Bluetooth Channel Quality Simulation, Estimation and Adaptive Packet Selection Strategy

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Abstract: - A full duplex Bluetooth simulation model is presented by Simulink of MATLAB. The model includes Bluetooth physical layer and baseband layer. A short range wireless communication channel model is established. The channel model is used that takes into account positioning, propagation effects and radio characteristics. Based on those, the radio performance of Bluetooth system is investigated by simulation, including the throughput of data transmission, Frame Error Rate and Bits Error Rate of SCO link etc. Through the simulation, we can see the detail transmission performances of different packet type. Furthermore, the model can simulate more scenario of Bluetooth communication, such as coexistences with other ISM devices or interferences from other Bluetooth piconets. In conclusion, the model can be used to do a lot of research work, if only little modification is made. Testing system and device designs early in the development process in this way can substantially increase productive efficiency and reduces the risk of design flaws. The transmission performances of Bluetooth 2.0+EDR specification are analyzed, including average maximum throughput under different channel quality. A new adaptive select strategy based on the history of the packets errors is suggested. The channel quality is estimated by the packet error statistics of recent transmission packets. The type of next packet need to send is judged and can be adjusted dynamically. The simulation results show that when the number of the packets used to be decided is about 30, the throughput is greatly close to the average maximum throughput. The strategy takes little overhead of the hardware and software. The judgment procedure is simple and quick. The strategy can be used in the Bluetooth system which has any control unit.

Key-Words: - Bluetooth, Packet, Channel Quality, Throughput, Packet Error Rate

1 Introduction

It is widely accepted that wireless personal area networks (WPAN) will form an important segment of the future market for wireless devices. Consumers are notoriously unforgiving, and a particular challenge for Bluetooth [1] and other WPAN technologies is to ensure satisfactory performance under difficult operating conditions. Of particular importance is the maintenance of the link itself: users will often accept a modest back off in terms of 'speed' (i.e. throughput) in order to sustain a connection that may have taken some time or effort to establish. For example in TCP/IP based applications it is common to incur a time-out even on relatively high speed links due to long delays when re-assembling network layer packets. Packet segmentation and re-assembly should therefore be carefully scrutinized to ensure that round trip delays are minimized [2] [3].

Other problems exist because short-range wireless links are susceptible to high bit error rate (BER) conditions. These conditions are caused by insufficient link margin to sustain the required SNR, for example, in the presence of physical layer impairments such as human body obstruction, multipath fading and clutter. As failed packets will have to be retransmitted the resulting network performance will depend on physical layer aspects such as the degree of forward error correction (FEC) and packet size. In Bluetooth systems, the designer has some flexibility in the choice of packet and the aim of this work was to examine the performance of asynchronous packet types under variable BER and dataloading conditions.

In this paper, a full duplex Bluetooth simulation model is presented. The model includes Bluetooth physical layer, Bluetooth baseband layer, control logic, Bits Error Rate test and so on. Furthermore, a short range wireless communication channel model is established. The channel model is used that takes into account positioning, propagation effects and radio characteristics. Based on the channel model, the radio performance of Bluetooth system is investigated by simulation. Such as ACL link data Bits Error Rate (BER) and throughput, SCO link Frame Error Rate (FER), BER and Resident BER (RBER). On the other hand, we put forward an advance packet selection scheme to Bluetooth v2.0+EDR systems. By selecting packet type and modulation type according to these rules, Bluetooth systems can has the maximum data throughput while having the minimum transmission delay at any given channel quality.

This paper is organized as follows. In Section 2, a brief overview over the Bluetooth system from the radio communication perspective is given. The full duplex Bluetooth simulation model for data and voice transmission is presented in Section 3 and the channel model used for Bluetooth system is introduced in Section 4. Section 5 provides some simulation results of Bluetooth and its channel model. In Section 6, PER (Packet error rate) and throughput of Bluetooth system are analyzed in terms of Es/No (symbol energy per noise density). In Section 7, we propose the strategy for packet and modulation type selection in Bluetooth v2.0+EDR systems and discuss the channel quality estimation schemes. Finally, conclusions are given in section 8.

2 Bluetooth Overview

Bluetooth system is considered one of the promising WPAN systems since the Bluetooth system is low cost, has a simple hardware and is robust, thus facilitating the realization of protected ad-hoc connections for stationary and mobile communication environments.

A Bluetooth transceiver is a frequency hopping spread-spectrum (FHSS) device that uses the unlicensed (worldwide) 2.4GHz ISM (Industrial, Scientific, Medical) frequency band. In most countries, there are 79 channels available; however, some countries allow the use of only 23channels. The nominal bandwidth for each channel is 1MHz.FCC part 15.247 regulations restrict the maximum allowed peak power output to 1 watt and require that at least 75 of the 79 channels be used in a pseudorandom manner. A device cannot operate on a given channel for longer than 0.4 seconds within any 30-second period. These limits (or restrictions) were put into place to minimize the amount of interference in the ISM band, which is also used by 802.11 b/g devices, HomeRF devices, portable phones and microwave ovens.

