Influence of the Interfernce Due to Co-Existence of Bluetooth and Wi-Fi Transmissions

Er.Gurpreet kaur
M.Tech Student
Department of ECE
PTU University Campus, Punjab Technical University ,India

Dr.Dalveer kaur
Assistant Professor
Department of ECE
PTU University Campus, Punjab Technical University ,India

Abstract

There are various emerging technologies in the field of wireless communcation which are communication, operated on unlicensed ISM (Inductrial, Scientific and Medical). Therefore, they lead to interference due to coexistence on same frequency band such as Bluetooth and Wi-Fi. The growth of devices within 10 meters is growing on day by day as the advancements in technologies. But the interference is a big issuse in the case of voice transmission , as the Bluetooth supports both transmission of data and voice using ACL and SCO packets reapectively. In this paper we investigate the inference in voice packets using Connection Oriented Repeated Transmission for SCO links. For sake of experimental verification , we provide a comprehensive simulation results using Matlab simulink.

Keywords: SCO, Bluetooth, 802.11, Interference, ACL, Celluler system

I. INTRODUCTION

The advancements in the wireless technologies make the world comfortable. These comforts transformed our daily life iin such a situation that nobody can imagine to live without cellphones, internets , computers etc. The wireless networks are getting interconnected these devices through adding up more and more nodes into each minute . There is the celluler phone which is latest and modern example of emerging technologies in which both the most popular technologies IEEE802.11 and Bluetooth exist These technologies uses radio frequency for communication . Unfortunately , IEEE802.11 and Bluetooth both operated on unlicensed and uncontrolled 2.4 GHz ISM frequency band . There are various versions of 802.11 available like 802.11a, 802.11b, 802.11g,802.11n . But we consider the 802.11b ,operated on 2.4 GHz as shown in figure 1.

As in the case of Wi-Fi or 802.11b while sending packets through wireless networks, the it will check firstly that the channel or medium is occupied or busy with any RF transmission . if it is not detecting any RF energy or transmission in the channel then it will issuse a CTS (Clear To Send) request . This command is used for adaption of wireless network for now start packet transmission to destination. The destination sends back a small RTS (Ready To Send) to sending node.As the transmitting node receives RTS from destination node, both the transmitting and receving nodes start communicating with each other by transmitting the regular data packets. Using same technique, while another co-located IEEE802.11 network tries to send the packet , it will postpone the transmission.

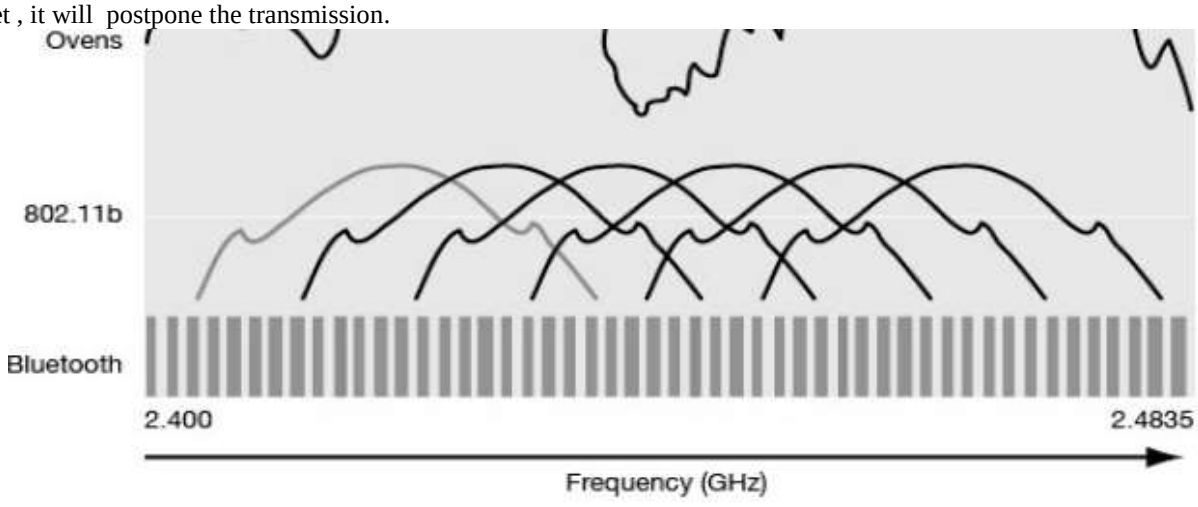

Figure 1: 2.4 GHz ISM Spectrum

This technique provides a good resolution for mutual interference between co-located IEEE802.11 networks but when Bluetooth and Wi-Fi comes co-located networks and they don't communicate with each other then there is a defnite chance of collision on same frequency band at same channel at a same time.

A Bluetooth device can hephazardly start transmission of packets while Wi-Fi is transmitting a frame . it is the cause of interference due to which the packet loss or connection loss happens and no RTS is received from destination due to lack of co-ordiantion between the source and the destination.

The objective of this paper is to build a simulation model of Bluetooth and interference model of Wi-Fi to study the impact of interference between both devices . we also study a new Bluetooth packet for voice transmission to reduce the effect of interference, which is proposed by IEEE working group on co-existence.

