Metrics on IEEE 802.15.4 and 802.15.6 Standards in Wireless Body Area Network

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Abstract — Low data rate, low duty cycle and low energy consumption are vital characteristics of the low-rate wireless personal area network. Simultaneously, the IEEE 802.15.6 standard is optimized for low cost, low power consumption, and reliable communication in wireless body area networks (WBAN). A comprehensive analysis of the two norms has been demonstrated in this paper under identical simulations and prototyping conditions under the MAC layer CSMA/CA-based scheme. An extensive scope of simulation conducted using NS2 and Opnet modeler to assess the throughput, delay, and energy depletion of the two norms in WBAN. The results show that IEEE 802.15.6 outperforms average throughput, delay, and energy consumption.

Inspect Classification: C5620

Keywords—LR-WPAN, WBAN, performance analysis.

I. INTRODUCTION

Novel technological concepts wireless personal area network (WPAN) and wireless body area network (WBAN) were introduced as a result of the tremendous study in the area of low power systems such as Bluetooth and IEEE 802.15 [1], [2]. WBAN terminology was familiarized by Van Dam back in 2001. In WBAN, tiny computational devices are practiced to measure bio-signals [3]. There are two standards defined for the bodily functions, i.e., IEEE 802.15.4 and IEEE 802.15.6. IEEE 802.15.4 sets a framework for a low rate, low cost, and low power communication known as low rate wireless personal area network (LR-PAN). Whereas, IEEE 802.15.6 termed as WBAN. The wireless network is a collection of sensor nodes featuring a low computational and sensing power. These tiny computational devices communication is of two types, i.e., in body communication and on-body communication. The medical implant communication system (MICS) is practiced for in-body communication, and the industrial and scientific (ISM) band is used for on-body communication [4]. Full network functionality is supported by full functional (FFDs), whereas partial tasks are performed by using reduced functional devices (RFDs) [5]. In both standards, super-frame is practiced to regulate the duty cycle of the nodes.

BO is the value that determines the beacon interval, and SO is used to determine super-frame duration. The values of these two parameters depict the performance metrics of the standard. Beacon is the signal sent along with every slot of the super-frame, and it contains network management information, resource allocation, and clock synchronization information. The PAN coordinator transmits the beacon periodically [6]. The IEEE 802.15.6 standard is optimized for cost effective, low power consumption, and reliable communication in WBAN. It operates on the MAC and PHY layer and uses a one-hop or multi-hop star topology. In star topology, nodes are directly linked to the hub, whereas in a two-hop star topology, all nodes are connected to access points with other nodes. The sensor nodes in WBAN are heterogeneous in naturess, as different physiological data are monitored by these tiny nodes [7]. These nodes monitor three types of data traffic. Patient routine surveillance is identified as normal traffic. In on-demand data traffic, the healthcare information can be accessed by a doctor while in emergency traffic, unpredictable traffic is reported [8].

To assess the efficiency of both IEEE 802.15.4 and 802.15.6 standards, we have conducted experiments in NS-2 and Opnet under the same simulation parameters setting and environment. Both standards are evaluated in terms of network throughput, end-to-end delay, and energy consumption.

The rest of the paper is structured as section II outlines the IEEE 802.15.4 and 802.15.6 standards, section III offers methodology, In Section IV, simulation and Results are discussed, Section V concludes results.

II.OVERVIEW OF IEEE 802.15.4 AND IEEE 802.15.6 STANDARDS

A. IEEE 802.15.4 Standard

This standard delineates the medium access control (MAC) and physical layer (PHY) of the open System interconnection (OSI) model [9]. The PHY layer is liable for initiating or deactivating the radio transceiver, send or receive data packets, and to measure the signal power and quality [10]. The MAC layer has two operation modes: beacon-enabled mode, and non-beacon enabled mode [11]. To synchronize and make the association of nodes, and to transmit data signal,

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the hub practices a beacon in super-frame structure that consists of two periods, as presented in Figure 1 [13]. The active period furthermore consists of 16 slots divided into two different access periods. In contention access period (CAP), the random transmission of the signal takes place however, within the time slot, which restricts devices not to start the communication of the packets in the mid of the time slot [14]. In CAP, CSMA/CA sachem is used for communication. Whereas in contention free period (CFP), guaranteed time slots (GTS) are used to access the medium. There are seven GTS that a coordinator can assign [15].

The non-beacon-enabled approach is used for those devices that remain inactive for a while. Any event triggers the device active and sends alert data to PAN using an unslotted CSMA/CA scheme. In contrast with beacon-enabled mode, devices do not require synchronization in this mode. As there is no synchronization of slots, super-frame channel access is done casually [16].

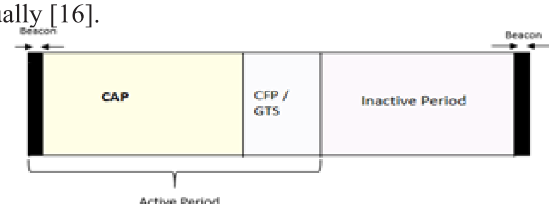

Figure 1. Super-frame Structure of IEEE 802.15.4.

