WPAN

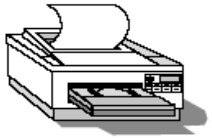
Wireless Personal Area Network

IEEE 802.15 Working Group for Wireless Personal Area Networks

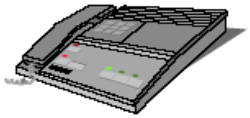
- The 802.15 WPAN effort focuses on the development of consensus standards for Personal Area Networks (PAN) or short distance wireless networks
- WPANs address wireless networking of portable and mobile computing devices such as: PCs, tablets, peripherals, cell phones, and consumer electronics; allowing these devices to communicate and interoperate with one another.

Example of home equipment demanding network operations






Home Computing
Desktop computer
Laptop
Printer
Scanner
QuickCam

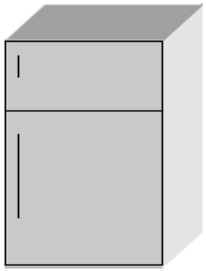
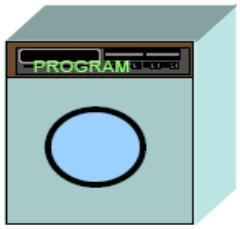



Phone appliances
Standard phone
Inter Comm
Cordless phone

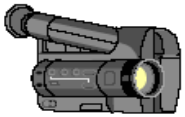

Location / Navigation
locating children and pets
navigating handicaps


Entertainment Audio/Visual appliances
Analog/Digital TV
VCR / DVD
Camcorder
Stereo system
Speakers / Headphones

Smart appliances
Oven(s)
Fridge(s)
Washing machine(s)

