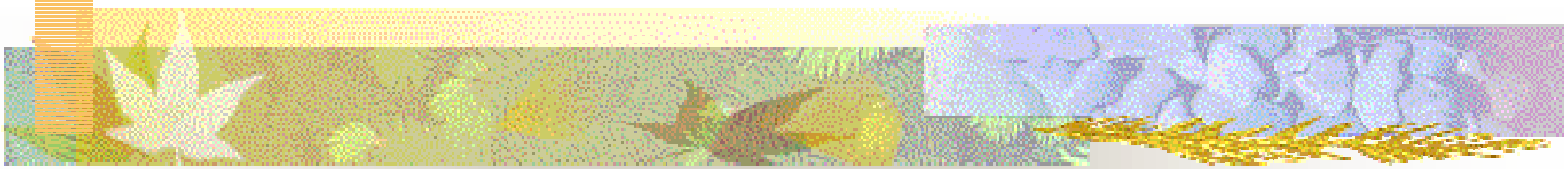
Technologies and standards in wireless communication



Seminar Mobile Computing

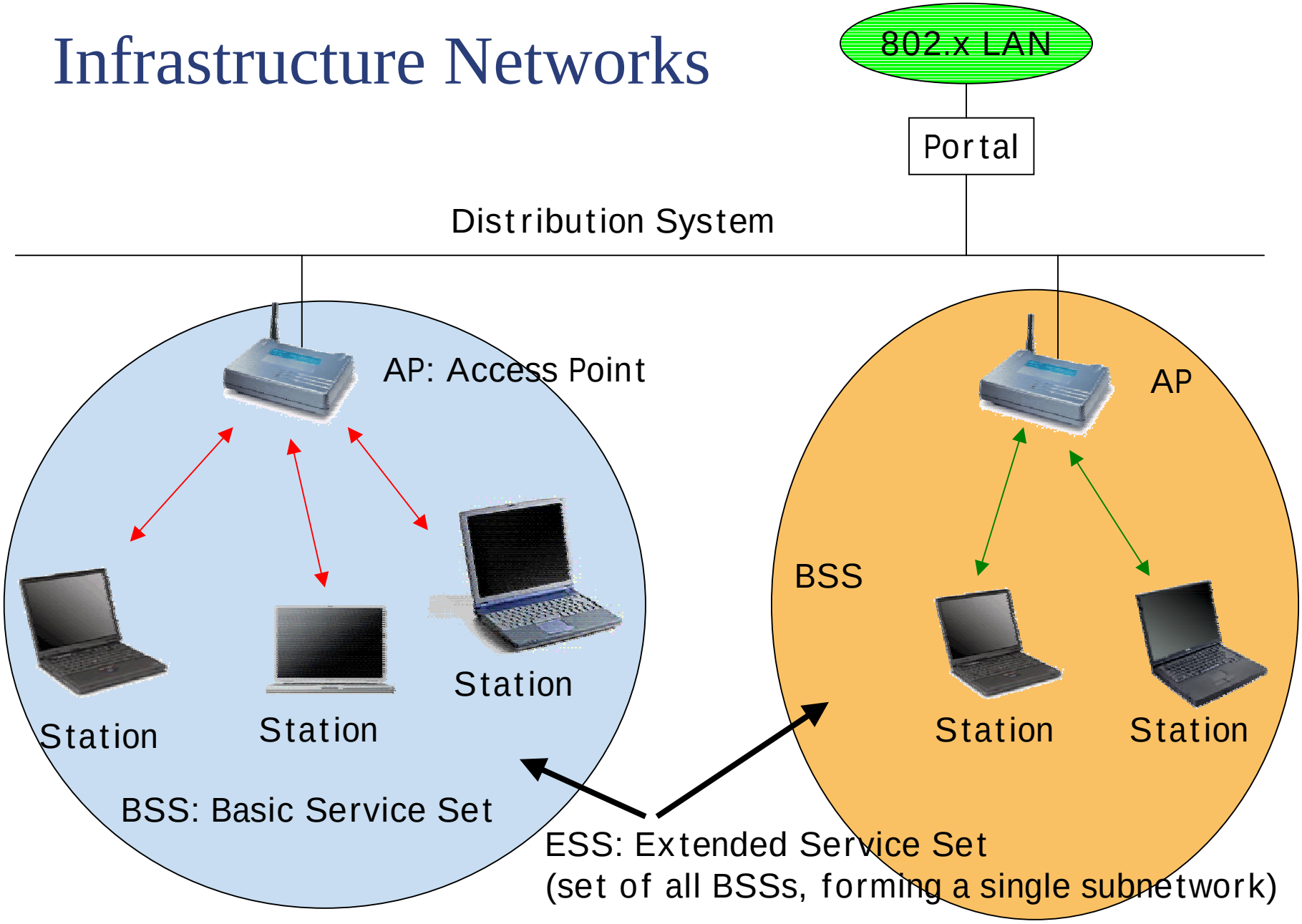
24 April 2001

Markus Huebscher

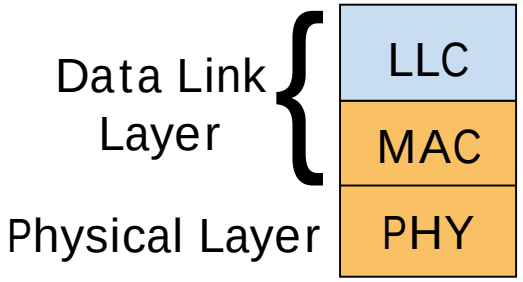
Topics

- Infrastructure Networks
  - IEEE 802.11 (802.11b, 802.11a)
  - HIPERLAN2
- Ad Hoc Networks
  - 802.11, HIPERLAN2 ad hoc mode
  - Bluetooth
  - WPAN (IEEE 802.15)
- Mobile Computing & Small devices
  - Problems and Issues
  - Suitability of standards
  - Future/Present of mobile computing

Infrastructure Networks



IEEE: 802.11



- new MAC layer, using CSMA/CA
- 1997: 3 PHY, 1 and 2 Mb/s:
  - Diffused Infrared
    850-950 nm, typ. 10m range
  - FHSS (Frequency Hopping Spread Spectrum)
  - DSSS (Direct Sequence Spread Spectrum)
- FHSS & DSSS: 2.4 GHz unlicensed ISM band
  - (83.5 MHz wide in N. America and Europe, 26 MHz in Japan)
- 1999: 802.11b: DSSS extended to 5.5 and 11 Mb/s
- 1998: 802.11a: 5 GHz unlicensed band, 6-54 Mb/s
  - 300MHz N. Amer., 455MHz Europe, 100MHz Japan

IR vs. Radio (GHz bands)

+ simple, cheap
+ electrical devices do not interfere

- low bandwidth
  IrDA 1.0: 115 kbit/s
  IrDA 1.1: 1.152 and 4 Mbit/s
- easily shielded, interference by sunlight, heat sources
- high data rates: LOS needed

IR cannot be used when device hidden (behing an obstacle, in a pocket or briefcase).

+ can cover large areas
+ radio waves can penetrate walls, furniture
+ high trasmission rates (50Mbit/s)

