Wireless-LAN: a Complement to 3G for Wireless Access

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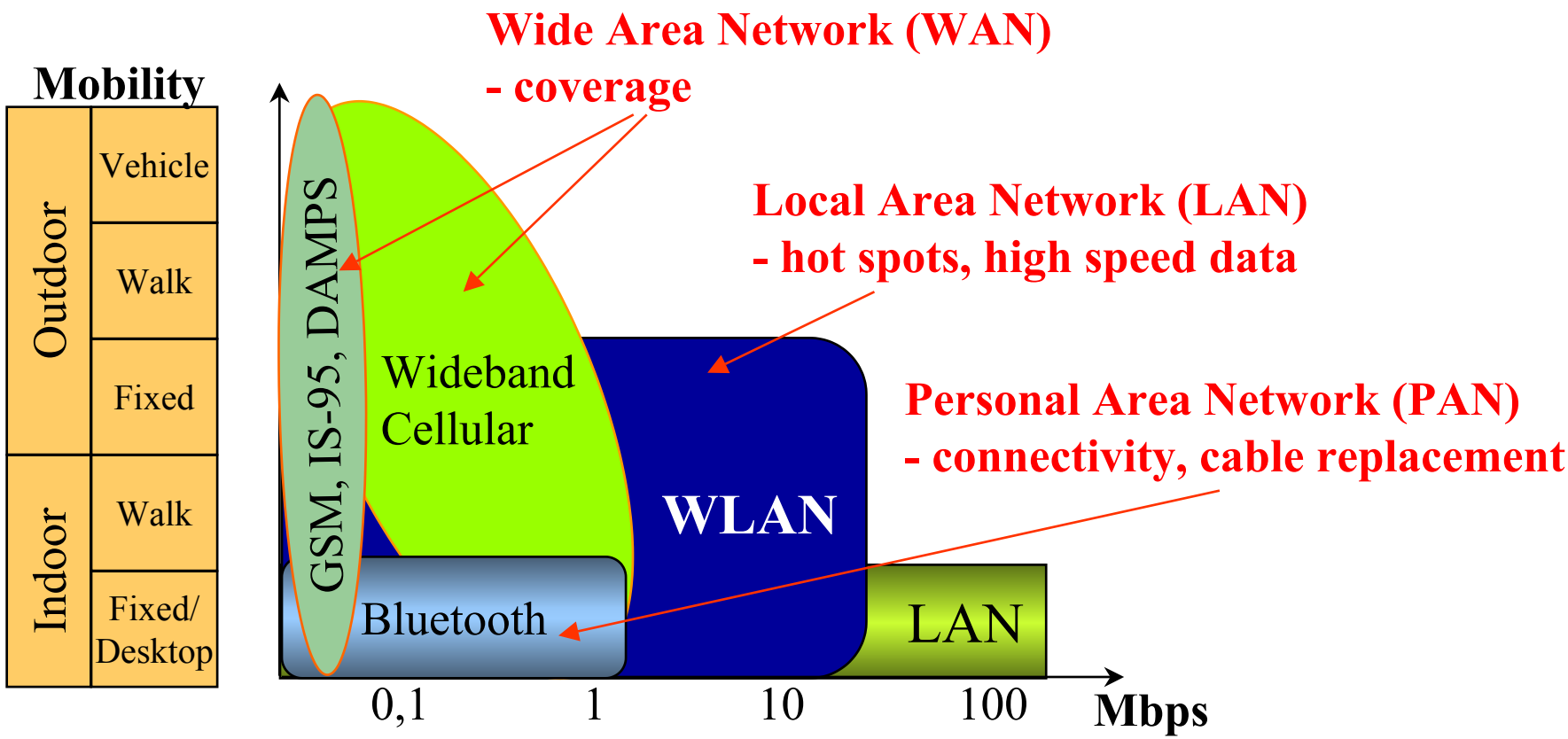
What is WLAN?

- WLAN = Wireless Local Area Network
- The 2.4 and 5 GHz bands
- WLAN as a complement to 2.5G and 3G – not a competitor
- Comparison of standards: ETSI HiperLAN2 better than IEEE 802.11
- Getting a 455 MHz allocation in the 5 GHz band
- Interworking with 2.5 and 3G systems

