Bluetooth: An Attractive Solution To Internet Of Things

A. S. Shirsat, Dr. D. M. Yadav, Dr. P. B. Mane, S. A. Shirsat

Abstract: Presently, various applications are proposed and developed in the Internet of Things (IoT) area. These applications include smart home, office automation, agriculture, and big molls, where data transmission wirelessly, within the prescribed area, is one of the crucial tasks. Cost-effective, wireless transmission of the data over short-range with low power is essential. Bluetooth, an ad-hoc wireless network, can be one of the suitable candidates in this scenario. An attempt is made through this paper to modify the Bluetooth protocol and provide a high data rate, high throughput, spectral efficiency, cost-effective solution to IoT applications for short-distance communication. Modulation scheme, packet type, and transmission power are made adaptive to available channel link quality. During high traffic channel condition robust BPSK modulation scheme with small data packets are transmitted, while in low traffic, a higher-level DQPSK modulation scheme is used with large packet size and during average traffic the GFSK modulation technique is employed with the medium size data packet. This increases the average throughput by 14.92%, and spectral efficiency by 4.18%

Index Terms: Bluetooth, BPSK, Data Rate, DQPSK, Modulation scheme, Internet of Things, Spectral Efficiency.

1 INTRODUCTION

Recently, various electronic gadgets, equipment, and IoT applications have been developed to get wireless connectivity with the internet. These devices need to have a fast data rate, high throughput and required coverage area to send the voice and data[1][2]. These radio devices are using the 2.4GHz unlicensed Industrial Scientific and Medical (ISM) band. Due to more numbers of applications emerging in the ISM band, it becomes more crowdy, which makes it difficult in the intended functionality of radio devices working in this band[3]. Major Radio Accesses Devices (RADs) operating in ISM bands are Bluetooth, ZigBee, Wireless Local Area Networks (WLAN), cordless phone, and Bluetooth enabled devices. Bluetooth, a low power, a short-range, ad-hoc protocol, is a cost-effective solution in this scenario[4]. Bluetooth uses robust Gaussian Frequency Shift Keying (GFSK) modulation, and frequency hopping spread spectrum technique with 1600 hops per second. The emergence of Bluetooth 5 with high data rate and throughput increase the opportunities to use in various applications. However, due to a heterogeneous environment, the performance of Bluetooth gets hampered[5][6][7]. To enhance the performance of Bluetooth in the heterogeneous wireless environment is a difficult task. These are challenges in present RADs to get the required performance in this scenario[8]. For the internet of things application such as home automation, power management, agriculture applications, moll automation, telemedicine, e-health, traffic control, it is required to have wireless communication device which is capable of transmitting the data at a fast rate with better throughput[9]. Collocated services make channel crowdy. Packet Error Rate (PER), data rate and throughput of Bluetooth are the parameters suffered from these collocated services.

- *A. S. Shirsat is pursuing Ph.D. from AISSMS's Institute of Information Technology, Savitribai Phule Pune University, Pune, India. Ph-+91 9822110071. E-mail: asshirsat@gmail.com*
- *Dr. D. M. Yadav is currently working as Director, G. H. Raisoni College of Engineering and Management, Pune, India.*
- *Dr. P.B. Mane is working as Principal, AISSMS's Institute of Information Technology, Pune, India.*
- *Mrs. S. A. Shirsat is working as an assistant professor in Sinhgad College of Engineering, Pune, India E-mail: sashirsat.scoe@sinhgad.edu*

In this paper, an attempt is made to enhance the data rate and throughput of the Bluetooth heterogeneous wireless environment. The proposed technique is developed and simulated in MATLAB simulation. The results obtained are encouraging, and it is clear that Bluetooth is one of the distinguishing candidates as an alternative to other short-range RADs used in IoT applications. This paper is organized in different sections. Section 2 gives review of the related work in this area. The methodology and simulation model used are expressed in section 3. Section 4 gives the results obtained and their inferences. Finally, concluding remarks are presented in section 5.