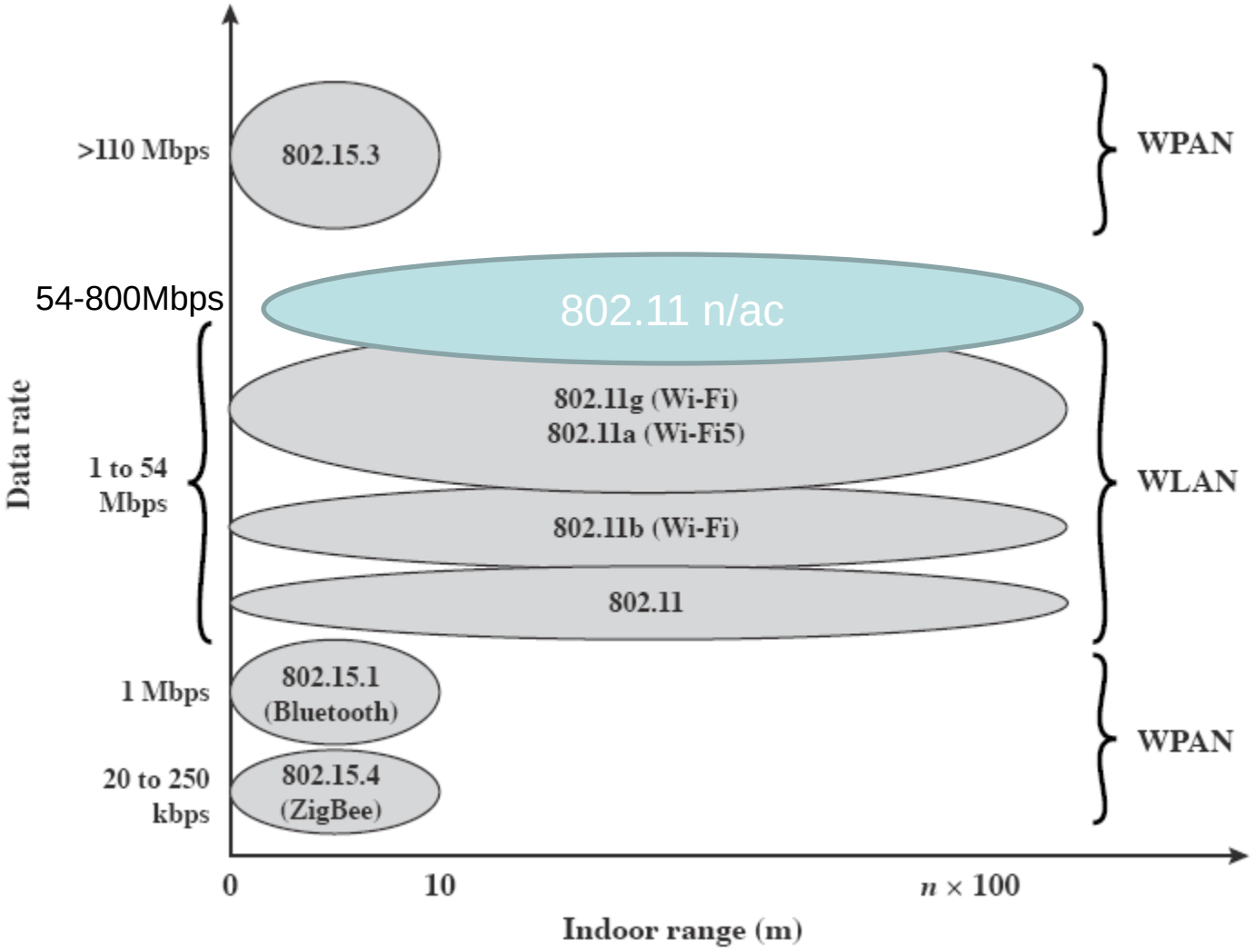



Security Systems
Motion detectors
Door pins
System control unit
Camera
Alarm

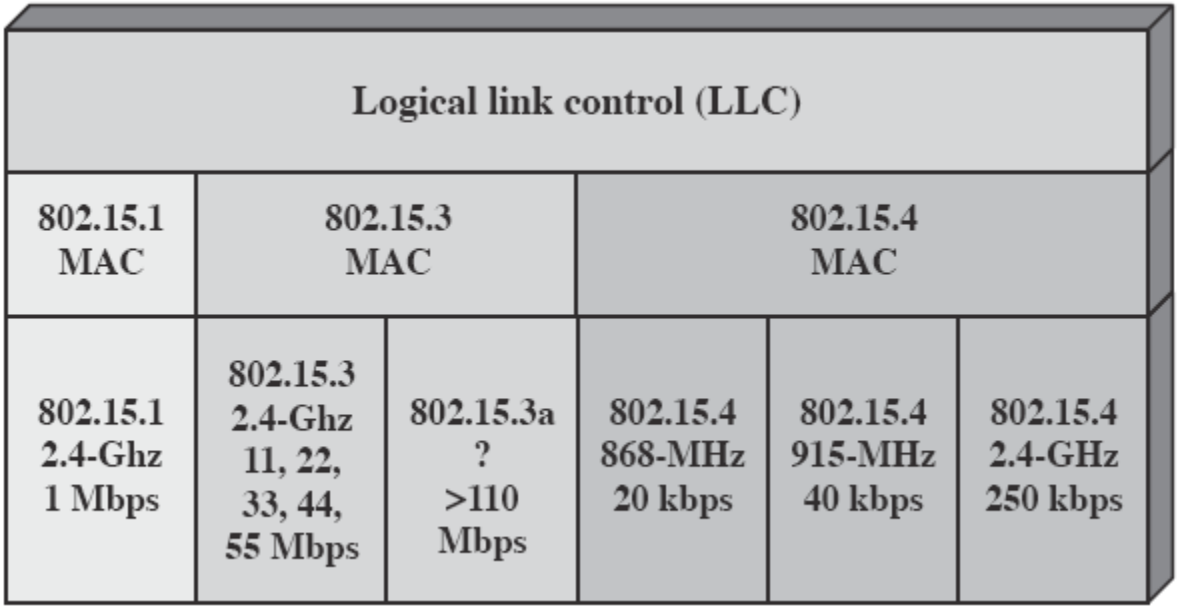


Utility metering
Electricity
Gas
Fuel
Water

Wireless Local Networks



IEEE 802.15 Protocol Architecture



IEEE Project 802

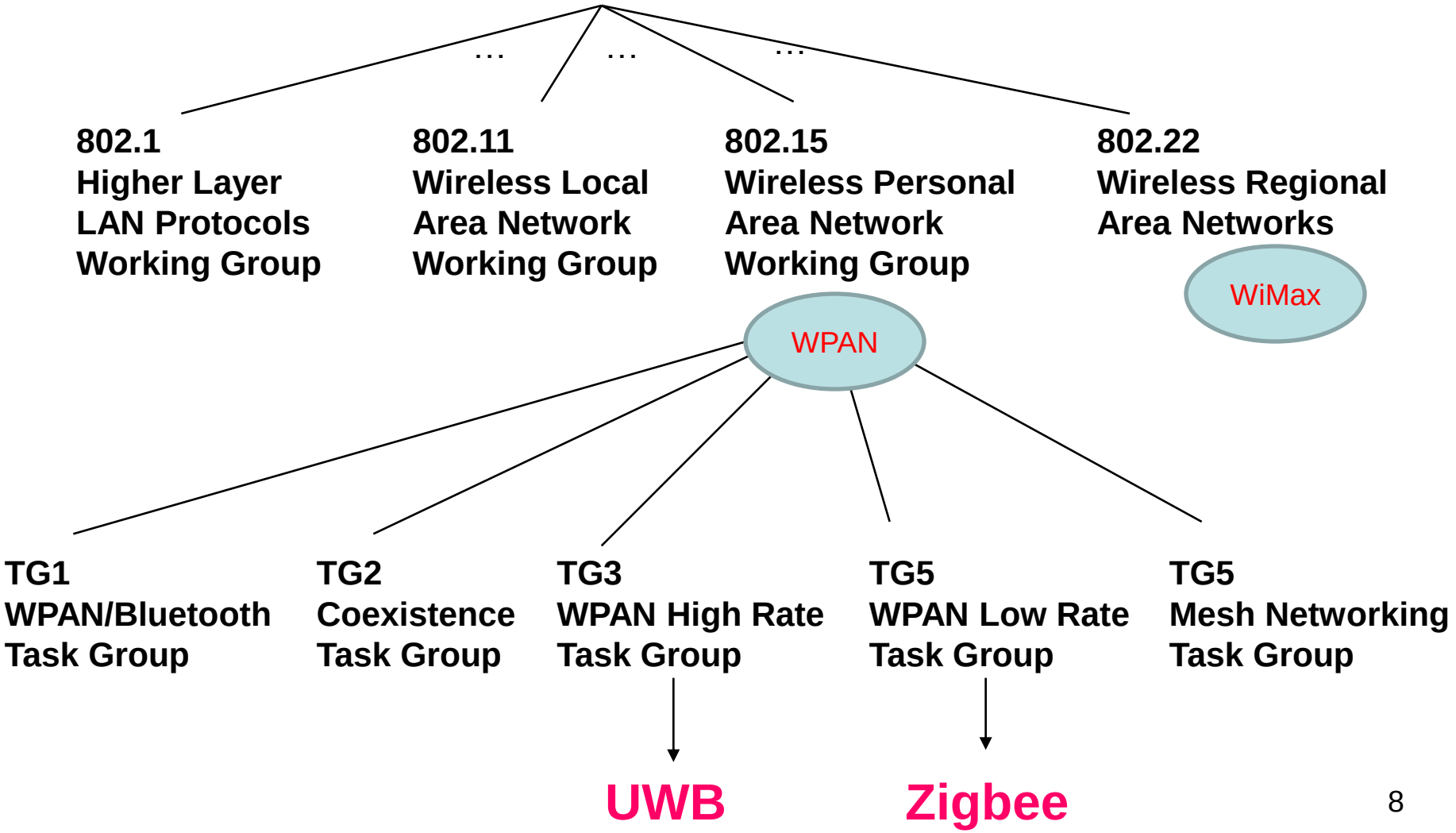
- IEEE 802 LAN/MAN Standards Committee (LMSC or IEEE Project 802)
- The first meeting of the IEEE Computer Society “Local Network Standards Committee” was held in February of 1980
- Lowest 2 layers of the Reference Model for Open Systems Interconnection (OSI)
- Well-known Working Group
  - 3: Ethernet
  - 11: WLAN
  - 15: WPAN

802.15 Working Group

- Wireless Personal Area Networks (WPAN)
- TG1: based on the Bluetooth v1.1 Foundation Specifications
- TG2: to facilitate coexistence of WPANs (802.15) and WLANs (802.11)
- TG3: for high-rate (20Mbit/s or greater) WPANs
- TG4: to investigate a low data rate solution with multi-month to multi-year battery life and very low complexity
- TG5: to determine the necessary mechanisms that must be present in the PHY and MAC layers of WPANs to enable mesh networking

IEEE 802.15 Working Group

IEEE 802 LAN/MAN Standards Committee



Comparison Between WPAN

Project	Data Rate	Range	Configuration	Other Features
802.15.1 (Bluetooth)	721 kbps	1 M (class3) 100 M (class1)	8 active device Piconet/ Scatternet	Authentication, Encryption, Voice
802.15.3 High Rate	22, 33, 44, 55 Mbps	10 M	peer-to-peer	FCC part 15.249 QoS, Fast Join, Multi-media
802.15.4 Low Rate	Up to 250 kbps	10 M nominal 1~100 M (based on settings)	Star peer-to-peer	Battery life: multi-month to multi-year

Bluetooth
(IEEE 802.15.1)

Overview

- Initially developed by Swedish company Ericsson in 1994
  - Several thousand companies have signed on to make Bluetooth the low-power, short-range wireless standard
- Standards are published by an industry consortium known as “Bluetooth SIG (special interest group)”
  - IEEE 802.15.1
  - Newer version v1.2
- A universal short-range wireless capability on 2.4 GHz band
- In 10 meters, two Bluetooth devices can share up to 720Kbps rate
- Support data, audio, graphics, and even videos

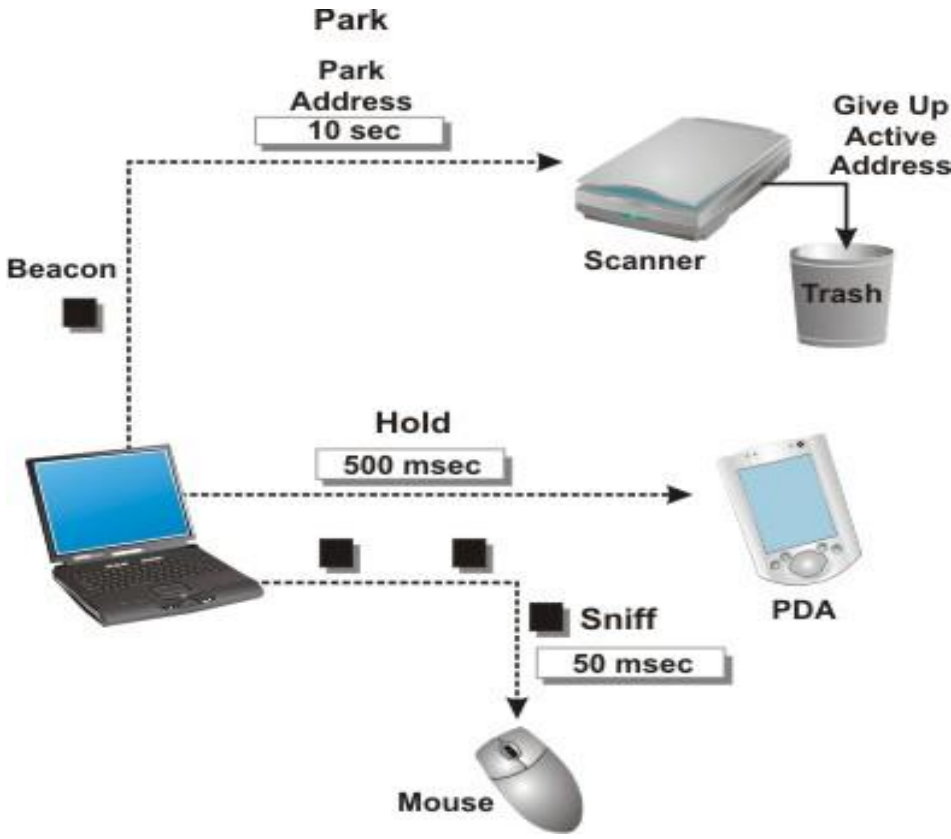
Bluetooth

- In 1998 – Ericsson, IBM, Toshiba, Nokia and Intel form Bluetooth Special Interest Group (SIG).
- Harald Bluetooth – Danish king who lived more than 1000 years ago

