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Core Technologies of Bluetooth Systems

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Abstract

The Bluetooth system is a communication system which enables both voice communication and data communication to be done on the same system. In 1998, it was made an open standard, with five American/Japanese/European firms as "promoters." Pieces of equipment which have received authentication are assured of having mutual connectivity. Our company has developed a chip set for use in Bluetooth systems, consisting of an RF transceiver LSI and base band controller LSI. This paper gives a summary description of the communications processing circuit and software which are built into the base band controller LSI.

1. Introduction

The concept of the Bluetooth system is to provide a wireless connection between equipment and it can potentially be applied to all kinds of electronic equipment. The number of companies which have registered with the Bluetooth SIG (Special Interest Group) endorsing this standard is more than 1880 firms as of the present (June, 2000.) The products which our company has developed, compatible with the Bluetooth system are: a chip set consisting of an RF transceiver LSI (ML 7050LA) and a base band controller LSI (ML7051LA), Bluetooth communication software, and a kit for system development. In this paper, after giving an overview of the Bluetooth system, we will describe in summary form the operation of the Bluetooth hardware and software for communications processing.

2. The Bluetooth system

The Bluetooth system is a wireless communication system which uses the 2.4 GHz band (ISM band) radio frequency which has been allocated for industrial/science and engineering/medical use without the need for a license. As shown in Figure 1, a variety of electronic equipment, such as portable telephones, personal computers, etc., can be connected in a "cable-less" manner.

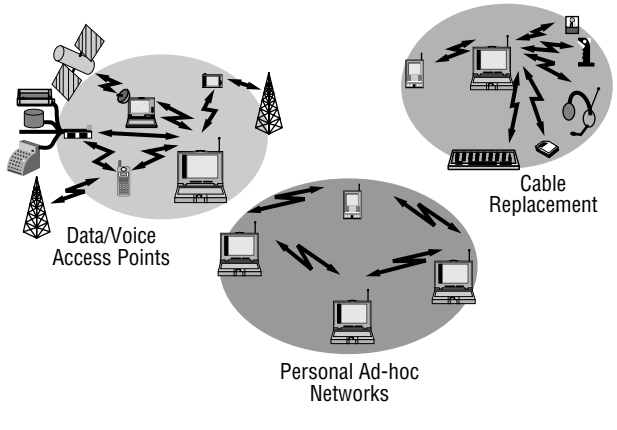

Figure 1: Bluetooth system usage model

Radio frequency range	2.4 GHz band (ISM band)
Frequency spacing	1 MHz
Number of radio channels	79 channels
Output power	Class 1: +20dBm (100mW); Class 2: 0dBm (1mW)
Duplex method	TDD: Time Division Duplex
Spread spectrum	FH-SS: Frequency Hopping Spread Spectrum
Frequency hopping bit rate	1600 hops per second
Modulation method	GFSK $m \leq 0.35$
Modulation bit rate	1 Mbps
Voice channel	64k PCM(A-law, μ-law), CVSD (Continuous Variable Slope Delta Modulation)
Maximum data channel rate	Symmetric communication: 432.6kbps, Asymmetric communication: 721kbps/56kbps

Table 1: Bluetooth specification table

The major specifications are shown in Table 1[1], while the types of Bluetooth communication forms are shown in Table 2[1]. The links shown in Table 2 are used as follows: the ACL (Asynchronous Connection Less) link for data communication, and the SCO (Synchronous Connection Oriented) link for voice transmission.

The wireless network configured with the Bluetooth system is shown in Figure 2. The Bluetooth network is configured with two kinds of wireless stations: master and slave stations.

As shown in the figure, a service area called a Piconet is created, centered around the master and having a radius of approximately 10 meters. The master can be placed in a state ("connection") where it can have a maximum of seven slaves as active slaves regularly communicating on the Piconet.

3. Bluetooth Communication Processing Circuitry

The ML7051LA base band controller LSI is configured centered on our company's proprietary platform (μPLAT™)*1

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*1 μPLAT™ is a registered trademark of Oki Electric Industry, Co., Ltd.

Packet type	FEC	CRC	Maximum symmetric rate (kpbs)	Maximum asymmetric rate (kpbs)	
				Forward	Reverse
ACL link					
DM1	2/3	Yes	108.8	108.8	108.8
DH1	No	Yes	172.8	172.8	172.8
DM3	2/3	Yes	258.1	387.2	54.4
DH3	No	Yes	390.4	585.6	86.4
DM5	2/3	Yes	286.7	477.8	36.3
DH5	No	Yes	433.9	723.2	57.6
AUX1	No	No	185.6	185.6	185.6
SCO link					
HV1	1/3	No	64.0		
HV2	2/3	No	64.0		
HV3	No	No	64.0		
DV	Voice: no Data: 2/3	Voice: no Data: yes	Voice: 64.0 Data: 57.6		

Table 2: Bluetooth link type table

which was developed according to the SPA (Silicon Platform Architecture) concept. The Bluetooth communication processing circuit is connected to the APB (AMBA Peripheral Bus) as a peripheral block of this platform, in the same way as the UART (Universal Asynchronous Receiver Transmitter) block and the USB (Universal Serial Bus) block.

