Telecommunication Laboratory and CWC:

Local Area Networks

Lecture 5:
HIPERLAN-2, Bluetooth, and UWB

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Overview of the Lectures

- **Day 1: Mon 5.5. (9-12:30): Intro to LAN and 802.11 WLAN (Chap 1)**
- **Day 2: Wed 7.5 (9-12:30): WLAN applications, IEEE 802.15 WPAN, and HAN (Chap 10)**
- **Day 3: Fri 9.5 (9-12:30): IEEE 802.3 Ethernet**
- **Day 4: Mon 12.5 (9-12:30): Wireless medium (Chap 2)**
- **Day 5: Wed 14.5 (9-12:30): IEEE 802.11 (Chap 11)**
- **Day 6: Fri 16.5 (9-12:30): IEEE 802.11b,a,g, HIPERLAN-2, Bluetooth and UWB (Chap 12, 13)**

Outline

- HIPERLAN-2
  - Architecture
  - MAC
- Bluetooth
  - Architecture
  - PHY
  - MAC
- UWB
  - PHY Layer

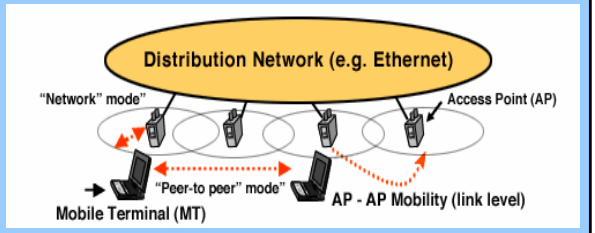
Why HIPERLAN-2?

- **HIPERLAN-2 is a better fit for integration into cellular systems**
  - **QoS capabilities**
  - **Spectral efficient MAC at high load**
  - **Improved security**
  - **Improved interoprability (Ethernet, IEEE1394 (Firewire), ATM, 3G)**
  - **Improved scalability**
  - **Ease-of-use through a set of auto-configuration tools**
- **Draw backs**
  - **Too complex**
  - **Operates at 5GHz**
    - **less efficient coverage**
    - **not backward compatible with 802.11b**

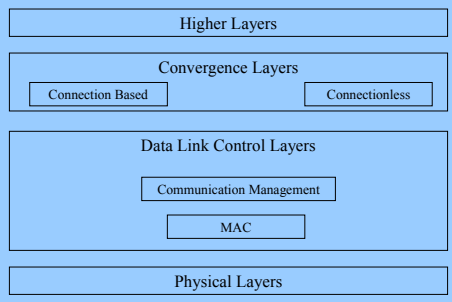
IEEE802.11 vs HIPERLAN-2

	802.11	802.11b	802.11a	HIPERLAN-2
Frequency	2.4GHz	2.4GHz	5GHz	5GHz
Max trans. rate	2Mbps	11Mbps	54Mbps	54Mbps
Max throughput	1.2Mbps	5Mbps	32Mbps	32Mbps
Freq Management	None			Dynamic Selection
Medium access	Through sensing			Centralized scheduling
Authentication	None			NAI/IEEE Add/X.509
Encryption	40-bit RC4			DES, 3DES
QoS support	PCF			ATM/802.1p/RSVP
Wired backbone	Ethernet			Ethernet/ATM/UMTS/FireWire/PPP/IP
Connectivity	Connectionless			Connection-oriented
Link quality control	None			Link adaptation

Overall Architecture



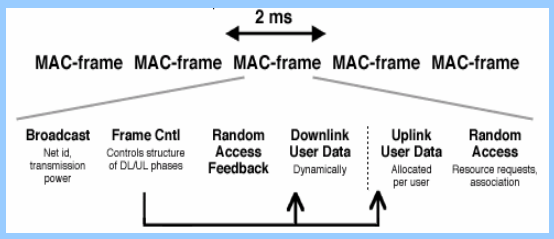
Protocol Stack of HIPERLAN-2



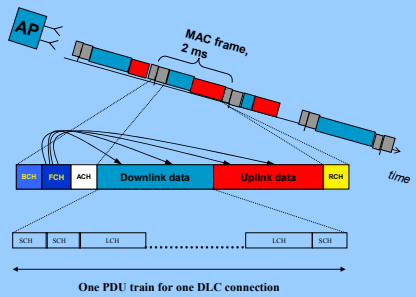
DLC: Data Link Control

- TDMA/TDD with fixed frames of 2 ms, implemented on logical channel transmission concept (close to the DECT)
- Supports AP to MT unicast/multicast as well as MT to MT peer-to-peer transmissions
- AP's centralized scheduling
  - Resource allocation to MT
  - Dynamic resource distribution to up- and down-links
  - Could consider QoS and link adaptation
  - Provision for collision free transmission
- Random access scheme
  - Defines association/deassociation
  - Random access from mobile uses slotted ALOHA with exponential backoff and ACK at next frame