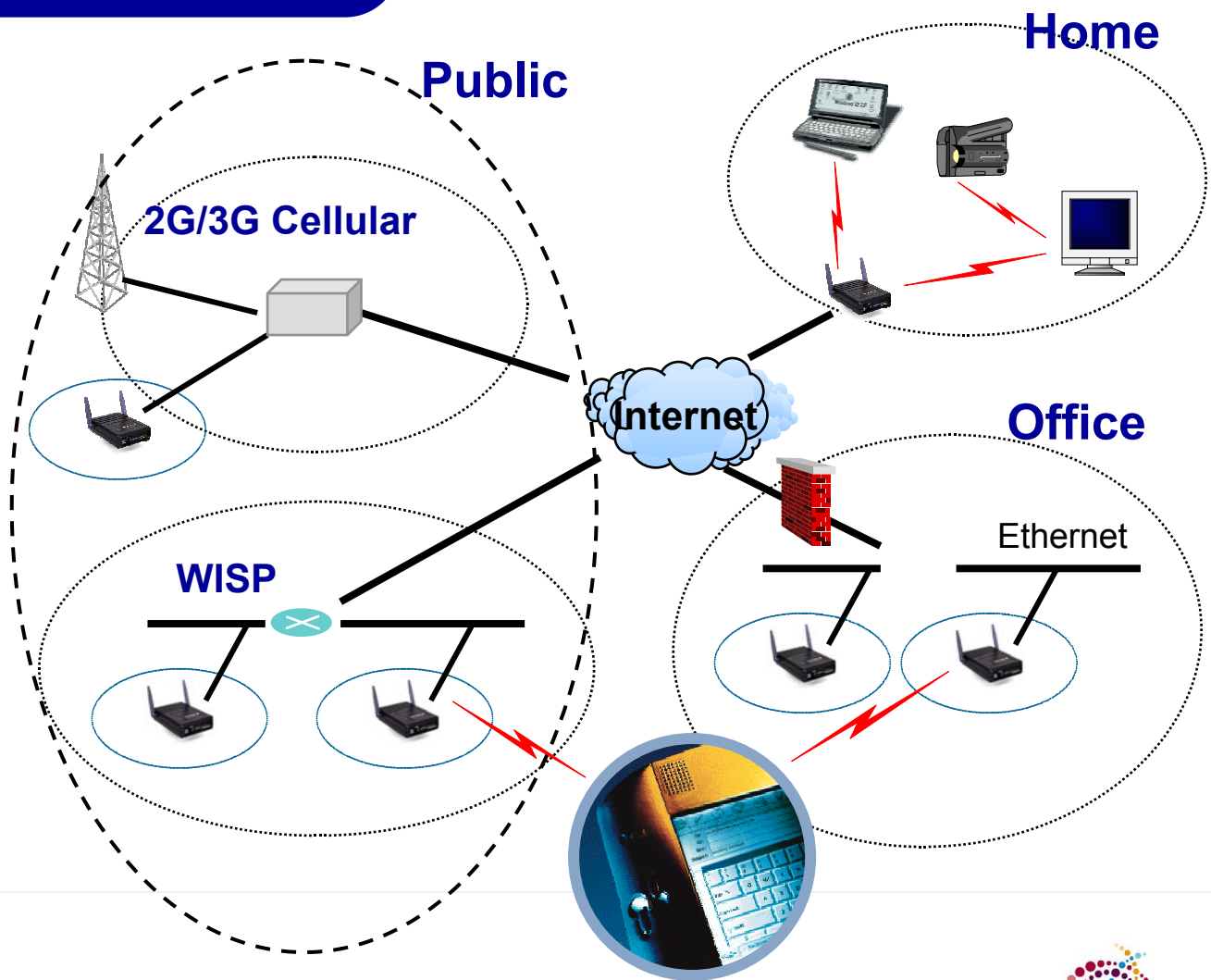
Relation to other wireless access systems



WLAN user environments

WLAN enables wireless access in many scenarios:

- Corporate/office
- Public/cellular
- Home networks



I. Wired vs wireless access

- Variability of the radio channel
- Limited spectrum resource
- Regulatory problems
  - Licensed: one single operator, interference management
  - Unlicensed: many operators, QoS-guarantees more difficult

- High spectral efficiency required, many bps/Hz
- Efficient radio resource management, medium access control (MAC)

WLAN vs cellular

- **Spectral efficiency (per cell)**
  - WLAN: >250 kbps/MHz/cell (HiperLAN2)
  - UMTS R4: 290 kbps/MHz/cell (mixed traffic)
  - EGPRS: 210 kbps/MHz/cell
- **Channel bandwidth**
  - WLAN: 20 MHz
  - GSM/GPRS: 200 kHz
  - UMTS: depends on data rate, 4 MHz spreading bandwidth
- **Range**
  - WLAN (5 GHz): 50 m indoors, up to 200 m outdoors
  - UMTS: 200 m - 10 km (or higher, depends on propagation conditions and load)
  - Standard GSM: max 37.5 km

WLAN vs cellular, cont'd

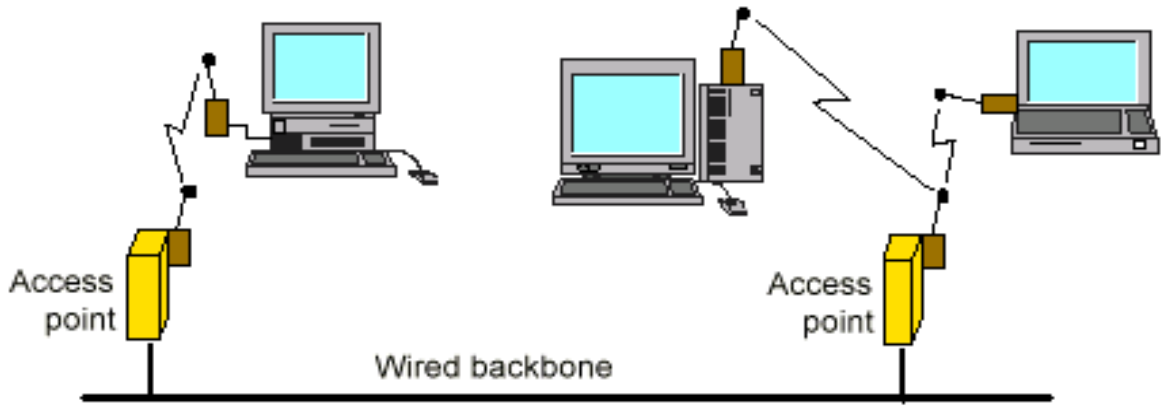
- **Data rates**
  - WLAN: up to 30 Mbps (user, Layer 3)
  - UMTS R4: 144-384 kbps (up to 2 Mbps)
  - EGPRS: up to 470 kbps
- **Mobility**
  - WLAN: "semi-mobile", walking speed
  - UMTS: 120 km/h assumed in the standardisation
- **Spectrum**
  - WLAN unlicensed: many co-existing operators
  - UMTS licensed

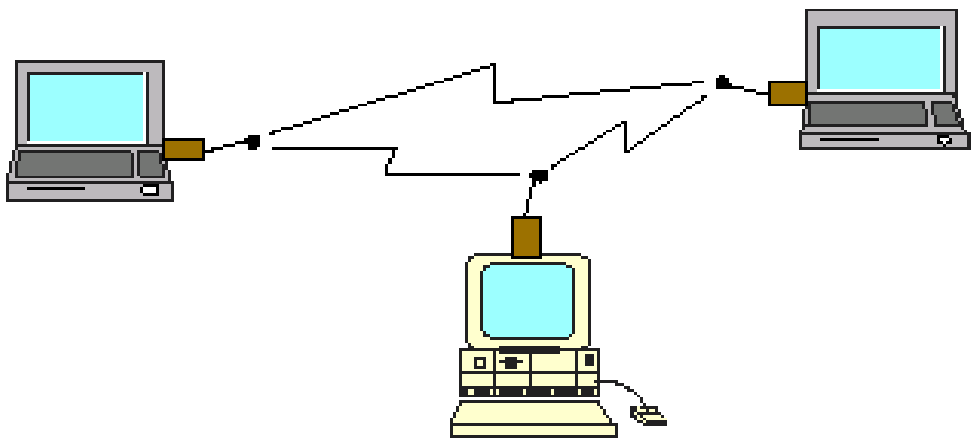
Hence…

- WLAN can improve the capacity of a wide-area cellular system in traffic hot spots
- WLAN is a complement rather than competing service
  - 3G provides range a medium data rates
  - WLAN high data rates locally
- private use, home