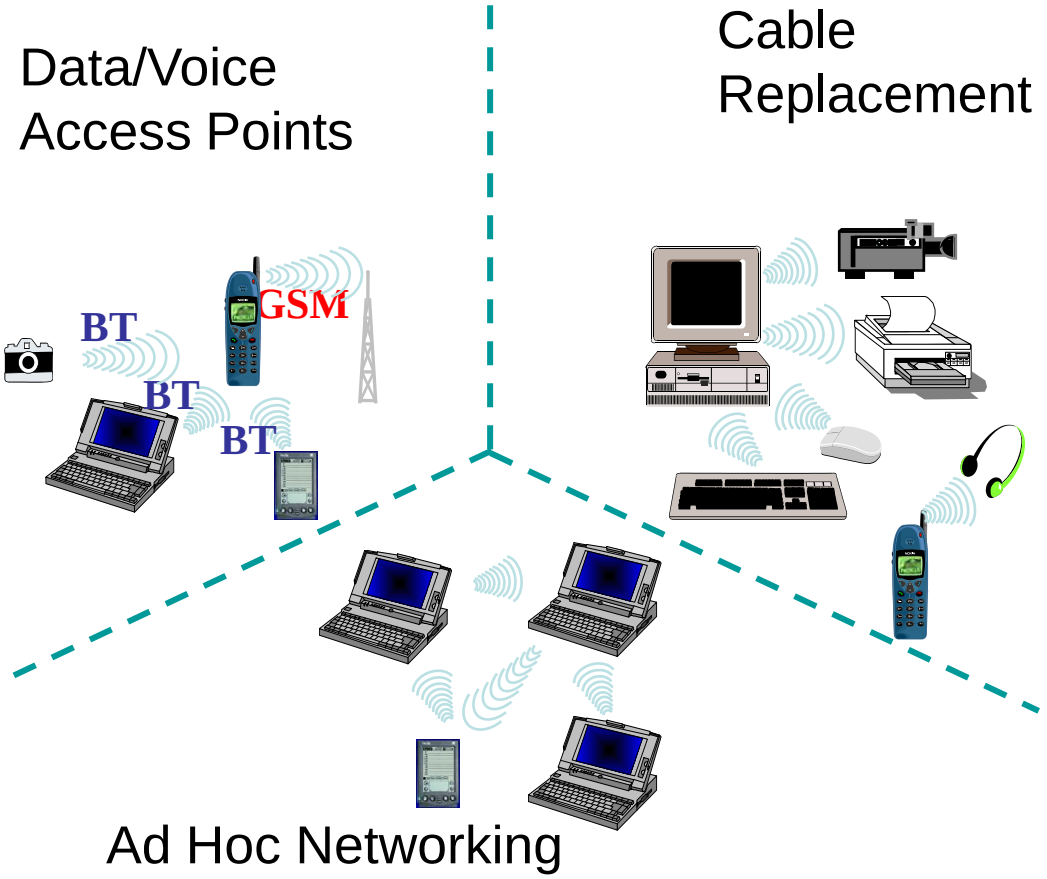
Universal short-range wireless capability

- Uses 2.4-GHz band
- Available globally for unlicensed users
- Devices within 10 m can share up to 720 kbps of capacity
- Supports open-ended list of applications
  - Data, audio, graphics, video
- Data rate – 1 Mbps
- Cable replacement
  - Eliminates need for numerous cable attachments for connection

- **Where to use Bluetooth?**
- Specifically, Bluetooth connects devices such as;
- Mobile phones, tablets, laptops, Pcs together
- Modems, headsets, computer mouse, keyboards
- Digital Camera
- Personal digital assistants
- Printers, Fax machines
- Car Kits etc….



Goals



Bluetooth Drivers

- low cost implementation
- small implementation size
- low power consumption
- robust, high quality data & voice transfer
- open global standard

Wireless Link Between All Mobile Devices

Networking Capability Brief

- Up to 8 devices can communicate in a small network called a “piconet”
- 10 piconets can coexist in the same coverage range
  - With insignificant degradation
- Security mechanism to protect each wireless link

Standards Documents

- > 1500 pages
- Divided into two groups:
  - core
    - protocol layers, architecture, radio, timer
  - profile
    - each profile specification discusses the use of the core spec. to implement a usage model
    - to define a standard of interoperability
    - two categories: cable replacement and wireless audio