B. IEEE 802.15.6 Standard

Formerly IEEE 802.15 defined BAN as norm for power-efficient devices that work nearby of the human body. User mobility and other biological functions are easily examined with these physiological sensors in WBAN. The shared medium is fragmented into super-frames or beacons of identical length for better resource allocation [17]. There exist several time-slots in a beacon, which are used for data transmission. Beacons are slots sent along with every super-frame and communicate with the coordinator in the beacon period.

The hub is responsible for selecting beacon boundaries [18]. In Beacon mode with super-frame boundaries, hub transmits beacon except for the inactive period. The super-frame is divided into four different phase's exclusive acces period (EAP), reserved for emergency data traffic. Managed access phase (MAP) revered for blink, uplink, and downlink allocation. Random access phase (RAP) and contention access phase (CAP) reserved for unexpected traffic [19] illustrated in Figure 2

Figure 2. Beacon mode with super-frame boundaries.

III. METHODOLOGY

The simulator model comprises three main modules, i.e., physical process, wireless channel, and sensors. NS-2 and Opnet provide a radio model for the integration of real demonstration of IEEE 802.15.4 IEEE 802.15.6 operated on the frequency of 2.4 GHz with star topology. The sensor module comprises 10 sensor nodes, including one coordinator node and the rest acting as network edge devices. By using CSMA / CA scheme, the nodes join the wireless channel.

This research work is based on a star topology in beacon-enabled mode with super-frame structure in 802.15.4 and 802.15.6 standard. BO and SO are responsible for choosing beacon intervals and active periods in the beacon interval. The active portion further consists of CAP and CFP. When a sensor device needs access to the medium, the start of the next time slot must compete for the medium. Based on CSMA/CA, this period is known as CAP. In both standards, the PAN has the authority to assign GTS to some sensors devices during this period. These nodes only access the channel, and this period is known as CFP. There are seven GTS slots in CFP. In this research work, only CAP is considered, and GTS, which is an optional mode, is not used. Opnet modeler is used to developing and using a graphical interface for the simulation of 802.15.6 standard, and the devices used are the main coordinator and end devices. The implementation is carried out on the MAC layer with the CSMA/CA scheme.

Simulation of the performance metrics throughput, delay, and energy consumption of the 802.15.4 standard accomplished in ns2, whereas the Opnet modeler is practiced for the analysis of performance parameters of the 802.15.6 standard. For the BO and SO adjustment in the LR-WPAN, a trace file is generated. The trace file is a text-based file that collects all the string throughout the simulation. When trace files are executed, it generated NAM files which are processed by AWK scripts. The NAM file visualizes the ns simulations. The NAM file includes information on nodes, topology, links, and packet trace information. AWK script was used to process the text-based data either in data steams or in files. Each line of the trace file is read by the AWK script one at a time, and the result is accomplished. The parameters that were taken in account for simulation, are presented in Table 1.

Parameters	**Values**
Nodes	10
Topology	Star
Standards	IEEE 802.15.4 IEEE 802.15.6
Access Mechanism	CSMA/CA
Frequency Band	2.4Ghz

Evaluation Parameters	Throughput, Delay, Energy Consumption
Simulation Time	60 sec
Simulator	NS2, Opnet

Table 1: Simulation Parameters

IV. RESULTS

To decide the most appropriate system for health care, we compared both standards in beacon-enabled mode with super-frame structure. Simulation shows that the IEEE 802.15.6 standard gives optimum results in terms of throughput as compared to the LR-WPAN standard, as shown in Figure 3. Figure 4 reveals that with supplying different payloads, the IEEE 802.15.6 outperforms compared to the LR-WPAN standard in terms of average delay. Figure 5 depicts that energy consumption is less in the IEEE 802.15.6 standard than LR-WPAN Standard by applying higher data rate. There is also a decreased packet loss in the IEEE 802.15.6 standard with different payload compared to LR-WPAN illustrated in Figure 6.

A. Throughput Analysis

Packets received per node, considered as throughput, were compared for both the two forms IEEE 802.15.4 & IEEE 802.15.6. By applying BO less than SO at various data-rate results are illustrated in Figure 3.The findings validate that, irrespective of the traffic rate of the entity, sensors used to measure health condition, IEEE 802.15.6 delivers more throughput compared to IEEE 802.15.4. An even more significant aspect is, while BO outdoes 10 higher beacon interval is resulted, thus the throughput is significantly impacted by communication issues across members of the PAN and Coordinator.