- 83 MHz at 2.4 GHz (unlicensed), maybe 455 MHz at 5 GHz (license exempt)
- IMT-2000: 2×60 MHz (licensed)

II. WLAN architecture: centralised vs ad-hoc





WLAN standards

- Types of standards
  - Interoperability: all devices compliant with the standard must be able to communicate
  - Co-existence: only rules for spectrum sharing, devices has to be from a certain vendor
- IEEE 802.11: ad-hoc and ”centralised functionality”
  - Wireless Ethernet
  - 802.11b in the 2.4 GHz band, 802.11a at 5 GHz
  - Many other extensions: d,e,f,g,h,i
- ETSI HiperLAN2: centralised and ”direct mode”
  - Infrastructure based
  - 5 GHz band
- Japanese version of HiperLAN2: ARIB HiSWANa

Multiple access: sharing the medium

- Many users access common radio resources
- TDMA, time division, time slot assigned to user (GSM)
- FDMA, frequency division, (frequency) channel assigned to user
- Spread spectrum: CDMA, code division, code assigned to user (UMTS)
- CSMA: Carrier Sense, sensing the medium

- The Medium Access Control (MAC) protocol determines who transmits and when

Introduction to the IEEE 802.11 standard: use of spread spectrum

- Frequency hopping (FHSS)
  - Fast hopping between frequencies according to a predefined pattern
  - Interference is ”avoided”
  - 802.11 FHSS (2.4 GHz) and Bluetooth
- Direct Sequence Spread Spectrum (DSSS)
  - Bandwidth expansion: the transmitted sequence multiplied by a faster sequence, normally 10-20 times ”spreading ratio”
  - Compare also DS Code Division Multiple Access when used for multiple access like in UMTS
- Regulatory requirement in the 2.4 GHz band

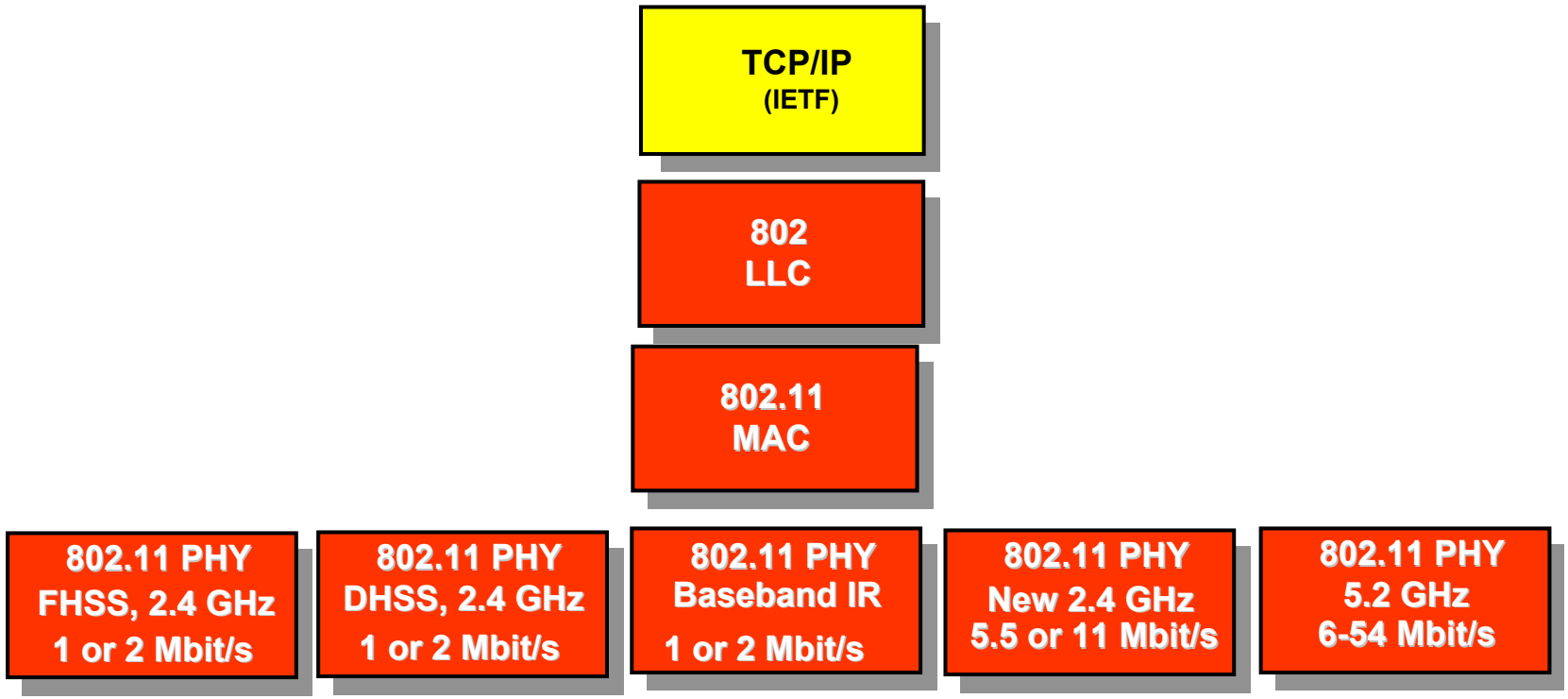
Original IEEE 802.11

- **Radio in 2.4 GHz ISM band** (2.400 - 2.483 GHz)
- Addresses interoperability
- Three PHY modes, all 1 and 2 Mbit/s
  - Frequency hopping (FHSS)
    - 79 channels à 1 MHz, >2.5 Hop/s, normally 50 hop/s
    - Modulation by 2GFPSK (4GFPSK): Gaussian filtered PSK
  - DSSS
    - 3 channels à 22 MHz, spreading by 11 Mbps sequence
    - Modulation by DBPSK (DQPSK): Differential PSK
  - IR
- Ad hoc architecture with possibilities for centralised access, MAC is contention protocol
- IEEE standard 1997, ISO/IEC standard 1998

