is dramatically increasing for example, a number of sensor-enabled internet devices were less in last years but in 2018 their number is increased up to six times throughout the world according to the growth rate of the population [3]. Resource-constrained nature of all the sensor based devices in IoT, sensor networks, fog computing, etc. it is very vital to adopt the battery lifetime and power wisely and efficiently to welcome the future technologies too. For the proper and reliable communication with effective energy utilization, the role of the wireless channel is necessary, which helps to rectify the delay-sensitive slots of the overall system. So, in this channel optimization entities are considered at the various OSI layers for example, network, MAC, and Physical with the state-of-the-art techniques. Efforts for the adaptive and stable channel have rarely been put, so the primary goal of this research is to focus at the channel-aware novel energy-efficient mechanism for the healthcare applications i.e., IoMT. Besides, channel status and energy management based on the duty-cycle adaptation, time switching between sensor nodes in IoMT is touched by very few researchers, so it is dire need to explore that area with deep digging tools. This study emphasis on the point-to-point communication in IoMT system, through considering the single-hop star topology with transmitter and base station (BS) over the dynamic wireless channel. By examining the features of the data transmission in association with the wireless channel in medical healthcare, we focus at the three OSI layer with separate energy optimization ingredients in order to achieve the maximum energy-efficiency. This paper proposes the duty-cycle based channel-aware energy-efficient algorithm (CEA) by considering the features of three OSI layers with different optimization parameters in the IoMT. In the start channel conditions (i.e., good and bad)