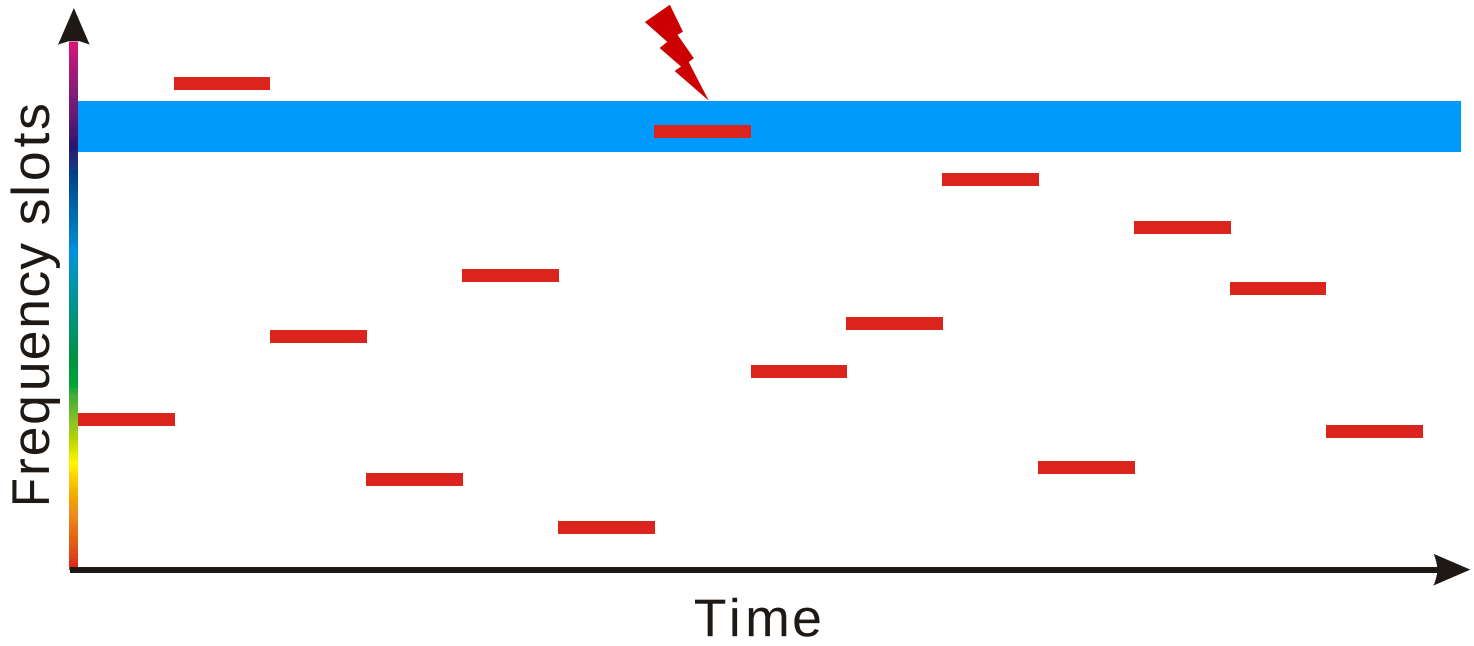
- shielding more difficult
- interference by other senders and electrical devices
- limited license-free bands available worldwide

Radio: Spread Spectrum

- trade off bandwidth efficiency for reliability and security
- allows to share the spectrum without explicit cooperation and with minimal interference
- two types:
  - Frequency Hopping
  - Direct Sequence

FHSS (Frequency Hopping Spread Spectrum)

- typ. 79 frequency channels, 1MHz wide (max)
- hopping sequence pseudo-random
- a hopping sequences defines a logical channel



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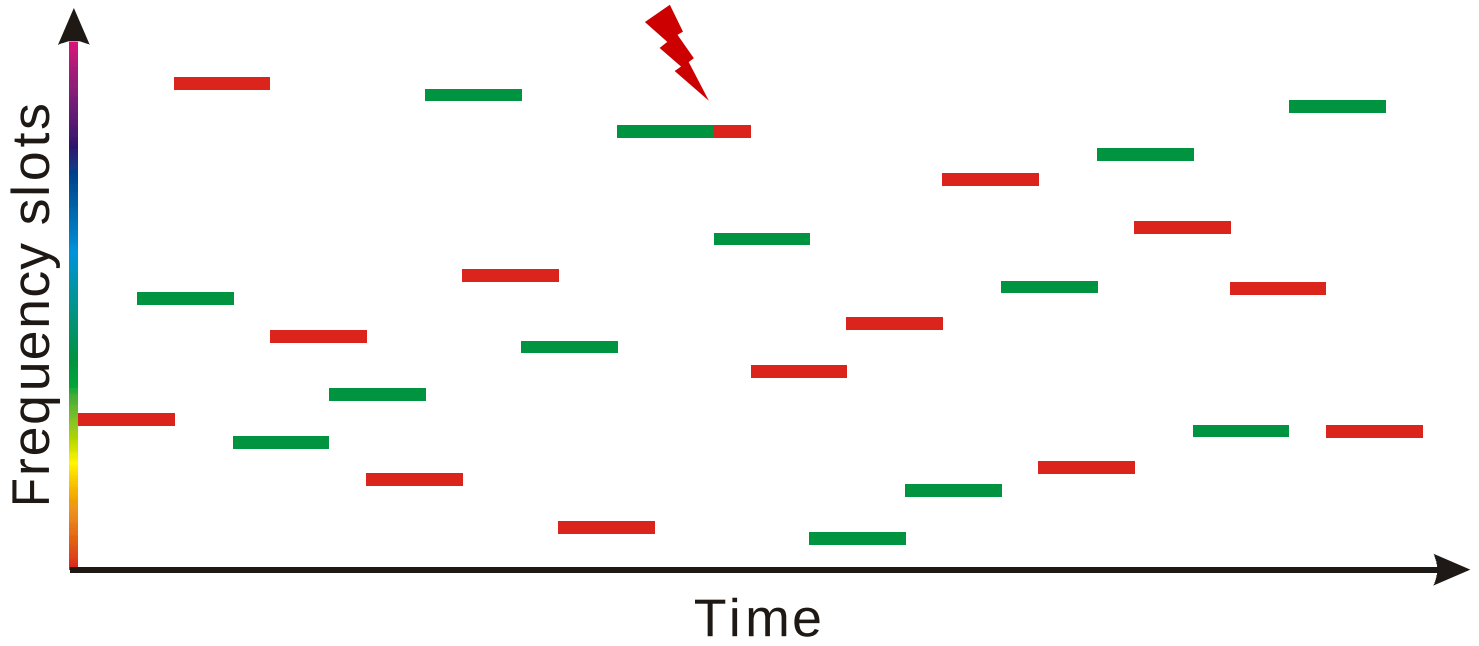
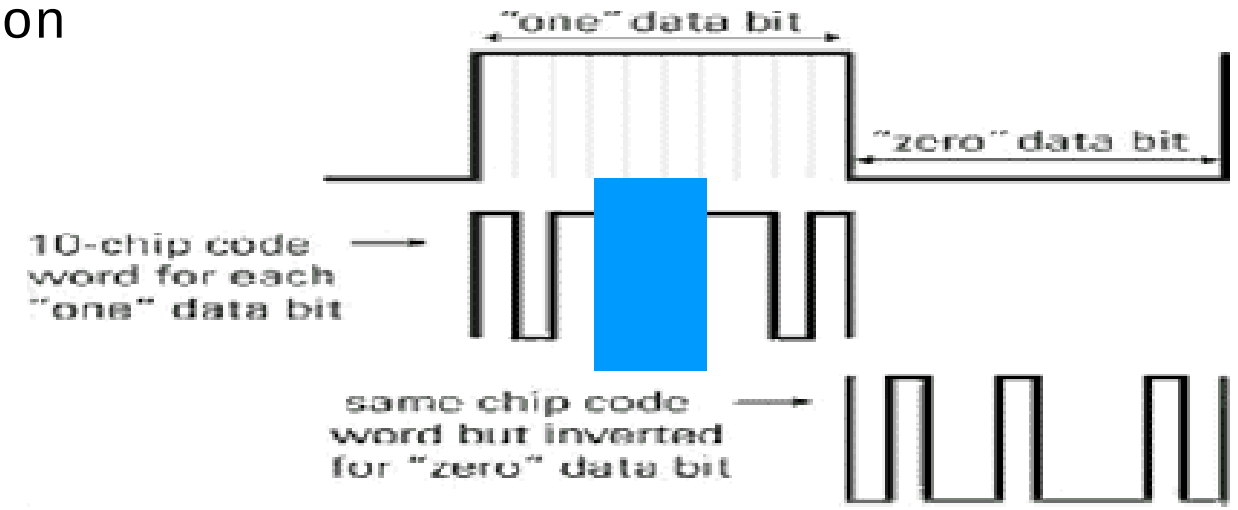


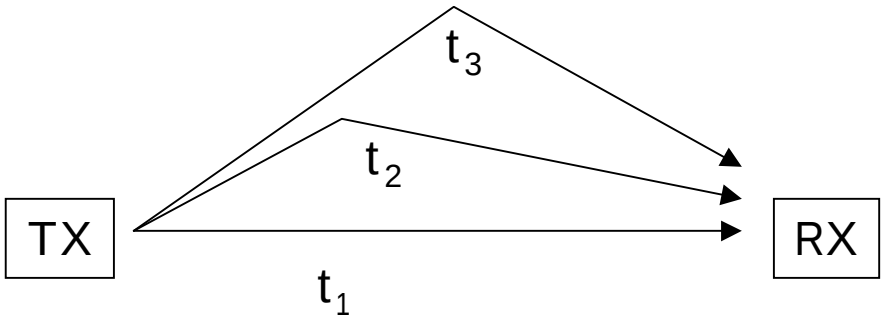
DSSS (Direct Sequence Spread Spectrum)