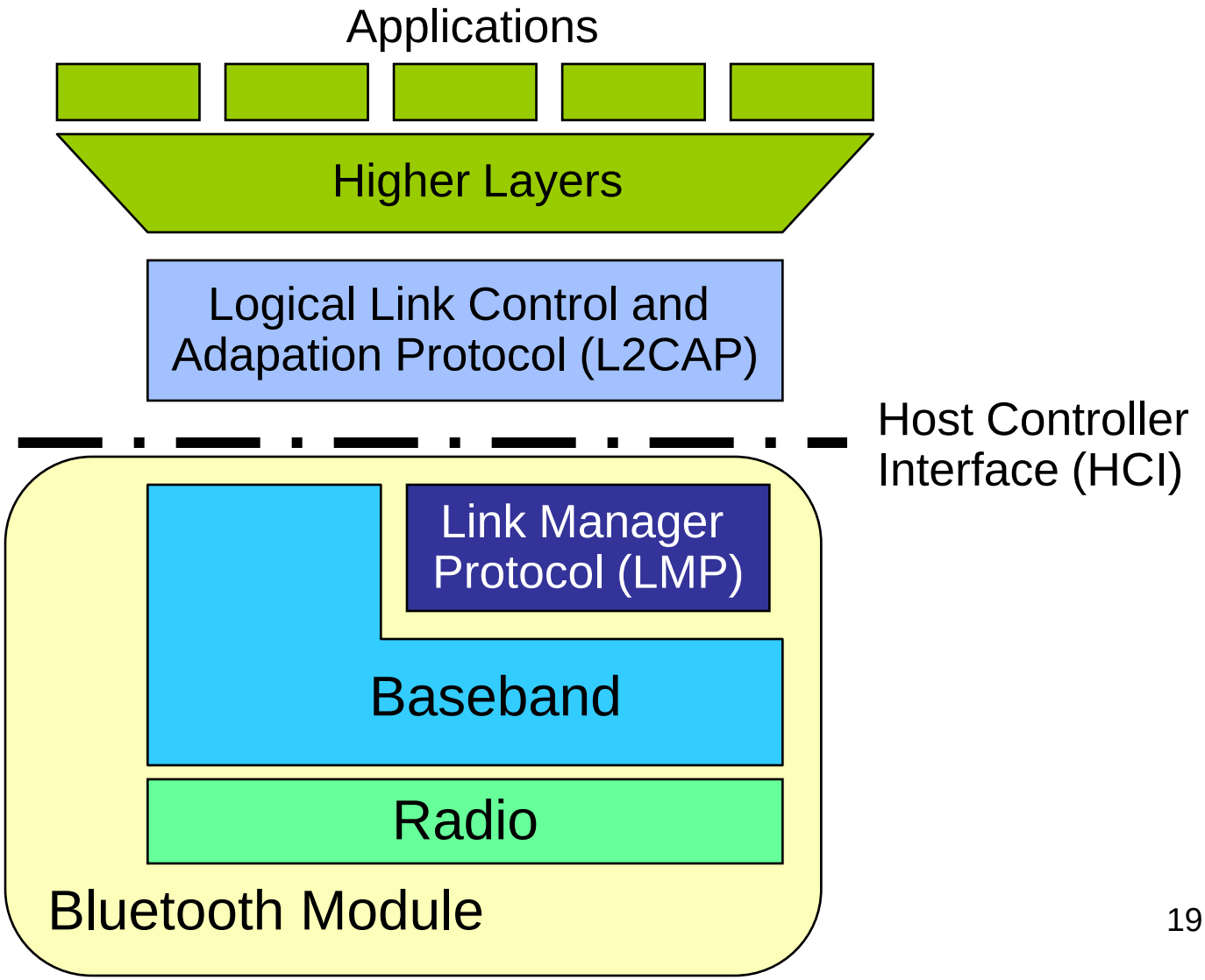
Protocol Architecture

- Radio:
  - interface, frequency hopping, modulation, transmit power
  - GFSK modulation yields 432 kbps bidirectional / 721 kbps asymmetrical
- Baseband:
  - connection establishment in a piconet, addressing, packet format, timing, power control
- Link Management Protocol (LMP):
  - link setup, authentication, packet size

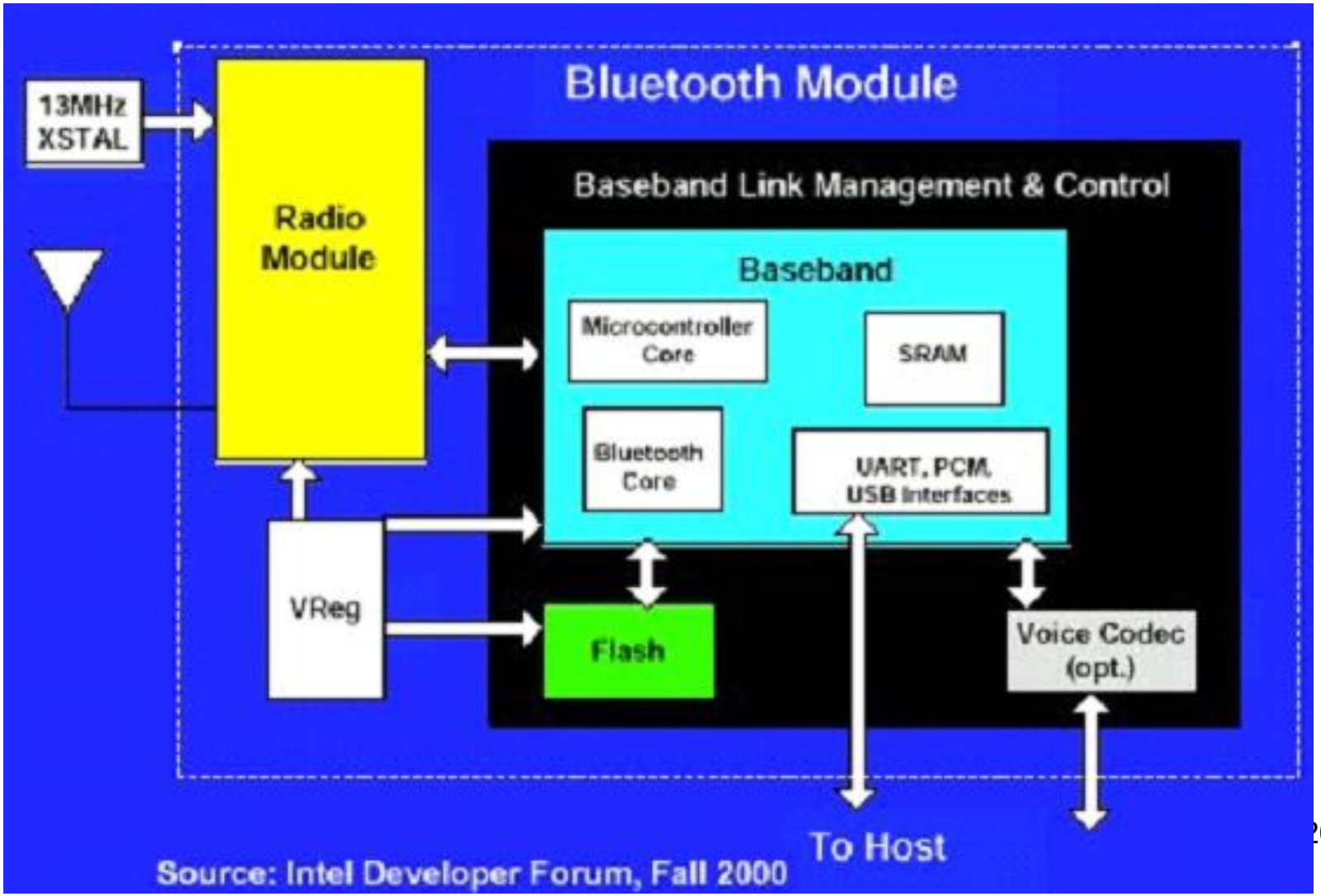
Protocol Architecture (cont'd)

- Logical Link Control and Adaptation Protocol (L2CAP):
  - adapts upper-layer protocols to baseband, connectionless service, connection-oriented service
- Service Discovery Protocol (SDP):
  - device info (service, characteristic), service query

Protocols

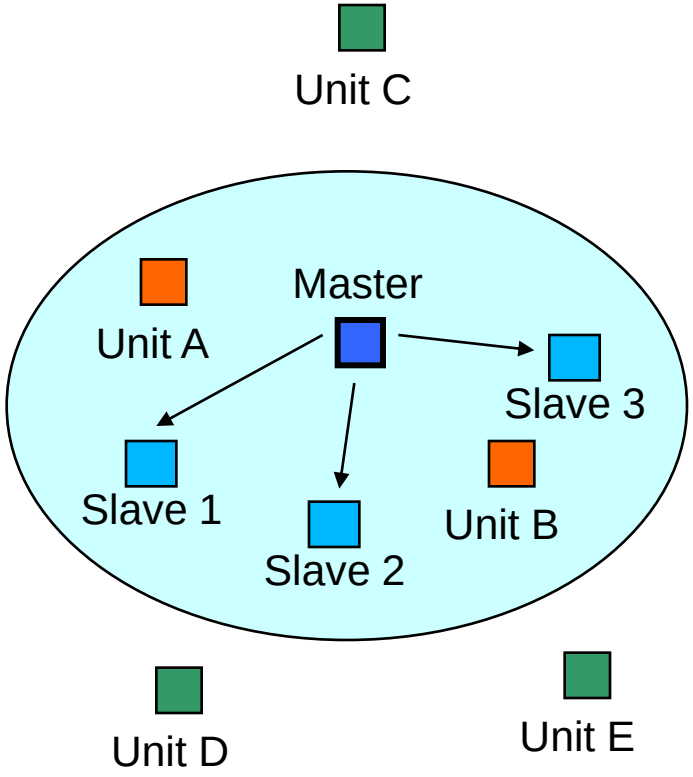

Applications
Higher Layers
Logical Link Control and Adapation Protocol (L2CAP)
Host Controller Interface (HCI)
Link Manager Protocol (LMP)
Baseband
Radio
Bluetooth Module