The Bluetooth communication processing circuitry, as shown in Figure 3, is composed of ten kinds of small blocks. These blocks, through control by means of software, perform the functions of wireless control, communication processing for each link, voice processing, and timing control, which are specified by the Bluetooth specifications.

We will explain about the operation of these circuits.

1. Wireless Control

This chip performs transmission control, receive control, and frequency control of the RF transceiver LSI (ML7050LA.) In addition, it performs radio frequency processing based on a frequency hopping sequence which occurs 1600 times per second and, during receiving, the clock recovery processing and sync signal detection processing.

2. Communication processing for each link

As shown in Figure 4[1], for each packet, Bluetooth packet composition and decomposition processing are done, according to the packet type and data length specified by the software. During transmission, scrambling and encrypting of the data stored in the transmission buffer is performed and payload data is created. Together with creation of access codes and packet headers, composing of the entire transmission packet is also done. Because the packet type shown in Table 2 is set by software, link switching, switching of packet sizes, and selection of error correction coding are performed according to these settings.

During receiving, packet header and payload are separated. The payload data is error corrected, descrambled, and deciphered and stored in the receiving buffer. Through packet header analysis, discrimination as to packet size and link type are done, and notice is sent to the software.

3. Voice processing

Depending on the software settings and on the format of the voice signal transmitted by the SCO link, coding/decoding processing by PCM coding and CVSD coding are performed. At a voice transmission data speed of 64kbps, three kinds of voice coding schemes can be handled: μLaw PCM, A Law PCM, and CVSD.

4. Timing control

This block controls the operation timing of each block of the Bluetooth communications circuit. For the wireless block, that includes transmission control, receive control, setting of frequencies, sending of transmission data and receiving data decompose. It also controls the generation of interrupts to the CPU.

4. Software

4.1 Operation flow[1]

Bluetooth communication is structured with software controlling the communication processing circuits described above. This processing software consists of the LC (Link Controller) and LMP (Link Manager Protocol.) Here we describe the operation flow up to the point where Bluetooth transitions to the "connection" state.

1. inquiry/inquiry scan

Master: when configuring a Piconet, first, an "inquiry" operation is performed. While periodically sending the "inquiry" signal, information gathering is done to collect the addresses, etc. of the slaves which exist on the periphery.

Slave: to be accepted by the master, an "inquiry scan" operation is performed. While periodically switching the receiving frequency, it waits for the "inquiry" signal from the master. Upon receiving an "inquiry" signal, the address information, etc. of the slave is transmitted to the master.

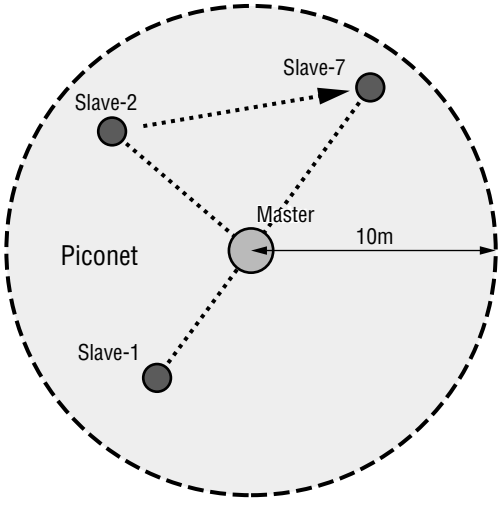

Figure 2: Bluetooth Piconet topology

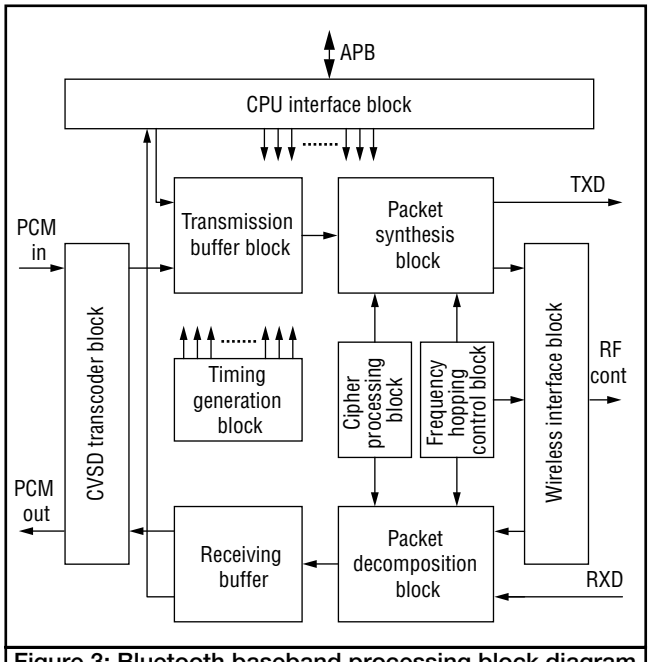

Figure 3: Bluetooth baseband processing block diagram

2. page/page scan

Master: to transition the slave to the "connection" state, the "page" operation is performed. Within the "page" operation, the slave is notified of active member addresses, the master address, and clock phase information.