- Band divided into channels. No hopping
- To compensate for noise on a channel: chipping:
  - Each bit converted into a redundant bit pattern, called “chip” sequence
  - An n-chip code spreads signal by a factor of n
  - Error correction



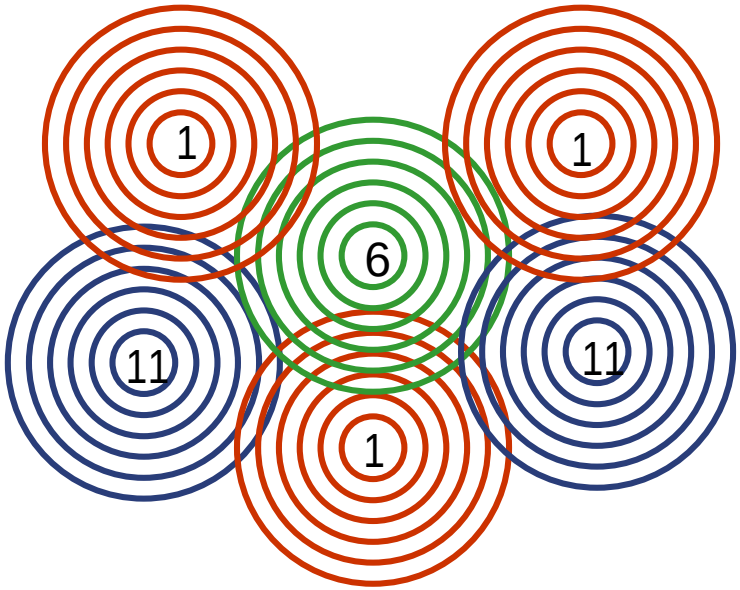
802.11b

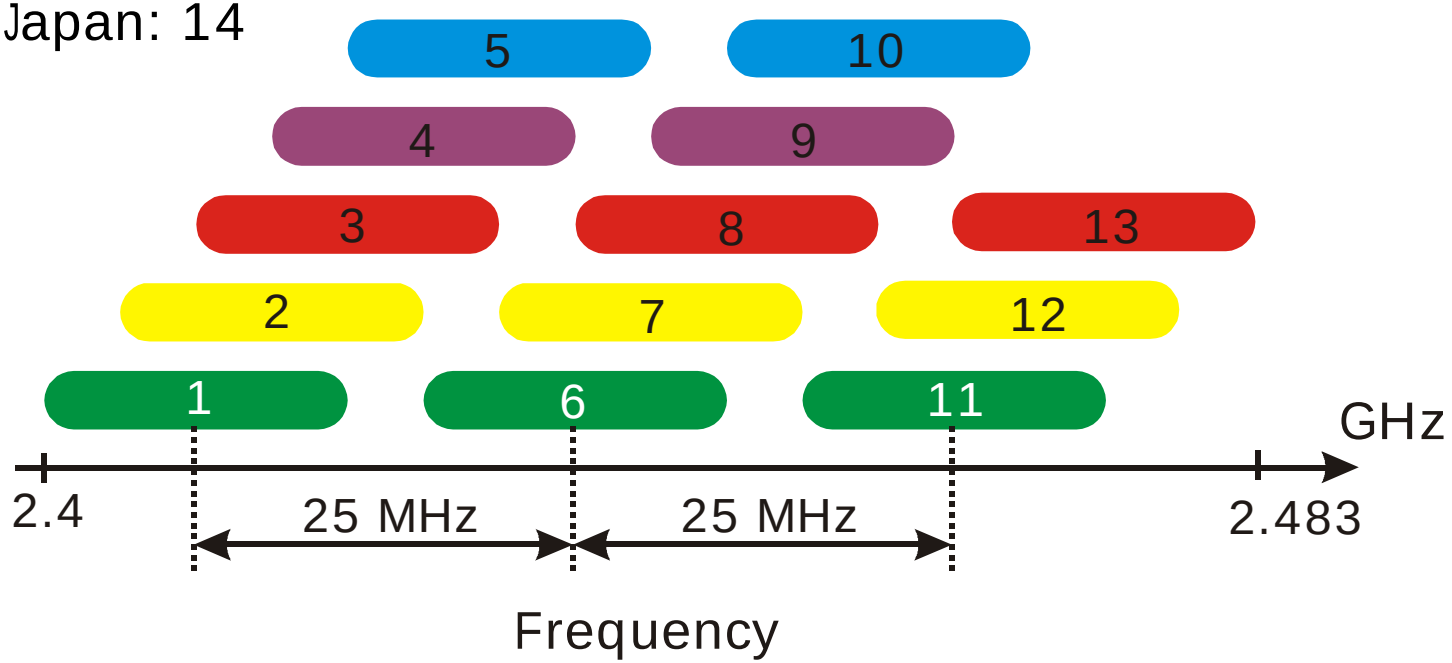
- 1, 2, 5.5, 11Mb/s, 2.4GHz (83.5 MHz wide)
  - multipath delay spread limits bitrates and range
- Transmit power typ. 30mW, range ~100m
- DSSS: 14 channels, 22MHz wide, 5MHz spacing
- Channels overlap one another partially
  (3 channels completely nonoverlapping)