When connected to other Bluetooth devices, a Bluetooth device hops (changes frequencies) at the rate of 1600 times per second for typical use, with a residence time of 625 μ sec. When in inquiry or page mode, it hops at 3200 hops per second with a residence time of 312.5 μ sec.

A Bluetooth transceiver uses all 79 channels, and hops pseudo-randomly across all channels at a rate of 1600 hops per second for standard transmissions. It has a range of approximately 10 meters, although ranges up to 100 meters can be achieved with amplifiers. Because the transceiver has an extremely small footprint, it is easily embedded into physical devices, making it a truly ubiquitous radio link.

The Bluetooth specification uses time division duplexing (TDD) and time division multiple access (TDMA) for device communication. A single time slot is 625 μ sec in length, representing the length of a single-slot packet. At the Baseband layer, a packet consists of an access code, a header, and the payload, as shown in Fig. 1.

The access code contains the piconet address (to filter out messages from other piconets) and is usually 72 bits in length. The header contains link control data, encoded with a forward error-correcting code (FEC) with a 1/3 rate for high reliability. Such code is a repetition code and thus every bit in the header is transmitted three times. The header is usually 18 bits in length, and includes the active member address for a currently active slave. The payload can contain from 0 to 2745 bits of data, and may be protected by a 1/3 rate FEC (simple bit repetition, for SCO packets only), a 2/3 rate FEC (which is a (15,10) shortened Hamming code capable of correcting all one-bit errors and detecting all two-bit errors), or a 3/3/ rate (no FEC). For SCO connections, packets must be exactly one time-slot in length. For ACL links, packets may be 1, 3, or 5 time slots in length.

Bluetooth uses polling-based packet transmission. All communication between devices takes place between a master and a slave, using time-division duplex (TDD), with no direct slave-to-slave communication. The master will poll each active slave to determine if it has data to transmit. The slave may only transmit data when it has been polled. Also, it must send its data in the time slot immediately following the one in which it was polled. The master transmits only in even numbered time slots, while the slaves transmit only in odd-numbered time slots. In each time slot, a different frequency channel f is used (a hop in the hopping sequence).

The Bluetooth specification defines a piconet as an ad-hoc, spontaneous clustering of Bluetooth devices. In it, one device holds the role of master, while the rest of the devices are slaves. While there is no limit to the total number of slaves in a piconet, a maximum of seven slaves can be active in a piconet at any given point in time. If there are more than seven slaves, the rest of the slaves must be "parked." The maximum number of "parked" slaves is 255 per piconet with direct addressing via a parked slave address as defined by the SIG; however, indirect addressing of parked slaves by their specific Bluetooth device address is also permitted, effectively allowing any number of parked slaves. To reactivate a parked slave, the master must first place a currently active slave into a parked state.

When two Bluetooth devices enter into communication range, they will attempt to communicate with each other. If no piconet is available at that time, a negotiation process will ensue. One device will become the master (usually the device which initiated the communication) and the other will become a slave.

Any Bluetooth device can function within a piconet as a master, a slave or a bridge. These roles are temporary and exist only as long as the piconet itself exists. The master device selects the frequency, the frequency-hopping sequence, the timing (when the hops will actually occur) and the polling order of the slaves. The master is also responsible for instructing the slave devices to switch to different device states for periods of inactivity.

A master and slave must exchange address and clock information in order for the slave to join the master's piconet. Bluetooth devices each have a unique Global ID used to create a hopping pattern. The master radio shares its Global ID and clock offset with each slave in its piconet, providing the offset into the hopping pattern. A slave must be able to recreate the frequency-hopping sequence of the piconet it has joined, must know which frequency to use at which time, and must synchronize itself with the master's clock. The slave device does not actually adjust its own clock. Rather it tracks the amount of clock drift between its clock and the master's, and adjusts its transmission schedule accordingly.

A Bluetooth bridge device (or gateway) interconnects two or more piconets for multi-hop communication. The bridge communicates with all the piconets connected to it by aligning itself with the clocking of each piconet when it is ready to communicate. However, it can only communicate with one piconet at a time. Because the bridge incurs additional overhead shifting from one clocking to another to communicate with each connected piconet, it has the potential to become a bottleneck.

A bridge device may be a slave in all of the piconets to which it is connected, or it may be a master in one piconet and a slave in the others. The interconnection of two or more piconets via bridge devices results in the formation of a Bluetooth scatternet.

A Bluetooth device can be in one of the following states: standby, inquiry, page, connected, transmit, hold, park or sniff. A device is in Standby mode when it is powered on but has not yet joined a piconet. It enters the Inquiry state when it sends out requests to find other devices to which it might connect. A master of an existing piconet may also be in a Page state, sending out messages looking for devices that it can invite to join its piconet.

When successful communication is made between the master and the new device, the new device assumes the slave role, enters the Connected state, and receives an active address. While connected, the slave can transmit data when the master polls it. During the transmission of its data, the slave is in a Transmit state. At the end of its transmission, it returns to the Connected state.