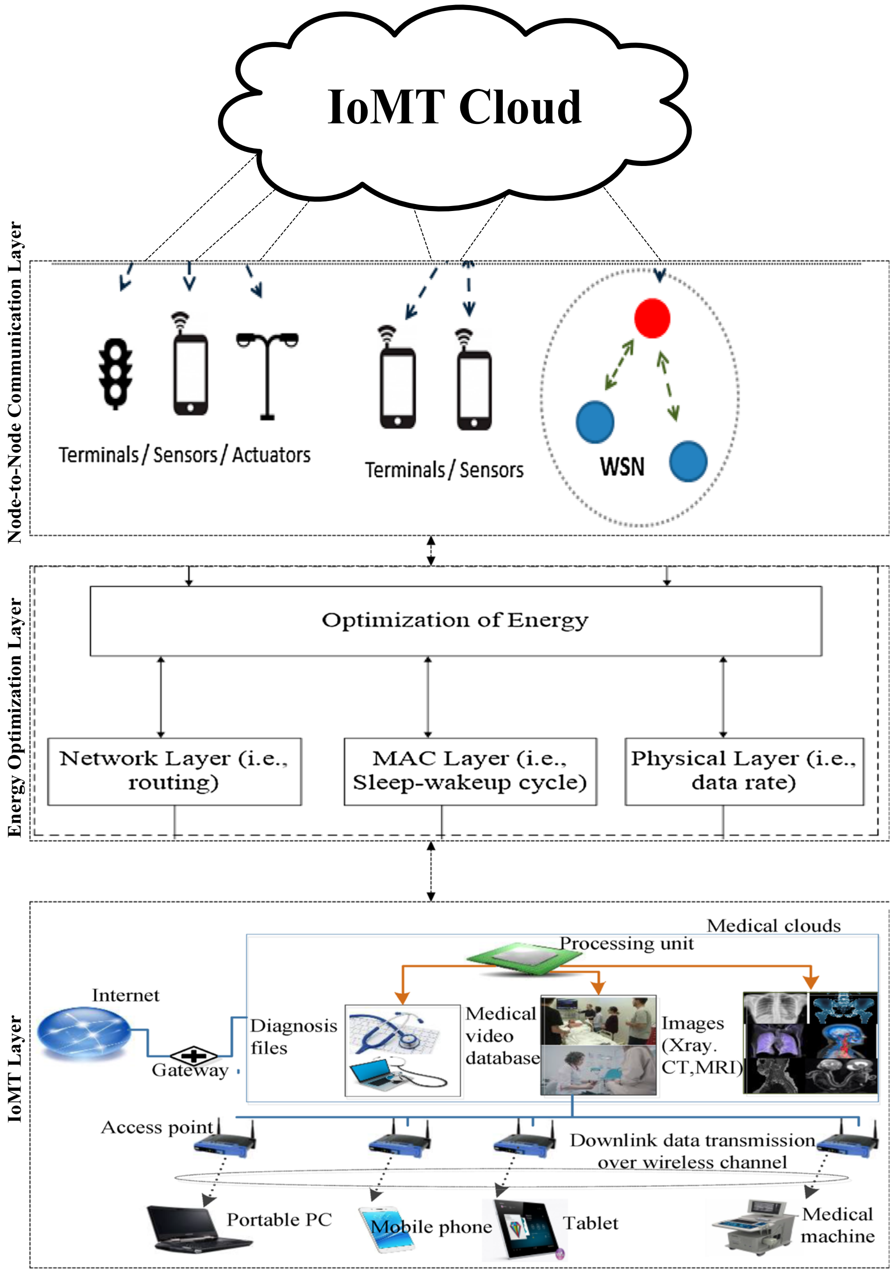

Fig. 1 The framework of node-to-node communication in IoMT

are recognized based on the sleep and wake-up times, then energy saving is predicted by following those results. The beauty of the proposed CEA is that it does not need the feedback information; because it occupies several resources. Only the duty-cycle optimization is the key component to decide the range of the energy saving in the IoMT [4].

There are several challenges while dealing with the wireless channel, for example, transmission errors in it due to shadowing and fading mechanisms, in order to fix these link-layer enabled techniques for instance, automatic repeat request and forward error correction are playing the active role. Also ARQ's performance widely accepted that the FEC and is further categorized into three sub-parts i.e., stop–stop and wait, go back-N, and selective repeat (SR). Much work is done on these conventional channel error correction methods in wireless, sensor and cellular networks with generic applications but the work on healthcare application with adaptive channel and energy optimization is still un-touched domain [5, 6].

With other efficient techniques, adaptive modulation and coding (AMC) is the key element [7] to include for the effective resource allocation and in the IoMT during node-to-node communication. AMC is the Physical layer related quantity for the active power allocation and data rate adaptation. Moreover, it has the direct link with the duty-cycle at the MAC layer and route discovery at the network layer. Channel-aware techniques in collaboration with various optimizing entities at the different OSI layers are very supportive in the fade and shadowing environment to manage the resource in the IoMT [8, 9]. In this research re-transmission of the lost/dropped packets is considered but only the transmission from transmitter sensor node to the BS is entertained by optimizing the duty-cycle in the IoMT because the feedback mechanism will consume the more power in the sensitive information sharing health platform [10, 11]. Many research works are presented in association with the packet re-transmission but these techniques are not the suitable for the sensitive healthcare domains, and static fading and shadowing enabled Friis wireless models [12]. Our paper proposes the CEA based on the duty-cycle based energy optimization with performance indicators over various OSI layers for sustainable IoMT system which is very important in a healthcare environment. Besides, the emerging value-added importance and impact of the wireless channel on the transmission mechanism are presented by adaptation of the numerous energy optimization entities over the three OSI layers. The proposed CEA is very supportive in numerous IoMT based healthcare platforms where rapid and frequent packet sequences are gathered and transferred over the short and long distance accordingly.

The main contribution of this paper is twofold. First, the novel energy-efficient framework and channel-aware energy-efficient algorithm (CEA) for the IoMT system in medical healthcare domain is proposed. Second, channel quality analysis indicators such as received signal strength indicator (RSSI) and transmission power levels are adopted. Besides, main open systems interconnections (OSI) layers, for example, network, MAC and Physical with crucial energy optimization attributes, i.e., route discovery, duty-cycle, and modulation level or data rate during node-to-node communication in IoMT are adopted to see the effect with and without using CEA in the IoMT system.

The remaining paper is arranged as follows. A rigorous literature review is presented in Sect. 2. Section 3, proposes the system mode, framework, and change-aware energy-efficient algorithm in a detailed manner. Results are extracted in Sect. 4. Finally, Sect. 5 concludes the entire paper.

2 Related Work

Several researchers worked on the different domains such as energy efficient systems, Internet of Things, Physical layers, MAC layers, etc. But this paper present the novel idea of a channel-aware energy-efficient IoMT system with the unique framework.

Authors in [1], develop the various channel modeling approaches for the medical applications such as on-body, in/implantable by considering the shadowing and fading components. Krishna Kumar et al. [2], develop the frameworks, challenges and various solution to optimize the energy in the IoT systems. Bagula et al. [3], propose the novel energy model for the IoT platform. Yang et al. [4], present a cross-layer based energy model for the multi-media sensor networks. Besides, their research adopts the several OSI layers for the energy maximization in the general multimedia sensor networks, but they do not focus on the channel modeling and its emerging role in the IoMT system. Mukherjee et al. [5], propose a generalized link-layer communication mechanism to show the movements/deviations in the channel for enhancing the energy. Their communication strategy does not consider the fading component and duty-cycle optimization for classifying the channel accordingly. Zhang et al. [6], develop the adaptive channel enabled access algorithm by adapting the ACK parameter in the ZigBee networks, but the duty-cycle based techniques with the channel categorization and energy saving are not the key focus.