MAC Structure



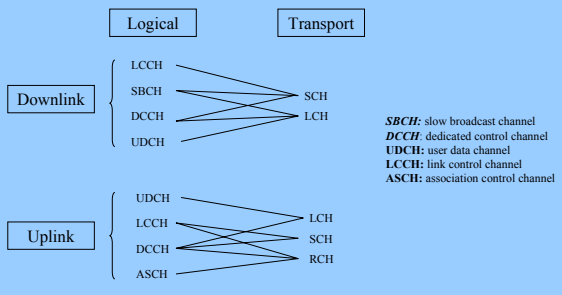
MAC Frames



One PDU train for one DLC connection

All data are transmitted in dedicated time slots except contention channels that are used to reserve time slots

Logical vs Transport Channels

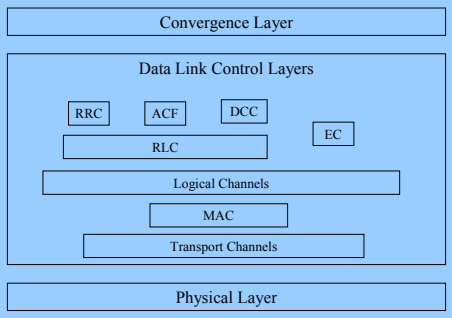


SBCH: slow broadcast channel
DCCH: dedicated control channel
UDCH: user data channel
LCCH: link control channel
ASCH: association control channel

Logical Channels

- Transport logical channels
  - BCH (broadcast channel), FCH (frame control channel) ACH (access feedback channel), RCH (random channel) , SCH/LCH (short/long transportation channels).
- Logical Channels
  - BCCH, FCCH, RACH, RFCH (rand fbk), RBCH (RLC BCH), DCCH (Dedicated Cont.), LCCH (Link), UDCH (User Data)

Protocol Implementation



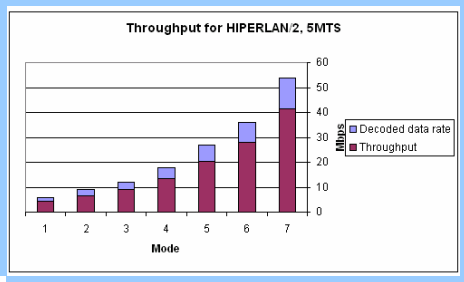
Data Link Control Protocols

- RRC: frequency selection, data rate selection, and power control.
- ACF: association signalling with optional authentication
- DCC: connection set-up
- EC: data link error control

HIPERLAN/2 Convergence Layer

- Multiple convergence layers operating one at a time to map higher layer (PPP/IP,ATM, UMTS,Firewire,Ethernet) packets to DLC.
- Provides following services
  - Segmentation and reassembly
  - Priority mapping from 802.1p
  - Address mapping from 802
  - Multicast/broadcast handling
  - Flexible QoS classes

Throughput of HIPERLA-2



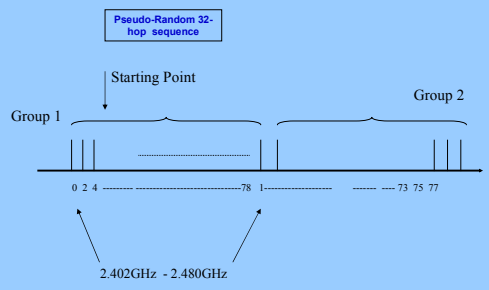
Bluetooth Summary

Topology	Supports up to 7 simultaneous links	200 live nodes
Flexibility	Has a number of software protocols	Easy to implement applications
Data rate	1 MSPS, 720 Kbps	Varies with use and cost
Power	0.1 watts active power	1mW in US
Size/Weight	25 mm x 13 mm x 2 mm,	A few grams
Cost	Long-term $5 per endpoint	Mass production
Range	10 meters or less with 1mW	Up to 100 meters with 100mW
Universal	Works anywhere in the world	Coverage varies
Security	Link layer security	Spread Spectrum radio