This paper is distinguished in various sections : Section II describes about the specifications of Bluetooth technology for voice and data transmission. Section III explains the simulation model with a brief discussion ,Section IV represents the Connection Oriented Repeated Transmission for SCO link the new voice packet . Testing of model and results are presented in Section V . finally , the Section VI contains the conclusion of the work.

II. SPECIFICATIONS OF BLUETOOTH TECHNOLOGY

Bluetooth is a technology that used for replacing short distance cables . It supports both data and voice packet transmission with a data rate of 1 Mbps through radio channel . Bluetooth is a PAN (Personal Area Network) having operating range is 10 meters. Bluetooth tranmitted power is low about 1mw. It uses GFSK modulation to control the spectral width of the transmitted signal as well the 1600 hops occurred in one second during transmission of data . FHSS (Frequency Hopping Spread Spectrum) is used to reduce the effect of interference from other devices. The interference problem can be recovered or avioded using various co-existing techniques. The Bluetooth transmission slots are presented in figure 2. In this paper we consider Connection Oriented Repeated Transmission for SCO links to reduce the impact of interference n voice packets.

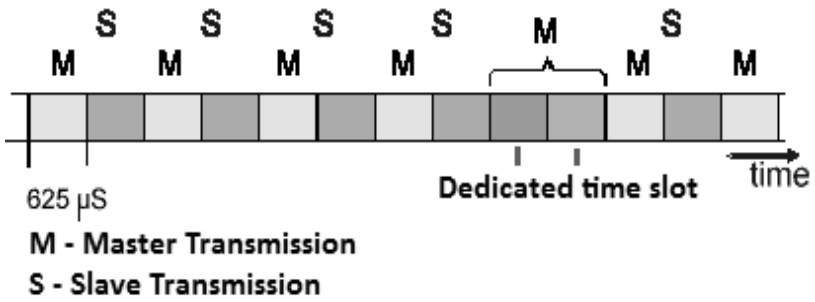

Fig. 2: Bluetooth time Slot

A TDD (Time Division Duplexing) is used to divide the channel into slices of 625μs as in figure 5. A new frequency hop is used for each slot. Bluetooth supports both the voice and data transmission uses SCO (Synchronized Connection Oriented) and ACL (Asynchronized Connectionless Link) respectivley. SCO link is established between a master and a slave device in a piconet as in figure 3. The first row shows the master slots and the second row is of slave device 1 and third row of slave 2 device as in figure 3.

SCO link uses reserved time slots for voice transmission . Bluetooth master device uses the reserved time slots to maintain the connection and transmission of information . An ACL link is used for data transmission and it can establish between one master and sever slave devices in a piconet . ACL packets are communicated in free time slots after SCO transmission. ACL packets occupy upto 1,3 and 5 time slots.

A. SCO LINK FOR VOICE PACKET TRANSMISSION

In Bluetooth , voice signals like (speech , music files ,videos etc) are transferred through SCO link . The SCO link is for symmetrically point to point voice communication and tranmitt & receives voice packet at regular interval of time. SCO packets transmitted in only every sixth time slot having time period is 3.75 ms . the return path from slave to master places to next slot. Bluetooth can support a maximum of upto three voice calls at the same time. In figure 4 T1,T2,T3 are transmitt slots for each SCO master and R1,R2,R3 are return path for slaves.