Kao et al. [7], present the three key contributions by proposing underwater channel model, its challenges and evaluation consequently. But their work do not emphasise the duty-cycle based channel aware energy saving environment for the IoMT system. Sodhro et al. [8], propose the joint IoT and their product lifecycle management algorithms to extend the battery lifetime and hence save the power. Their state-of-the-art techniques are based on the transmission power control and duty-cycle for managing for optimizing the battery charge consumption. But they do not consider the wireless channel and energy optimization parameters at the network and physical layers in IoMT. Deng et al. [9], establish the tradeoff between power consumption and transmission delay in the fog-cloud computing domain. Besides, they consider the work-load management policies for the wireless networks. While the duty-cycle and channel-aware based energy saving in the IoMT is not the center of attention. Wang et al. [10], present sensing layer-based approach to analyse the power dissipation amount in several sensor nodes. Besides, they design the novel architecture based on the sensing, gateway, and control layers, but they duty-cycle and channel-aware energy saving in association performance indicators and OSI layers is not entertained. Kaur et al. [11], presents the novel framework for the IoT application with main focus at the three layers, for example, sensing, and control, information processing and presentation. But they do not focus on the channel-aware energy saving techniques by adopting the various optimizing indicators over the network, MAC and Physical layers for the IoMT system. Kaur et al. [12], propose the software-defined network and edge enabled environment in the presence of big data for the industrial IoT. While the duty-cycle and channel-aware techniques with various optimization parameters over distinct OSI layers are not emphasized. Zhong et al. [13], design the software-defined networks based architecture with various layers to explore the challenges, issues, and solutions. But the channel enabled energy optimization techniques in collaboration with multiple entities in IoMT and healthcare is not the primary interest. Singhal [14], highlights the critical on-going problems and designs the potential cross-layer architecture to explore the importance and impact of the quality of experience (QoE) in the emerging future networks especially, television and multimedia platforms. While the channel-aware and the duty-cycle based energy-efficient mechanism is not the main attention for the IoMT system.

Smulders [15], discuss that short-range wireless networks are supporting data rates up to high level, i.e., in Gigabytes for the ultra-high applications in the today's emerging machine-to-machine communication. While they do not focus on the channel and duty-cycle optimization based energy saving algorithms in association with the network, MAC and a physical layer for IoMT networks. Rani et al. [16], present the various challenges of the energy saving in the IoT networks and then design the framework with different novel layers. While they do not consider the channel-aware and duty-cycle based algorithm in collaboration with various OSI layers in IoMT system. Sodhro et al. [17], develop the electrocardiogram chip for the human heart-rate data collection and filtering that data by proposing the various filters. Besides, they recommend the energy-efficient algorithm based on the transmission power control mechanism to effectively transmit the data. Xu et al. [18], design the power control based resource-saving method but they do not consider the channel-aware and duty-cycle based policies for the energy optimization in IoMT. Dong et al. [19], propose the joint power control and time time-slot changing mechanism for the QoS optimization in wireless power transfer technology. While they do not adopt the channel and duty-cycle based techniques for the energy management in the IoMT platform. Ibarra et al. [20], develop human energy harvesting based QoS optimization and energy enhancement in WBSNs, besides their work presents extensive experimental evaluation.

Pirbhulal et al. [21], present the comparative analysis of the fuzzy-vault based security algorithms for the medical healthcare applications. Sodhro et al. [22], proposes the Green IoT system for the medical healthcare system, they proved through experimental analysis that their algorithm outperforms the conventional one. Pirbhulal [23], propose the IoT based biometric security algorithms for the home automation applications. Xu et al. [24], discuss in detail the survey of wireless power transfer and power control based techniques with novel algorithms. Conversely, they have been established and examined independently. Hao et al. [25], develop an energy harvesting based BAN system for smart medical applications, their research proposed a novel energy-efficient framework for the healthcare industry. Hence, because of the heterogeneous nature of the networks, there is a time synchronization, large latency, more power drain issues and very less attention has been pain to fix these with state-of-the-art methods. Sodhro et al. [26], develop the various energy-efficient algorithms for the medical healthcare applications especially, BSN with the novel concepts with several proves. Authors in [27–30], propose the novel security based algorithms for and physiological monitoring for healthcare, they tested their algorithms both on the software and hardware.

