Bluetooth

Part 2: Baseband

Outline

- Definition of baseband
- System timing
- ACL and SCO links
- Packet structure
- Channel coding

Baseband Defined

Baseband Part of a device which controls the radio (see Figure 2-1). It is responsible for low level timing, error control, and management of link within the domain of a single data packet transfer

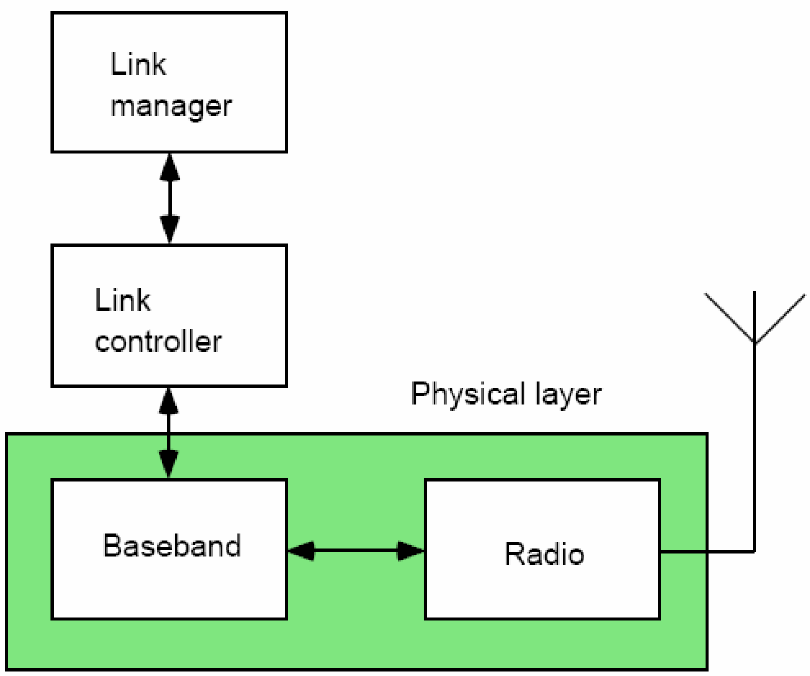

Figure 2-1 Link control and the baseband

System Timing

CLKN Real time clock. Implemented by 28 bit count which is reset to 0 at power up. Incremented every half slot, or 312.5 μs

All Bluetooth devices use CLNK to:

- synchronize Tx-Rx data exchanges between devices
- differentiate between lost and re-sent packets
- generate predictable and reproducible sequence of hop channel numbers

Piconet Clock

Each Slave in a piconet adds an offset value onto its CLNK (see Figure 2-2). New value—denoted CLK and called **piconet clock**—is an estimate of Master's CLNK

Master adds another offset to its CLNK to obtain an estimate, CLKE, of the CLK in a Slave device. CLKE is used to connect to Slave before Slave is synchronized to Master

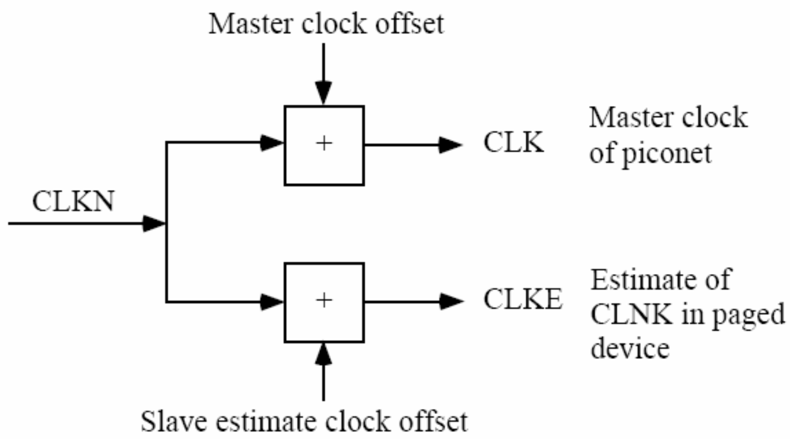

Figure 2-2 Conceptual Bluetooth CLK offset application

ACL Links

ACL (Asynchronous Connectionless) links provide packet-switched connections:

- A Master may have a number of ACL links to different Slaves
- Only one ACL link can exist between a Master and a Slave
- A Master need not transmit to a Slave in regular fashion
- Master determines which Slave to transmit to and receive from on a slot by slot basis

More on ACL Links

- Most ACL packets facilitate error checking and re-transmission
- ACL links carry data to and from L2CAP and Link Manager (LM) layers
- Data carried in **DH** (Data High rate) packets and **DM** (Data Medium rate) packets. DM packets carry less data, but provide extra error protection
- Broadcast packets are ACL packets that are not addressed to a specific Slave

SCO Links

SCO (Synchronous Connection Oriented) links provide circuit-switched connections:

- Symmetric link between Master and Slave with reserved bandwidth in the form of reserved slots
- Intended for use with time-bounded information such as audio
- Master can support up to three SCO links to the same Slave or to different Slaves

More on SCO Links

- SCO packets are not retransmitted
- A SCO link is set up by a LM command from the Master to the Slave. Message contains timing parameters to specify the reserved slots

Packet Structure

Every packet consists of (see Figure 2-3):

Access code Used to detect the presence of a packet. Identifies the packet as being from or to a specific Master

Header Contains all control information associated with the packet and link, such as address to intended Slave

Payload User data and control information from higher layers

68 or 72 bits access code	54 bits header	0-2745 bits payload

Figure 2-3 Bluetooth packet structure

Access Code

Access code consists of (see Figure 2-4):

- 4 bits preamble used to detect edges of received data
- 64 bits synchronization word
- 4 bits trailer

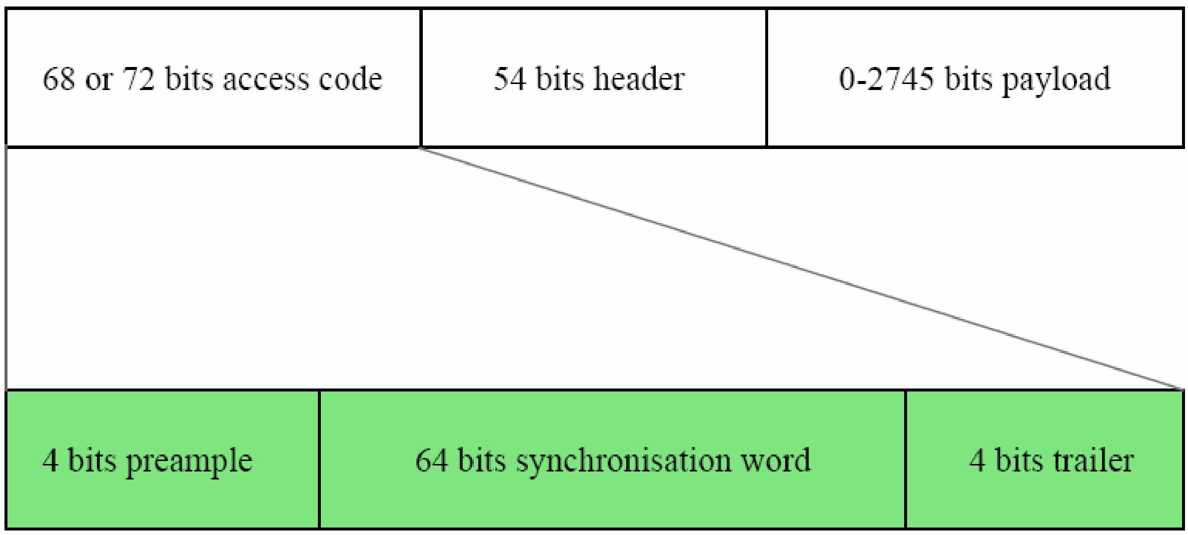

Figure 2-4 Access code structure

Synchronization Word Algorithm

1. Determine 24-bit Lower Address Part (LAP) of Bluetooth device address (48 bit IEEE MAC address)

2. Append 6-bit Barker sequence to LAP to improve auto-correlation properties

3. XOR new sequence with bits 34 to 63 of full length, 64-bit Pseudorandom Noise (PN) sequence

4. Encode resulting 30-bit sequence with (64,30) BCH (Bose-Chaudhuri-Hocquenghem) block code to obtain 34 parity bits

Algorithm Continued

5. 34-bit parity word XOR'd with the remaining bits, 0 to 33 of PN sequence to remove cyclic properties of block code