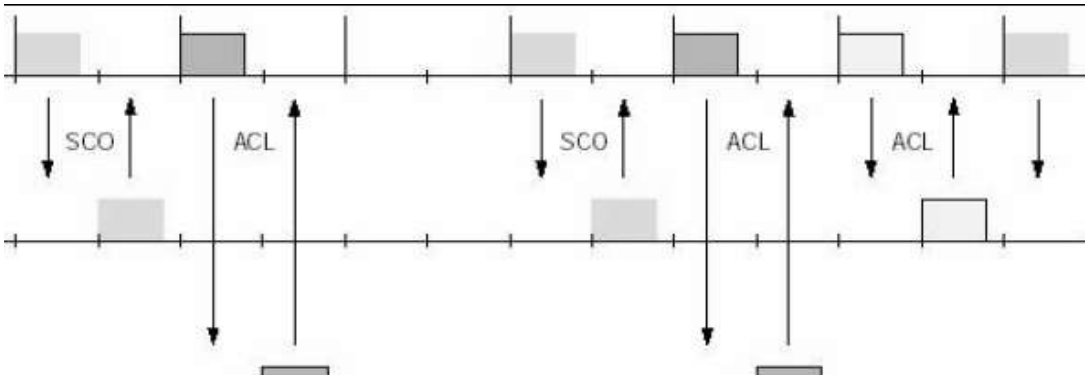

Figure 3: Bluetooth SCO & ACL

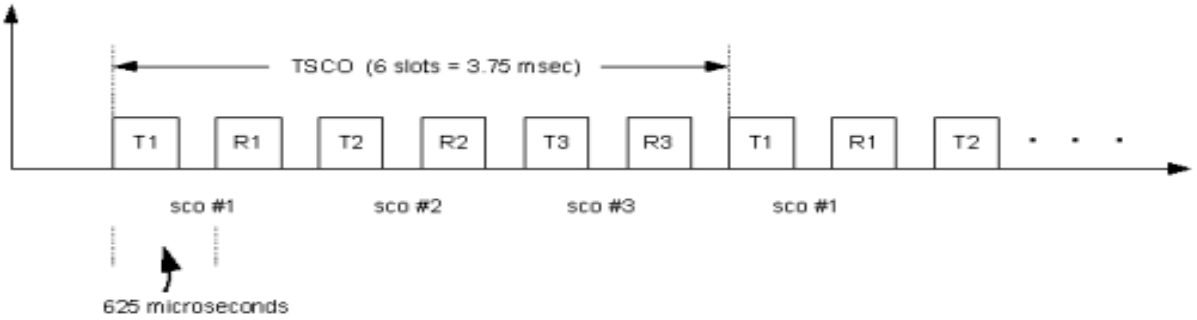

Figure 4: Bluetooth SCO voice slot

A master device (transmitter) starts and controls SCO link . Maximum of three SCO links can be maintained by a master device at same time . At a aacurate time when master device transmitts SCO packet in a slot , the slave sends back in the next or following slot. It shows that the packet transmission is symmetric that means data rate is same in both directions and length of Bluetooth SCO packet is always one time slot. There is one important thing that thereis no acknowledgement for SCO link . SCO packet communicate in reverse slots at regular time intervals like two, four or six slots .

There are various types of SCO voice packets like HV1, HV2, and HV3. HV1 carries 10 data bytes and is transmitted every 2 slots, HV2 carries 20 data bytes and is transmitted every 4 slots and HV3 carries 30 data bytes and is transmitted every 6 slots .The data rate of HV1, HV2, HV3 packets are 64Kbps. HV1 and HV2 uses 1/3 and 2/3 rate Forward error correcting (FEC) mechanisms respectively. There is no FEC in HV3.

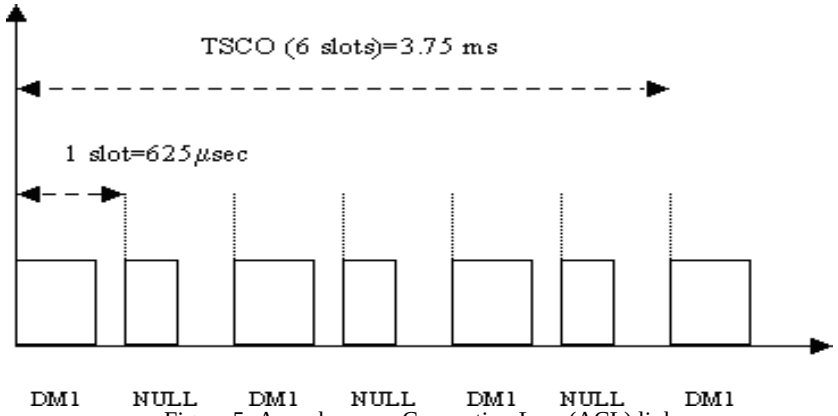

Figure 5: Asynchronous Connection Less (ACL) link

B. ACL LINK FOR DATA TRANSMISSION

ACL packets are used for data transmission in Bluetooth , which differenitate it from SCO link in many aspects . there is no margin for errors in data transmission if there is an errors occur in packets , those packets must be re-transmitted . Different techniques can be used to implement it.

Unlike SCO packets ,ACL packet transmission have acknowledgement system . As the CTS (Clear To Send) transmitted then the acknowledgement is send back from the receiver to transmitter. The transmitter sends the packet as it receives the acknowledgement from receiver , it will send the packets repeatly till a positive acknowledgement is received . The receiver will check the received packet and verify the CRC (Cyclic Reduncy Check) to make sure the packet is received correctly . The throughput must be check (in bps) in ACL packet transmission. The throughput will degrade if a packet has to be transmitted again and again . The receiver sets the ARQN (Automatic Repeat Request Number) bits in the header part (made of 54 bits) of the packet. The ARQN is transmitted to transmitter in the return path. This is the way that how the ARQ is

transmitted by the receiver to transmitter. By checking the logical value of ARQN , the transmitter sense that the packet transmission was successful or not . If the ARQN value logicc 1 is received then it means a successful trancmission happened . If ARQN value logic 0 is received then it is a sign of failed transmission and require repeated transmission .

In a case of one way like master to slave communication. The slave sends back a dummy packet in the next time slot. Dummy or NULL packet does not having any payload. Figure 5 shows the DM1 packet being transmitted in first time slot and the slave replied with a NULL packet contain ACK in immediately following slot. Then , the master sends the packet with payload in the next time slot.

III. BLUETOOTH SIMULATION MODEL

The simulation model of network is shown below in figure 6 which is build in Matlab simulink. This model simulates Bluetooth full duplex communication mode. We have used two similar devices , each with a transmitter and a receiver. One of them should be set as master and the other is slave. Other than two Bluetooth devices, we also have an 802.11b packet generating block as an interference source, error reading meters and instrumentation.