The Sniff state is a low-power consumption state in which the slave "sleeps" for a pre-determined number of time slots. It wakes up at its appointed time slot for data transmission. It then returns to the inactive state until its next designated Sniff time slot arrives. The Hold state is another low-power state in which the slave is not active for a predetermined amount of time. However, there is no data transfer within the Hold state.

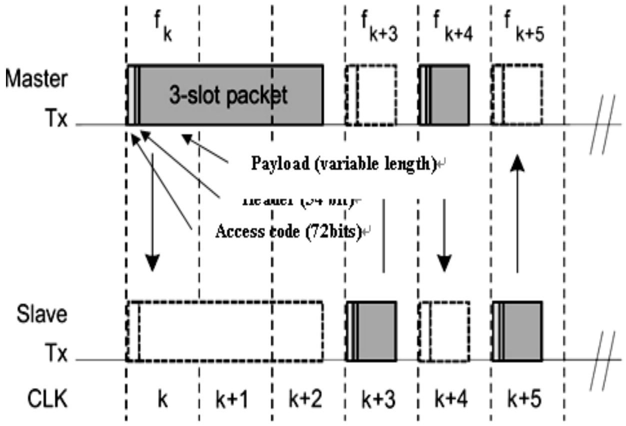

Fig.1 Transmission timing and frequency hopping example

Table 1 ACL packet type in Bluetooth specification Version2.0+EDR

Type	Payload Size	FEC	No. of Slots	Modulation Mode of Payload	Asymmetric Max. Rate (kb/s)
DM1	0~17	2/3	1	GFSK	108.8
DH1	0~27	-	1	GFSK	172.8
DM3	0~121	2/3	3	GFSK	387.2
DH3	0~183	-	3	GFSK	585.6
DM5	0~224	2/3	5	GFSK	477.8
DH5	0~339	-	5	GFSK	723.2
2-DH1	0~54	-	1	DQPSK	345.6
2-DH3	0~367	-	3	DQPSK	1174.4
2-DH5	0~679	-	5	DQPSK	1448.5
3-DH1	0~83	-	1	8DPSK	531.2
3-DH3	0~552	-	3	8DPSK	1766.4
3-DH5	0~ 1021	-	5	8DPSK	2178.1

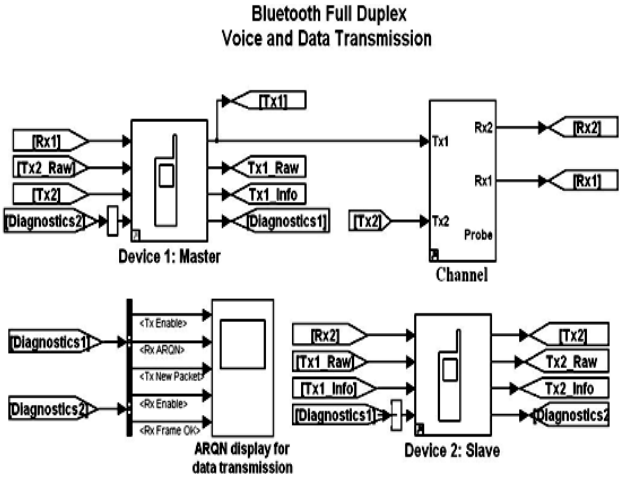

Fig. 2 Simulation Model of Bluetooth Full Duplex Transmission

When a slave device has no data to send or receive, the master may instruct the slave to enter the Park state. When it enters a Park state, the slave relinquishes its active address in the piconet. The address will then be given to another slave that the master is reactivating from Park state.

Considering the frequent change of the wireless channel condition, the estimation of the channel quality is necessary to determine the packet type of all others to achieve the maximum data throughput. In paper [4], packet selection scheme in Bluetooth version 1.0 based on channel quality estimation is described. The results show that selecting packet adaptively based on channel quality estimation can maximize data throughput while minimizing the transmission delay at any given BER (Bit Error Rate) of received data. Recently, Bluetooth v2.0+EDR specification [5] which supports not only GFSK but DQPSK and 8DPSK modulation types on ACL link. In a given channel quality, different modulation types have a different BER. Therefore, packet selection scheme in [4] is not suitable for Bluetooth v2.0+EDR system.

3 Bluetooth Simulation model

The Simulink simulation model of Bluetooth system described in the paper covers the signal processing characteristics of the baseband section of the Bluetooth specification (part B), and some of the radio section (part A). This includes typical physical layer components, such as speech processing, framing, coding, modulation, and frequency hopping, which are implemented in digital hardware or DSP software. Figure 2 shows the top-level of the complete full duplex Bluetooth model. It comprises a master device, radio channel, a slave device and instrumentation. The hierarchical modelling features allow large complex designs to be managed and modularized into subsystems. Opening up these subsystems reveals further levels of detail.