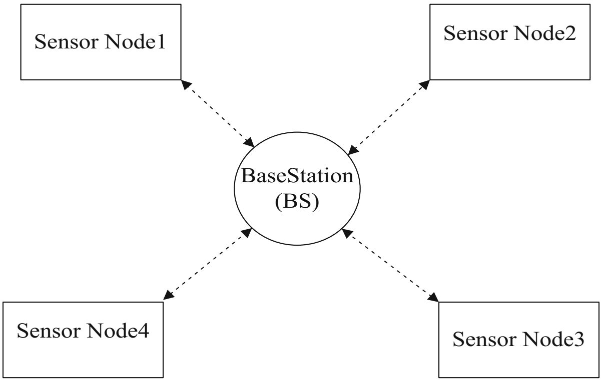

Fig. 2 Single hop network topology for IoMT

3 Proposed Channel-Aware Algorithm

In this section, we present the detailed discussion of the proposed channel-aware energy-efficient algorithm (CEA), system model and framework for the IoMT. Each of these is described one by one as follows.

3.1 System Model

A single-hop star network topology is used which consists of a single Base Station (BS) and four interconnected sensor nodes as depicted in the Fig. 2. The sensor nodes rapidly collect the channel information, i.e., bad or good quality according to the wakeup and sleep time of the transceiver accordingly. Then the various optimization entities are considered at the three OSI layers such as network, MAC, and Physical for the energy saving in the IoMT systems in the medical healthcare.

IoMT intends to allow the sensor nodes to exchange the sensitive health information by following the needs of the patients and physicians by the channel behavior. But the traditional wireless channel models are not the complete the guidance to fulfill the criteria of the healthcare platforms. Thus proposed channel-aware energy-efficient algorithm is proposed which works by the duty-cycle adopted strategy over the three OSI layers. Transmitter and BS are the leading entities to transfer the data packets at intermittent intervals. Besides, in IoMT system BS receives one data packet from the sensor node and responds to respective data packet after the short inter-frame space period (PFS) after analyzing the sleep and wake-up period of the transceiver and hence, examining the channel quality of the of the entire system. By the duty-cycle mechanism, an immediate acknowledgment (I-Ack) will be sent to the BS while getting the complete information regarding successful packet delivery, less delay and high energy saving in the IoMT as represented in the Fig. 3.

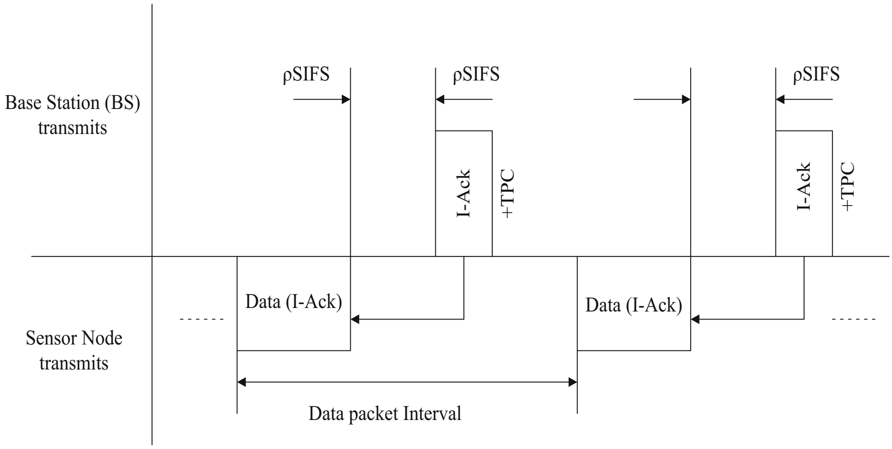

Fig. 3 Periodic transmission of the data packet with immediate acknowledgment [10]