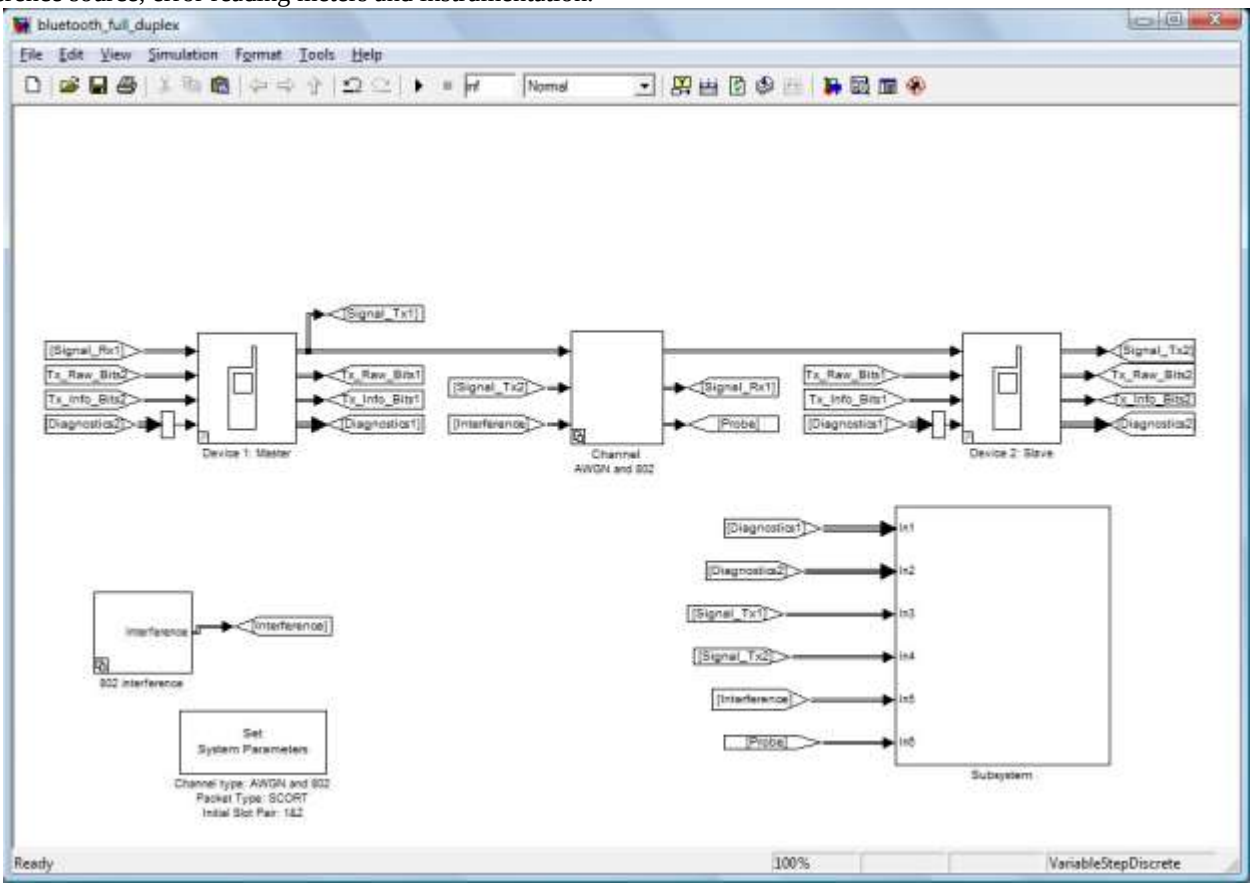

Figure 6. Bluetooth Interference Simulation Model

In the first step there is a need to build a transmitter of Bluetooth and then the AWGN channel is used because of its own specifications and then the Bluetooth receiver is have to be made . One thing is most important the Wi-Fi interfere model is used only not the whole system because there is only the impact of interference is detecting on Bluetooth system.

A. Transmitter Design

The tranmitter mode shown above in Bluetooth simulink model . The Bluetooth transmitter mode consists of Data source and transmitter controller,Audio source and speech coding,Forward error correction (FEC),Transmitter,Frequency hopping code sequence,Slot enable . All the blocking parameters have their own features to tranmitt a regular input signal of data and voice packets. The transmitter mode is shown in Figure 7. Figure7 shows the state flow diagram of the data transmission. It also performs Header Error Control (HEC) using FEC. Buffering and GFSK modulation is also done at the transmission side as shown in Figure 7. Frequency hopping is the transmission modulation technique. When the “ACL_packets” is entered, the transition to “Transmit_blank_packet” will happen. The “Enable_Audio=0" & "Get_blank_Packet=1" actions activates to disable audio and to generate a new data packet. When the next slot is about to transmit, the transmitter checks the status of ARQN bit that either logic 0 or logic 1 is received returned from the receiving device.

