

15-496 : A Hand-on Introduction to Wireless Networks

Lecture 8: PAN

Peter Steenkiste
 Departments of Computer Science and
 Electrical and Computer Engineering
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<http://www.cs.cmu.edu/~prs/wireless08/>

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Outline

- 802 protocol overview
- Wireless LANs – 802.11
- Personal Area Networks – 802.15
 - › Applications and positioning
 - › Bluetooth
 - › High speed WPAN
 - › Zigbee
- Wireless Access – 802.16
- Cellular

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IEEE 802.15: Personal Area Networks

- Target deployment environment: communication of personal devices working together
 - › Short-range
 - › Low Power
 - › Low Cost
 - › Small numbers of devices
- Four standards:
 - IEEE 802.15.1 – "Bluetooth"
 - IEEE 802.15.2 – Interoperability (e.g. Wifi)
 - IEEE 802.15.3 – High data rate WPAN
 - IEEE 802.15.4 – Low data rate WPAN

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Some Common Themes

- Master/slave notion
 - › Or simple node versus coordinator
- Use of "piconets"
 - › Small groups of devices managed by a master or coordinator
- Support for QoS
 - › Want to support voice and other media
- But many small variants in how functionality is supported

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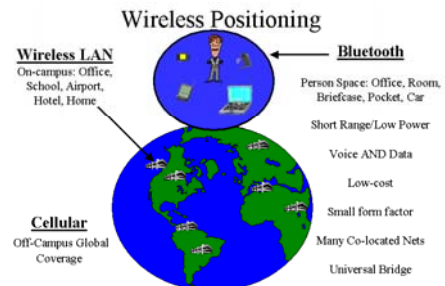
Bluetooth

- Think USB, not Ethernet
 - › Cable replacement technology
- Created by Ericsson
- PAN - Personal Area Network
 - › Up to 1 Mbps connections
 - › 1600 hops per second FHSS
 - › Includes synchronous, asynchronous, voice connections
 - › Piconet routing
- Small, low-power, short-range, cheap, versatile radios
- Used as Internet connection, phone, or headset
- Master/slave configuration and scheduling

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IEEE 802.15.1 - Positioning

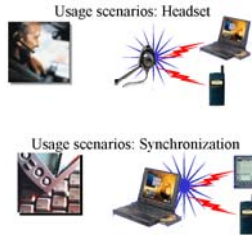


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Bluetooth Applications

- **Data and voice access points**
 - › Real-time voice and data transmissions
- **Cable replacement**
 - › Eliminates need for numerous cable attachments for connection



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IEEE 802.15.1

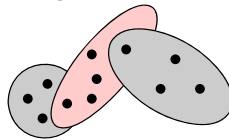
- Adopted the Bluetooth MAC and PHY specifications
- IEEE 802.15.1 and Bluetooth are almost identical regarding physical layer, baseband, link manager, logical link control and adaptation protocol, and host control interface
- Range of up to 30 feet, uses FHSS
- Data transfer rates of up to 1 Mbps
 - › Up to 3 Mbps for version 2
- Not designed to carry heavy traffic loads

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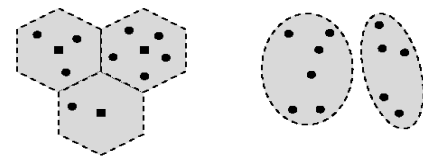
Piconets are Basis for Topology

- **Master with up to 7 active slaves**
 - › Slaves only communicate with master
 - › Slaves must wait for permission from master
- **Master picks radio parameters**
 - › Channel, hopping sequence, timing, ...
- **Scatternets can be used to build larger networks**
 - › A slave in one piconet can also be part of another piconet
 - › Either as a master or as a slave
 - › If master, it can link the piconets