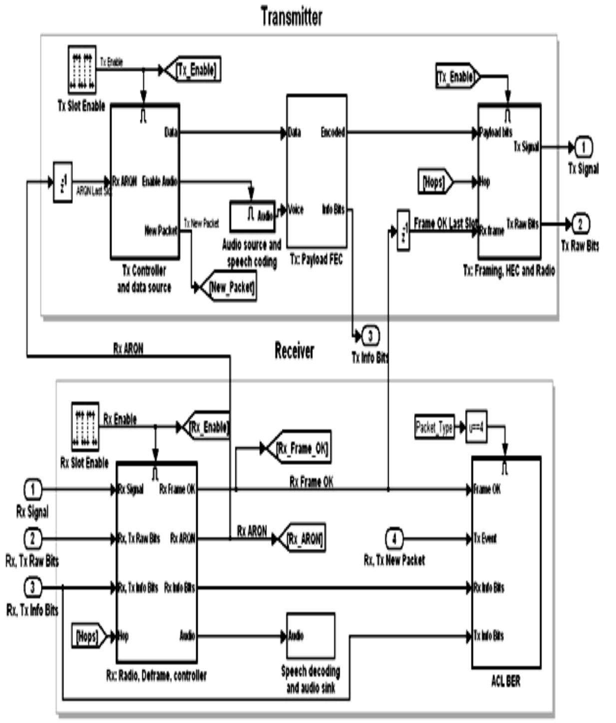

Fig. 3 Transmitter and receiver

Figure 3 shows the details of the Bluetooth model including transmitter, receiver and some test instruments. In the transmitter subsystem, the first part is logic control and data source, which charges packets type need to send and enable the audio data. The payload is generated in the second part. The last part is composed of packet framing, and radio. Fig. 4 shows the detail of the packet framing. The header is created first, including slave address, packet type code, flow control and so on. The header is protected by CRC. Then the access code, header and payload are concatenated to form a whole frame. In the receiver subsystem, as shown in the below part of Fig. 2, the incoming RF signal is demodulated by the radio part and the raw binary data stream is generated. The raw data contained the whole packet is separated as shown in Fig. 5. Then the packet is deframed into three parts: access code, header and payload. Whatever those right or not, the indications are sent to the test instruments such as Bits Error Rate (BER). So the BER, Packets Error Rate (PER) and throughput can be calculated as the results of system performance.

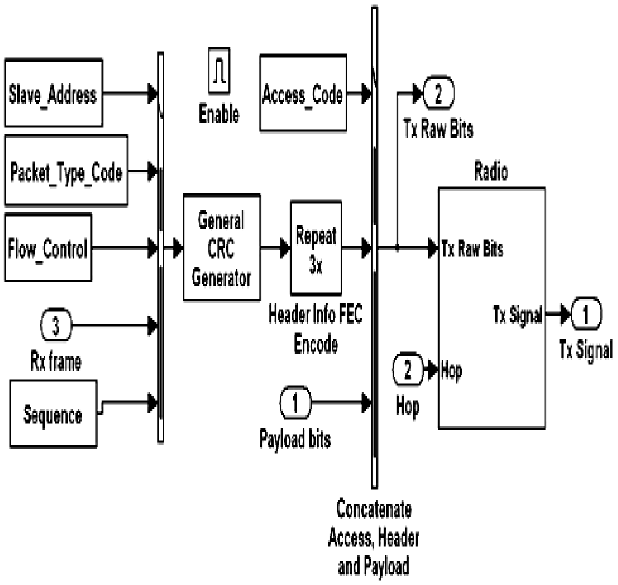

Fig. 4 Packets framing and sending

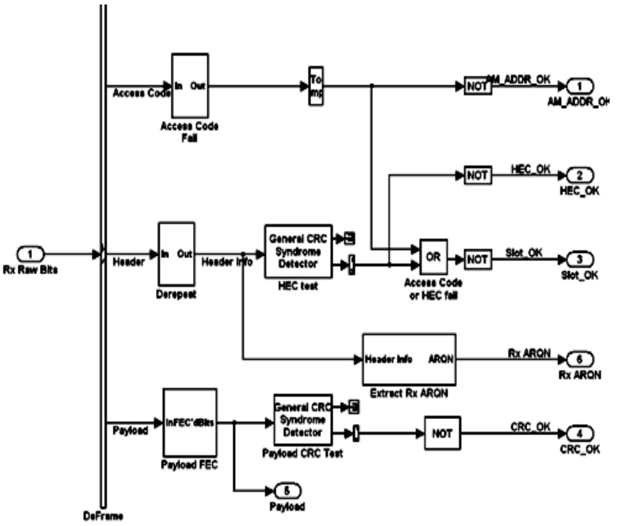

Fig. 5 Packets receiving and deframing

4 Radio Propagation and Channel model

The considered scenario is a two-dimensional complanate environment. The sessions happen between a master and its single slave. At the beginning of each session, the positions of the respective master and slave are drawn anew. Within a session, units do not move.