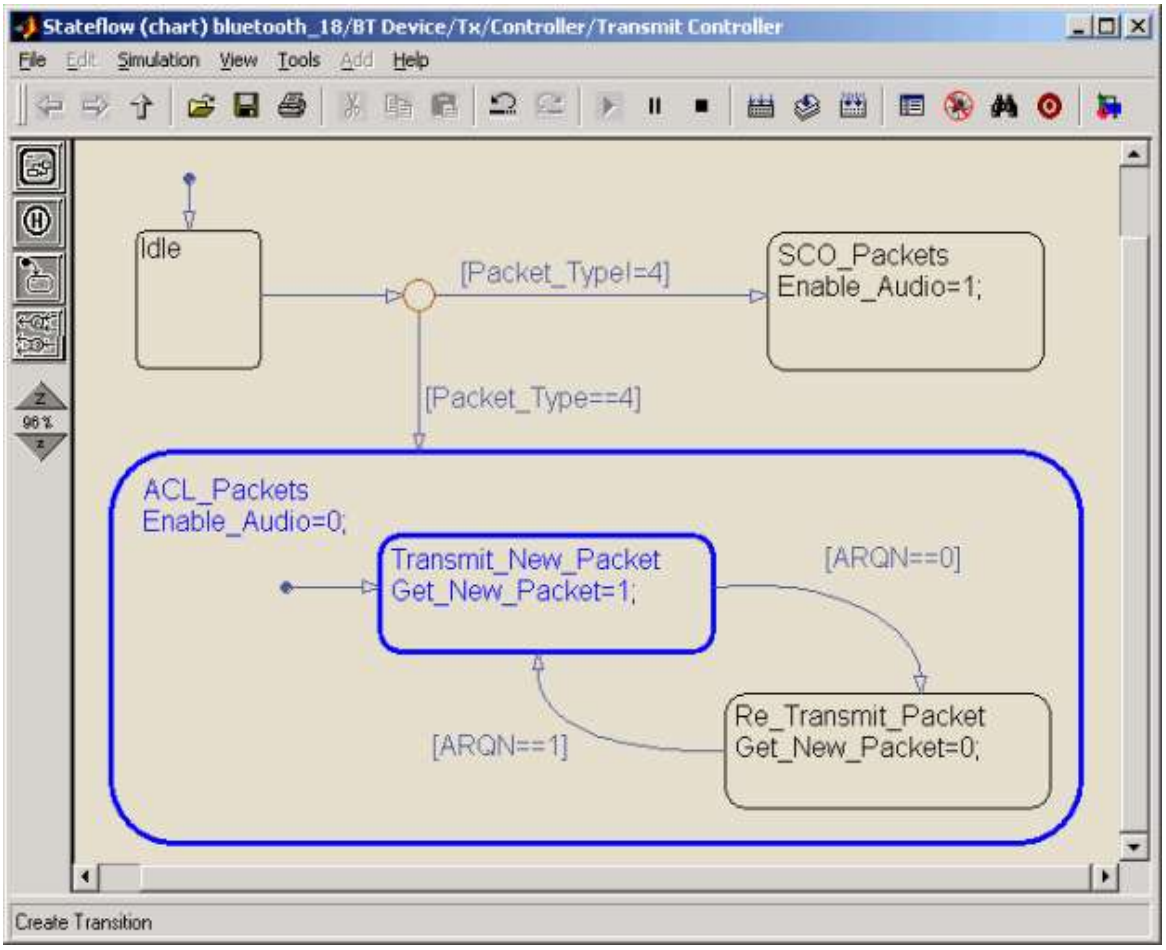

Figure 7. Transmitter state flow diagram

If it is in "Transmit_blank_Packet" ARQN is one, it stays in that particular state and transmits another new packet. If ARQN is zero, it shifts to the "Re_Transmit_Packet". This simulation model uses frame based processing. It can transmit samples having high number of frames in each step of the simulation. This technique enables quick simulation of digital systems. In this particular model, a top sample rate of 100 MHz is used.

Figure 7 shows the state flow diagram of the data transmission. When the “ACL_packets” is entered the transition to “Transmit_blank_packet” will happen. The “Enable_Audio = 0" & "Get_blank_Packet = 1" actions activates to disable audio and to generate a new data packet.

When the next time slot is about to transmit, the transmitter will check the status of ARQN bit returned from the receiving device. If it is in "Transmit_blank_Packet" ARQN is one, it stays in the state and transmits another new packet. If ARQN is zero, it shifts to the "Re_Transmit_Packet". If the transmitter is in “Re_Transmit_Packet", and ARQN is one, it shifts to “Transmit_blank_Packet" else it will not shift and will stay in "Re_Transmit_Packet".

B. RECEIVER DESIGN

The state flow diagram of receiver is shown in Figure 8. It can be seen in Figure 8 that the Bluetooth receiver waits a new packet all the time. When it senses the arrival of a packet it will register the arrival. It will also make sure the decoder is enabled. The above mentioned sequence of events is triggered because of the detection of an arriving packet. The Bluetooth receiver has to make a number of decisions to make sure whether the received packet is correct or incorrect.