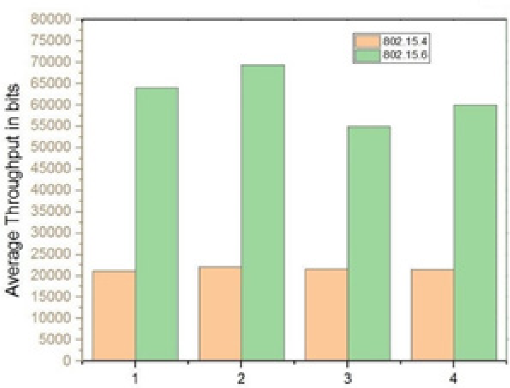

Figure 3. Average Throughput of IEEE 8202.15.4 and 802.15.6 Standards.

B. Delay Analysis

An extremely important factor in WBAN is delay, a term that defines how much time it takes for data packet to go from source to target destination. Delay ensures that data is transmitted on time and the healthcare taker may access data immediately. The differences in latency for successfully transmitted packets through the two forms are demonstrated in Figure 4. It is observed that, at low payload average delay is less in both forms, as payload becomes higher the 802.15.6 standard outperforms.

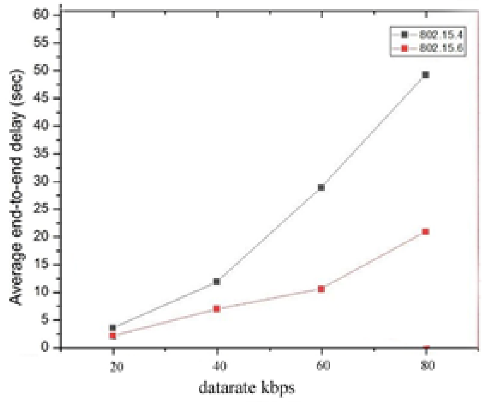

Figure 4. Average Delay of IEEE 8202.15.4 and 802.15.6 Standards

C. Energy Depletion Analysis

The most critical considerations that needs to be considered when designing a WBAN MAC protocol is the energy usage. The cumulative energy expended by both protocols was therefore, assessed. They were subjected to various conditions simultaneously and depicted in micro joules in the form of a graph, as presented in Figure 5.

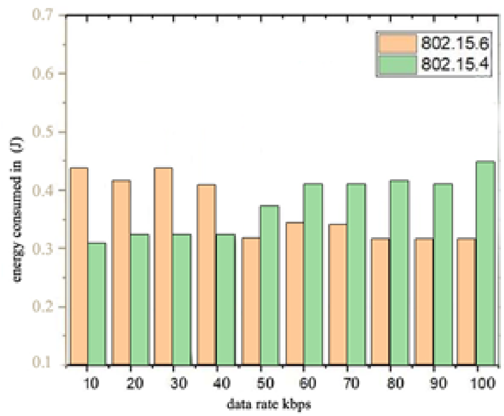

Figure 5. Energy consumption of IEEE 802.15.4 and 802.15.6 Standards.

D. Packet Loss Ratio

Variance in the packet loss is observed and shown in Figure 6 at various BO and SO values in CSMA/CA-based schemes in both standards. IEEE 802.15.6 induces less packet drop in contrast with IEEE 802.15.4 Standard, whereas IEEE 802.15.4 is advantageous in low data rate conditions. A higher traffic rate up to 1 GB/s is offered by the IEEE 802.15.6 standard, which has a significant increase in bandwidth than IEEE 802.15.4, which provides 250 kbps data rate.

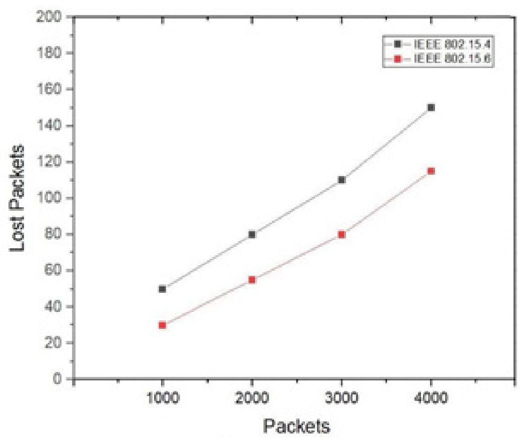

Figure 6. Packet Loss IEEE 802.15.4 and 802.15.6 Standards.

V. CONCLUSION

In this research work, we compared IEEE 802.15.4 standards and IEEE 802.15.6 standards for adopting the technology providing optimal results in regular data traffic. The performance parameters throughput, delay, and energy consumption were taken into account. Using ns2 for 802.15.4 standard and Opnet for 802.15.6 standard overall simulation shows that IEEE 802.15.6 determines an improved performance in terms of throughput and delay, while IEEE 802.15.4 delivers less energy depletion if the data rate is less than 40 kbps. Yet, 802.15.6 outperforms as data rate exceeds 40 kbps. However this requires a more profound knowledge of the underlying principles related to the functioning of WBAN. Therefore, this provides excellent opportunities to design energy-efficient MAC protocols that can work with multiple standards to improve the efficiency of existing BAN.

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