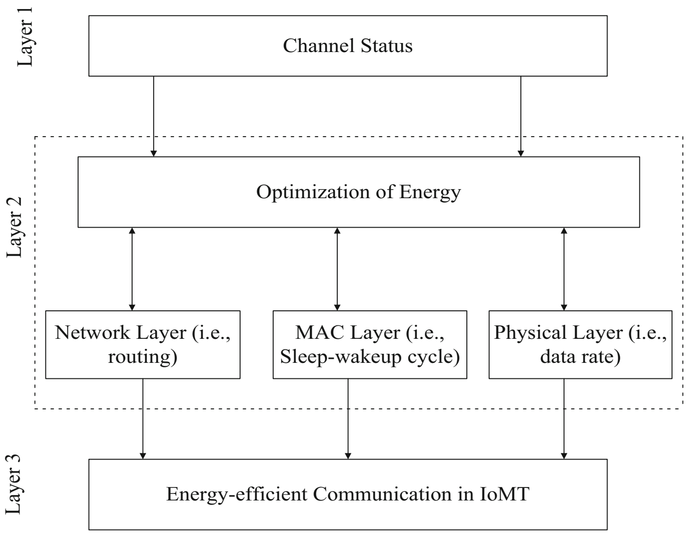

Fig. 4 Framework of energy-efficient communication in IoMT

3.2 Energy-Efficient Framework for IoMT

This sub-section proposes the novel energy-efficient framework for the IoMT (Fig. 4) which is based on the key features of the wireless channel. Channel states are classified in the good and bad entities at layer 1. Energy is optimized at layer 2 with the network (i.e., routing), MAC (i.e., sleep-wakeup cycle) and Physical (i.e., data rate or modulation level) layers. Finally, the layer three energy is optimized for the IoMT healthcare domain.

The channel states are the differentiated by the channel gain or received signal strength indicator (RSSI) level for checking the stability or deviation in the entire communication system of IoMT. Duty-cycle is the significant attribute to be considered for the vast analysis of the channel and hence the energy in the IoMT.

We consider network, MAC, and Physical layer interconnection with various optimization and tuning entities to save energy in the IoMT. The two key transmitter and BS nodes are leading entities while exchanging and transferring information. The system is divided into various time slots by the duty-cycle mechanism or the sleep and wake up a pattern of the transceiver, which is very helpful to analyze the channel quality and hence energy optimization level. The short slot duration time of $\rho SIFS$ sec is introduced between sleep and wake-up intervals at the MAC layer. Channel remains more stable after examining the performance indicators, and then channel gain and RSSI values are adapted accordingly. In this way, our proposed CEA does not need the feedback or acknowledgment information form the BS. In this way, no more overhead packets are required because more power is consumed.

The proposed energy-efficient framework for the IoMT system is the guideline for effective duty-cycle based applications. On the basis of the channel quality and sleep wakeup time of the transceiver time slots are separated by sending the short interval $\rho SIFS$ as a feedback to the transmitter or checks the energy saving level by following the channel quality (i.e., bad or good). Packets will be lost if there is a bad channel state and vice versa, then the RSSI level or channel gain values are adopted accordingly. Moreover, we can say that the channel is considered to be in good condition when the transceiver is sleeping for the longtime and bad state is achieved when the transceiver is an inactive state for a long time. Furthermore, the proposed energy-efficient framework interlinked with the channel-aware energy model to optimize the energy in the IoMT system. Channel characteristics are the key ingredients to be further exploring the vitality of the healthcare platform regarding the critical performance indicators, for example, RSSI, channel gain, deviation in the RSSI and packet loss ratio (PLR), etc.

3.3 Channel-Aware Energy-Efficient Algorithm (CEA)

As proposed channel-aware energy-efficient algorithm (CEA) is based on the medium access control (MAC) layer working principle in which channel state is determined by sleep and wakeup periods of the transceiver. If the transceiver is a wakeup for longtime, then more energy will be dissipated and transmission will not be continued longer due to the bad channel state. Similarly, good channel state can be observed if the transceiver sleeps longer which saves more energy and higher duty-cycle as shown in the Fig. 5. So, it can be said that duty-cycle the critical attribute to save more power by the channel state in the IoMT system. Moreover, we present the joint integration of wireless channel and energy models to optimize more energy during transmission in the sensor-enabled IoMT system, as shown in the Eqs. (1)–(4). A key goal of the proposed CEA is to save the energy in IoMT system by following the channel characteristics.

We calculate average transmission power of typical conventional baseline technique and our proposed CEA then measure the energy per bit and average energy saving for both former and later respectively. Moreover, the channel state is determined by sleeping and wakeup conditions of the transceiver in the IoMT. Here, we adopted the