Bluetooth Chip Architecture



Communication Topology: Bluetooth Piconet

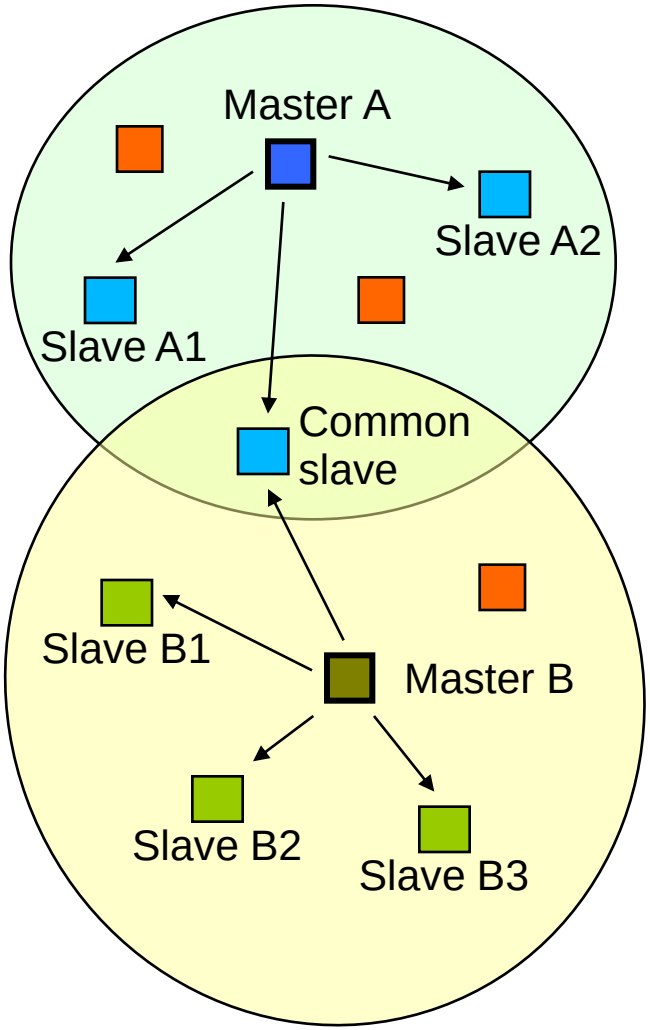
- Collection of devices connected in an *ad hoc* fashion
- One unit will act as **master**
  - Sets clock and frequency hopping pattern
  - Can connect to 7 **active** or 255 inactive (**parked**) **slaves**
  - Determines bit rate allocated to each slave
- Unique frequency hopping pattern/ID
- All devices participating in the **piconet** are synchronized to a common clock and hopping sequence.
- Slaves can communicate only with the master and not with other slaves.



Communication Topology: Bluetooth Scatternet

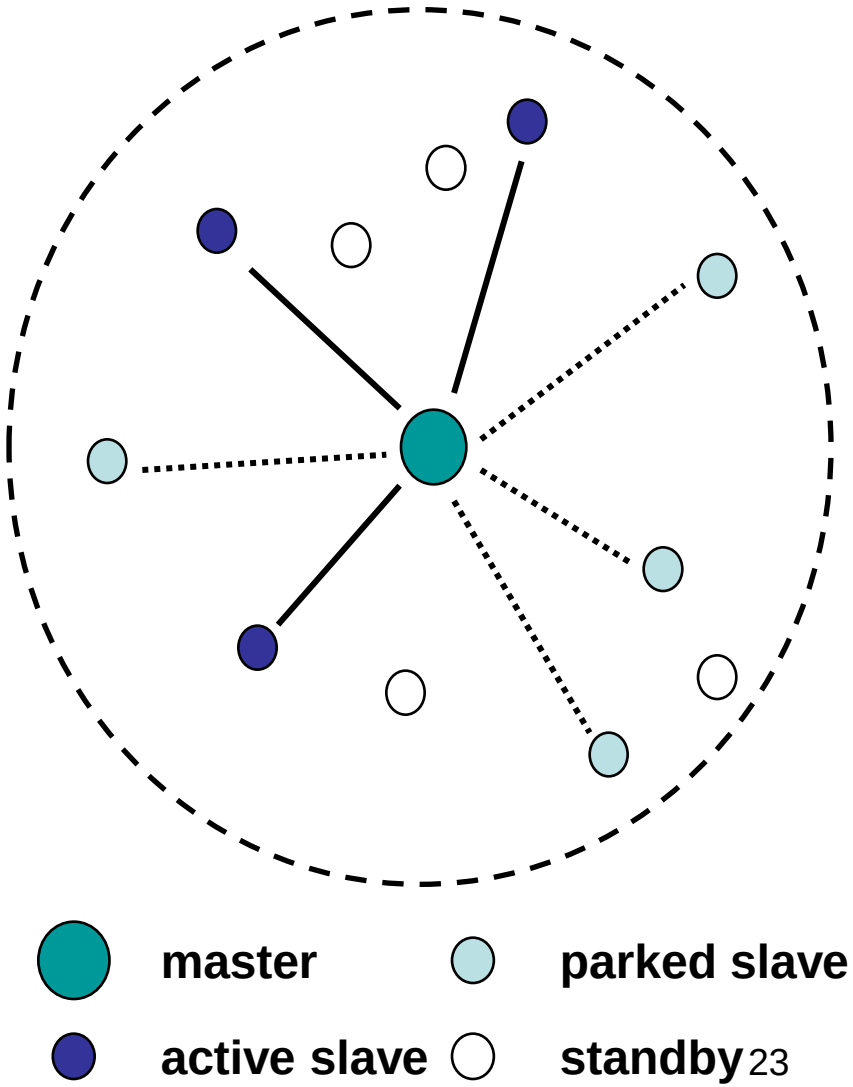
- A device may participate concurrently in two or more piconets on time-division multiplexing (TDM) basis.
- A device can be both master and slave.
- A device can never be a master of more than one piconet.

- Two or more piconets that include one or more devices participating in more than one piconet form a **scatternet**.



Piconet

- Star Topology
  - 1 Master, up to 7 active (sniff, hold) slaves
  - 256 parked slaves
- Master:
  - determines hopping scheme and timing
  - Administers piconet (polling)
- Logical Channels
  - Asynchronous, packet oriented
  - Synchronous, connection-oriented (voice, slot reservation)



Connecting Steps

- Inquiry
  - used by master to find the identities of devices within range
- Inquiry scan
  - listening for an inquiry message
- Page
  - used by master to send PAGE message to connect to a slave by transmitting slave's device address code (DAC)
- Page scan
  - slave listening for a paging packet with its DAC

