

## Chapter 3.1

# Enabling Technologies for Pervasive Computing

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### INTRODUCTION

Bluetooth (Bluetooth SIG, 2004) and ZigBee (ZigBee Alliance, 2004) are short-range radio technologies designed for wireless personal area networks (WPANs), where the devices must have low power consumption and require little infrastructure to operate, or none at all. These devices will enable many applications of mobile and pervasive computing. Bluetooth is the IEEE 802.15.1 (2002) standard and focuses on cable replacement for consumer devices and voice applications for medium data rate networks. ZigBee is the IEEE 802.15.4 (2003) standard for low data rate networks for sensors and control devices. The IEEE defines only the physical (PHY) and medium access control (MAC) layers of the standards (Baker, 2005). Both standards have alliances formed by different companies that develop the specifications for the other layers, such as network, link, security, and application. Although designed for

different applications, there exists some overlap among these technologies, which are both competitive and complementary. This article makes a comparison of the two standards, addressing the differences, similarities, and coexistence issues. Some research challenges are described, such as quality of service, security, energy-saving methods and protocols for network formation, routing, and scheduling.

### BLUETOOTH

Bluetooth originated in 1994 when Ericsson started to develop a technology for cable replacement between mobile phones and accessories. Some years later Ericsson and other companies joined together to form the Bluetooth Special Interest Group (SIG), and in 1998 the specification 1.0 was released. The IEEE published the 802.15.1 standard in 2002, adopting the lower

layers of Bluetooth. The specification Bluetooth 2.0+EDR (Enhanced Data Rate) was released in 2004 (Bluetooth SIG, 2004).

Bluetooth is a low-cost wireless radio technology designed to eliminate wires and cables between mobile and fixed devices over short distances, allowing the formation of ad hoc networks. The core protocols of Bluetooth are the radio, baseband, link manager protocol (LMP), logical link control and adaptation protocol (L2CAP), and service discovery protocol (SDP). The radio specifies details of the air interface, including frequency, modulation scheme, and transmit power. The baseband is responsible for connection establishment, addressing, packet format, timing, and power control. The LMP is used for link setup between devices and link management, while the L2CAP adapts upper-layer protocols to the baseband layer. The SDP is concerned with device information and services offered by Bluetooth devices.

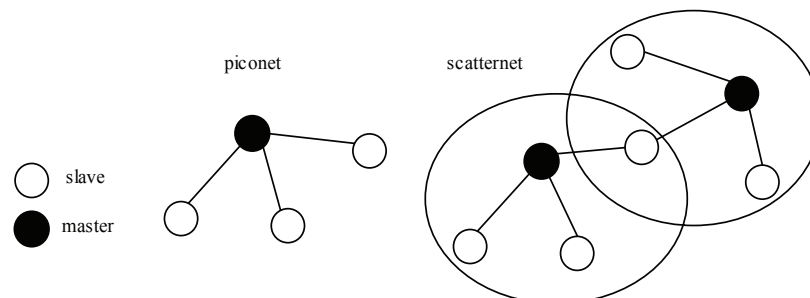
Bluetooth operates on the 2.4 GHz ISM (Industrial, Scientific, and Medical) band employing a frequency-hopping spread spectrum (FHSS) technique. There are 79 hopping frequencies, each having a bandwidth of 1MHz. The transmission rate is up to 1 Mbps in version 1.2 (Bluetooth SIG, 2003) using GFSK (Gaussian frequency shift keying) modulation. In version 2.0+EDR new modes of 2 Mbps and 3 Mbps were introduced. These modes use GFSK modulation for the header and

access code of the packets, but employ different modulation for data. The  $\pi/4$  differential quadrature phase-shift keying (DQPSK) modulation and 8 differential phase-shift keying (DPSK) modulation are employed in 2 Mbps and 3 Mbps mode, respectively.

The communication channel can support both data (asynchronous) and voice (synchronous) communications. The synchronous voice channels are provided using circuit switching with a slot reservation at fixed intervals. The asynchronous data channels are provided using packet switching utilizing a polling access scheme. The channel is divided in time slots of 625  $\mu$ s. A time-division duplex (TDD) scheme is used for full-duplex operation.

Each Bluetooth data packet has three fields: the access code (72 bits), header (54 bits), and payload. The access code is used for synchronization and the header has information such as packet type, flow control, and acknowledgement. Three error correction schemes are defined for Bluetooth. A 1/3 rate FEC (forward error correction) is used for packet header; for data, 2/3 rate FEC and ARQ (automatic retransmission request). The ARQ scheme asks for a retransmission of the packet any time the CRC (cyclic redundancy check) code detects errors. The 2/3 rate FEC is a (15,10) Hamming code used in some packets. The ARQ scheme is not used for synchronous packets such as voice.

Figure 1. Piconet and scatternet



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