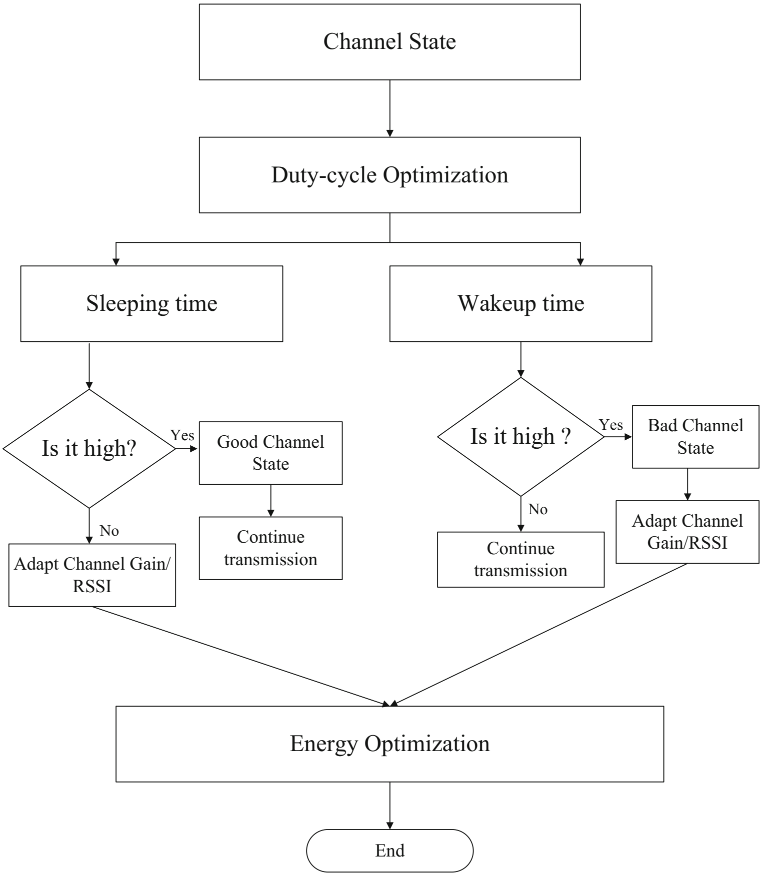

Fig. 5 Proposed channel-aware energy-efficient algorithm

free space channel model based on the duty-cycle of the sensor nodes in association with the route-discover and date rate or modulation level at the network and physical layers of the OSI model. Path loss model helps the CEA to get the entire information about the channel from the dropped/lost packets, which also plays the significant role in determining the duty-cycle optimization and hence the energy saving in the IoMT. Also, we can that path loss is associated with the distance to realize the overall performance of the healthcare platforms due to their sensitive and critical information sharing capabilities. Equation (1), exploits the basic path loss model which leads to identifying the features of the channel to optimize the energy in IoMT system.

$$PL_{dB}(d) = PL_{dB}(d_0) + 10 \times n \times \log10(d/d_0) + S \quad (1)$$

whereby, S, $PL_{dB}(d_0)$ and n are the shadowing (i.e., standard deviation), path loss exponent at initial distance, respectively.

$$PL_{dB}(d_0) = -\ 20 \times \log10(\lambda/4\pi d_0) \quad (2)$$

$$\lambda = \frac{c}{f}, \quad \text{where } c = 3 \times 10^8 \text{ m/sec and } f = 2.4 \text{ GHz}.$$

To optimize the energy in the IoMT system based on the channel state by recognizing the strong link between the base station and the sensor nodes accordingly.

$$E_{bit} = \frac{P_{ac}T_{ac} + P_{sl}T_{sl}}{L} \tag{3}$$

$$E_{tot} = \frac{P_{ac}T_{ac} + P_{sl}T_{sl}}{L} + PL_{dB}(d) \tag{4}$$

L is the packet length

$$P_{ac} = P_{PA} + P_c \tag{5}$$

$$P_{PA} = P_{amp} + TP \tag{6}$$

$$P_{amp} = \beta TP \tag{7}$$

$$\beta = \frac{PAR}{\rho} - 1 \tag{8}$$

Put Eq. (15) into Eq. (14), we have

$$P_{PA} = TP + P_{amp} = (1 + \beta)TP = \frac{PAR}{\rho}TP \tag{9}$$

$$T_{ac} = \frac{L}{R} \tag{10}$$

$$T_{total} = T_{ac} + T_{sl} \tag{11}$$

$$T_{sl} = T_{total} - T_{ac} \tag{12}$$

As P_{sl} and P_c are transmission power in sleeping mode and circuit respectively. Where, transmission power (TP) in Eq. (6) is transmission power. Put Eqs. (5), (10), (12) into Eq. (3) we will get energy per bit for each transmission power control method as discussed above.

4 Results and Discussion

In this study, 30 subjects between the age of 20 and 70 years are recruited from available public database MIT-BIH Arrhythmia Database (mitdb). This section presents the experimental set-up for the IoMT with the channel-aware energy-efficient algorithm (CEA) throughout our paper data packet, data frame and RSSI sample is used interchangeably. In this section, we compared and evaluated the performance of our proposed CEA algorithm with baseline through experimental in MATLAB concerning average values of RSSI and transmission power for the healthcare applications.

The MAC layer based duty-cycle optimization based on the channel-aware conditions for the healthcare platform, it is analyzed that more wakeup time saves more energy than the longer active time. Besides, it is analyzed that data rate and duty-cycle are inter-related for energy saving in IoMT for healthcare paradigms.