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

(b) Conventional ad hoc systems



(c) Scatternets

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Bluetooth Standards

- **Core specifications: defines various layers of Bluetooth protocol architecture**
 - › Radio
 - › Baseband
 - › Link manager protocol (LMP)
 - › Logical link control and adaptation protocol (L2CAP)
 - › Service discovery protocol (SDP)
- **Profile specifications: use of Bluetooth technology to support various applications**
 - › Cable replacement and telephony control protocols
 - › Adopted protocols

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Applications Protocols

- **Cable replacement protocol**
 - › RFCOMM
- **Telephony control protocol**
 - › Telephony control specification
- **Adopted protocols**
 - › PPP
 - › TCP/UDP/IP
 - › OBEX
 - › WAE/WAP

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Frequency Hopping in Bluetooth

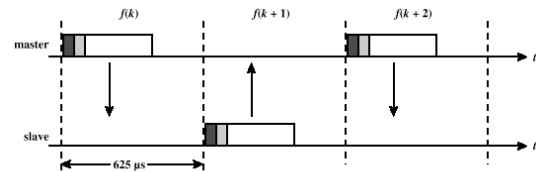
- Provides resistance to interference and multipath effects
- Provides a form of multiple access among co-located devices in different piconets
- Total bandwidth divided into 1MHz physical channels
- FH occurs by jumping from one channel to another in pseudorandom sequence
- Hopping sequence shared with all devices on piconet
 - » Remember that all communication is with the master

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Sharing the Channel

- Bluetooth devices use time division duplex (TDD)
- Access technique is TDMA
- FH-TDD-TDMA



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

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Bluetooth Packet Fields

- Access code – used for timing synchronization, offset compensation, paging, and inquiry
 - » Channel access code (CAC) – identifies a piconet
 - » Device access code (DAC) – used for paging and subsequent responses
 - » Inquiry access code (IAC) – used for inquiry purposes
- Header – used to identify packet type and carry protocol control information
 - » Packet type, slave address, flow control, ARQ, HEC
- Payload – data and payload header, if present
 - » Channel information, L2CAP information

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ARQ Scheme Elements

- Error detection – destination detects errors, discards packets
- Positive acknowledgment – destination returns positive acknowledgment
- Retransmission after timeout – source retransmits if packet unacknowledged
- Negative acknowledgment and retransmission – destination returns negative acknowledgement for packets with errors, source retransmits

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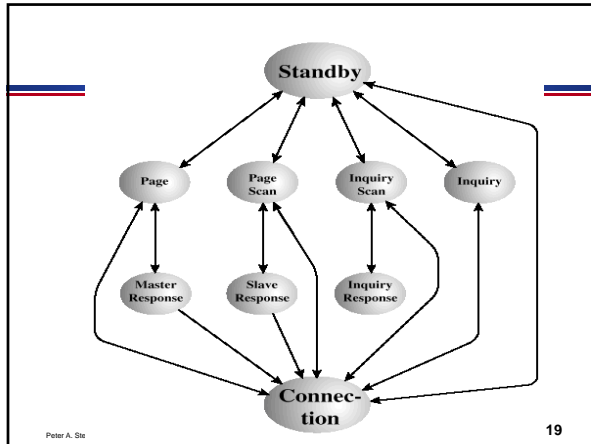
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Channel Control

- States of operation of a piconet during link establishment and maintenance
- Major states
 - » Standby – default state
 - » Connection – device connected
- Inquiry: master identifies nearby slaves
- Paging: establishing a connection between a master and a slave