The link gain $g = P_r / P_t$, being the ration between received and transmitted power, is given by the following short range propagation model consisting of distance dependent attenuation, shadowing and multipath fading [2][3].

$$g = g_0(d) \cdot s(d) \cdot r^2(d)$$

The distance dependent attenuation is modelled as free space propagation.

$$g_0(d) = 10^{-4} \cdot d^{-2}$$

The shadowing factor $s(d)$ is lognormally distributed random variable, i.e. $10\lg s = N(0,\sigma)$ is an unbiased normally distributed variable in dB domain with a standard deviation σ depending on the distance d according to.

$$\sigma = \min\left\{\frac{d}{2},\quad 6\right\}$$

The multipath fading variable $r(d)$ is a Rician random variable with mean power $E\{r^2\} = 1$. The Rice factor K in dB is model also as a function of the distance d.

$$K = 12 - d$$

5 Simulation Results

In this section, we will analyze the potential performance tradeoff between the different packet formats supplied by the Bluetooth .The analysis that follows has been carried out considering the transmitter power Pt=0dBm, the noise power N0=-70dBm.

5.1 Performance of ACL packet data links

Scenarios are considered that contain only ACL data traffic. Within each simulation, the same ACL packet type from Table 1 is used for all forward links. The reverse link transmits only acknowledgments. The available spectrum contains 79 carrier frequencies.

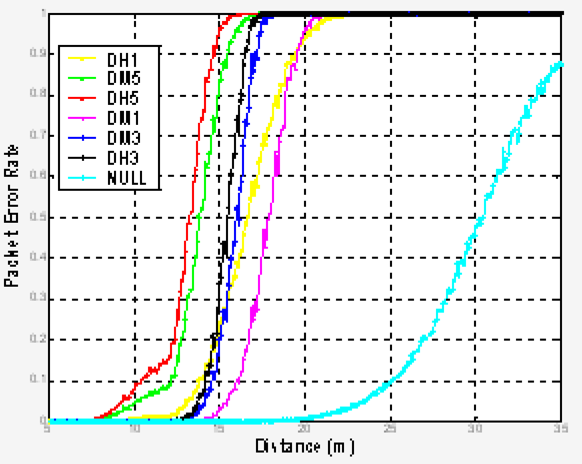

Fig.6 Distance vs. PER

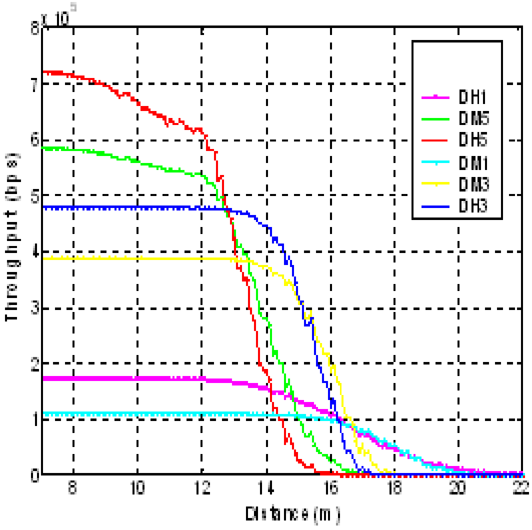

Fig.7 Distance vs. Throughput

Fig. 6 shows the average Packets Error Rate (PER) as a function of the distance. Packets receives failure can cause by the access, header or payload error. From the simulation results, we can see that when the distance becomes far, PER of the all packet type is increasing. Of the data packets, DM1 packet has most robust anti-jamming capability and DH5 packet has least one of the all ACL data packets. Since NULL packet has no payload, its PER is exactly the Frame Error Rate (FER) for all the packets. Fig. 7 shows the average link throughput of all ACL packets and their degradations due to radio propagation loss.

5.2 Performance of SCO packet data links

For SCO links, FER and Residual Bit Error Rate (RBER) are the two considered link quality measures of SCO links. From 5.1 we know, the FER is in fact equal to the PER of NULL packet. The RBER is collected only from those packets that had no erasure. Fig. 8 shows the averages of these quality measures s functions of the communication distance. Regarding the raw BER is close from HV1 to HV3, since but RBER is significant different. Access code and header of the different packet types are coded in the same way, but HV1 have higher successful ratio more robust since it uses more robust anti-jamming code.