Extending 802.11: TG b

- 802.11b: higher data rates in 2.4 GHz for DS
- 5.5 and 11 Mbit/s, backwards compatible with DSSS
- Complementary Code Keying (CCK): modulate 4(8) information bits onto 8 (of 11) chips, gives 5.5 (11) Mbps (PHY data rate)
- Requires higher SNIR than DSSS modes, gives smaller range but higher capacity
- Link adaptation, fall-back to more robust modes
- Spectral spreading still achieved

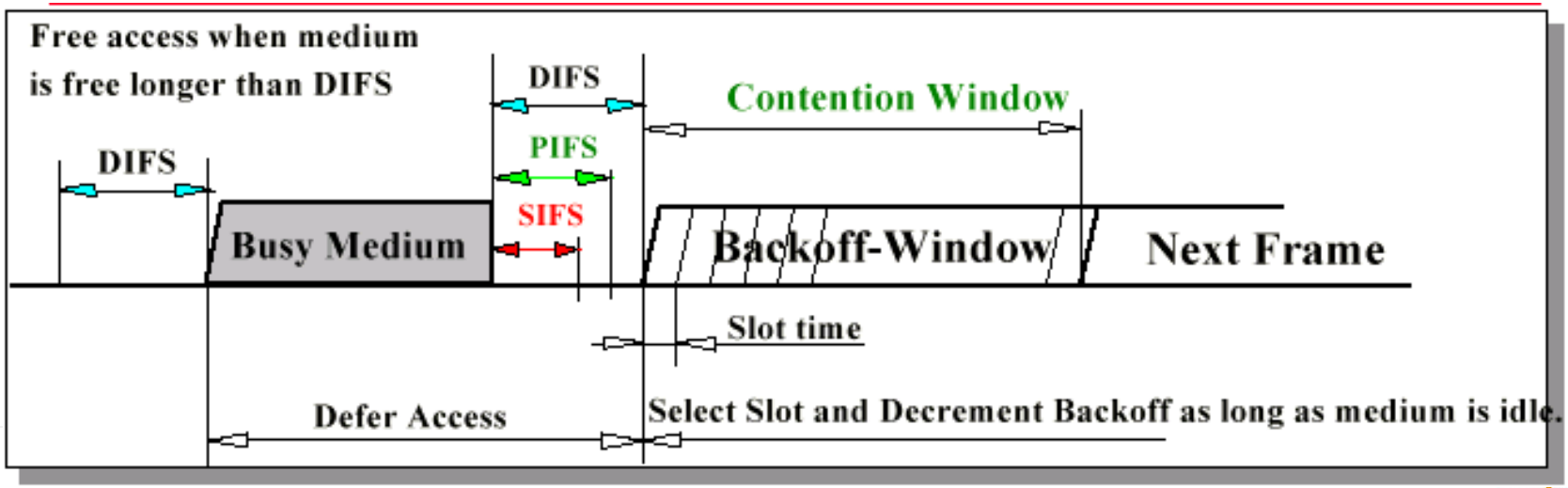
802.11 specifications



- Common MAC
- More PHY and MAC extensions currently being standardised

Basic MAC in IEEE 802.11

- CSMA/CA (CA = Collision Avoidance): Carrier Sense Multiple Access
- Non-real time via Distributed Coordination Function (DCF) and DCF InterFrame Space
- Real time via Point CF and PCF-IFS
- Control packets (ACK etc) via Short IFS



802.11 in the 5 GHz band: TG a

- 802.11a: higher data rates in 5 GHz band (UNII)
- Orthogonal Frequency Division Multiplexing (OFDM)
- Multi-carrier to combat intersymbol interference
- Frequency channel divided into orthogonal subcarriers
- 20 MHz bandwidth (16.7 MHz used)
- Link adaption from 6 - 54 Mbps
- Same PHY as ETSI HIPERLAN/2 and ARIB HiSWANa (Japan)

ETSI HIPERLAN Type 2

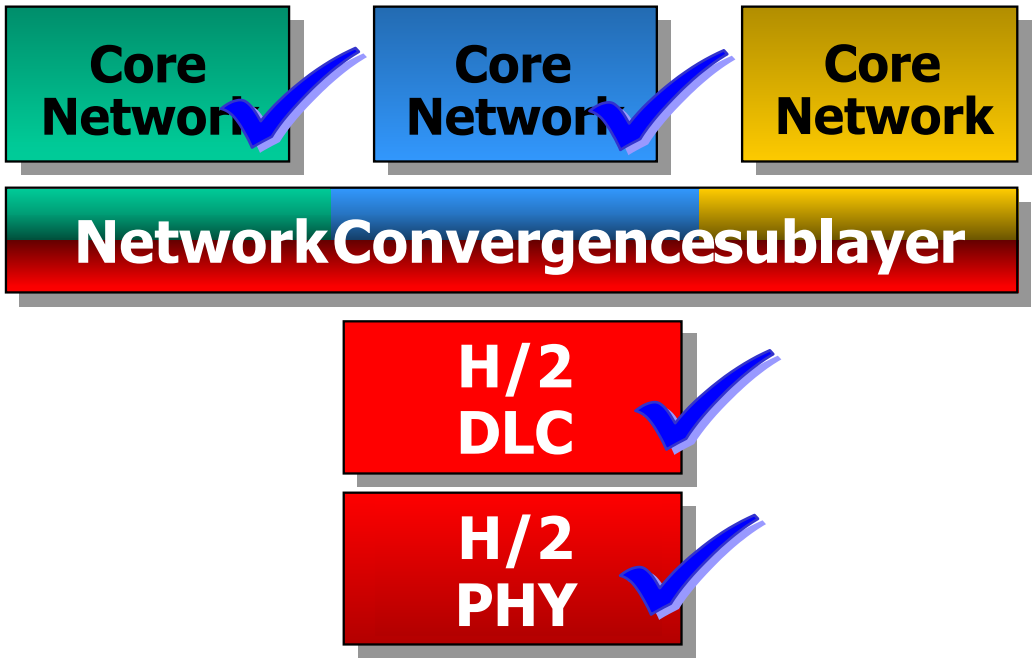
- HIgh PErformance Radio LAN
- Short range mobile system developed by ETSI BRAN (Broadband Radio Access Networks)
- Up to 54 Mbps PHY data rate, same as 802.11a
- Designed for high capacity and QoS guarantees
- Centralised architecture with ad hoc possibility
- Designed to interwork with different core networks, IP/Ethernet, ATM, GPRS/UMTS and IEEE 1394
- Designed for interoperability