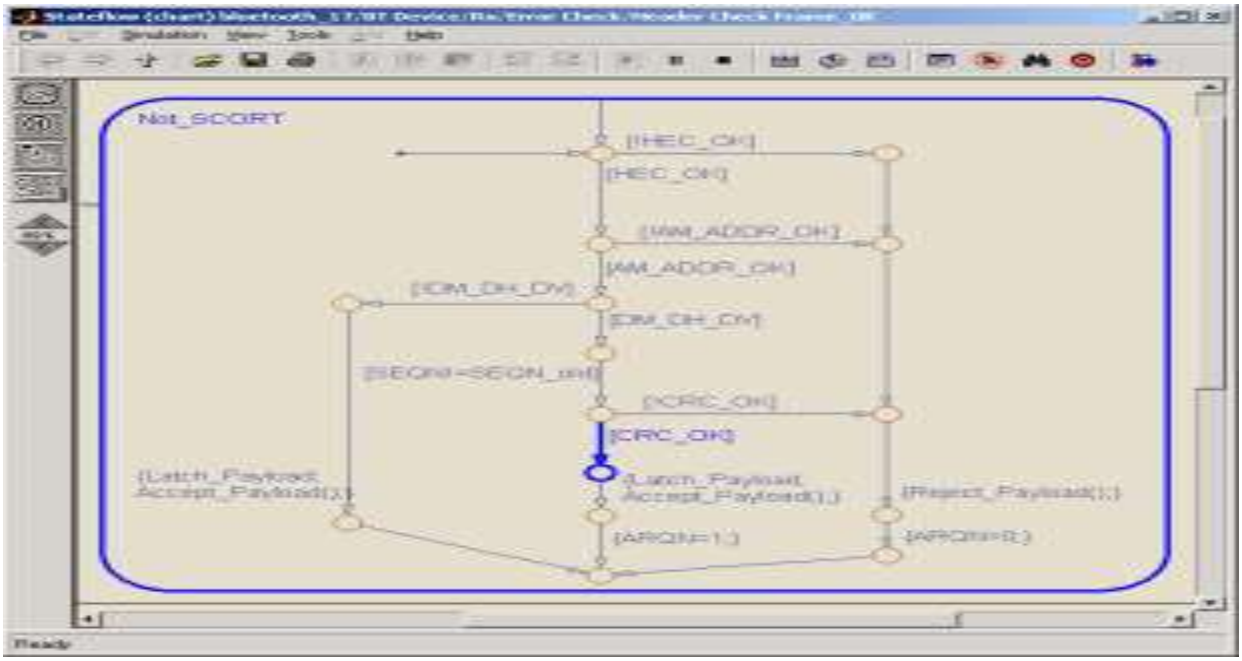

Figure 8. Receiver state flow diagram

A DM1 packet will be checked for integrity. The receiver performs a HEC. The PIN, Header address is also verified. The receiver makes sure the packet is new and is not a duplicate. It also checks the CRC. If all these checks are correct, the packet will be accepted else the packet will be rejected. This happens in the case of a repeated packet arriving or in the case of its CRC failing. This flow diagram is implemented in State flow semantics as shown in Figure 8. This image has been captured during a simulation, illustrates the animation provided with State flow which highlights the decision path (in bold) through the flow chart.

C. AWGN CHANNEL AND WI-FI INTERFER MODEL

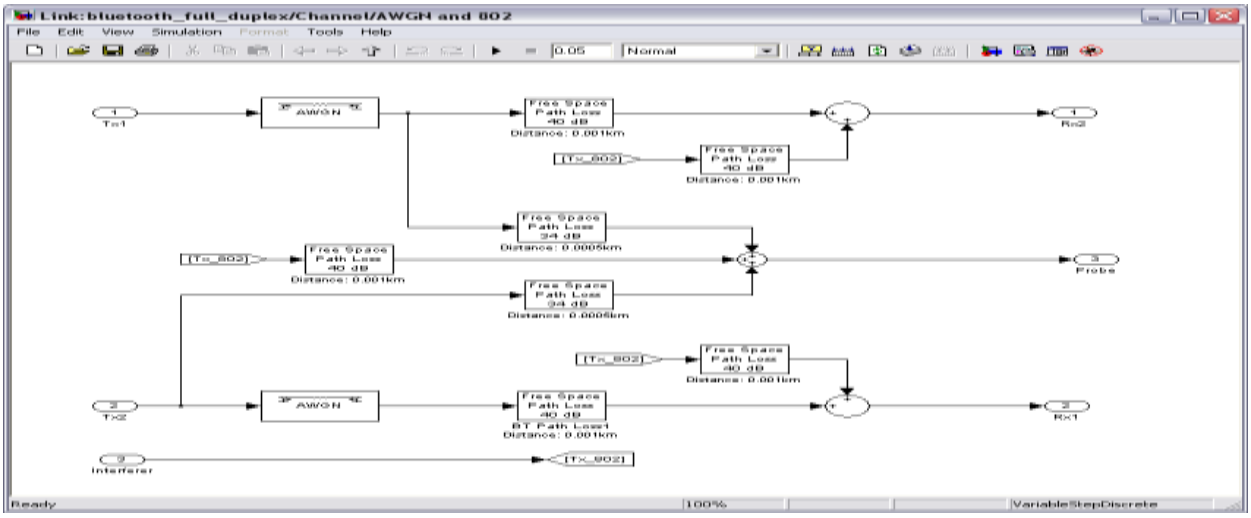

Figure 9. 802.11b Interference Source added

The 802.11b channel bandwidth is approximately 22 MHz. The Simulation model has a block which produces signals in this bandwidth. This block can be configured to specify mean packet rate, packet length, power, and frequency location in the ISM band. This block with free space path loss is then connected to the channel where the distance between the interference source and Bluetooth system can be varied. Figure 9 shows the addition of 802.11b interference into the channel. We use this model in our experimental verifications to determine the behavior of added interference and the impact of interference on Bluetooth system.

