Bluetooth

Part 5: The Host Controller Interface

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Outline

- *Host Controller Interface* (**HCI**)
- Advantages of HCI
- HCI packet types, transport layer, and flow control
- Configuring controllers
- Inquiring and paging
- Sending and receiving data

Definition of HCI

HCI The interface which links a Bluetooth **host** to a Bluetooth **controller** (or module). Data commands and events pass across this interface

- The Bluetooth controller may be a PCMCIA card and the host may be a portable PC
- Baseband and Link Manager run on one processor in the Bluetooth controller with higher layers and applications running on separate Bluetooth host processor

Advantages

- The HCI makes it possible to mix and match higher and lower layers, e.g., one set of higher layer software on a PC can run with PCMCIA cards from different manufacturers

- Host PCs have spare capacity to handle higher layers, allowing Bluetooth device to have less memory, and less powerful processor, thus reducing costs

- Host device can sleep and be awoken by an incoming Bluetooth connection

HCI Packet Types

- **Command packets** used by the host to manage the controller and to monitor its status
- **Event packets** used by the controller to inform the host of changes in the lower layers
- **Data packets** to pass voice and data between host and controller

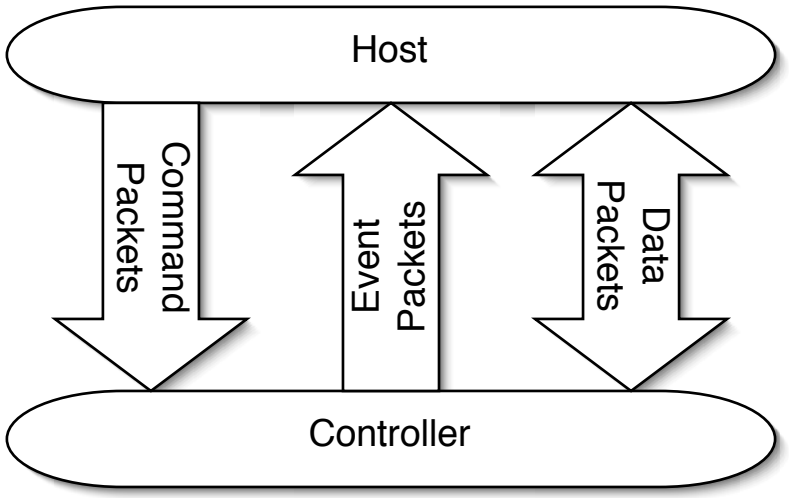

Figure 5-1 The three types of HCI packets

HCI Command Packets

- An HCI command packet contains:
  - an OpCode identifying the type of the command
  - field giving total length in bytes of the following parameters
  - parameter fields

- **HCI_Command_Complete** event returned if HCI command can complete immediately, else an **HCI_Command_Status** event is returned immediately, and another event is returned later

HCI Data Packets

- HCI data packets are used to pass both data (ACL) and voice (SCO) information across the HCI

- An HCI data packet for ACL data contains the fields:
  - connection handle identifying ACL connection for the data
  - Packet Boundary (PB) flag identifying whether packet data carries the start of higher layer L2CAP packet, or is a continuing fragment
  - BroadCast (BC) flag identifying point to point data from broadcast data
  - field giving total length of data in bytes

... HCI Data Packets

- An HCI packet used to transfer SCO data has a very similar structure to an ACL packet with a few differences:
  - there are no PB or BC flags; their places are reserved
  - the length of the data field is restricted to 255 bytes
- The data length is restricted to support two-way audio with limited delay

HCI Event Packets

- The format of HCI Event Packets is similar to HCI command packets. A packet contains the following fields:
  - event code identifying the event
  - total length of parameters in bytes
  - parameter fields
- The Bluetooth host may mask or filter events

HCI Transport Layer

- A transport layer is needed to get HCI packets from the host to the Bluetooth controller

- Bluetooth defines three transport layers:
  - USB: Universal Serial Bus
  - RS-232: serial interface with error correction
  - UART: Universal Asynchronous Receiver Transmitter, a serial interface without error correction

Flow Control

- It is necessary to slow down the data transport across the HCI when the Bluetooth controller's buffers are overloaded

- Bluetooth solves this problem by providing flow control of the HCI. There are three types of flow control:
  - command flow control
  - flow controlling data from Bluetooth host
  - flow controlling data from Bluetooth controller

Command Flow Control

- When the system is first turned on, the host may only send one command until it receives an **HCI_Command_Complete** or **HCI_Command_Status** event

- These events contain a **Num_HCI_Command_packets** field, which tells the host how many command packets the Bluetooth controller can buffer

Flow Controlling Data from the Host

- The **HCI_Read_Buffer_Size** command is used to determine the buffer space of the Bluetooth controller
  - Bluetooth controller replies with the number of SCO and ACL packets it can buffer, as well as the maximum size of the HCI SCO data and HCI ACL data packets
- Once the host has filled up the controller's buffer, it must wait for a **HCI_Number_Of_Completed_Packets** event from the controller. This packet contains information on all active connections

Flow Controlling Data from the Bluetooth Controller

- Flow control of the Bluetooth controller is switched on with the command **HCI_Set_Host_Controller_To_Host_Flow_Control**
- The **HCI_Host_Buffer_Size** command is used to notify the controller of the host's buffering capabilities
- Host utilizes the **HCI_Host_Number_Of_Completed_Packets** command to inform the Bluetooth controller how many packets have been processed on each connection

Configuring Controllers

HCI provides configuration commands to inquire a local controller or a remote device about

- *Standard version supported* (HCI version and revision, LMP version and sub-version, manufacturer name)
- *UTF-8 encoded name* up to 248 bytes long
- *Device class*
- *Voice settings*

- *Optionally supported features* (partial list):
  - multi-slot data packets—single slot is mandatory
  - encryption and authentication support
  - master/slave switch and slot offset between Master and Slave
  - timing accuracy (long-term drift and jitter)
  - low power modes—hold, park, and sniff
  - SCO channel support

Inquiring: Discovering Bluetooth Devices

All aspects of the inquiry process are controlled by the HCI:

- The host uses the **HCI_Inquiry** command to initiate an inquiry
- The controller utilizes an **HCI_Inquiry_Result** event to respond to an inquiry from the host
- The **HCI_Set_Event_Filter** command can be used to set an inquiry result filter such that some devices will not be repoted in an **HCI_Inquiry_Result** event

Inquiry Scan: Becoming Discoverable

- A Bluetooth device allows other devices to discover it by conducting inquiry scans

- A device conducting an inquiry sends out ID packets containing an Inquiry Access Code (IAC). An inquiry scanning device uses a correlator to listen for the IAC

- An inquiry scanning device scans for short bursts ($\approx$ 11ms). Maximum interval of about 2.6s between the start of two consecutive inquiries

Paging: Initiating Connections

- A Bluetooth device connects to other devices by paging them

- The host uses an **HCI_Create_Connection** command to begin paging. The command contains all the information that the controller needs to establish a connection

Page Scan: Receiving Connections

- A Bluetooth device allows other devices to connect to it by entering page scan mode

- A device in page scan mode listens for its own ID in packets sent from a paging device

Sending and Receiving Data

- When a connection is set up across HCI, a connection handle is returned to the host in the **Connection_Complete** event

- This handle is used in the **HCI_ACL_data** packet

Summary

- A Bluetooth device can be made up of two parts: a host implementing the higher layers (L2CAP and above), and a controller implementing the lower layers (LMP and below)

- The *standardized* HCI provides a interface between a Bluetooth host and its controller

- HCI commands allow the host to completely control a Bluetooth controller and to transfer any data required