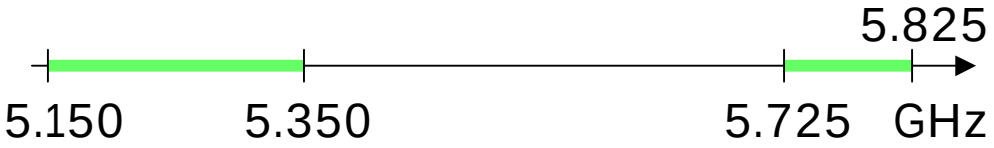
802.11b: Channels

- N. Amer.: 1-11
- Europe: 1-13
- Spain: 10-11
- France: 10-13
- Japan: 14



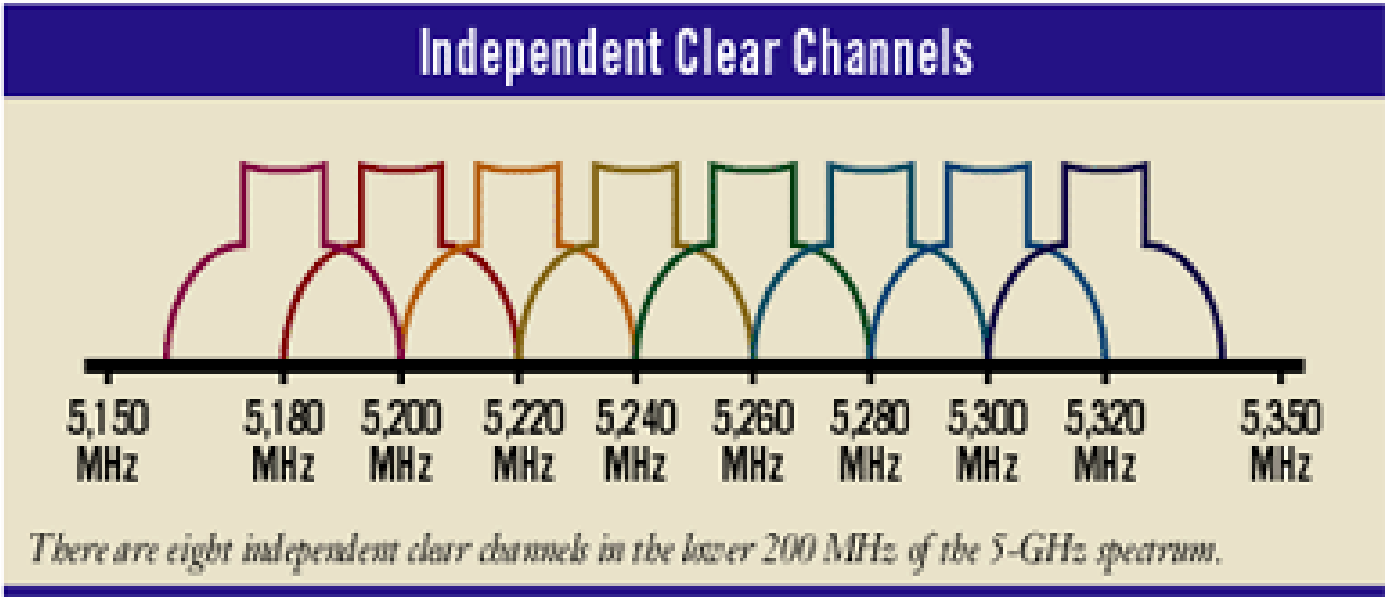


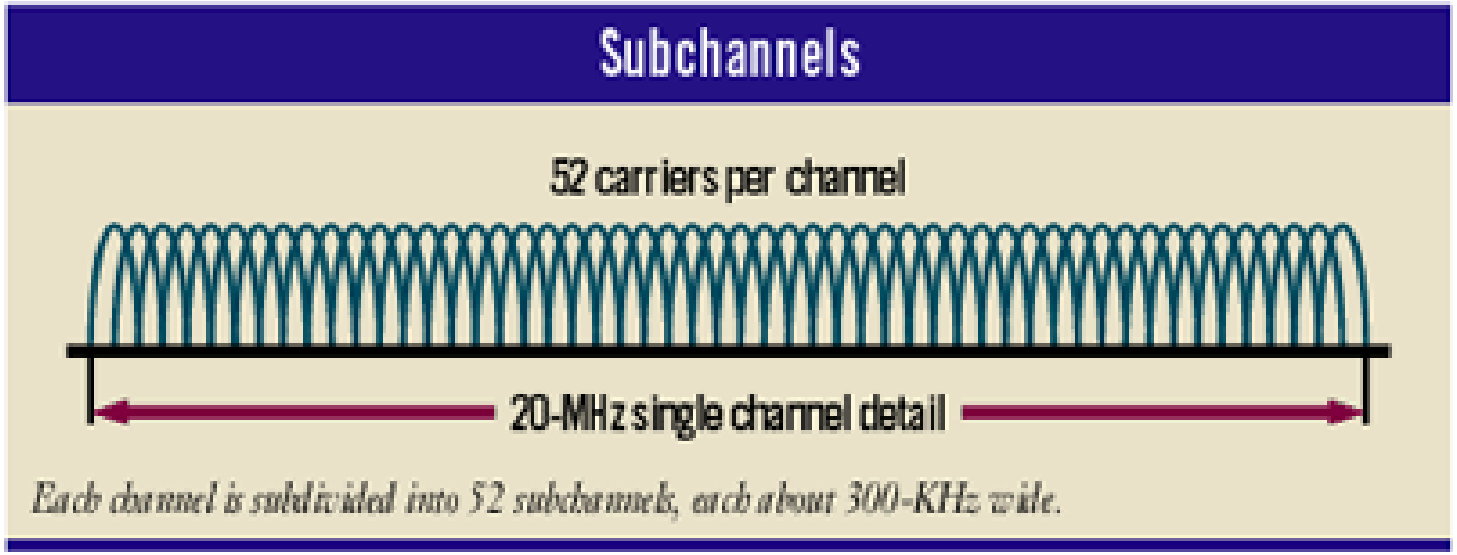
802.11a



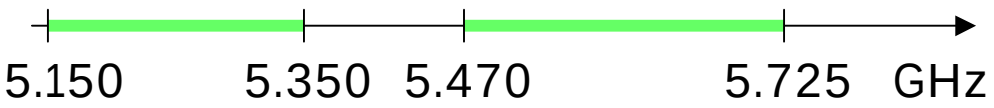
- first products 2002
- 5 GHz unlicensed Band (300 MHz wide N. Amer.)
  - 12 channels, 20 MHz wide (N. Amer.)
  - less interference than 2.4 GHz
  - propagation loss at 5 GHz is greater than at 2.4 GHz
- 6-54 Mb/s
- OFDM (orthogonal frequency-division multiplexing)
  - split high-rate data stream into lower-rate streams transmitted simultaneously over a number of subcarriers
    20 MHz channel $\Rightarrow$ 52 subchannels, 312.5 kHz wide
  - multipath delay spread and inter-symbol interference (ISI) decreased

OFDM


Independent Clear Channels
5,150 MHz
5,180 MHz
5,200 MHz
5,220 MHz
5,240 MHz
5,260 MHz
5,280 MHz
5,300 MHz
5,320 MHz
5,350 MHz
There are eight independent clear channels in the lower 200 MHz of the 5-GHz spectrum.


Subchannels
52 carriers per channel
20-MHz single channel detail
Each channel is subdivided into 52 subchannels, each about 300-KHz wide.

ETSI: HIPERLAN2



- competitor to 802.11
- specifies MAC and PHY
- centralized MAC based on wireless ATM with full QoS
- PHY based on OFDM, similar to 802.11a, 6-54 Mb/s
- 5 GHz band, (455 MHz wide in Europe)
- 19 channels (Europe), 20 MHz wide
- DFS (Dynamic Frequency Selection) and TPC (Transmit Power Control) to combat radio interference

802.11 vs. HIPERLAN2

- simple MAC (in terms of processing power)
- low performance (relative throughput) at high data rates
- limited QoS
- good for low quality applications

- complex MAC (requires powerful processor)
- high performance at any data rate
- high QoS support
- good for high end users

Will there be space for two different WLAN standards?

Topics

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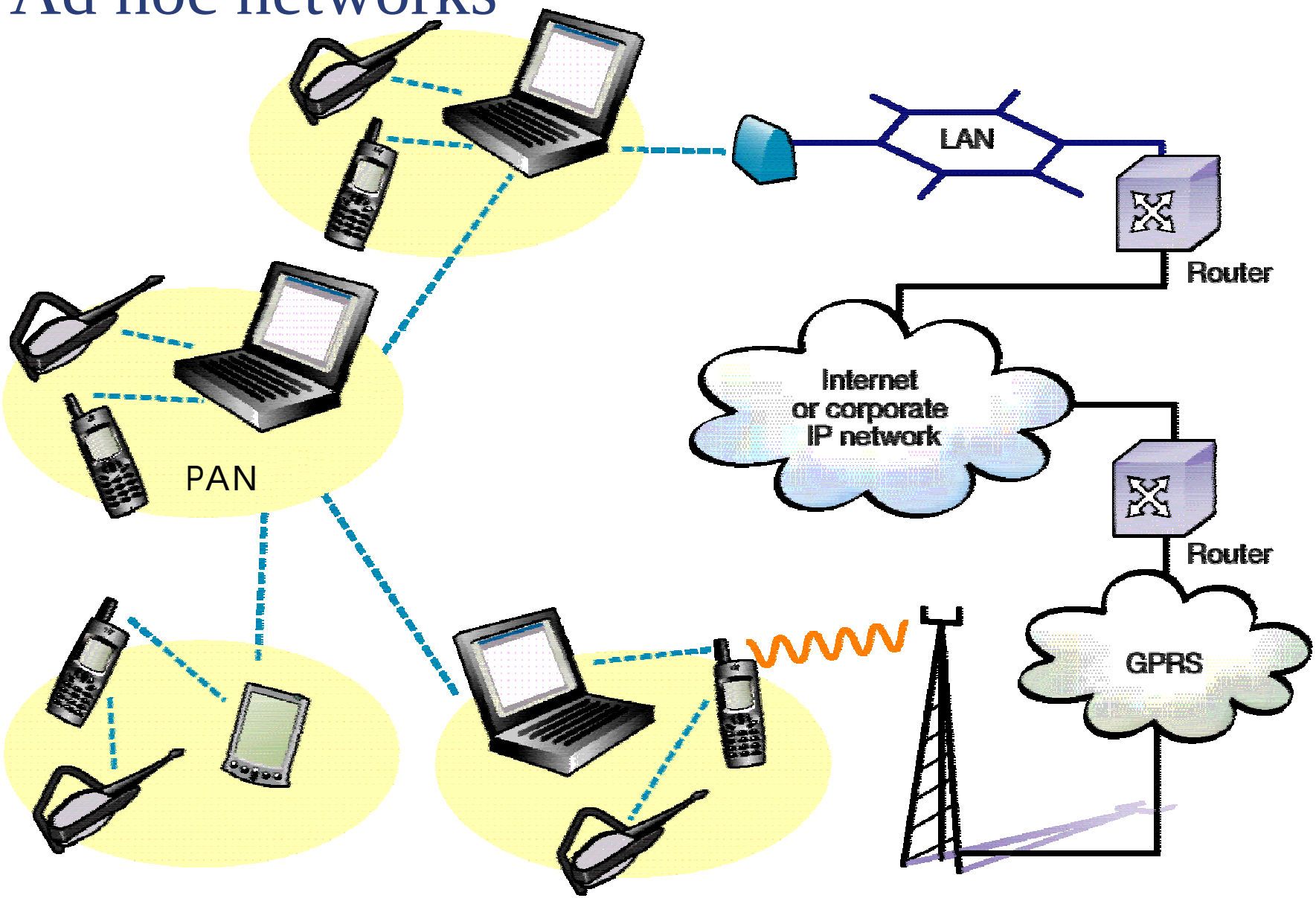
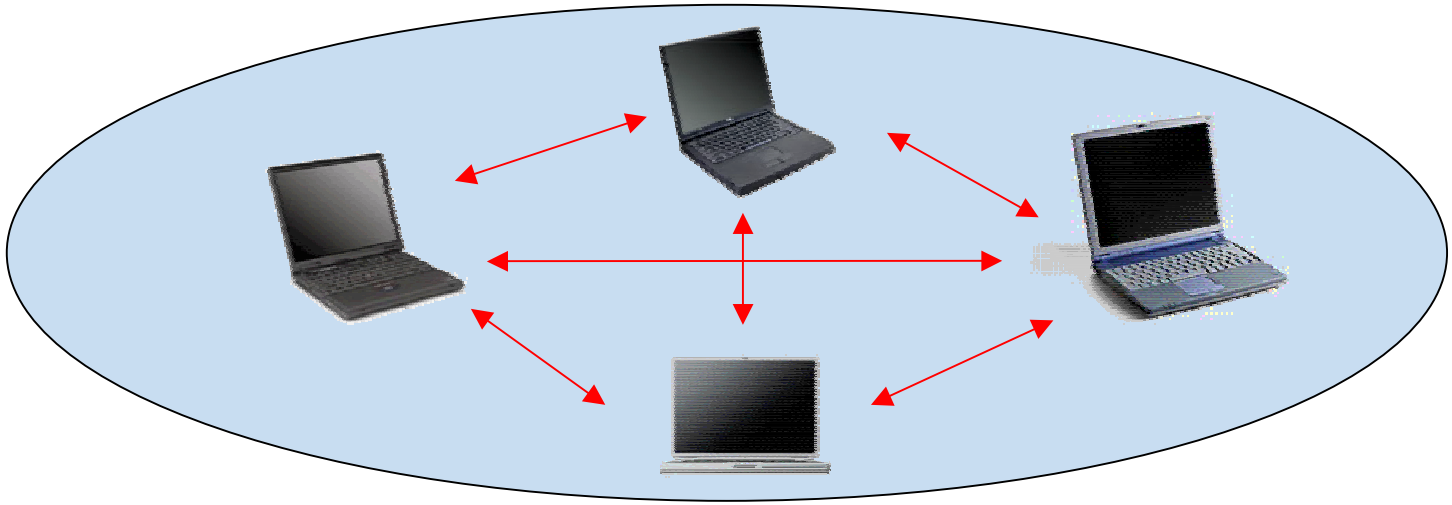
Ad hoc networks