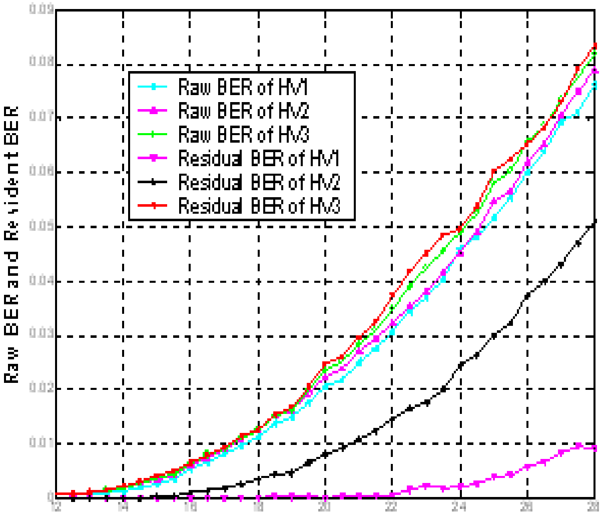

Fig.8 Distance vs. BER on SCO links

6 Packet error rate and throughput in terms of Es/No in Bluetooth system

The description of packet format is given as follows. Every packet is composed of three parts: access code, header and payload. The access code and header are of fixed size: 72 bits and 54 bits respectively. Payload has different data lengths according to the packet type. Each part of the packet uses different error correction scheme. Access code has non-coding rate. Header has 1/3 FEC coding, a simple 3-time repetition, which can correct 1 bit error out of 3 bits. Payload field of ACL link packets has either non-coding for DHx (x:1, 3, 5) packet or 2/3 FEC coding, a (15,10) shortened Hamming code correcting 1 bit error out of 15 bits, for DMx.

The received packets are considered success packets when all five parts of access code, header, payload in the packet sent and access code, header in the next receiving packet succeed. To calculate PER and throughput in termed of BER, we define that $P_1(\gamma)$, $P_2(\gamma)$ and $P_3(\gamma)$ are the success probability of access code, header and payload respectively. We can obtain the success probability of each part as follows.

$$P_1(\gamma) = \sum_{k=0}^{n} \binom{72}{k} (P_{GFSK}(\gamma))^k (1 - P_{GFSK}(\gamma))^{72-k} \qquad (1)$$

$$P_2(\gamma) = (3P_{GFSK}(\gamma))(1 - P_{GFSK}(\gamma))^2 + (1 - P_{GFSK}(\gamma))^3)^{18} \qquad (2)$$

$$\begin{cases} P_3(\gamma) = (1 - P_e(\gamma))^{\frac{m}{k}} \\ P_3(\gamma) = (15P_e(\gamma)(1 - P_e(\gamma))^{14} + (1 - P_e(\gamma))^{15})^{\frac{m}{15k}} \end{cases} \qquad (3)$$

Where n is a tolerance for bit error of synchronization word (synch word) of access code, and it is assumed that the value of n is 7 in this paper. We know that i is the length for DMx, and j is the one for DHx. $P_{\text{GFSK}}(\gamma)$ is the BER of GFSK modulation. $P_e(\gamma)$ is the BER of GFSK, DQPSK or 8DPSK, which depends what type of packet used. k is 1 for GFSK, 2 for DQPSK and 3 for 8DPSK.

The performance of GFSK modulation can be found using the following set of equations (4).

$$\text{P}_{\text{GFSK}}(\gamma) = e^{-\gamma/2}\{\frac{1}{2}I_0(ab) + \sum_{k=1}^{\infty}(\frac{a}{b})^k I_k(ab)\} \qquad (4)$$

$$a = \sqrt{\frac{\gamma}{2}(1 - \sqrt{1-\rho^2})} \quad b = \sqrt{\frac{\gamma}{2}(1 + \sqrt{1-\rho^2})} \qquad (5)$$

$$\rho = \frac{\sin(2\pi h)}{2\pi h} \qquad (6)$$

The SER (symbol error rate) performance of DQSK is

$$P_{\text{DQSK}}(\gamma) = 1 - [1 - \frac{1}{2} erfc(\sqrt{r/2})]^2 \qquad (7)$$

The SER performance of 8DPSK when γ is large enough is

$$P_e(\gamma) \approx e^{-r\sin^2(\pi/8)} \qquad (8)$$

Then, PER of the various packet types can be obtained as follows:

$$P(\gamma) = 1 - P_1(\gamma)^2 P_2(\gamma)^2 P_3(\gamma) \qquad (9)$$

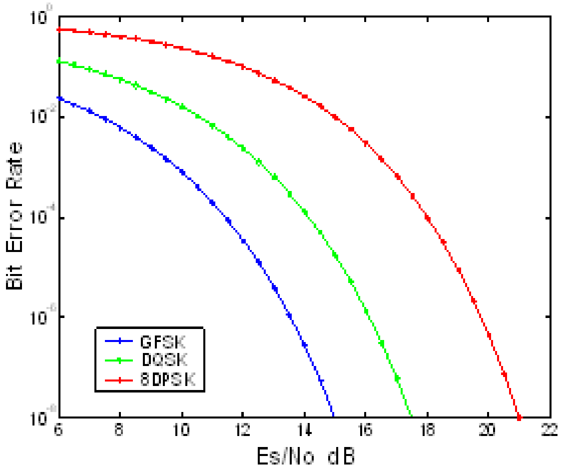

Fig. 9 PER vs. Es/No in different packet

Also, maximum throughput of asymmetric transmission of any packet is given by

$$R_{MAX} = \frac{L}{(\text{ES}+1)625 \times 10^{-6}} \qquad (10)$$

Where L is the length of payload, ES is effective slot size. In case of symmetric transmission, ES+1 is changed to 2ES.