In this section, we evaluate the experimental results with and without using the proposed channel-aware energy-efficient algorithm for the IoMT system by considering the various performance indicators such as channel gain, RSSI, duty-cycle, modulation level, transmission power, etc. Joint integration of energy model and the shadowing channel is adapted to save the energy in the medical healthcare applications efficiently. Besides, experimental results are obtained by considering energy per bit and total energy with a RSSI level over the wireless channel in the IoMT system.

Also the performance of the proposed CEA is analyzed in terms of different channel states for example, bad and good on the basis of the wakeup and sleeping schedules accordingly in the IoMT platform. Different parameters are tuned into the network, MAC and physical layers to optimize the energy in the entire IoMT system. Channel-aware technique plays the significant role in the understanding the entire performance of the IoMT system.

Due to dynamic nature of the channel, it fluctuates at large extent and frequency with the RSSI and channel gain deviation. When the channel conditions are varying the duty-cycle should be adapted by the wakeup and sleep time of the transceiver by considering the characteristics of the OSI layers for the efficient energy optimization pattern in the IoMT domain. At the high deviation rate in the wireless channel it also necessary to minimize the errors by adopting the data rate or modulation accordingly in the IoMT system. So, by keeping dire needs into mind, we propose the CEA that optimizes the energy in the IoMT systems on the basis of the channel states and performance indicators for example, modulation level or data rate at the Physical layer, duty-cycle at the MAC layer and route discovery at the networking layer consequently.

Channel gain or received signal strength indicator (RSSI) is shown in Fig. 6a in relation with time. It is observed that higher the gain (in dBm) better the channel state and more the energy saving in the IoMT and vice versa. Besides, duty-cycle is the critical element to recognize the relationship between the channel conditions for the healthcare applications. Figure 6b, c, shows the relationship between time and transmission power level, RSSI for IoMT. It is revealed that channel state plays the major role in recognizing overall system performance. Besides, Fig. 6, exhibits the bad channel state due to variation in the RSSI and channel gain. In Fig. 7a, b, present the coordination modulation level or data rate and energy level per bit by adopting/not adopting the channel knowledge at various distance values. It is examined that more energy is dissipated in the absence of channel knowledge as in Fig. 7b. Similarly, less energy drain is achieved in the presence of the channel information with CEA as presented in Fig. 7a. In addition, it is observed that energy depletion increase in direct proportion with the rise in the distance in the IoMT system. Figure 8a, b, depicts the relationship between duty-cycle and total energy consumption at various distance values in the presence and absence of the proposed CEA. We analyzed that more energy is drained when offered CEA is not used while less energy is consumed in the presence of CEA. Besides, it is revealed that energy depletion is directly proportional to the distance value in the IoMT system for healthcare applications.

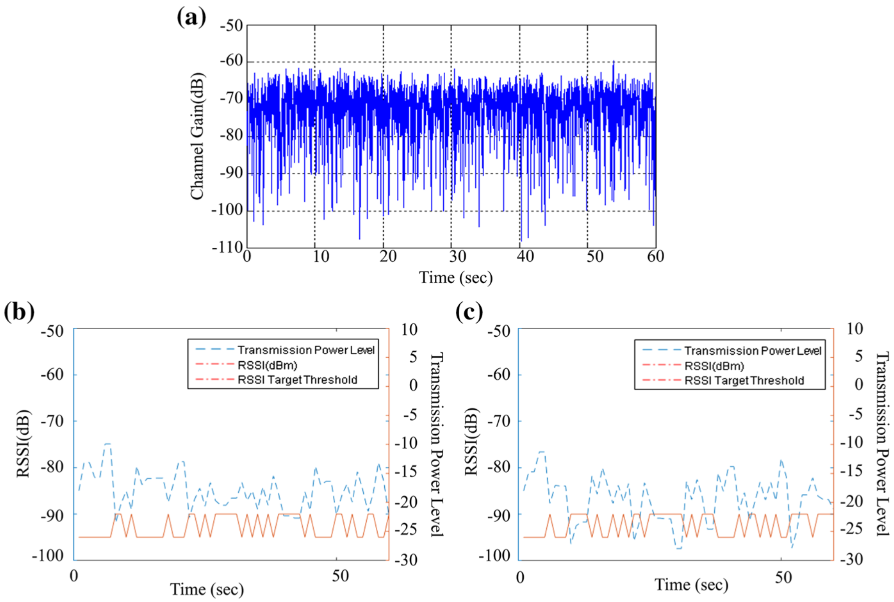

Fig. 6 Relationship between time and channel gain, RSSI, transmission power, **a** channel gain, **b** BAD channel state, **c** good channel state