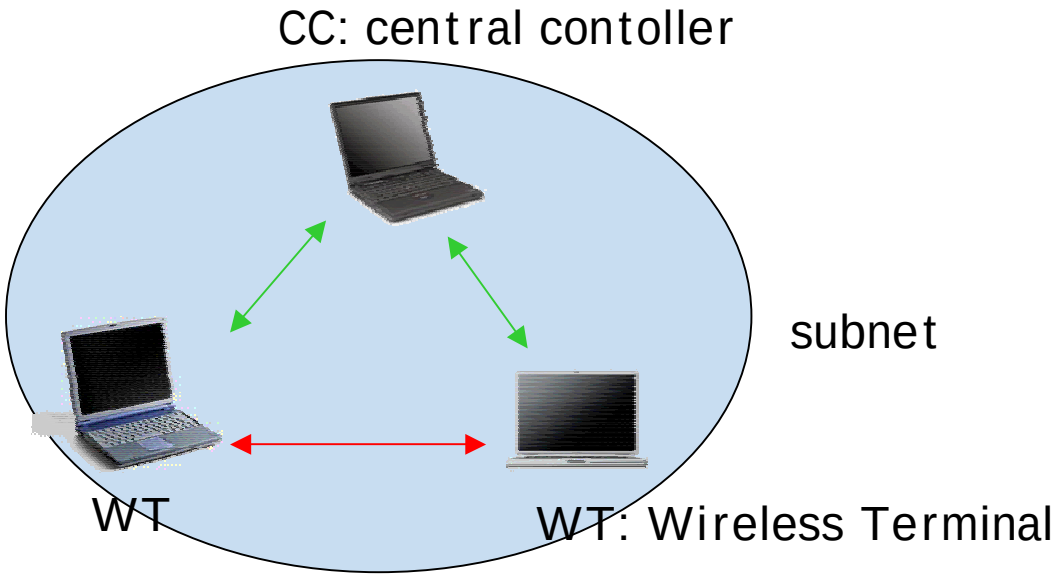
802.11: Ad hoc

- Two modes: Infrastructure mode and Ad hoc mode
- Ad hoc mode
  - part of functionality of AP performed by end-user stations
  - no time-bounded services
  - no frame-relaying (forwarding)
  - no power saving
  - ex.: notebooks at a conference share data



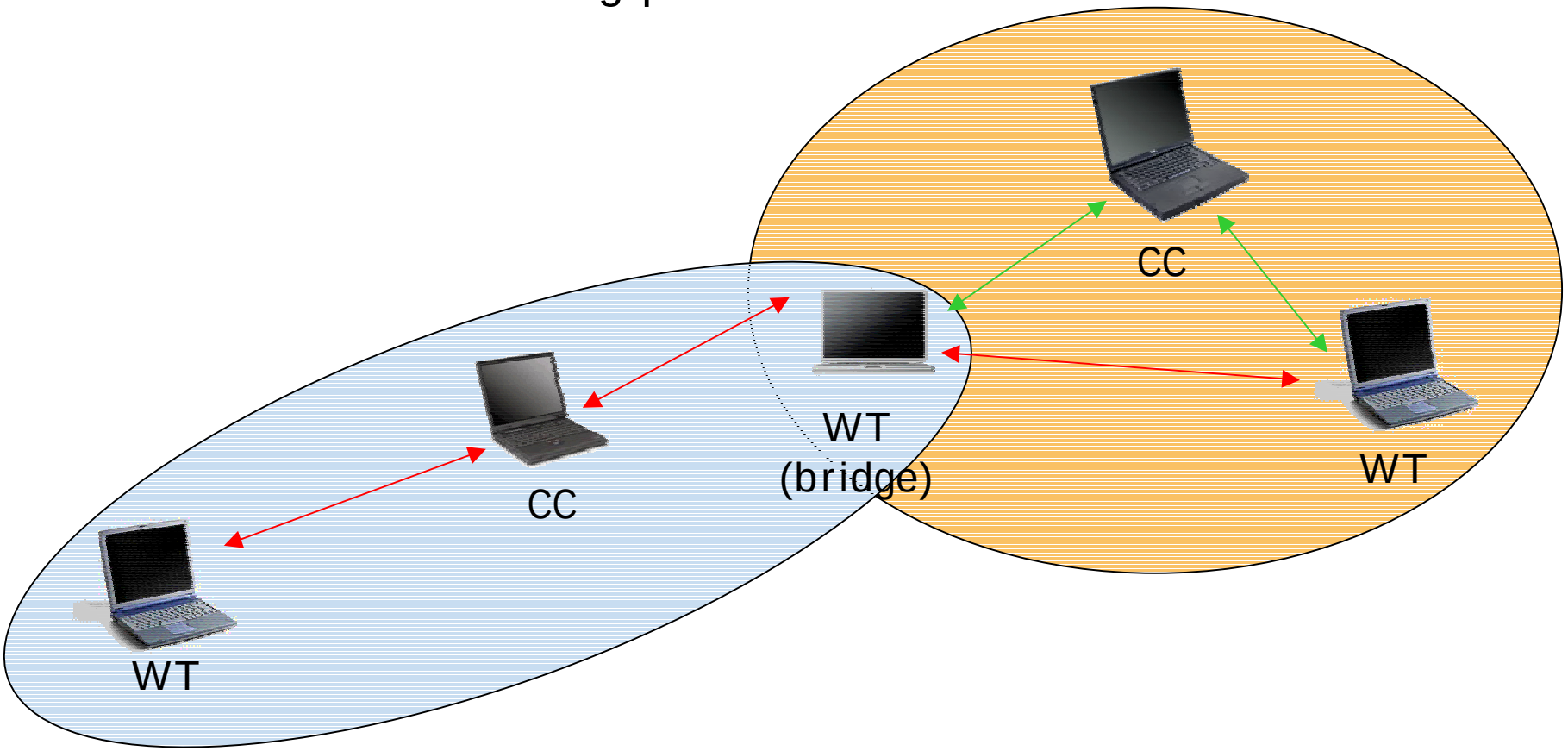
HIPERLAN2: Ad hoc

- H/2 Home Network Specification
  - CC controls access of the medium (one CC per subnet)
  - WT can communicate directly with each other under coordination of CC