Remark: 34 bits BCH parity word exhibits very high auto-correlation and very low co-correlation properties. Thus, a correlator can be used to obtain a match between the received and expected (reference) synch world

Packet Header

- 54 bits packet header (see Figure 2-5) contains 18 bits of information encoded with a rate 1/3 repetition code, i.e., each information bit is transmitted 3 times

- The large amount of overhead is included because each header field is crucial to the correct operation of the link

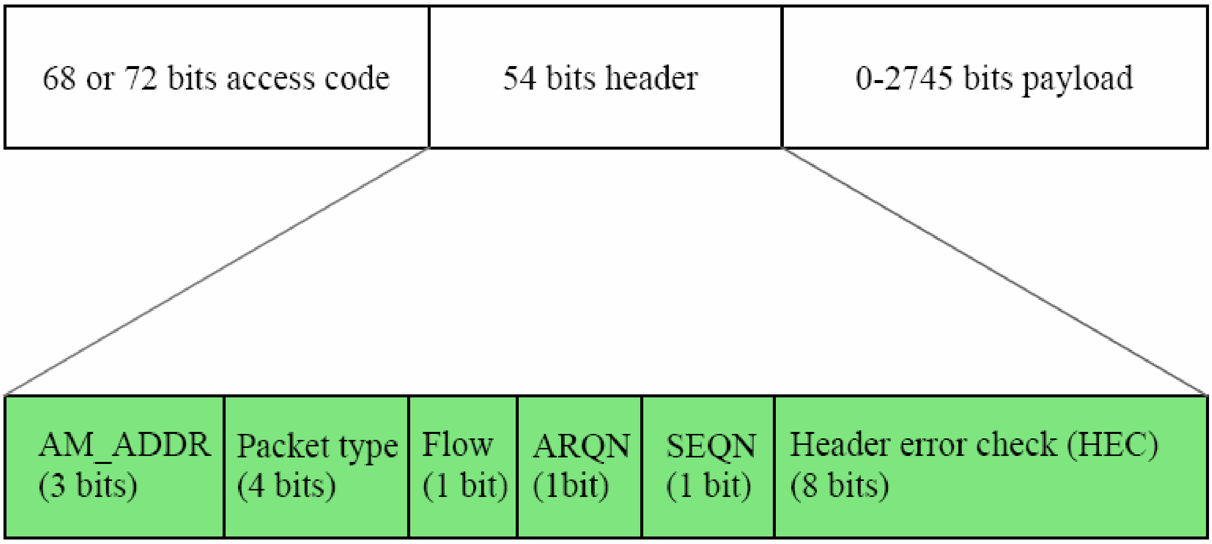

Figure 2-5 Packet header structure

Header Fields

AM_ADDR Master assigns Active Member ADDRess (AM_ADDR) to Slave. 3-bit field sufficient for 7 Slaves. Broadcast packet has address zero

Flow Flag asserted when device is unable to receive any more data due to full receiver buffer

ARQN and SEQN SEQN toggled each time new packet with CRC is transmitted, ACK represented by ARQN=1 and NAK by ARQN=0

Header Error Check (HEC) 8-bit CRC

More Header Fields

Packet type Defines which type of traffic is carried by packet:

- SCO, ACL
- **ID** packet consists of access code, used during "pre-connection"
- **NULL** packet consists of access code and header, used for flow control or to pass ARQ
- **POLL** packet same structure as NULL packet, must be acknowledged
- FHS (Frequency Hop Synchronization)