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- ### Inquiry Procedure
- Potential master identifies devices in range that wish to participate
 - » Transmits ID packet with inquiry access code (IAC)
 - » Occurs in Inquiry state
 - Device receives inquiry
 - » Enter Inquiry Response state
 - » Returns FHS packet with address and timing information
 - » Moves to page scan state
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- ### Page Procedure
- Master uses device address to calculate a page frequency-hopping sequence
 - Master pages with ID packet and device access code (DAC) of specific slave
 - Slave responds with DAC ID packet
 - Master responds with its FHS packet
 - Slave confirms receipt with DAC ID
 - Slaves moves to Connection state
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- ### Logical Link Control and Adaptation Protocol - L2CAP
- Provides a link-layer protocol between entities with a number of services
 - Relies on lower layer for flow and error control
 - Makes use of ACL links, does not support SCO links
 - Provides two alternative services to upper-layer protocols
 - » Connection service
 - » Connection-mode service
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- ### L2CAP Logical Channels
- Connectionless
 - » Supports connectionless service
 - » Each channel is unidirectional
 - » Used from master to multiple slaves
 - Connection-oriented
 - » Supports connection-oriented service
 - » Each channel is bidirectional
 - Signaling
 - » Provides for exchange of signaling messages between L2CAP entities
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- ### Flow Specification Parameters
- Service type
 - Token rate (bytes/second)
 - Token bucket size (bytes)
 - Peak bandwidth (bytes/second)
 - Latency (microseconds)
 - Delay variation (microseconds)
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IEEE 802.15.3

- High data rate WPAN
- Higher bandwidths than currently supported with 802.15.1
 - › 100 Mbs within 10 meter
 - › 400 Mbs within 5 meter
 - › Typical rates are in 10s of Mbs
- Data, High quality TV, Home cinema

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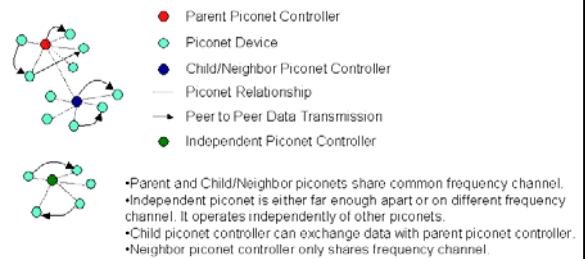
IEEE 802.15.3 - Features

- Dynamic topology
 - › Mobile devices often join and leave the piconet
 - › Short connection times
- High spatial capacity
- Multiple Power Management modes
- Secure Network
- Based on piconets
 - › Data Devices (DEV) establish peer-to-peer communication
 - › Includes also a Piconet Coordinator (PNC)

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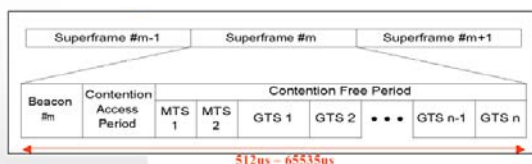
IEEE 802.15.3 - Topology



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IEEE 802.15.3 – Frame Structure



- Beacon
 - › Control information
 - › Allocates GTS
 - › Synchronization

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IEEE 802.15.3 – Media Access

- Contention Access Period - CAP
 - › Allows contention via CSMA/CD
 - › Command exchange between DEV and PNC
 - › File transfers from DEV without request
- Contention Free Period - CFP
 - › Time slot allocation specified in the beacon
 - › Reserved bandwidth for DEV
 - › Management Time Slots for commands
 - › Guaranteed Time Slots (GTS) for data

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IEEE 802.15.3 - Reservations

- **DEV sends a Channel Time Request (CTR) to PNC**
 - Isochronous data: number and duration of slot(s)
 - Asynchronous data: Total amount of data
- **PNC allocates GTSSs to DEV via CTA**
- **DEV is responsible of utilizing allocated GTSSs**
- **Two types of GTSSs**
 - Dynamic GTS
 - Location within a superframe may change
 - PNC can optimize channel utilization
 - Pseudostatic GTS
 - Only for isochronous data
 - Fixed location within a superframe
 - May be changed only after notification of the DEV

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IEEE 802.15.3 - QoS

- **IEEE 802.15.3 supports both synchronous and asynchronous data**
- **CAP offers only best-effort**
- **The PNC will allocate resources in the CFP**
 - Through admission control
 - Synchronous data: Based on number of time slots per superframe, duration of slot, priority and GTS type
 - Asynchronous data: Based on total data and priority
- **After performing admission control, GTSSs may be allocated**