Slave: to receive the "page" operation from the master, the "page scan" operation is performed.

While periodically switching the receiving frequency, the slave waits for the "page" signal from the master. Upon receiving a "page" signal, the master's address and clock-offset information are received.

3. connection

After completing "page/page scan," master and slave can mutually exchange linked information and "connection" has been established. The slave obtains the information for frequency hopping and synchronizing the scrambler by calculating it based on the address and clock phase information which the slave receives from the master.

4.2 Software configuration

Figure 5 shows the Bluetooth software configuration specified by Bluetooth Profile 1.0B[2]. Our company's lineup of software which runs on the base band controller LSI (ML7051LA) consists of three types.

1. Pack 1

This is the software for configuring a Bluetooth module using ML7050LA / ML7051LA, and consists of LC and LMP described in item 4.1. For interfacing to a host, HCI (Host Controller Interface) is specified by Bluetooth Core 1.0B[1]. For its physical interface, HCI is compatible with UART and USB.

2. Pack 2

This software is intended for the case where, the system is built into a piece of equipment, using ML7050LA

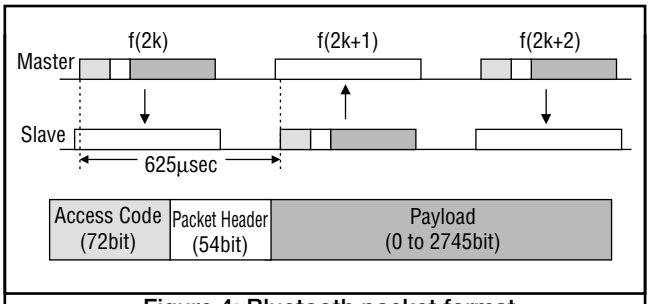

Figure 4: Bluetooth packet format

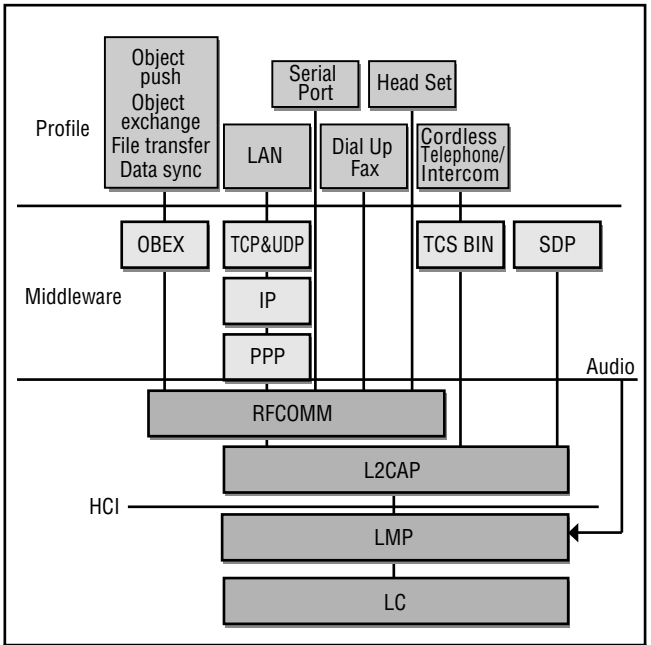

Figure 5: Bluetooth software stack architecture

/ML7051LA. In addition to the Pack 1 software, L2CAP (Logical Link Control and Adaptation Protocol), RFCOMM, and SCP (Service Discovery Protocol) are incorporated. All this software is specified by Bluetooth Core 1.0B[1]. It is assumed that application programs will be processed by the processor of the equipment itself, while software related to Bluetooth will operate on the ML7051LA. We also provide our company's proprietary host interface.

3. Pack 3

This software is for cases where a stand-alone Bluetooth product (e.g. a piece of equipment) is configured with ML7050LA / ML7051LA. All of the application software supplied by the equipment operates on the ML7051LA. Depending on the requirements of the equipment, profiles[2] adapted to each application and any necessary middleware can be built in.

5. Conclusion

In this paper we have explained the basics of a Bluetooth system and have described our company's Bluetooth communications processing circuit, the "Bluetooth Base

Band Controller LSI" (ML7051LA) and our Bluetooth software. In the future, our company will continue product development in response to new specifications and profiles which become accepted as standards by the Bluetooth SIG, and will supply those to the market.

6. References

1. Bluetooth SIG Specification of the Bluetooth System Core v1.0B, December 1, 1999
2. Bluetooth SIG Specification of the Bluetooth System Profiles v1.0B, December 1, 1999