IV. CO-EXIATENCE SOLUTION – CONNECTION ORIENTED REPEATED TRANSMISSION FOR SCO LINK FOR VOICE TRANSMISSION

The coexistence task group working on coexistence has suggested the use of a special voice packet to fight interference. The Connection Oriented with Repeated Transmission for SCO link, this voice packet achieves more robust transmission by replacing bit-level redundancy with packet-level redundancy.

It works by repeating the transmission of the same packet three times in one SCO interval. It does not have any error correction and is transmitted every second time slot. As the same packet is being transmitted three times in a row, only one voice link will be there which is a full duplex link. If interference destroys the transmission during first slot, there are still three other slots or have opportunities to communicate the packet. This provides an improvement for frame-error rate (FER) in an interference scenario. It does not affect the BER of the payload.

V. EXPERIMENTS AND RESULTS

Using the Bluetooth simulation model including Wi-Fi interfere model, we perform a series of tests to evaluate the performance of a Bluetooth system under interference. We used DM5 packet type to check the performance of ACL pakcet for data transmission. The HV1 packet is used to evaluate SCO voice transmission performance. Finally we used new voice packet type Connection Oriented Repeated Transmission for SCO link to calculate the BER (Bit Error Rate) of the received signal for better performance.

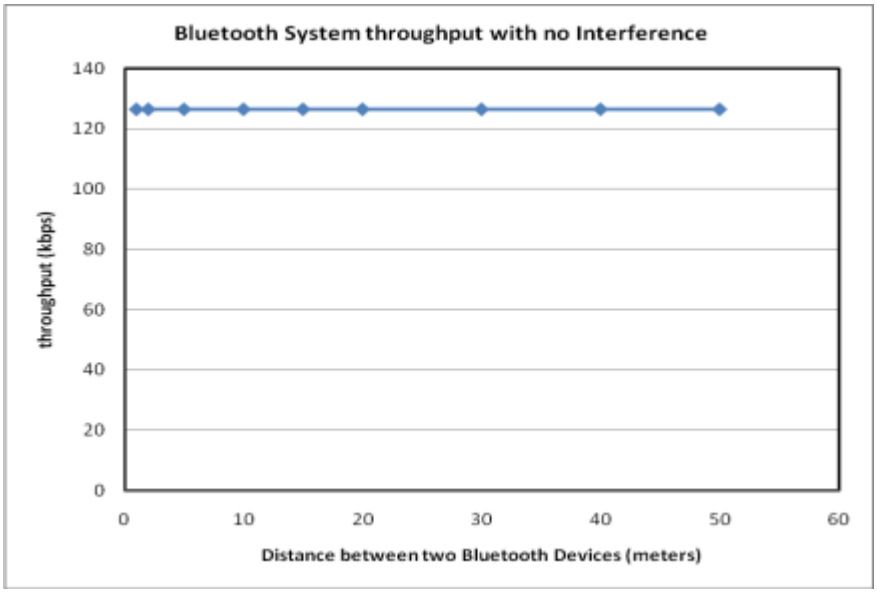

Figure 10. Bluetooth system throughput with respect to the distance between Bluetooth master and Bluetooth receiver

Figure 10 depicts the Bluetooth system throughput. The throughput (in kbps) has been evaluated by varying the distance between the Bluetooth device and the Wi-Fi interference source. It should be noted in Figure 10 that a consistent values of throughput is achieved with respect to a constant increase in the distance between the Bluetooth master and slave devices. From Figure 10, we can see that the throughput of a Bluetooth system is about 128 kbps without 802.11b interference source.

It is predicted from figure 11 demonstrates the BER performance with respect to Eb/No of Bluetooth model without Wi-Fi interfere model. It should be noted in Figure 11 that the BER decreases linearly over the values of Eb/No as there is a low value of BER without WI-fi and less impact of interference. But in figure 12 Bluetooth model including Wi-Fi interference have much impact of interference on the signal output. However, the BER divergence in Figure 12 is very rapid and acceptable for a maximum value of Eb/No.

VI. CONCLUSION

In the modren era of development , Bluetooth and 802.11 network devices are part of our daily life. This paper presented a model for the interference of these two popular standards Bluetooth and Wi-Fi.