HiperLAN2, cont'd

- Effective and simple power saving mechanisms
- Spectrum sharing with other systems due to
  - DFS (Dynamic Frequency Selection)
  - TPC (Transmit Power Control) and link adaptation
- Support for mobility and security
- Most specs approved now, major parts completed by end of 2000, demo by Panasonic at CeBIT 2002

- IEEE 802.11 TG e (QoS), TG h (DFS & TPC), TG i (security), and more extensions…

HiperLAN2 basic protocol stack



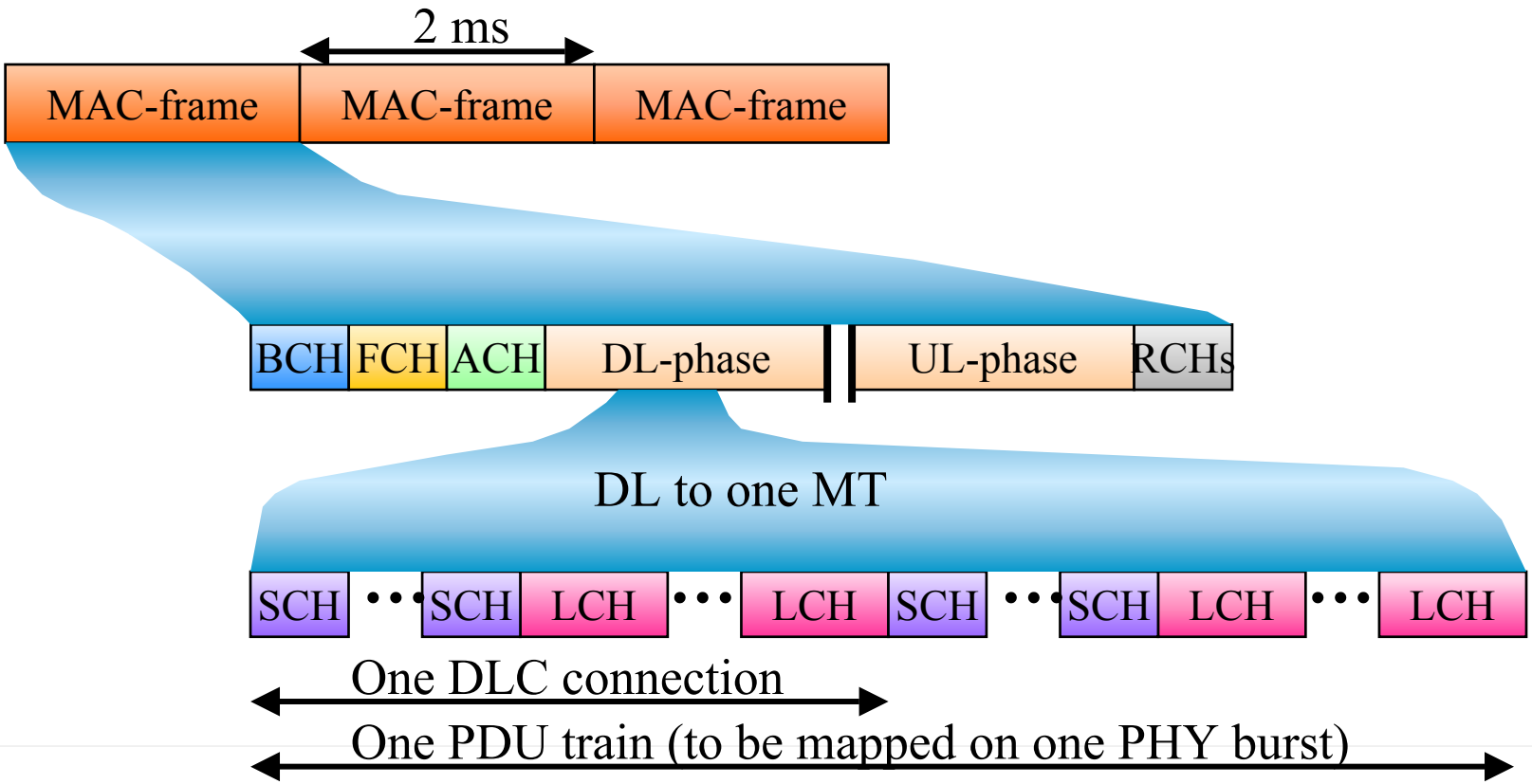
Core Networks:

- Ethernet / IP / PPP
- ATM
- UMTS
- IEEE 1394
- …

- CL: mapping between higher layer and DLC connections
- DLC: error control (ARQ), radio link control (RLC)
- PHY: modulation, synchronisation and RF

HiperLAN2 MAC: frame structure

- Load adaptive TDMA/TDD (Time Division Duplex)