ACL Payload

The ACL payload is divided into three fields (see Figure 2-6):

- payload header with fields:

  L_CH (Logical CHannel) Field indicates whether payload is start or continuation of message

  Flow Controls data transfer at L2CAP level

  Length Number of data bytes in payload

- payload data
- CRC, calculated over both payload header and payload

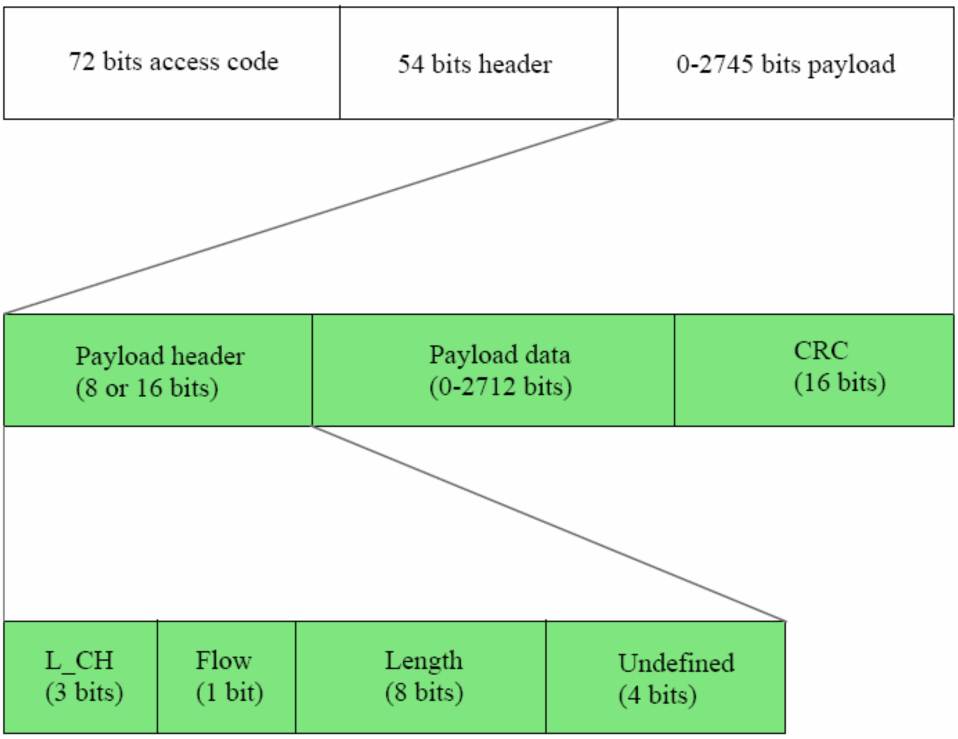

Figure 2-6 ACL payload and payload header structure

SCO Packet Structure

- Same access code and header as ACL packets
- ARQ and SEQ fields in header redundant since flow control and retransmission are not used
- CRC field in header not used
- Payload size fixed at 30 bytes (240 bits), error control code with rate 1/3, 2/3, or 1 (no code) used for source data size of 10, 20, or 30 bytes

More on SCO Packet Structure

Research Opportunity: Maximum overhead for SCO packet is equal to the maximum number of control bits divided by the total number of bits in packet:

$$\frac{72 + 54 + 160}{72 + 54 + 240} = \frac{286}{366} \approx 0.78$$

Is this really neccessary?

Error Control Coding and Encryption

CRC Performed on all packet headers and ACL payload data

FEC (Forward Error Correction) Non, rate 1/3 repetition code, and rate 2/3 shortened (15,10) Hamming code

Encryption Chiper stream produced by encryption engine XOR'd into bitstream data path

Bitstream Processing

Whitening or bit randomization Pseudo random bit sequence mixed with data bitstream. Reduces DC bias, thus avoiding channel drift

Summary

- Baseband responsible for coding, timing, and link management within the domain of a single data packet transfer
- Devices exist in two modes of operation, namely Slave and Master
- SCO data links for time bounded data and ACL links for packet based data