BT Radio Specifications

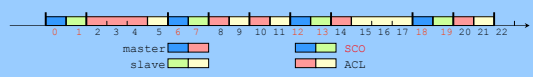
- Operates in 2.4GHz ISM bands (similar to 802.11)
- Transmission specification
  - Modem: GFSK (K=0.3) modulation with non-coherent detection using simple FM demodulators.
  - Transmission rate: 1Mbps
  - Power: 0dBm (10m coverage) with an option for 20dBm (100m)
- *Fast* FH-CDMA/TDD (one packet per hop)
  - 1600 hops per second (625μsec dwell time)
  - 79 hops available in ISM bands
  - Radios alternate between transmit and receive mode
  - At each slot “Master” decides and ***polls*** a “Slave”

Two FH Groups

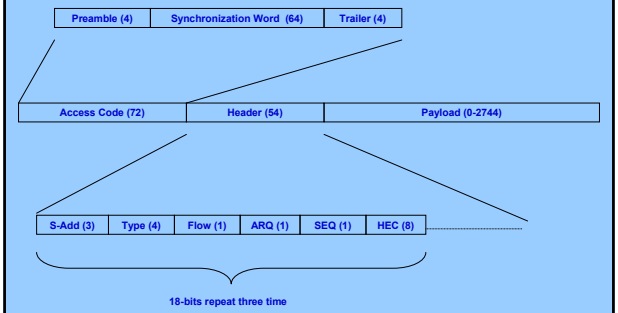


Link Definition

- Synchronous Connection-oriented Link (SCO)
  - Point-to-point
  - Reserves duplex slots at regular intervals (64Kbps)
  - Synchronous and symmetric
- Asynchronous Connectionless Link (ACL)
  - Point-to-multipoint
  - Uses remaining slots with Master scheduling (polling)
  - Asynchronous, asymmetric and symmetric



Overall Frame Format



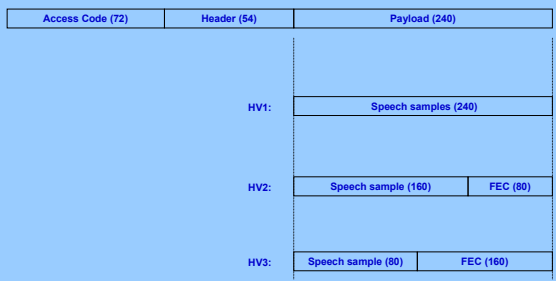
Frame Format Description

Access code
- •A PN sequence with piconet ID
- •Slaves only accept packets with their Master's access code ID

Header (18-bits protected with 1/3 FEC codes)
- •3-bit Slave address
- •1-bit ACK/NACK for automatic repeat request (ARQ)
- •4-bit payload type (four control, 12 different services: sync/async-multiple slots)
- •8-bits CRC error correcting codes

Four control packets
- •ID: only access code used for signaling
- •NULL: access code and header, used to convey header
- •POLL: similar to NULL with master request to response
- •FHS: FH-Synchronization packet

SCO 1-Slot Packet



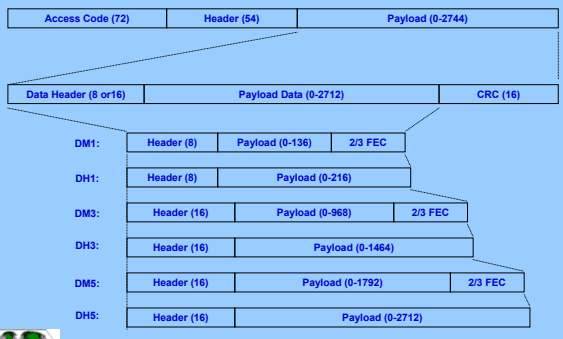
SCO Rate Calculation

EXAMPLE 6: DATA RATE OF HIGH QUALITY VOICE PACKETS

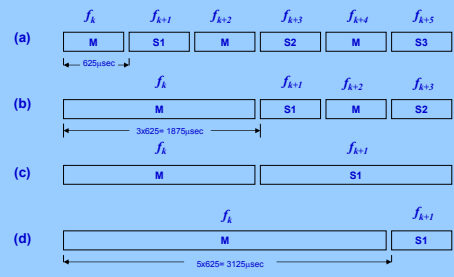
THE HV1 PACKETS ARE 240 BITS LONG, AND SO THEY ARE SENT EVERY 6-SLOTS. THE PACKETS ARE 1-SLOT PACKETS SENT AT THE RATE OF 1600 SLOTS/SEC. THEREFORE, WE HAVE