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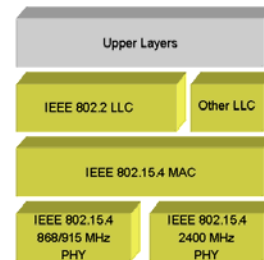
IEEE 802.15.4 - Overview

- **Low Rate WPAN (LR-WPAN)**
- **Simple and low cost**
- **Low power consumption**
 - Years on lifetime using standard batteries
- **Mostly in sensor networks**
- **Data rates: 20-250 kbps**
- **Operates at multiple frequencies**
 - 868 Mhz, 915 Mhz, 2.4 GHz
- **Blends elements from 802.15.3 and 802.11**

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IEEE 802.15.4 - Protocol stack



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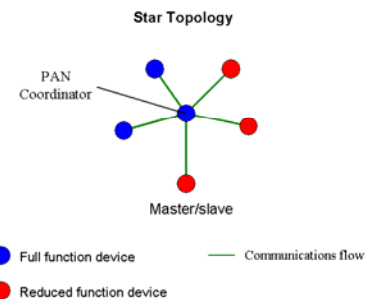
IEEE 802.15.4 - DEVs

- **2 or more DEVs form a PAN**
- **2 different types of DEVs**
 - Full functional Device (FFD)
 - Coordinator and simple node
 - Any topology
 - Talks to any device
 - Reduced Functional Device (RFD)
 - Simple node only, either source or destination
 - Star topology only
 - Talks to network coordinator only

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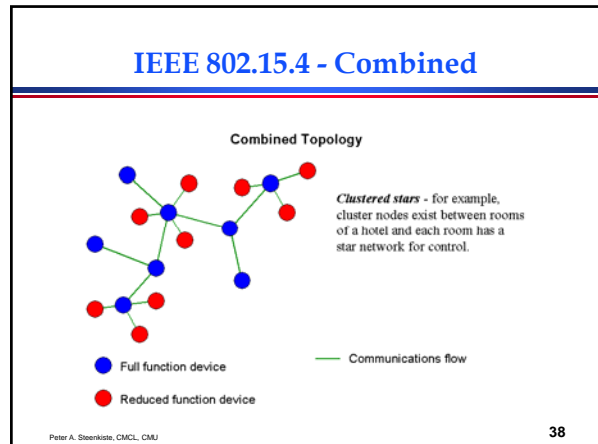
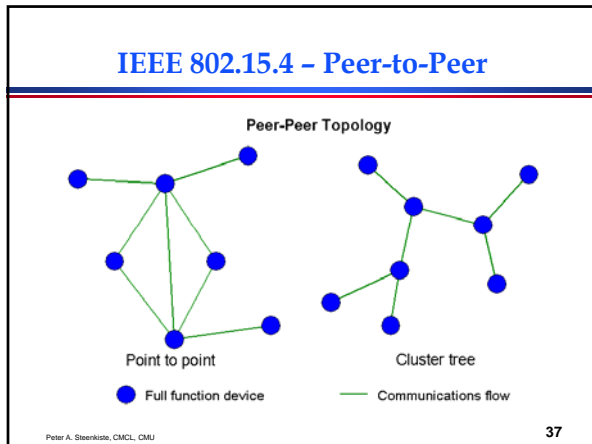
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IEEE 802.15.4 - Star



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- ### IEEE 802.15.4 - MAC
- **One PAN coordinator & multiple RFDs/FFDs**
 - » Association/disassociation
 - **CSMA-CA channel access**
 - » Reliable delivery of data
 - **Optional superframe structure with beacons**
 - » GTS mechanism
 - **AES-128 security**
 - **QoS - 3 traffic types**
 - » Periodic data: e.g. Sensor data
 - » Intermittent data: generated once a while, e.g. light witch traffic
 - » Repetitive low latency data: E.g. Mouse device traffic
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