HIPERLAN2: Ad hoc: bridging

- a WT in two overlapping subnets can become a bridge node
- inter-cell roaming possible



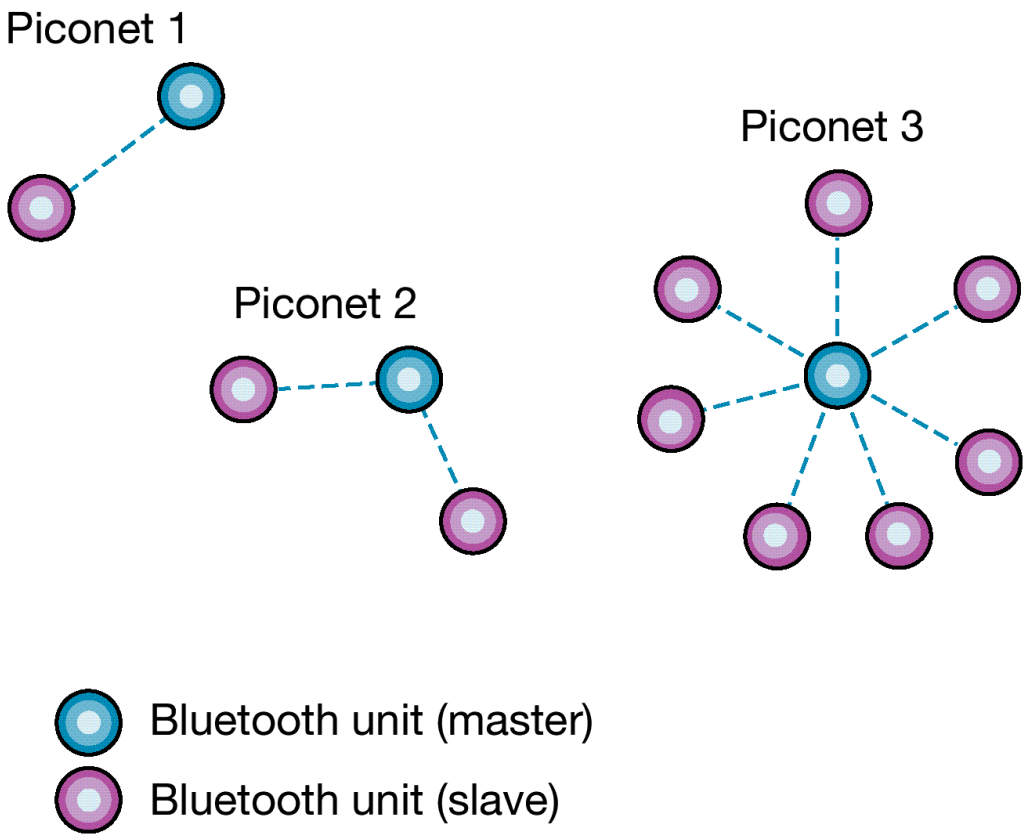
Bluetooth

- Frequency Hopping at 2.4 GHz Band
  - 79 frequency channels, 1 MHz wide
  - 1600 hops/s
  - Transmit power: typically 1mW (range ≤10m)
    but also 2.5 mW, 100 mW
  - low cost for mass market

- asymmetric: 723.2 kbit/s (57.6 kbit/s)
- symmetric: 2x433.9 kbit/s

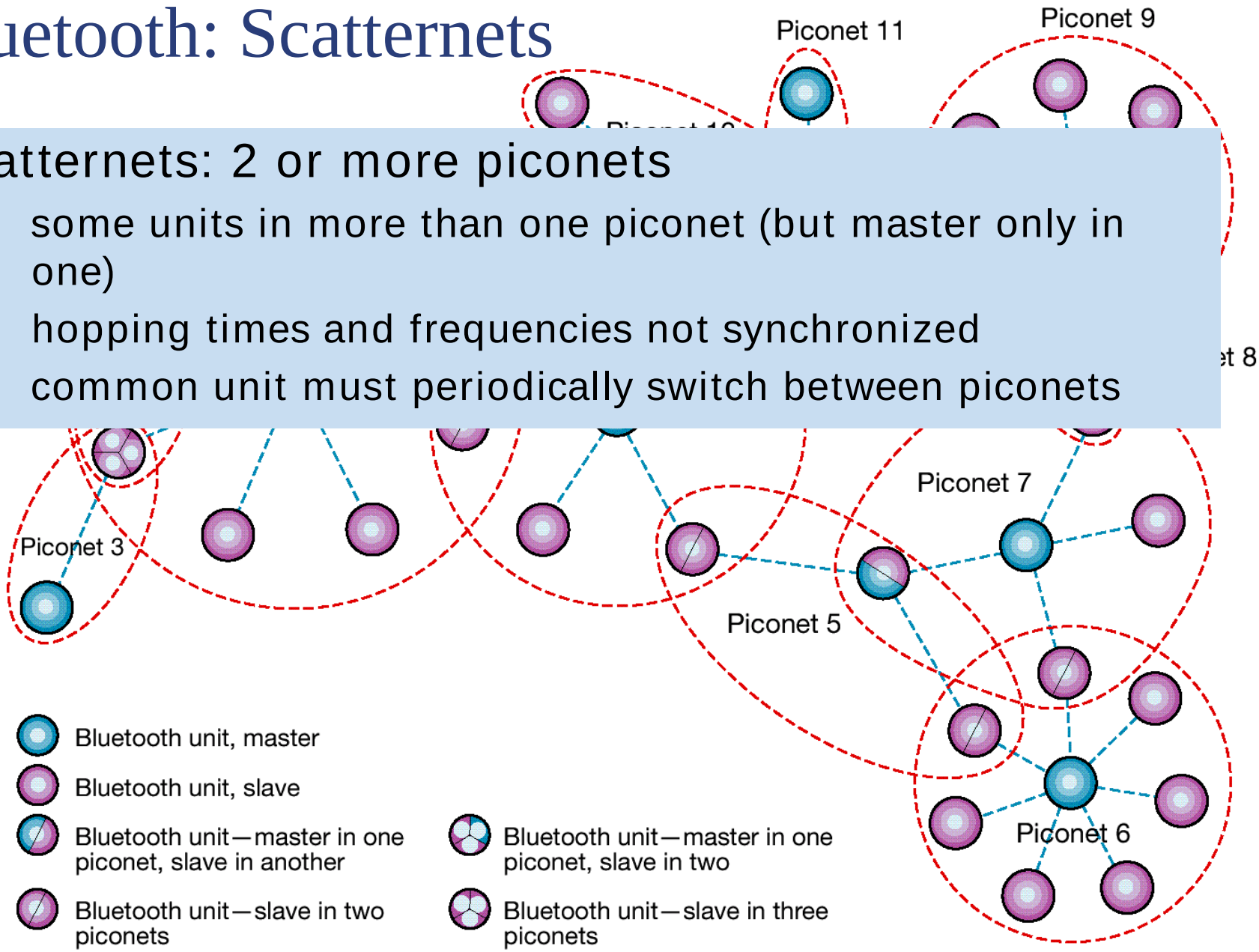
Bluetooth: Piconet

- Bluetooth units sharing a (frequency hopping) channel
- 1 master, up to 7 slaves (255 more in “parked mode”)
- only master-slave and slave-master communication
- up to 10 piconets in a coverage area



Bluetooth: Scatternets

- Scatternets: 2 or more piconets
  - some units in more than one piconet (but master only in one)
  - hopping times and frequencies not synchronized
  - common unit must periodically switch between piconets