Inquiry and Page Flowchart

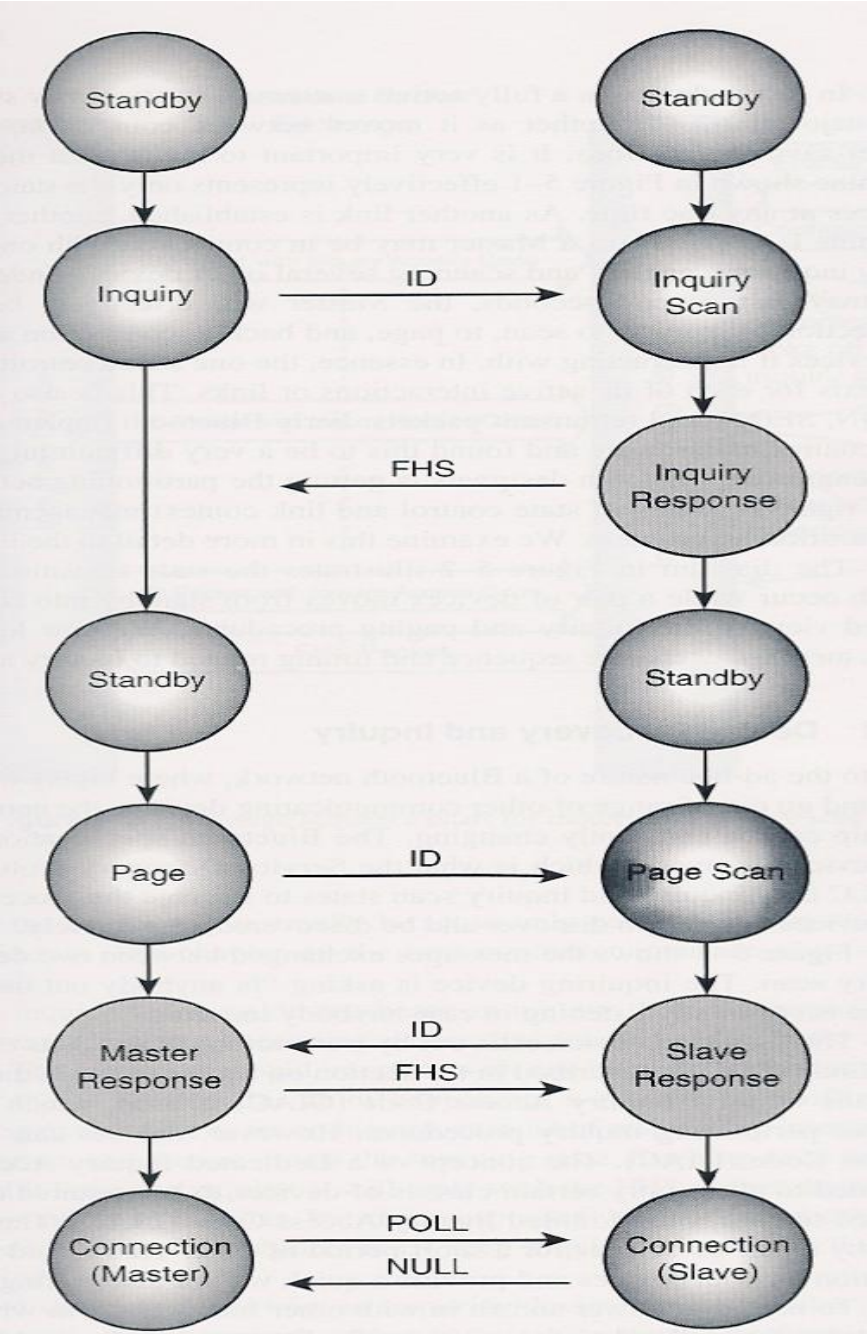


Figure 5–2 State transition from standby into connection.

Frequency Hopping

- Typically, FH scheme uses carriers spacing of 1 MHz with up to 80 different frequencies
- So, with FH, there are 80 logical channels (theoretically)
  - When two piconets choose the same 1MHz-band, collision occurs
- The same hopping sequence is shared by all devices in the same piconet
  - hopping rate = **1600 hops/sec**
  - one slot = 0.625 ms=625us

Frequency Hopping (cont'd)

Table 15.3 International Bluetooth Frequency Allocations

Area	Regulatory Range	RF Channels
U.S., most of Europe, and most other countries	2.4 to 2.4835 GHz	$f = 2.402 + n$ MHz, $n = 0,\ldots, 78$
Japan	2.471 to 2.497 GHz	$f = 2.473 + n$ MHz, $n = 0,\ldots, 22$
Spain	2.445 to 2.475 GHz	$f = 2.449 + n$ MHz, $n = 0,\ldots, 22$
France	2.4465 to 2.4835 GHz	$f = 2.454 + n$ MHz, $n = 0,\ldots, 22$

Radio and Baseband Parameters

Table 15.2 Bluetooth Radio and Baseband Parameters

Topology	Up to 7 simultaneous links in a logical star
Modulation	GFSK
Peak data rate	1 Mbps
RF bandwidth	220 kHz (−3 dB), 1 MHz (−20 dB)
RF band	2.4 GHz, ISM band
RF carriers	23/79
Carrier spacing	1 MHz
Transmit power	0.1 W
Piconet access	FH-TDD-TDMA
Frequency hop rate	1600 hops/s
Scatternet access	FH-CDMA

Transmitter Output Powers

- Class 1: greatest distance (100m)
  - 1mW (0dBm) to 100mW (+20dBm)
  - power control mandatory
- Class 2: (10m)
  - 0.25 mw(-6dBm) ~ 2.4mW (+4dBm)
  - power control optional
- Class 3: (1m)
  - lowest power, 1mW

FH-TDD-TDMA

- TDD
  - transmission alternates between TWO directions
- TDMA
  - multiple devices share the same piconet (logical) FH channel

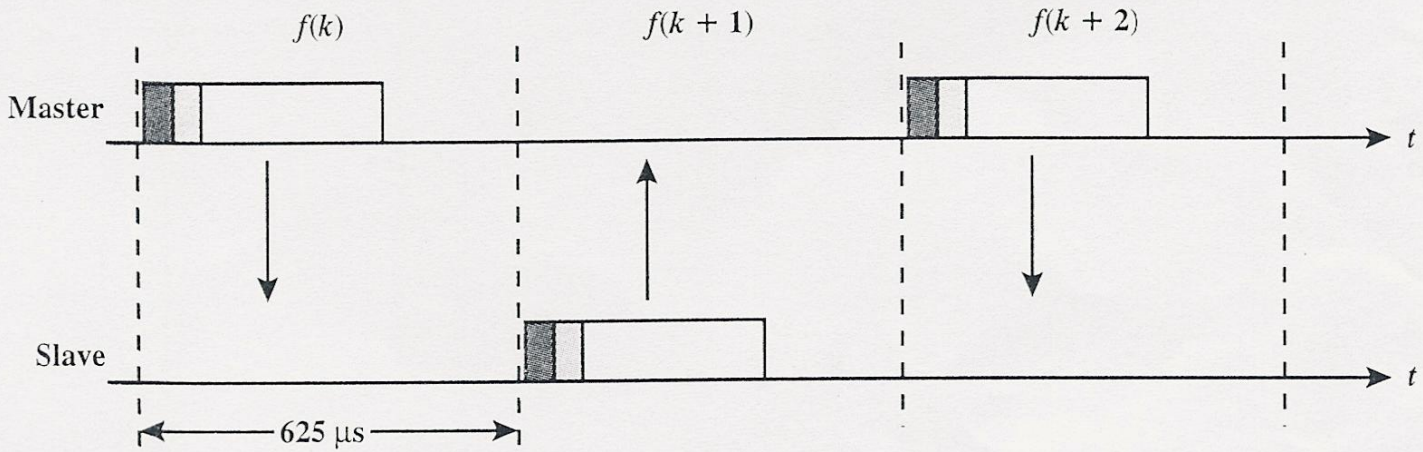
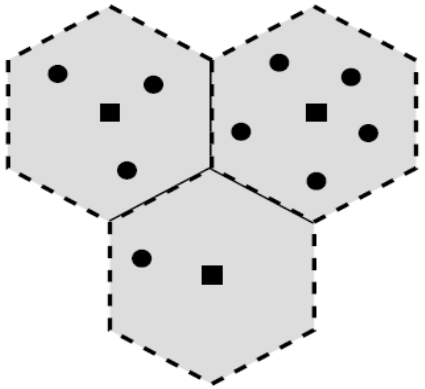


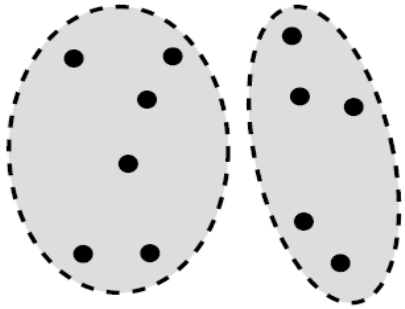
Figure 15.6 Frequency-Hop Time Division Duplex