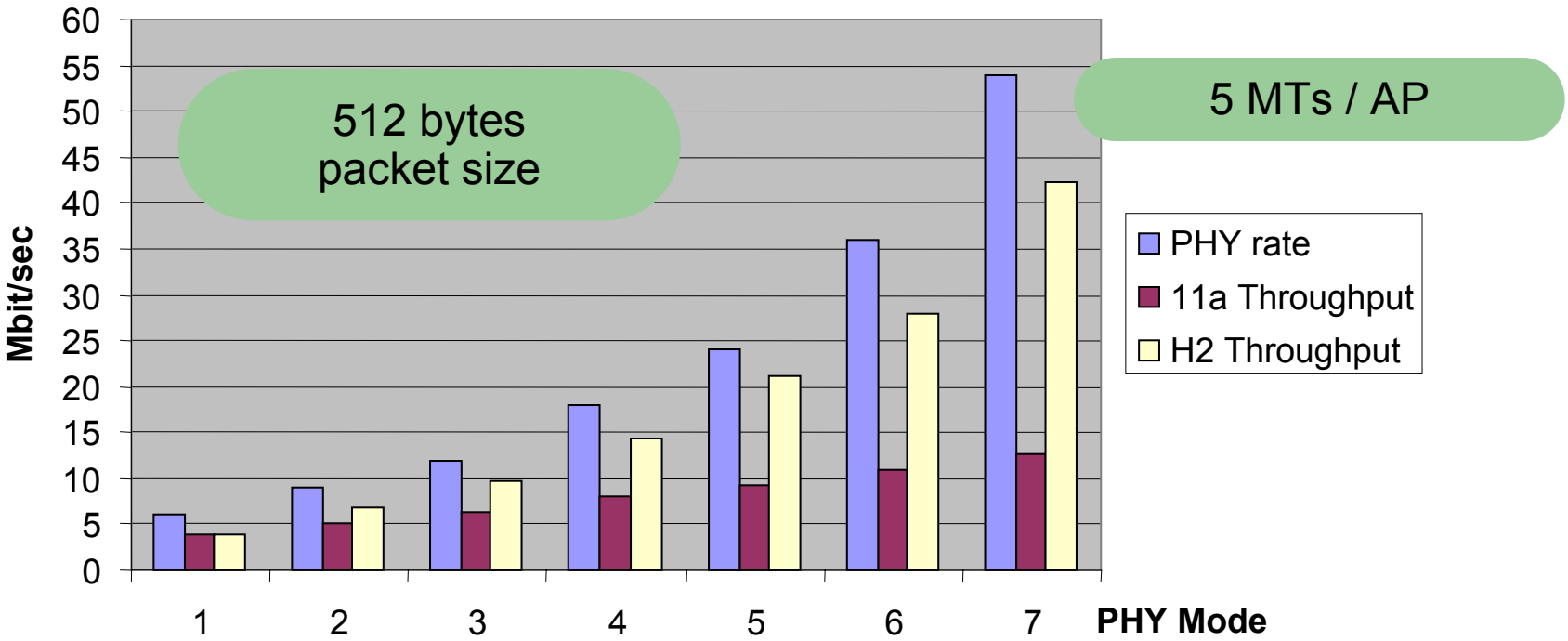


SCH 9 bytes control, LCH 54 bytes user data

Comparing IEEE 802.11a with HiperLAN2

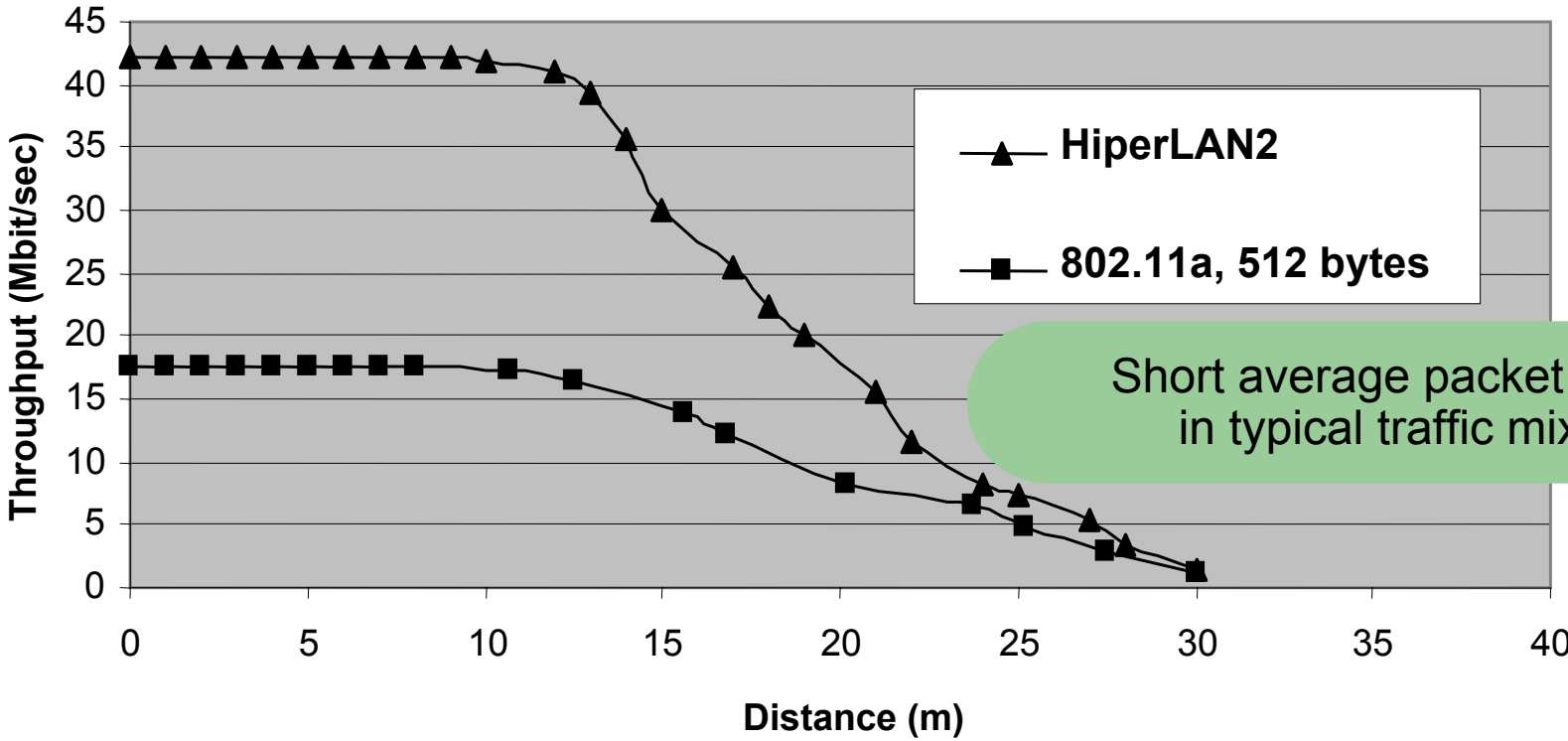
- IEEE 802.11a: wireless Ethernet
- HiperLAN2: based on a cellular concept
- Same PHY
  - 5 GHz OFDM with 20 MHz wide channels
  - 6/9/12/18/27/36/54 Mbps DLC user data per transceiver
  - BPSK/QPSK/16QAM/(64QAM) subcarrier modulation
  - Convolutional coding, block interleaving
- MAC completely different