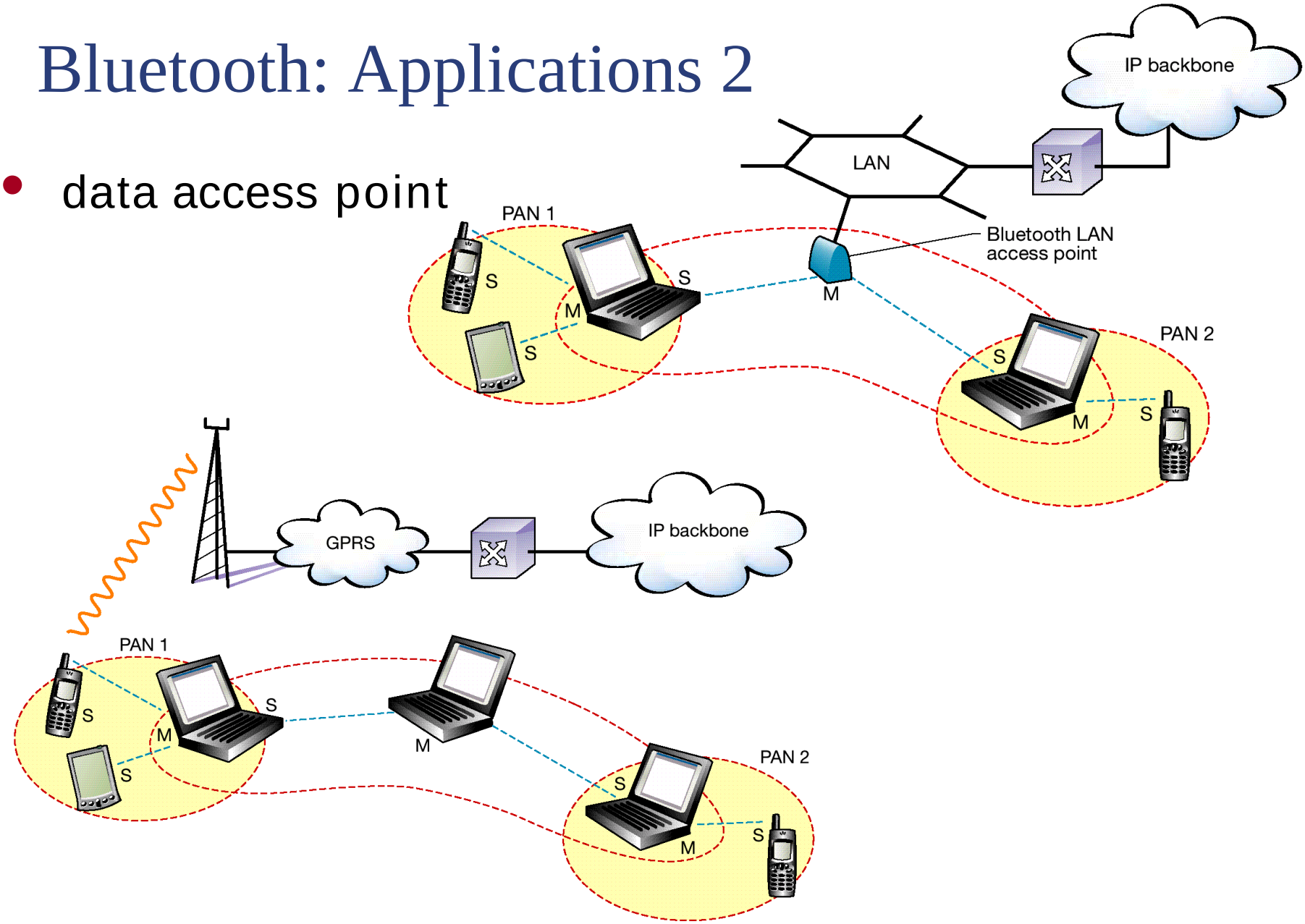


Bluetooth: Applications

- Designed for small devices (cheap 5$, low power, ...)
  - mobile phones, PDAs, headphones
- cable replacement (emulate serial port)
- wireless headphone
- file transfer
- automatic synchronizer

Bluetooth: Applications 2

- data access point



Bluetooth: Applications 3

- digital imaging, multimedia

IEEE: 802.15: Wireless Personal Area Networks

Small networks
Short-range
Low Power
Low Cost
Communication of devices withing a Personal Operating Space (<10m)

- low power, low cost
- digital imaging and multimedia applications
- compatibility with 802.15.1?

- 802.15.4: 10kbit/s up to 200kbit/s max
  - ultra low complexity, cost and power consumption
  - multi-month/multi-year battery life
  - sensors, interactive toys, smart badges, remote controls, home automation
  - location tracking for smart tags and badges

IEEE: 802.15: Wireless Personal Area Networks

- 802.15.1: WPAN based on Bluetooth (1Mbit/s)
- 802.15.2: Recommended Practices for coexistence of WPAN (802.15) and WLAN (802.11)
- 802.15.3: 20+ Mbit/s High Rate WPAN (2.4GHz)
  - low power, low cost
  - digital imaging and multimedia applications
  - compatibility with 802.15.1?
- 802.15.4: 10kbit/s up to 200kbit/s max
  - ultra low complexity, cost and power consumption
  - multi-month/multi-year battery life
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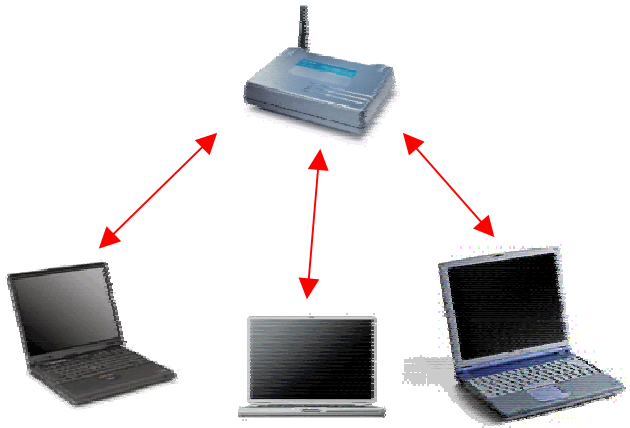
Small Devices & Mobile Computing

	WLAN	WPAN/Bluetooth

WLAN
(802.11, HiperLAN2)
WLAN in historic building
WLAN for mobile computing
group meetings (ad hoc)

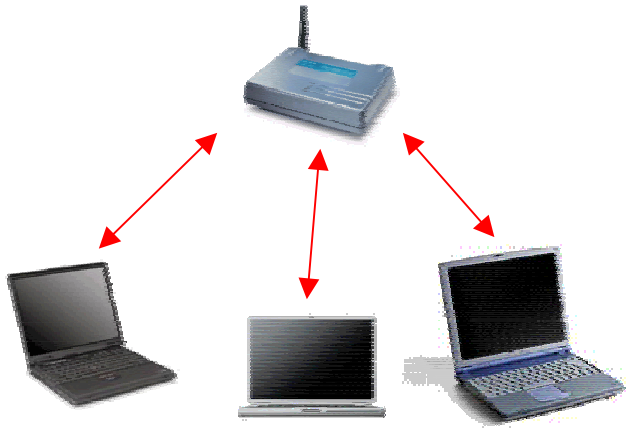
WPAN/Bluetooth
low power
limited range
no need for infrastructure



Small Batteries

Problem:
Very little battery power available.
Transmit power for 1 bit corresponds to executing 5000 operations (Bluetooth).

	WLAN	WPAN/Bluetooth
small batteries (transmit power)	30-100mW	1mW



Spontaneous

Issue:
Device should be able to, at any time, discover other devices in range, and automatically establish networks with them, and transmit data

	WLAN	WPAN/Bluetooth
small batteries	30-100mW	1mW
spontaneous networking	✓	✓

WLAN
automatic detection of other devices (AP)

Bluetooth
device in stand-by periodically “scan” for other devices to connect to (inquiry)