2 RELATED WORK

From last decades the work on various aspects of Bluetooth and its performances is very less as compared to shipments available in Bluetooth. Bluetooth performance should be focused on Packet Error Rate (PER), Throughput, Bit Error Rate (BER), latency, packet delay, discovery time, battery lifetime, security, and goodput in the presence of the heterogeneous wireless environment. Since the Internet of Things (IoT) needs devices with a high data rate, fast connectivity, and more battery life time[9][10][11]. Bluetooth can give better performance in this scenario and will be a better option for such applications. The emergence of Bluetooth 5 with the high data rate, range performance, increases the Bluetooth utility in various wireless applications. However, these performances should be maintained in heterogeneous wireless environments[12], [13]. From the available literature, performance of Bluetooth is affected in the presence of Radio Access Devices (RADs) operating in the same frequency spectrum. To mitigate the interference caused due to nearby radio devices working in the same 2.4GHz Industrial Scientific Medical (ISM) band various techniques were developed in Bluetooth. These techniques were based on collaborative and non-collaborative strategies. In collaborative techniques other Radio Access Technologies (RATs) such as Wireless Local Area Network (WLAN / Wi-Fi), ZigBee, and other Bluetooth networks make spectrum available to either network[7], [14]. This method is an advantageous due to no change in infrastructure is required, but it hampers the performance and spectral utility of RATs. Other non-collaborative techniques demands modification in physical infrastructure such as the MAC layer and the Physical layer [15]. In the physical layer, changes in modulation schemes were suggested to improve the performance of Bluetooth in terms of data rate and throughput with an increase in SNR. Few techniques suggested to modify in the receiver by employing Kalman Filtering (KF) with extended KF, linear KF, unscented KF, and interactive KF, to enhance Bluetooth performance[16]. Another widely used technique was Adaptive frequency hopping techniques (AFH), where right frequency channels were selected to improve Bluetooth transceiver performance. Based on available channel quality, an Adaptive packet selection scheme was proposed to improve the Bluetooth performance in the RADs scenario. Few techniques used Forward Error Correction (FEC) at the receiver to improve the Bluetooth performance[17]. In a few literature, link quality was assessed based on the recent packet received and the selection of packets was decided for transmission. At low link quality, Bluetooth performance is not sufficiently enhanced, so it is required to improve the performance in this scenario[18]. Wireless video transmission through Bluetooth in real-time requires high data rate, high throughput or compression of the video signal at good extend. The compression of the signal reduces the quality of recovered the signal. In the internet of things scenario, for voice transmission, power requirement was checked by [6], and it is seen that Bluetooth can support such applications. Authors used Bluetooth for agriculture IoT applications in a heterogeneous environment with RFID, Wi-Fi and other Bluetooth[20], [21]. Conclusions that can be drawn from the literature survey are the performance of Bluetooth degrades in a heterogeneous environment, mitigation techniques are insufficiently improving the performance, at low SNR values, there is scope to improve the performance of Bluetooth. Bluetooth protocol should have a high data rate, high throughput, and high goodput. It should maintain baseline performance and should be rejecting capable of rejection interference. It should support an adaptive strategy to select power, modulation scheme, and packet in different wireless environments.

3 BLUETOOTH SIMULATION MODEL

Fig. 01 shows the block diagram of the Bluetooth Transceiver. In the transmitter, the packets are formed with payload along with the header and trailer information. These packets are encoded, and then the modulation process is carried out according to the link quality. This data is transmitted over the AWGN channel with adaptive power. The hopping sequence is generated and synchronized at the transmitter and receiver. At the receiver, a signal is decoded and checked for the bit error performance in the presence of anther Bluetooth and other interferers. MATLAB Based simulation of Bluetooth is carried out in terms of BER and throughput. The developed Bluetooth transceiver system is used to enhance the data rate and throughput in a heterogeneous environment.