Then we can get the average throughput of asymmetric transmission:

$$R(r) = \frac{R_{MAX}}{1 - P(\gamma)} \qquad (11)$$

The relationships between PER and Es/No and between throughput and Es/No are shown in Fig. 9 and Fig. 10 respectively.

In Fig. 11, the fair data throughput of all type of data packets in the certain channel quality is given. From Fig. 11 we can infer the rule for maximum data throughput shown in the Fig. 12.

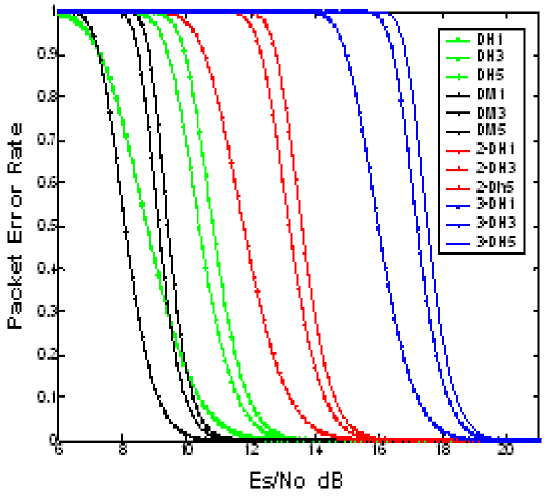

Fig. 10 Throughput vs. Es/No in different packet

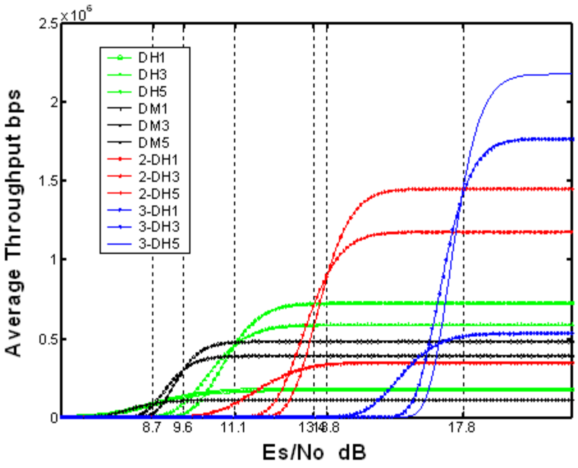

Fig. 11 PER vs. Es/No in different packets

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If     Es/No >17. 8      Then select 3-DH5
Elseif  Es/No >13.8      Then select 2-DH5
Elseif  Es/No >13.4      Then select 2-DH3
Elseif  Es/No >11.1      Then select DH5
Elseif  Es/No > 9.6      Then select DM5
Elseif  Es/No >8.7       Then select DM3
Else                     Then select DM1
End if
```

Fig.12 Strategy for Maximum Data Throughput