Piconets and Scatternets

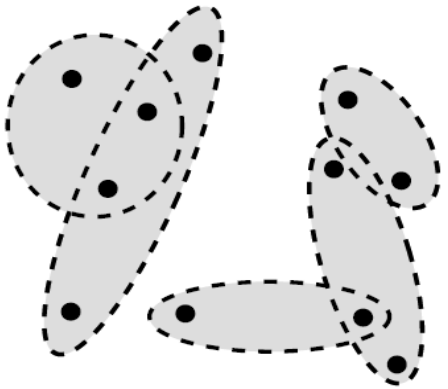
- Piconet
  - Basic unit of Bluetooth networking
  - Master and one to seven slave devices
  - Master determines channel and phase
- Scatternet
  - Device in one piconet may exist as master or slave in another piconet
  - Allows many devices to share same area
  - Makes efficient use of bandwidth



(a) Cellular system (squares represent stationary base stations)



(b) Conventional ad hoc systems



(c) Scatternets

Physical Links between Master and Slave

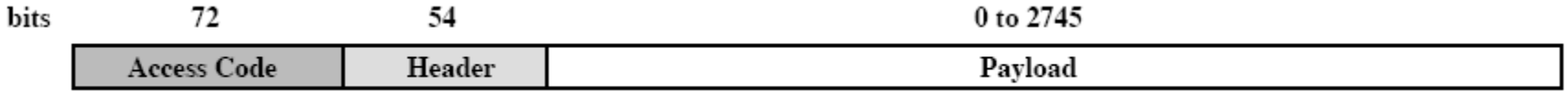
- Synchronous connection oriented (SCO)
  - Allocates fixed bandwidth between point-to-point connection of master and slave
  - Master maintains link using reserved slots
  - Master can support three simultaneous links
- Asynchronous connectionless (ACL)
  - Point-to-multipoint link between master and all slaves
  - Only single ACL link can exist

Frequency Hopping in Bluetooth

- Provides resistance to interference and multipath effects
- Provides a form of multiple access among co-located devices in different piconets

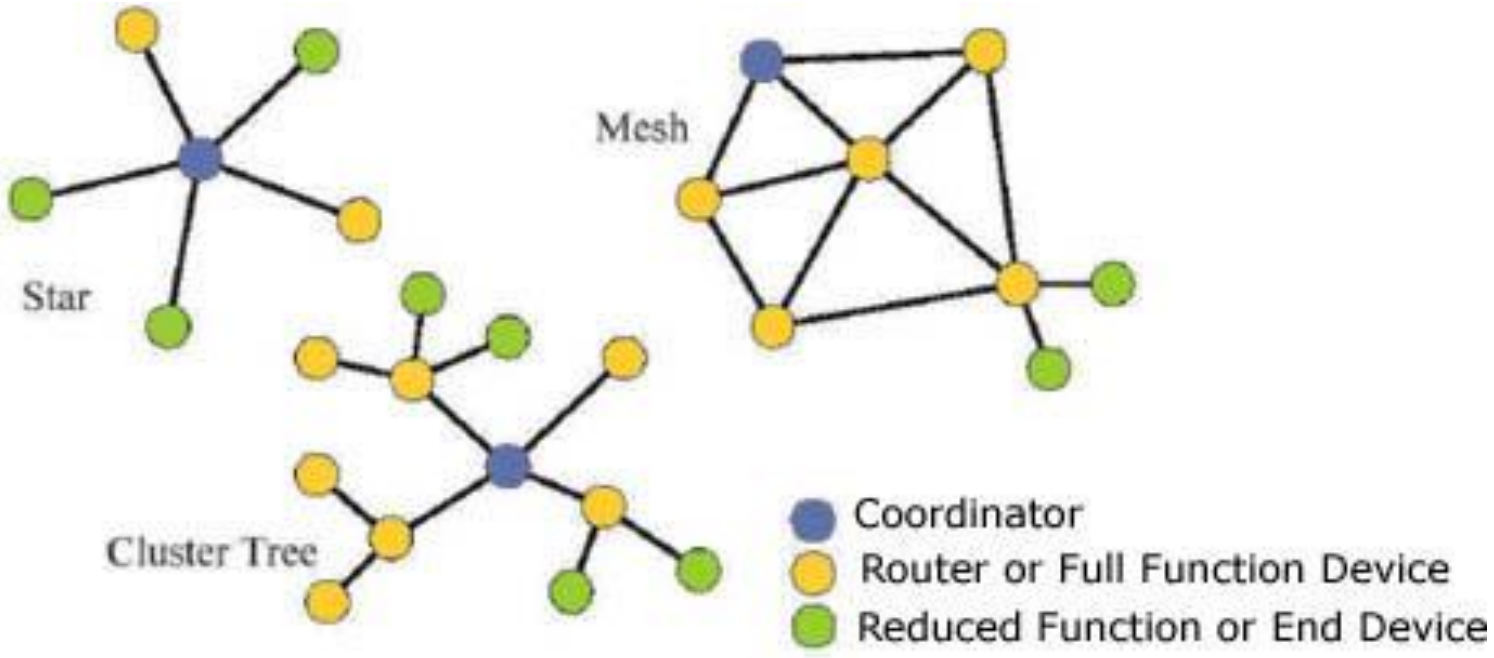
Bluetooth Packet Fields

- Access code – used for timing synchronization, offset compensation, paging, and inquiry
- Header – used to identify packet type and carry protocol control information
- Payload – contains user voice or data and payload header, if present



What is a ZigBee Wireless Network?

- ZigBee networks can be cluster, star or mesh networks as shown in the diagram.



Zigbee

- Each ZigBee network has one device that is setup as a coordinator that controls and initializes the network.
- Other devices can either be setup as routers that can pass data or as End Points, that can only have one connection.
- End points or Reduced Function Devices can be set to sleep mode so they use very little power and so can be battery operated.

ZigBee/IEEE 802.15.4

- Because of this very low power requirement, ZigBee is ideal for sensor networks or other control applications, which require:
- Low offered message throughput
- Low cost
- Low to medium data rates
- Lots of nodes (up to 65,565)
- Easy addition or removal of nodes from network
- robust mesh network that doesn't fall over if one node fails
- very low power, battery operated equipment
- Low to no QoS guarantees
- Flexible protocol design suitable for many applications