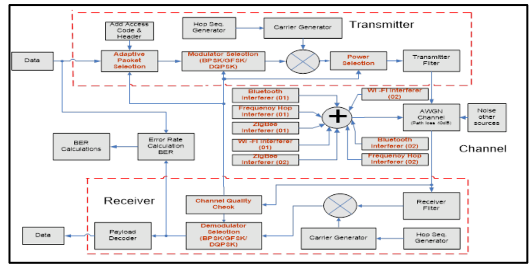

Fig. 1 *Block diagram of Bluetooth Transceiver model.*

The developed system evaluated in terms of Bit Error Rate for Bluetooth receiver with various interferers and the trade-off between Eb/No and BER, Eb/No, and throughput is calculated with and without interferers.

The developed system is used to analyse the performance of Bluetooth.

- Simulation of Bluetooth Transceiver model in MATLAB Simulink is carried out.
- Monte-Carlo simulation is done for several numbers of times to obtain BER with respect to Eb/No.
- From the obtained BER, the throughput of Bluetooth is calculated in the heterogeneous network.
- From the calculation of BER, link quality is assessed, and an adaptive technique is employed.
- For Adaptive technique (adaptive packets, modulation, and power) BER with respect to Eb/No is calculated in the presence of different interferers.

4 RESULTS AND DISCUSSIONS

This section gives MATLAB based simulation results of baseline BER performance of Bluetooth. Fig. 2 illustrates the BER performance of basic rate Bluetooth with respect to Eb/No. The throughput is calculated for voice packets.

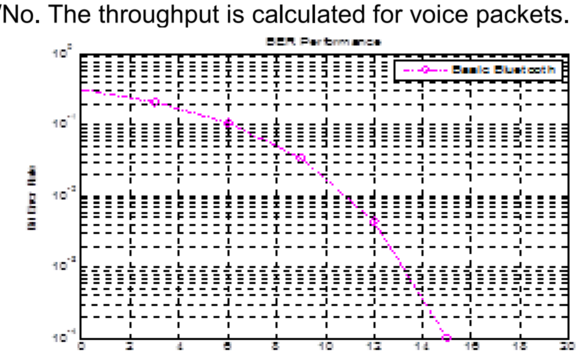

Fig. 2 *Baseline BER performance of Bluetooth.*

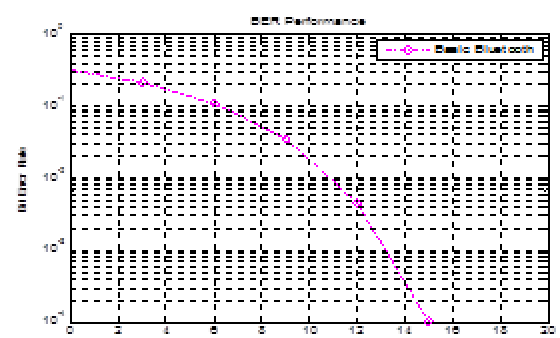

Fig. 3 *Baseline throughput performance of Bluetooth.*

The throughput of Bluetooth increases with an increase in Eb/No as depicted in Fig. 3. Fig. 4 shows the BER Performance of Bluetooth with different interferences. From the results obtained, it is clear that the performance of Bluetooth gets hampered due to interferences. The BER performance of Bluetooth degrades less with WLAN as compared to the other interference sources. Performance is affected more by other Bluetooth devices placed in close vicinity as compared to other interfering devices such as WLAN, ZigBee and hop interference. Above 15dB Eb/No interference caused by ZigBee is more than other interfering devices.