MAC efficiency – throughput for 5 GHz WLAN



HiperLAN2 throughput independent on PHY mode: 77%
.11a throughput decreases with packet size and higher PHY mode

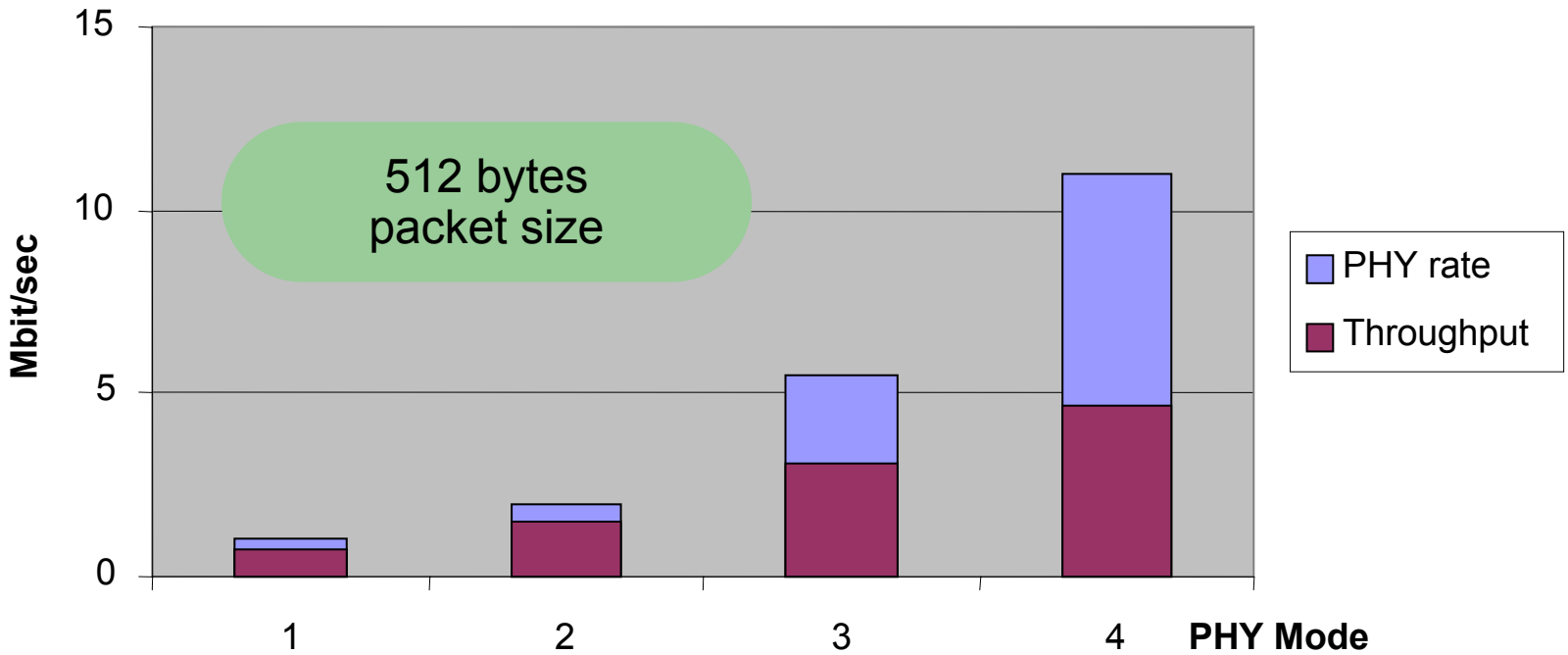
Range and throughput for 5 GHz WLAN



Short average packet size in typical traffic mix!

- HiperLAN2 has superior throughput over 802.11a

MAC efficiency – throughput for 802.11b (2.4 GHz)



No ‘AP control’ with Carrier Sense Multiple Access/Collision Avoidance
IEEE 802.11 MAC only efficient with low PHY rates and few MTs/AP

- Same MAC as 802.11a, but different PHY

III. WLAN spectrum

- 2.4 GHz (IEEE 802.11b): 83 MHz
  - 2.400-2.483 GHz ISM band (Industrial Scientific and Medical)
  - Spectral spreading required if output power > 1 mW (to facilitate sharing of the band); FHSS and DSSS provide this!
  - 1 MHz channel size (4/5 MHz also allowed), max 100 mW EIRP
  - Co-existence: sharing with (many) Bluetooth devices may become a problem (unlicensed band)
  - Lower throughput for 802.11b (and Bluetooth)
- 2.4 GHz band may become a ”trash band”
- Up to 455 MHz available in the 5 GHz band, but the (global) spectrum situation is unclear at the moment

5 GHz WLAN spectrum: regulations and restrictions

- Europe (by CEPT)
  - 5.15-5.35 GHz (8 ch.): 200 mW EIRP, indoor operation
  - 5.47-5.725 GHz (11 ch.): 1 W EIRP (23 dBm for one channel), outdoor (and indoor)
  - HIPERLAN only, DFS spread over 14 channels, TPC
- US (by FCC): the UNII bands
  - 5.15-5.25 GHz (4 ch.): 200 mW EIRP, indoor
  - 5.25-5.35 GHz (4 ch.): 1 W EIRP, outdoor
  - 5.725-5.825 GHz (4 ch., ISM): 4 W EIRP, outdoor
- Japan
  - 5.15-5.25 GHz (4 ch.): 200 mW (100 mW) EIRP
  - Carrier sense every 4 ms (impact on HiSWANa)