Scalability

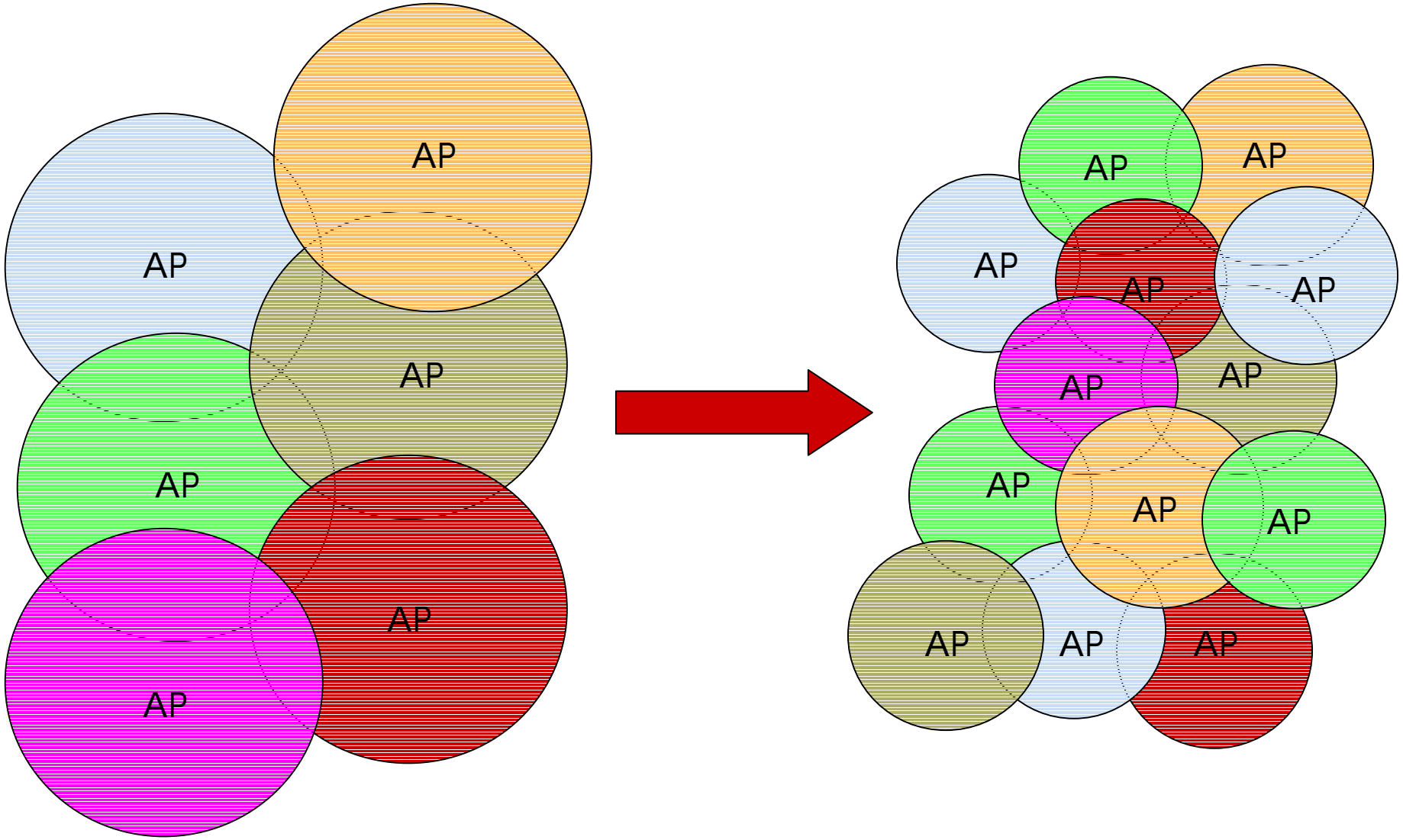
Problem:
High concentration of small devices should be supported

	WLAN	WPAN/Bluetooth
small batteries	30-100mW	1mW
spontaneous networking	✓	✓
scalability		

WLAN
802.11b: 11/13 channels, 3 non overlapping
802.11a/H2 non interfering channels,
possible to build picocell model

Bluetooth
8 devices active per piconet
255 more in parked mode
10 piconets in one region

Picocell model



Scalability

Problem:
High concentration of small devices should be supported

	WLAN	WPAN/Bluetooth
small batteries	30-100mW	1mW
spontaneous networking	✓	✓
scalability	✗802.11b ✓802.11a,H/2	✓

WLAN
802.11b: 11/13 channels, 3 non overlapping
802.11a/H2 non interfering channels,
possible to build picocell model

Bluetooth
8 devices active per piconet
255 more in parked mode
10 piconets in one region

Problem:
At any time, new devices can come and go

Topology

	WLAN	WPAN/Bluetooth
small batteries	30-100mW	1mW
spontaneous networking	✓	✓
scalability	✗802.11b ✓802.11a,H/2	✓
topology changes	✓	✓

All standards support roaming, hand-over (in infr. nets), master switching (in ad hoc)

Data Rates

	WLAN	WPAN/Bluetooth
small batteries	30-100mW	1mW
spontaneous networking	✓	✓
scalability	×802.11b ✓802.11	✓
topology c	✓	
data rates	11-56Mbit/s	1Mbit/s 0.01-20Mbit/s

WLAN
"faster is better"

WPAN/Bluetooth
trade off bit rate & range
for longer battery life

Problem:
Every person may carry many small devices.

Prices

	WLAN	WPAN/Bluetooth
small batteries	30-100mW	1mW
spontaneous networking	✓	✓
scalability	×802.11b ✓802.11a,H/2	✓
topology changes	✓	✓
data rates	11-56Mbit/s	1Mbit/s 0.01-20Mbit/s
Chipset-module 2000 Chipset-module 2004	$35-$150 $20-$90	$30-$75 $5-$35
	802.11	Bluetooth

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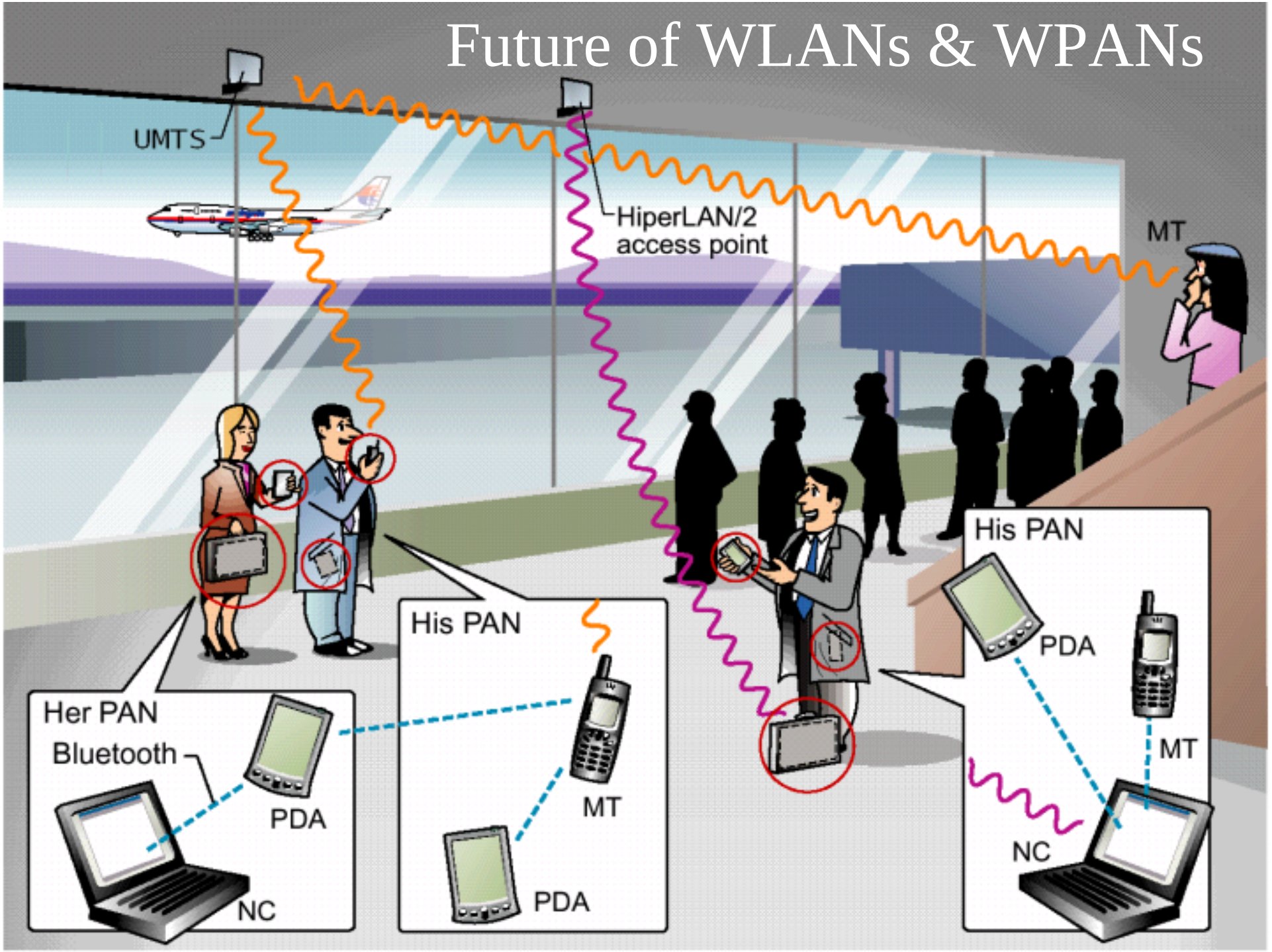
Future of WLANs & WPANs
UMTS
HiperLAN/2
access point
MT
His PAN
Her PAN
Bluetooth
PDA
NC
His PAN
MT
PDA
His PAN
PDA
MT
NC

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