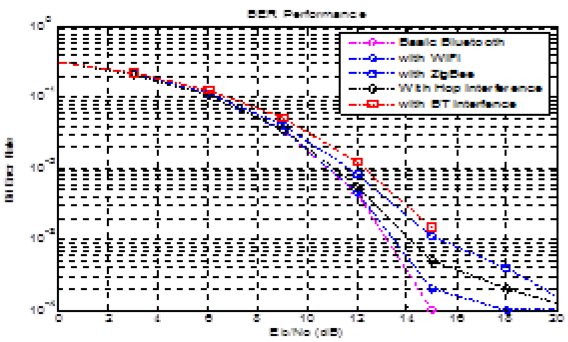

Fig. 4 *BER performance of Bluetooth with various interferences.*

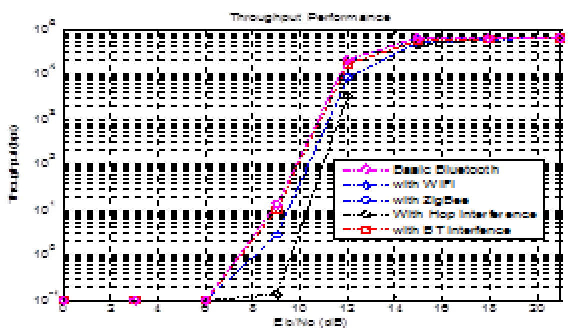

Fig. 5 *Throughput performance of Bluetooth with various interferences*

Fig. 5 gives a throughput performance of Bluetooth with different interferers. As interference increases, the throughput reduces. It enhances error rate causing degradation in throughput of primary Bluetooth device.

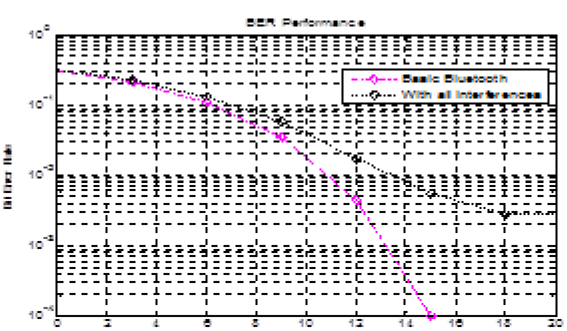

Fig. 6 *BER performance of Bluetooth with all interference Sources*

Fig. 6 shows overall BER performance of Bluetooth with all interferes. The throughput of Bluetooth is affected by all interference to a great extent. Throughput performance does not improve further even by increasing Eb/No above 18dB, as illustrated in Fig. 7.

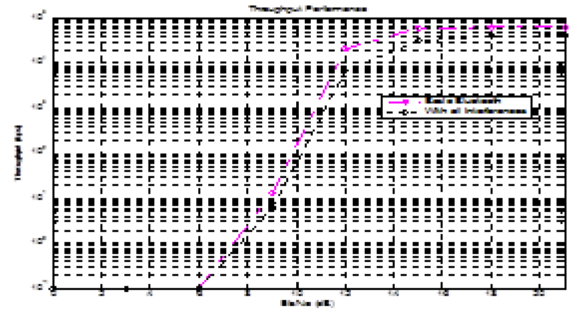

Fig. 7 *Throughput performance of Bluetooth with all interference Sources*

These are the difficulties which hampers the performance of Bluetooth in a heterogeneous environment. The developed system is capable of addressing this problem. In this system, the link quality is checked after every received packet. From the quality of the link, the transmission parameters of Bluetooth are selected to transmit in the next hopping cycle. For the low link quality, BPSK modulation is used; which is one of the strong modulation techniques and gives the best performance in this scenario.