Current 5 GHz spectrum issues

- Europe advocates CEPT rules globally (ITU-R), ”co-primary” with other services in the band
- US (FCC): keep WLAN secondary, operation on ”non-interference basis”
- Sharing with radar (above 5.25 GHz) most problematic for global allocation DFS required, but functionality not specified

  Outdoor use may not be allowed!
- HiperLAN2 supports DFS and TPC (reduces interference)

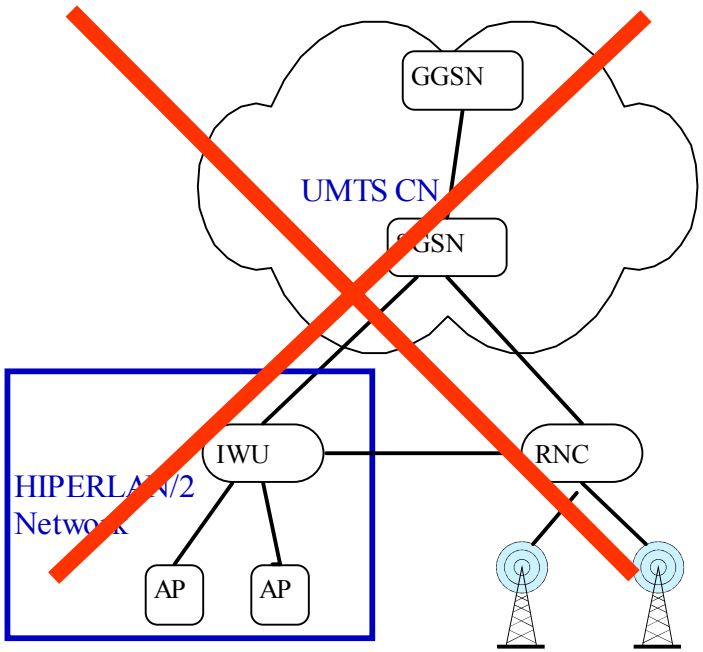
- Goal : global harmonised band at WRC-03, **DFS is the key**

IV. Beyond 3G: co-operating networks

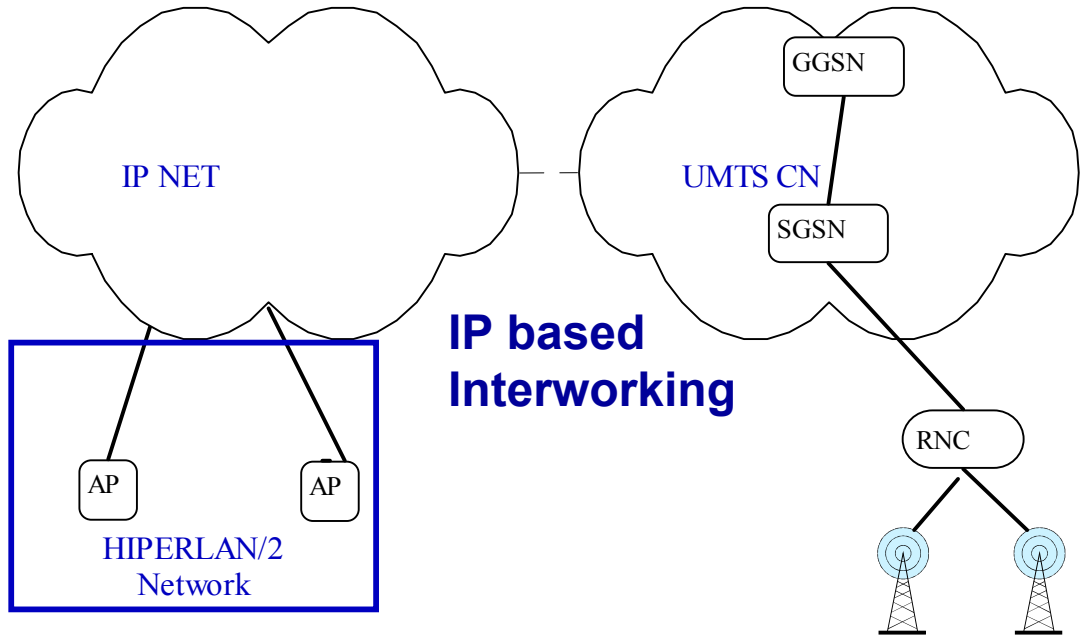
- Multi-access through interworking
  - (E)GPRS/UMTS wide-area coverage, HIPERLAN/2 in traffic hot spots
- Session continuity
- Interworking work item in ETSI BRAN
  - Specify the architectures and protocols of a HIPERLAN/2 network that interworks with 3G networks and also other types of networks. The work will include both the radio access part and the fixed part of the network
- Influence on 3GPP and IETF
- Work item in 3GPP

Interworking with 2.5 and 3G

Tight Interworking



Loose Interworking



V. Closing remarks

- WLAN: >20 Mbps in hot-spots, office and home
- IEEE 802.11b at 2.4 GHz
- IEEE 802.11a at 5 GHz for higher data rates
- ETSI HiperLAN2 (5 GHz) better than IEEE 802.11a, but weaker ”market support”
  - 802.11b ”sufficient” the next few years
- 455 MHz 5 GHz global harmonised band may be allocated to WLAN at WRC-03
- WLAN not a competotor to 3G… higher data rates but smaller range

WLAN Activities within Telia

- Telia Mobile is established as one of the most influential operator within the WLAN business
- Telia HomeRun, public access based on IEEE 802.11b
- Telia Research had a large influence on HiperLAN2
  - Contributions to Architecture, PHY, DLC, Ethernet CL and spectrum groups
- Telia is active in the HiperLAN2 Global Forum
  - The only operator among the founding members
- Contributed to the first steps of standardising interworking between WLANs and cellular systems
  - ETSI Technical specification on HiperLAN2-3G interworking
  - Feasibility study of WLAN-3G interworking in 3GPP