```
If     $T \ge T(17.8)$     Then select 3-DH5
Elseif  $T \ge T(13.8)$    Then select 2-DH5
Elseif  $T \ge T(13.4)$    Then select 2-DH3
Elseif  $T \ge T(11.1)$    Then select DH5
Elseif  $T \ge T(9.6)$     Then select DM5
Elseif  $T \ge T(8.7)$     Then select DM3
Else                       Then select DM1
End if
```

Fig. 13 Selection Strategy based on the recent packet sent

7 Packet Selection Strategy Based on Channel Quality Estimation

Considering the frequent change of the wireless channel condition, the estimation of the channel error probability is necessary to determine an effective length of a multi-slot. However, the estimation of the channel quality is difficult because multi-slot packets with different lengths are transmitted during a single Bluetooth connection. Besides, the estimation should be simple enough to be run on Bluetooth devices that require low power consumption. In [7], the authors propose a simple method to estimate the channel quality using single packet and furthermore find out the number of the packet which needs to estimate. In [8], the Maximum Likelihood Estimator (MLE) is used to estimate the channel error probability from the history of the packets errors. Both of the methods have a critical shortcoming that they have to use too many packets. In [7] the number of past packets is about 400 and in [8] it is about 100.

In this paper, an accurate error probability estimator is presented such that each Bluetooth device estimates the channel quality from its past transmission history. We first consider the throughput of a Bluetooth connection as a function of the packet type and the packet error probability. Then the selection strategy which gives the optimal packet type is presented through comparing the current throughput with the average throughput when the same packets are transferred. Our methods do not need so many past packets to estimate the channel quality but which is more fast and simple. The detail of the method is following.

Let N be the number of the last packets recently sent. In which, the number of packet type i is N_i and M_i is the number of packet type i that transferred successfully. Therefore,

$$N = \sum_i N_i \qquad (12)$$

And the actual data throughput of these packets is

$$T = \sum_i M_i R_{MAX_i} \qquad (13)$$

Under a given Es/No value, such as $\hat{r}$, the average throughput of Bluetooth system could reach is

$$T(\hat{r}) = \sum_i N_i R_{MAX_i} P_i(\hat{r}) \qquad (14)$$

If the real time receive Es/No value r is great than $\hat{r}$, usually have

$$T \ge T(\hat{r}) \qquad (15)$$

The greater the number N is, the more right Equation (15) is. It's the same the other way round. We can consider $r > \hat{r}$

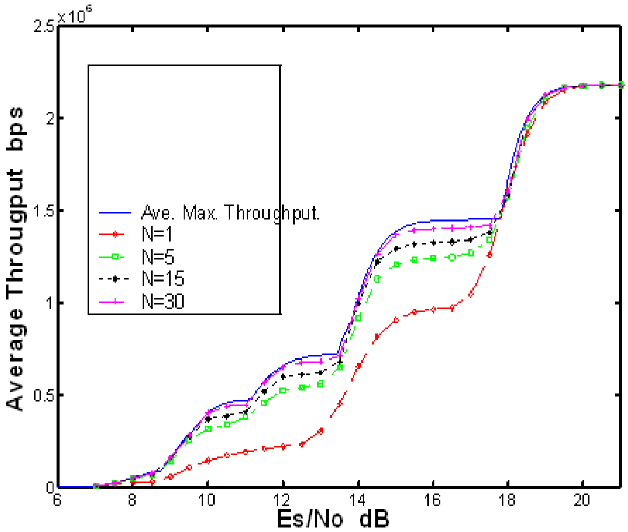

Fig. 14 The throughput is affected by N

So the packet selection strategy based on the recent packets sent is shown in Fig. 12. Fig.13 shows the affect of different value of N on the judgment for the optimal packet. We can see from Fig. 14 that the throughput based on our strategy is closed to the average maximum throughput when $N \geqslant 30$.

Since R_{MAX_i} $P_i(\hat{r})$ （$\hat{r}$=17.8, 13.8, 13 .4, 11.1, 9.6, 8.7） can be found out in advance, the computing overall of our method is very small. The advance packet selection strategy can be used in any Bluetooth system.

Fig.15 shows that the number of slots needed when system steadily selects the optimal packet using the selection strategy in a certain channel quality on N=30. We can see from the Figure that when the SNR is relatively low, the strategy need about 25 slots to steadily select the optimum packet. When the SNR is increasing, the optimal packet can be most fast acquired. But when the SNR is close to the two corners (9.6dB and 13.8dB), the strategy needs much more slots to reach the optimal packet. On all accounts, the performances of the selection strategy in our paper are far excelled than one of the methods in [7] and [8].

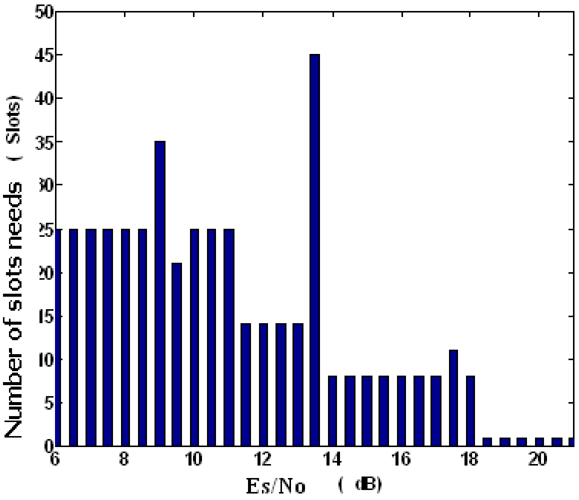

Figure 15 Number of slots needs when steadily select the optimal packet

8 Conclusion

In this paper, we presented a full duplex Bluetooth simulation model by Simulink of MATLAB. The model covers the signal processing characteristics of the baseband section and radio section of the Bluetooth specification. The model implemented data and voice transmission through ACL and SCO links. Meanwhile, we build up a new Radio propagation and channel model. The channel model is suitable to two-dimensional complanate environment. Based on this, we investigated the performances of Bluetooth system, such as the throughput of data transmission, Frame Error Rate and Bits Error Rate of SCO link etc. Through the simulation, we can see the detail transmission performances of different packet type.

The full duplex Bluetooth simulation model can simulate many scenarios of Bluetooth research work. For example, other ISM interferences could be added to the channel, we can compare and analyze the interference effect using the results of BER and FER. Another example is the inter-piconet interference between different piconets. In conclusion, testing system and device designs early in the development process in this way can substantially increase the chance of locating and correcting design flaws, for correcting and consummating them are inexpensive. Simulation research can increase productive efficiency and reduces the risk of design flaws.

On the other hand, we surveyed the transmission performances of Bluetooth 2.0+EDR system, including average maximum throughput under different channel quality. Furthermore, we proposed a new packet selection strategy base on the history of the packets errors. The channel quality is estimated by the error information of recent transmission packets. The type of next packet need to send is judged and can be adjusted dynamically. The simulation result shown that when the number of the packets used to decided is about 30, the throughput is greatly close to the average maximum throughput. The strategy takes little overhead of the hardware and software. The decide procedure is simple and quick and can follow the track of channel quality in very short time (about 100ms). The strategy can be used in the Bluetooth system which has any control unit.

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