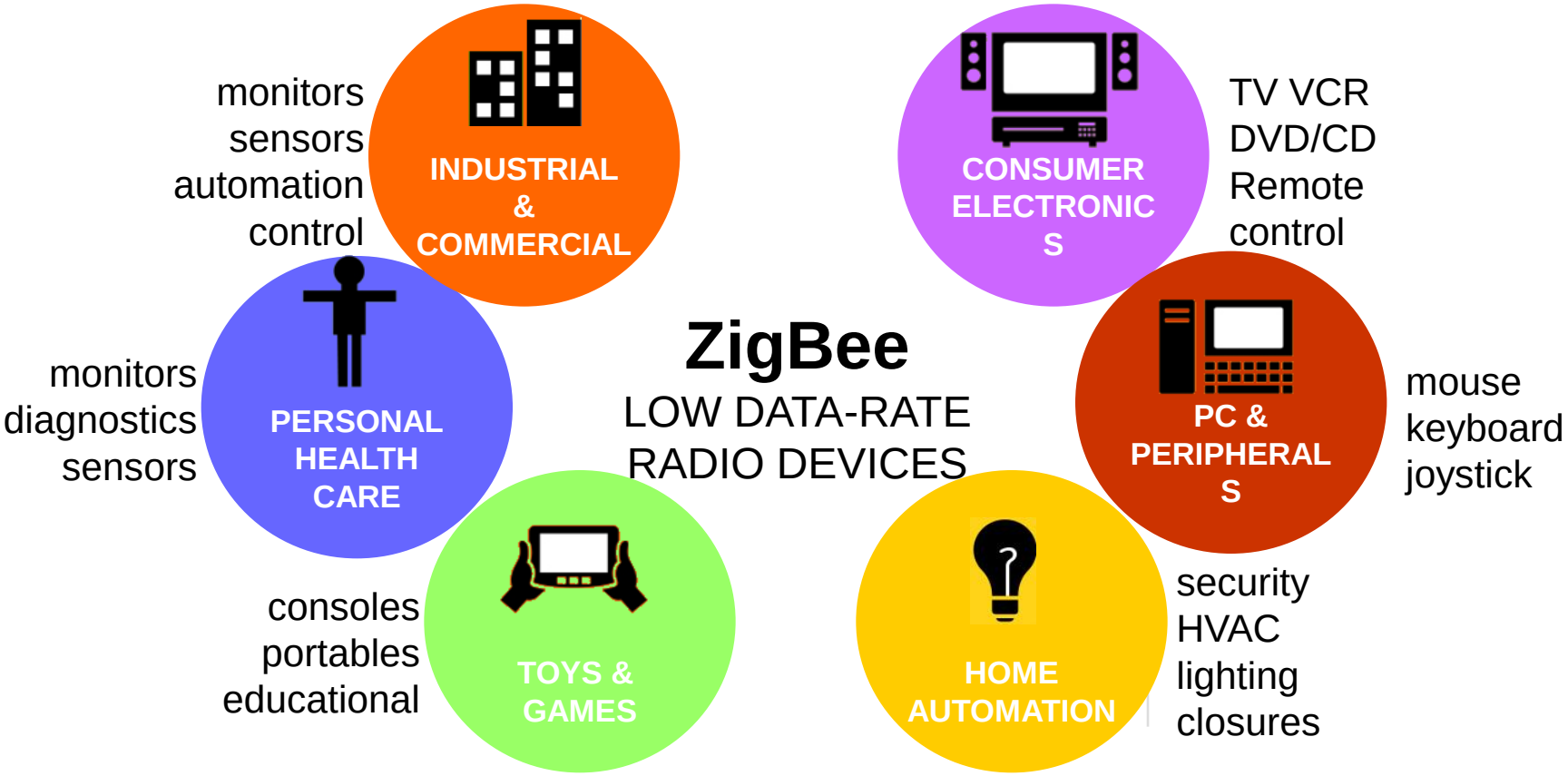
ZigBee/IEEE 802.15.4 Market Feature

- ZigBee is a low-cost, low-power, wireless mesh networking proprietary standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries, and the mesh networking provides high reliability and larger range.
- ZigBee can activate (go from sleep to active mode) in 15 msec or less, the latency can be very low and devices can be very responsive — particularly compared to Bluetooth wake-up delays, which are typically around three seconds.
- Because ZigBees can sleep most of the time, average power consumption can be very low, resulting in long battery life.

ZigBee/IEEE 802.15.4 Market Feature

- **Where to use ZigBee?**
- Building Automation
- Remote Control
- Home energy savings
- Health and fitness monitoring
- Smart homes
- Easy-to-use touchpads
- mice, keyboards, wands
- LED lighting control etc…
- **What can ZigBee do for you?**
- ZigBee protocols are intended for embedded applications requiring low data rates and low power consumption. The resulting network will use very small amounts of power — individual devices must have a battery life of at least two years to pass ZigBee certification
- Home Entertainment and Control — Home automation, smart lighting, advanced temperature control, safety and security, movies and music
- Wireless sensor networks — Starting with individual sensors

ZigBee Network Applications



Difference between ZigBee and Bluetooth: -

- ZigBee is broadly categorized as a low rate WPAN, and its closest technology is Bluetooth. A good bit of energy has been spent in analyzing whether ZigBee and Bluetooth are complementary or competing technologies, but after a quick look at the two, it can be seen that they fall a lot farther down the complementary side of the spectrum. They are two different technologies with very different areas of application and different means of designing for those applications.

- **Area of Application:**
- While ZigBee is focused on control and automation, Bluetooth is focused on connectivity between laptops, tablets, and the like, as well as more general cable replacement.
- **Data Rate:**
- ZigBee uses low data rate, low power consumption, and works with small packet devices; Bluetooth uses a higher data rate, higher power consumption, and works with large packet devices.
- **Supportable Number of Devices:**
- ZigBee networks can support a larger number of devices and a longer range between devices than Bluetooth.

- **Response Timing:**
- In timing critical applications, ZigBee is designed to respond quickly, while Bluetooth takes much longer and could be detrimental to the application.
- **Battery Charging:**
- As an example, for its applications, Bluetooth must rely on fairly frequent battery recharging, while the whole goal of ZigBee is for a user to be able to put a couple of batteries in the devices and forget about them for months to years.
- Figure below shows a comparison of the various 802 technologies for data rate and range.

Comparison

- Bluetooth is more oriented toward user mobility and eliminating short-distance cabling; ZigBee aims more for grand-scale automation and remote control.

	ZigBee	Bluetooth
Range	10-100 meters	10 meters
Networking Topology	Ad-hoc, peer to peer, star, or mesh	Ad-hoc, very small networks
Operating Frequency	868 MHz (Europe) 900-928 MHz (NA), 2.4 GHz (worldwide)	2.4 GHz
Complexity (Device and application impact)	Low	High
Power Consumption (Battery option and life)	Very low (low power is a design goal)	Medium
Security	128 AES plus application layer security	64 and 128 bit encryption

	ZigBee	Bluetooth
Typical Applications	Industrial control and monitoring, sensor networks, building automation, home control and automation, toys, games	Wireless connectivity between devices such as phones, PDA, laptops, headsets
Modulation technique Spreading	Direct Sequence Spread Spectrum (DSSS)	Frequency Hopping Spread Spectrum (FHSS)
Protocol stack size	28 Kbyte	250 Kbyte
Battery	Not rechargeable (one reason batteries will last for up to 10 years)	Intended for frequent recharging
Data Rate	250 Kbit/s	1 Mbit/s
Typical network join time	30 milliseconds	3 seconds
Application	Monitoring and Control	Cable replacement
Number of devices for Network	64K	7
Typical Applications	Industrial control and monitoring, sensor networks, building automation, home control and automation, toys, games	Wireless connectivity between devices such as phones, PDA, laptops, headsets
Physical/ MAC layers	IEEE 802.15.4	IEEE 802.15.1
Basic Cell	star	Piconet

	ZigBee	802.11 (Wi-Fi)	Bluetooth	UWB (Ultra Wide Band)	Wireless USB	IR Wireless
Data Rate	*20, 40, and 250 Kbits/s*	11 & 54 Mbits/sec 160-800Mbps	1 Mbits/s	100-500 Mbits/s	62.5 Kbits/s	20-40 Kbits/s 115 Kbits/s 4 & 16 Mbits/s
Range	*10-100 meters*	50-100 meters	10 meters	<10 meters	10 meters	<10 meters (line of sight)
Networking Topology	*Ad-hoc, peer to peer, star, or mesh*	Point to hub	Ad-hoc, very small networks	Point to point	Point to point	Point to point
Operating Frequency	*868 MHz (Europe) 900-928 MHz (NA), 2.4 GHz (worldwide)*	2.4 and 5 GHz	2.4 GHz	3.1-10.6 GHz	2.4 GHz	800-900 nm
Complexity (Device and application impact)	*Low*	High	High	Medium To High	Low	Low
Power Consumption (Battery option and life)	*Very low (low power is a design goal)*	High	Medium	Medium	Low	Low
Security	*128 AES plus application layer security*	Open to WPA2	64 and 128 bit encyption Simple security			
Other Information	*Devices can join an existing network in under 30ms*	Device connection requires 3-5 seconds	Device connection requires up to 10 seconds			
Typical Applications	*Industrial control and monitoring, sensor networks, building automation, home control and automation, toys, games*	Wireless LAN connectivity, broadband Internet access	Wireless connectivity between devices such as phones, PDA, laptops, headsets	Streaming video, home entertainment applications	PC peripheral connections	Remote controls, PC, PDA, phone, laptop links