Audio Streaming to IP-Enabled Bluetooth Devices

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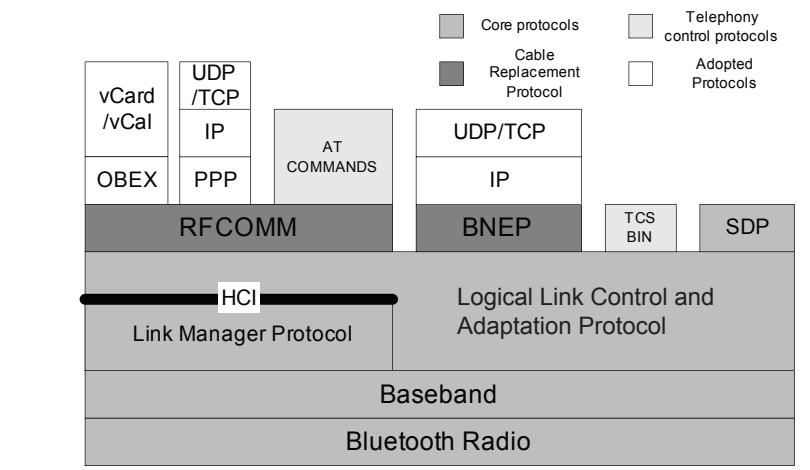
INTRODUCTION

Over the last few years, we have witnessed the emergence of many wireless systems and devices such as cellular phones, personal digital assistants, pagers, and other portable devices. However, they are often used separately, and their applications do not interact. One of the goals of personal area networks (PANs) (Bluetooth SIG, 2002a; Gavrilovska & Prasad, 2001) is to enable such a diverse set of devices to exchange information in a seamless, friendly, and efficient way. The emergence of Bluetooth (Bluetooth SIG, 2001b; Roberts, 2003) wireless technology promises such seamless networking. Bluetooth is an open industry standard that can provide short-range radio communications among small form factor mobile devices. Bluetooth is based on a high-performance, low-cost integrated radio transceiver and has been designed to provide a cable replacement technology with emphasis on robustness and low cost. Bluetooth supports two types of links: the synchronous connection-oriented (SCO) link and the asynchronous connectionless link (ACL). Figure 1 illustrates the Bluetooth protocol stack.

The link manager protocol (LMP) performs link setup and configuration functions. The logical link and control adaptation (L2CAP) layer supports protocol multiplexing and connection-oriented/connectionless data services. The host controller interface (HCI) layer provides an interface to access the hardware capabilities of Bluetooth.

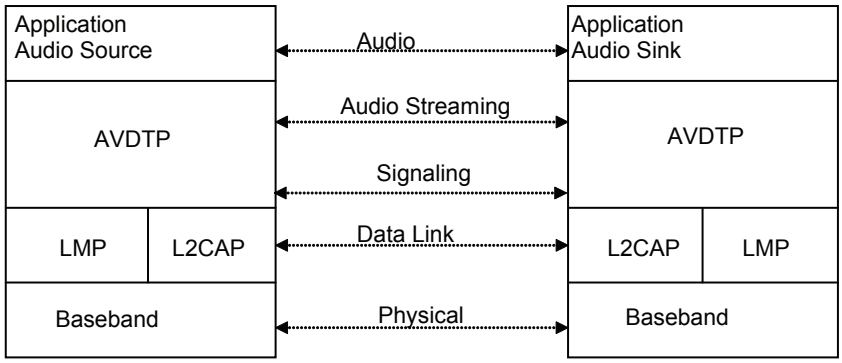
In this article, we focus on the design and implementation of an architecture that (a) provides interoperability and connectivity of Bluetooth networks with other networks using Internet protocol (IP) technology

Figure 1. The Bluetooth protocol stack



AT	= attention sequence (modem prefix)	SDP	= service discovery protocol
BNEP	= Bluetooth network encapsulation protocol	TCP	= transmission control protocol
IP	= Internet protocol	TCS BIN	= telephony control specification-binary
OBEX	= object exchange protocol	vCAl	= virtual calendar
PPP	= point-to-point protocol	vCard	= virtual card
FRCOMM	= radio frequency communications	HCI	= host controller interface
LMP	= link manager protocol	L2CAP	= logical link control and adaptation protocol
UDP	= user datagram protocol		

Figure 2. The AVDTP protocol stack in Bluetooth (only the audio portion of AVDTP is shown)



AVDTP: Audio/Video Distribution Transport Protocol
L2CAP: Logical Link and Control Adaptation
LMP: L ink Manager Protocol

and (b) enables Bluetooth mobile devices to wirelessly stream high-quality audio (greater bandwidth than toll quality voice) content from other Internet devices. We also investigate the efficiency of different design approaches that can be used by Bluetooth-enabled devices for high-quality audio streaming.

AUDIO/VIDEO TRANSMISSION OVER BLUETOOTH WITH AVDTP

The Audio Video Working Group has defined a Bluetooth profile that allows streaming of high quality mono or stereo audio directly over L2CAP from another device. This profile, the advanced audio distribution profile (A2DP) (Bluetooth SIG, 2002b), is based on the generic audio/video profile distribution profile (GAVDP) (Bluetooth SIG, 2002c), which in turn uses the audio/video distribution transport protocol (AVDTP) (Bluetooth SIG, 2002d). AVDTP specifies the transport protocol for audio and video distribution and streaming over Bluetooth ACL links. Figure 2 shows the protocol stack model for AVDTP.

AVDTP defines the signaling mechanism between Bluetooth devices for stream set-up and media streaming of audio or video using ACL links. Audio/video (A/V) streaming and signaling set-up messages are transported via L2CAP packets. A dedicated protocol/service multiplexer (PSM) value (the PSM value for AVDTP is 25) is used to identify L2CAP packets that are intended for AVDTP. AVDTP applies point-to-point signaling over connection-oriented L2CAP channel set up in advance between two devices participating in A/V streaming. Before A/V applications transport A/V streams over a Bluetooth link, AVDTP performs A/V parameter negotiation. Based on the result of this negotiation, applications transfer A/V content.

AUDIO STREAMING TO BLUETOOTH DEVICES OVER IP

Connecting Bluetooth Devices to IP-Based Networks

The proliferation of IP over all kinds of networks today makes it necessary to support Bluetooth applications over IP-based networks. However, an IP over Bluetooth profile was not specified in the Bluetooth specifications. There are currently two ways of running IP-based applications over Bluetooth: one approach is to use the local area network (LAN) profile (Bluetooth SIG, 2001c), and the other approach is to use the PAN profile (Bluetooth SIG, 2002a). The LAN profile defines how Bluetooth-enabled devices can access services of a LAN using the IETF point-to-point protocol (PPP) (Simpson & Kale, 1994). The PAN profile describes how two or more Bluetooth-enabled devices can form an ad-hoc network and how the same mechanism can be used to access a remote network through a network access point. It uses the Bluetooth network encapsulation protocol (BNEP) (Bluetooth SIG, 2001a) to provide networking capabilities for Bluetooth devices.