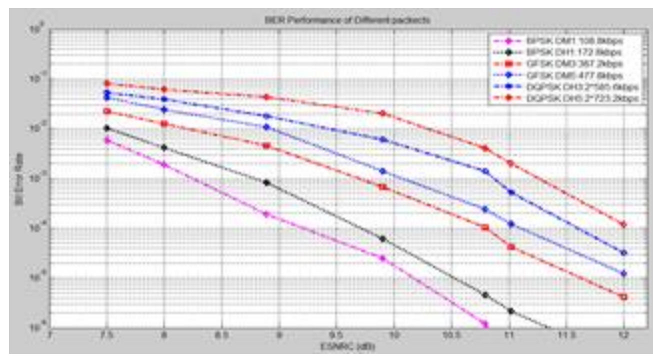

Fig. 8 *BER performance of Bluetooth.*

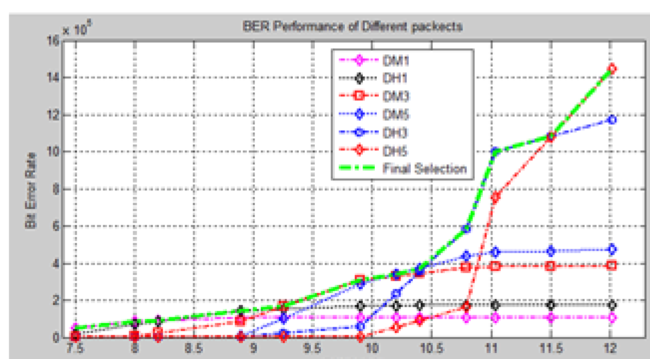

Fig. 9 *Throughput performance of Bluetooth*

GFSK technique with a Gaussian pulse shaper is employed in the medium link quality. The performance is good enough for these interferences. At the best link quality, a high data rate, throughput, and spectral efficiency are achieved by transmitting 10% more power by employing higher modulation scheme with high data rate packets. Fig. 8, 9 shows the enhanced performance of the Bluetooth network in the multiuser ISM band. At low Estimated Signal to Noise Ratio (E_{SNR}) of Channel (E_{SNRC}), throughput performance is best. From the E_{SNRC} 10.4 dB the data rate is doubled which leads to enhance the throughput in the presence of RATs.

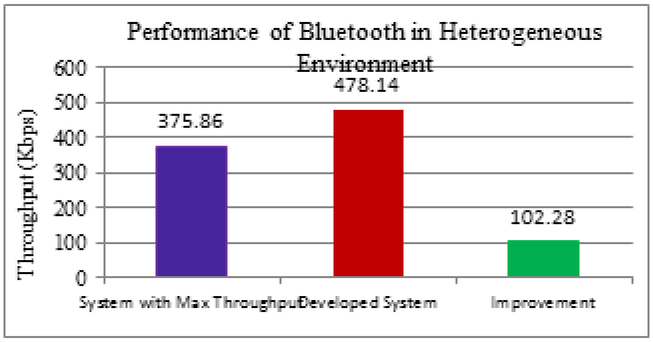

Fig. 10 *Comparison of throughput performance of Bluetooth with developed system.*

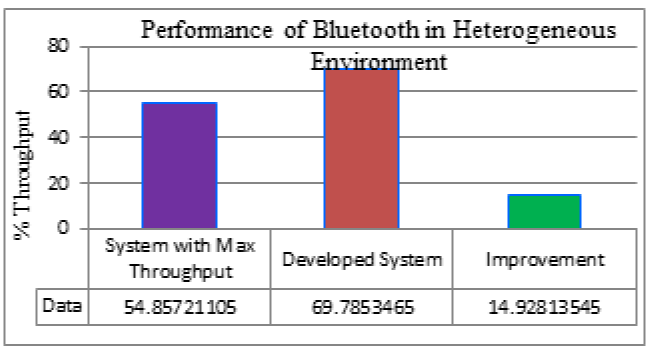

Fig. 10 *Comparison of % throughput performance of Bluetooth with developed system*

This improves the Bluetooth performance at low and high Eb/No, due to this average throughput performance is improved by an amount 102.28kbps. The percentage improvement seen is 14.93%, as depicted in Fig. 10 and Fig. 11. Spectral Efficiency (η) is defined as data rate per bandwidth. It is calculated from the average bits transmitted. In a system with high throughput, efficiency is as

η_{ave} = (Data Rate) / (Bandwidth) 01

η_{ave} = 585.6Kbps/ 1MHz

η_{ave} = 0.5856 bits/sec/Hz

For Developed System the value is

η_{ave} = 3764 kbps/1MHz

η_{ave} = 0.6274.

Improvement in Spectral efficiency η = 0.0418 (4.18%). The improvement in spectral efficiency in developed system is 0.0418 (4.18%).

5 CONCLUSION

In this paper, an attempt is made through the designed Bluetooth system to improve the throughput of the existing Bluetooth network required for the Internet of Things. The designed scheme works in a heterogeneous wireless environment. The developed technique is based on the link quality of recent packet received. From the simulation results tell that, by selecting a modulation scheme, an appropriate packet, and power depending on the available channel quality, throughput is enhanced close to maximum throughput. Our system is found suitable to enhance the throughput of Bluetooth by 14.928% and 4.18% improvement in Spectrum utility. This makes Bluetooth a suitable candidate for IoT based applications.

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