$$\frac{1600(slots/\sec)}{6(slots)} \times 240(bits) = 64Kbits/\sec .$$

ACL 1- 3- 5-Slot Packets



FH/TDMA/TDD Packets



ACL Data Rate Calculation

EXAMPLE 7: HIGH DATA RATE IN BLUETOOTH

A symmetric 1-slot DH1 link between an "M" and a "S" terminal carries 216 bits per slot at a rate of 800 slots per second (every other slot) in each direction. The associ ated data rate is $216(bits/slot)\times 800(slots/\sec) = 172.8(Kb/s)$.

EXAMPLE 8: MEDIUM DATA RATE IN BLUETOOTH

THE ASYMMETRIC DM5 LINK, SHOWN IN FIG 13.12D USES 5-SLOT PACKETS CARRYING 1792 BITS PER PACKET BY THE "M" AND 1-SLOT PACKET CARRYING 136 BITS PER PACKET BY THE "S" TERMINAL. THE NUMBER OF PACKETS PER SECOND IN EACH DIRECTION IS 1600/6 PACKETS PER SECOND. THEREFORE THE DATA RATE FROM "M" IS GIVEN BY:

$$1792(bits/packet)\times\frac{1600}{6}(packets/\sec) = 477.8(Kb/s)$$

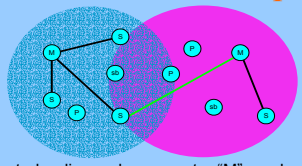
THE DATA RATE OF THE "S" TERMINAL IN THIS ASYMMETRIC CONNECTION IS:

$$136(bits/packet)\times\frac{1600}{6}(packets/\sec) = 36.3(Kb/s)$$

Data Rates for ACL

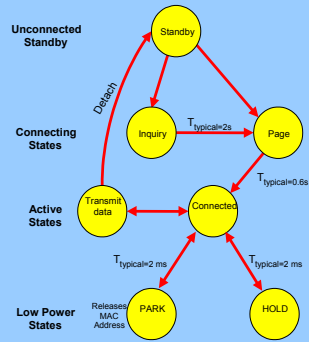
TYPE	symmetric	asymmetric	
DM1	108.8	108.8	108.8
DH1	172.8	172.8	172.8
DM3	256.0	384.0	54.4
DH3	384.0	576.0	86.4
DM5	286.7	477.8	36.3
DH5	432.6	721.0	57.6

Scattered Ad-Hoc Topology

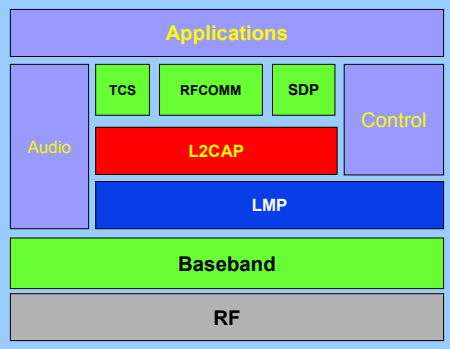


- Each connected radio can be a master "M" or slave "S" (ad-hoc)
- Radios can share piconets (scattered)
- "M" can connect 7 simultaneous and up to 200 active slaves in a pico-net
- If access is not available radios can go to standby "sb" mode waiting to join
- Up to 10 pico net can operate in one area
- A radio can be in a parked/hold, "P", in a low power connection.