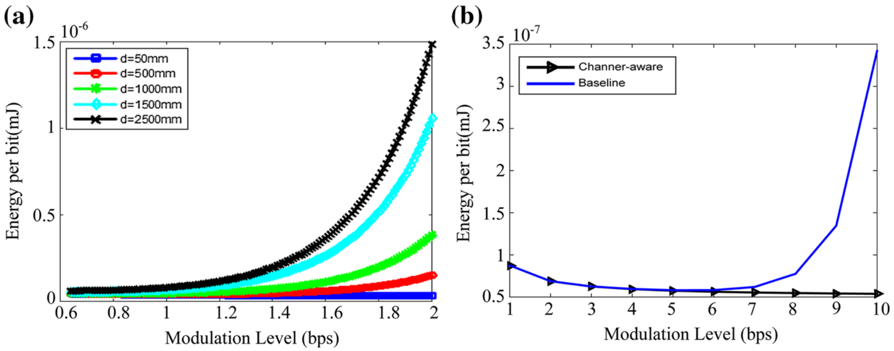

Fig. 7 Relationship between modulation level and energy per bit, **a** with channel-awareness, **b** without channel-awareness

5 Conclusion and Future Research

In this paper, we propose the channel-aware energy-efficient algorithm (CFA) for the energy saving in IoMT for healthcare application. The proposed CEA is based on the duty-cycle mechanism to save energy. The channel status is categorized on the basis of the sleeping and wake-up scheduling principle over the MAC layer. Proposed CEA intelligently optimizes the duty-cycle, route-discovery, network, and modulation level parameters at the MAC, network and Physical layer respectively to maximize the energy in the IoMT system. Besides, CEA does not use the feedback or acknowl-

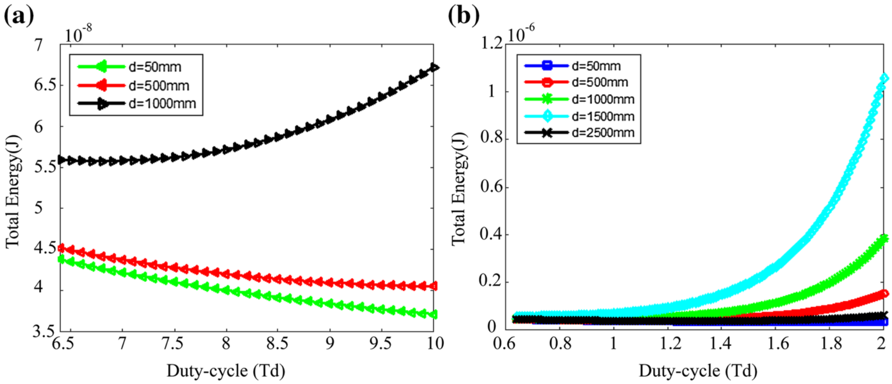

Fig. 8 Relationship between duty-cycle and total energy, **a** with channel-awareness, **b** without channel awareness

edgment pattern but follows the sleep and wakeup cycle of the transceiver to predict the energy saving in the healthcare fields. Channel is playing the emerging role in energy optimization of the IoMT. So, to obtain the desired outcome in this paper first, the novel energy-efficient framework and channel-aware energy-efficient algorithm (CEA) for the IoMT system in medical healthcare domain is proposed. Second, channel quality analysis indicators such as received signal strength indicator (RSSI) and transmission power levels are adopted. Besides, main open systems interconnections (OSI) layers, for example, network, MAC and Physical with key energy optimization attributes, i.e., route discovery, duty-cycle, and modulation level or data rate during node-to-node communication in IoMT are adopted to see the effect with and without using CEA in the IoMT system.

Following are the main limitations of our research work

- Channel-awareness contains some forward errors
- Proposed CEA includes slightly more RSSI deviations

In the near future we will develop the machine learning based secure and autonomous resource allocation schemes for the Fog computing, edge computing and IoMT in healthcare applications. It is also our future work to develop integrated low-power wearable devices and Bluetooth Low Energy (BLE) for real-time health monitoring.

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Author Contributions T. Han, M. Zeng, A.K. Sangaiah stated the research theme; T. Han and L. Zhang proposed the methods and performed experiments. M. Zeng and T. Han read the experimental results and wrote manuscript; and T. Han and A.K. Sangaiah assisted to organize the field activities and research.

Compliance with Ethical Standards

Conflict of interest The authors declare no conflict of interest.

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