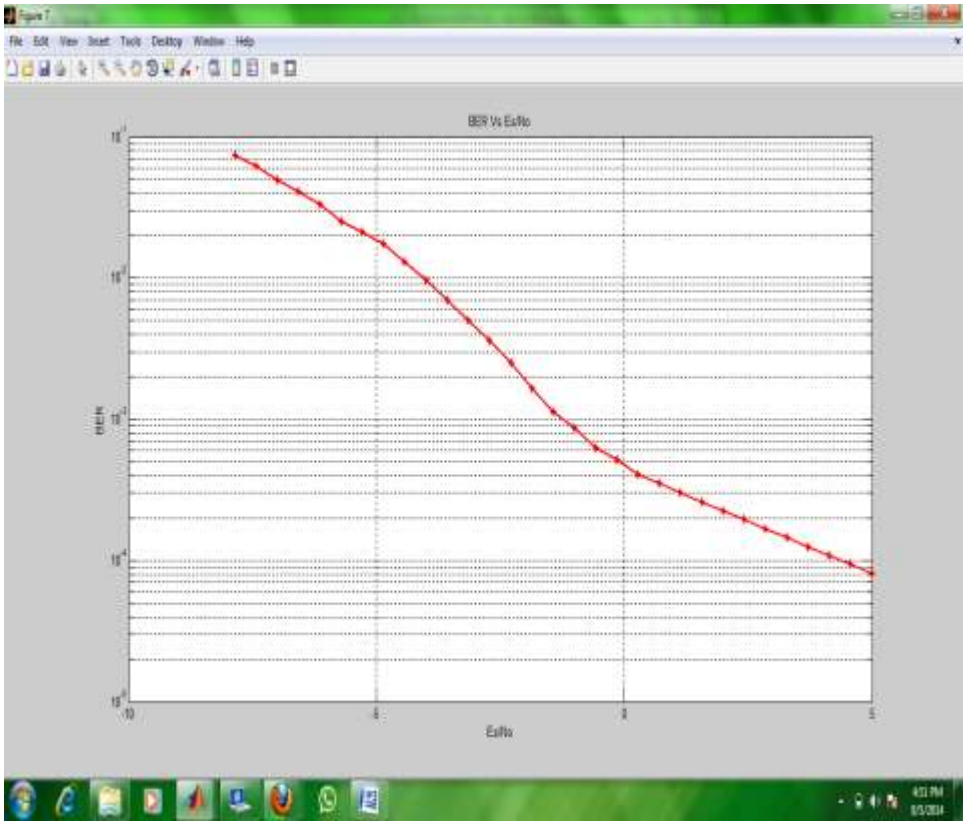

Fig : 11 BER Vs Es/No using HV1 and DM5 packets without Wi-Fi interfere model

Our analysis shows that the situation gets worse as more and more devices come into play .Such a situation calls for the urgency of congestion free network. Techniques such as Connection Orientation Repeated Transmission for SCO voice packets are a big leap in the future for such networks.

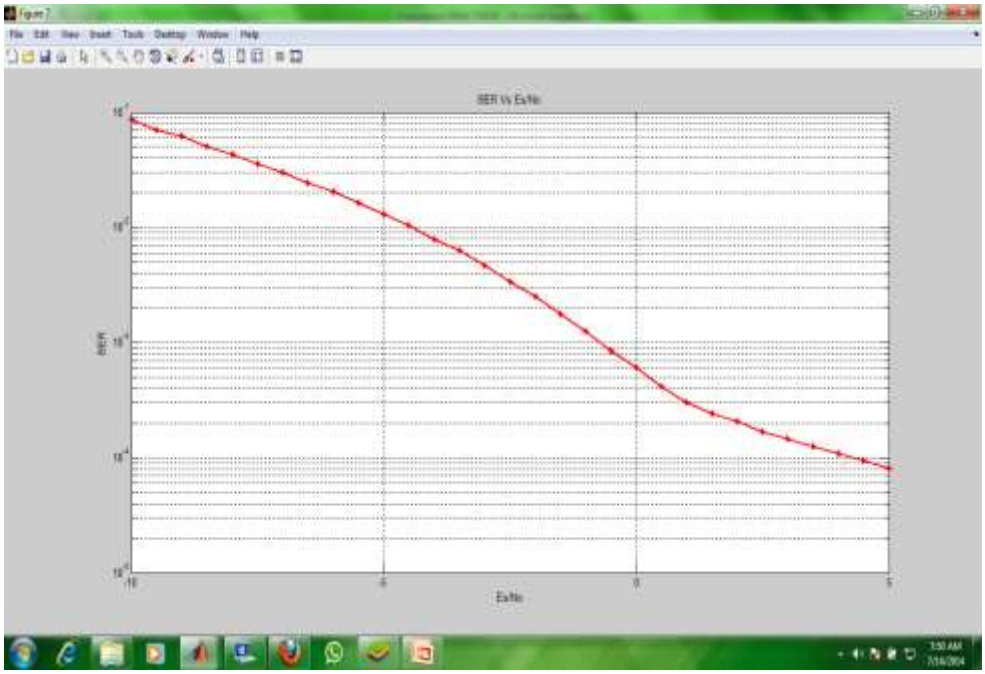

Fig : 12 BER Vs Es/No using HV1 DM5 data packets including Wi-Fi interfere model

By using Connection Oriented Repeated Transmission for SCO voice packets we can minimize the effect of interference. Hopefully in the future wireless communication industry will mature in such a way that smooth data and voice transmission will be achieved and finally a solution for Coexistence without compromise can be realized

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