Functional Overview



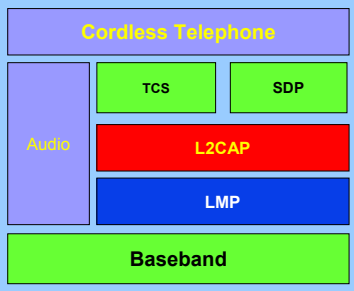
Protocol Stack



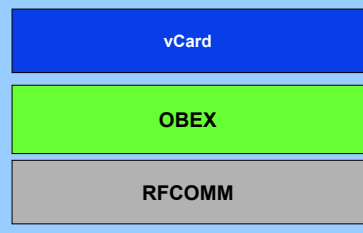
Protocol Descriptions

- LMP (link manager protocol) provides for link set-up: authentication and encryption, state of units in the piconet, power modes, packet size.
- L2CAP: logical link control and adaptation protocol: Provides connection-oriented and connectionless data services to the upper layer protocols: protocol multiplexing, segmentation and reassembly, and group abstractions for data packets up to 64 kilobytes in length.
- SDP: service discovery protocol finds the characteristics of service and connects two or more Bluetooth devices to support the service.
- RFCOMM is a “cable replacement” protocol emulates RS-232 control and data signals over Bluetooth baseband.
- TCS: Telephony Control protocol defines the call control signaling for the establishment of speech and data calls. In addition, it defines mobility management procedures. It is based on the ITU-T Recommendation Q.931.
- With this architecture it supports: PPP , UDP/TCP, IP/TCP, WAP, OBEX (IR), vCard/vCal (credit card).

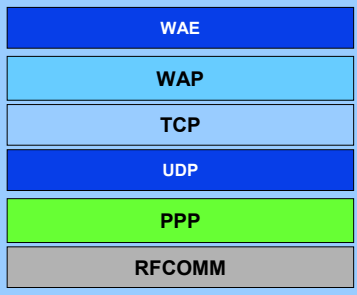
Cordless Telephone Implementation



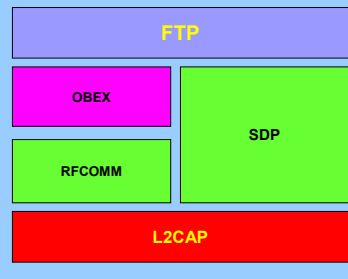
vCard Implementation



WAE Implementation



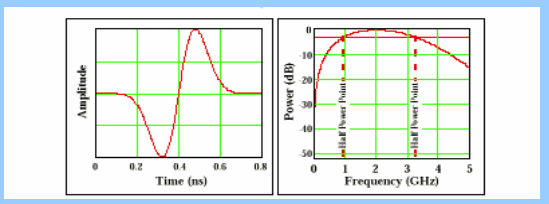
FTP Implementation

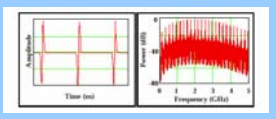


Pros and Cons of BT

- What is good in BT
  - Chip sets exists
  - Polling based MAC supports QoS
    - Good for voice applications
    - Good for integration of voice and data
  - Ah-hoc networking support
    - Automatic device discovery
    - Multi-pico-net participation
- Weaknesses
  - Limited data rate
  - Limited number of users
  - Slow association
  - Low accuracy for positioning

UWB Pulses





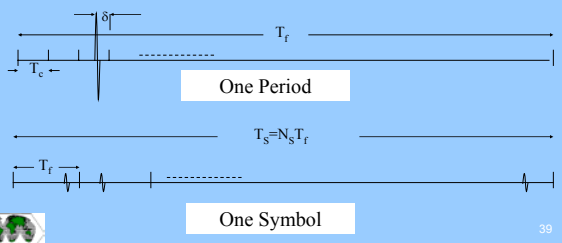
Time Hopping Spread Spectrum

$$x_{tr}^{\ k}(t^k) = \sum_{j=-\infty}^{\infty} w_{tr}(t^k - jT_f - c_j^k T_c - \delta d_{\lfloor j/N_s \rfloor}^k)$$

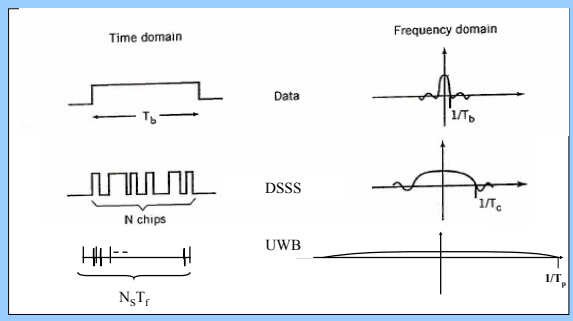
$$d_j = \{0,1\}$$

$$R_s = \frac{1}{N_s T_f}, N_h T_c \le T_f$$

Example values: $\delta = 0.156$ns, $T_f = 100$ns $R_s = 19.2$Kbps



Spreading the Signal



Refrences

- Chapters 12 and13 of the text
- http://www.hiperlan2.com/
- A system simulation of wireless local area networks operating in the 5 GHz band, MS thesis, Fredrik Kristensen and Magnus Sandgren, Department of Information Theory, Lunds Institute of Technology, Sweden, Aug 2001.