Wireless LAN Coexistence and Interworking

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PHILIPS

Overview

- **Wireless LANs, Home Networking and QoS Requirements**
- **Europe: ETSI BRAN HiperLAN/2**
  - Protocol Overview
  - Home Networking with HiperLAN/2
- **USA: IEEE 802.11(a/e/h)**
  - Protocol Overview
  - DFS and TPC: Task Group h
  - QoS Enhancements: Task Group e
  - Comparison with HiperLAN/2
- **Convergence Activities: 5G Study Group (5GHzPP)**
  - Coexistence / Interworking / Unified Standard
- **The 5GHz Band: U-NII and License Exempt, Spectrum Negotiation and Fairness**
- **Conclusions and Outlook**

Outline

- **Wireless LANs, Home Networking and QoS Requirements**
- Europe: ETSI BRAN HiperLAN/2
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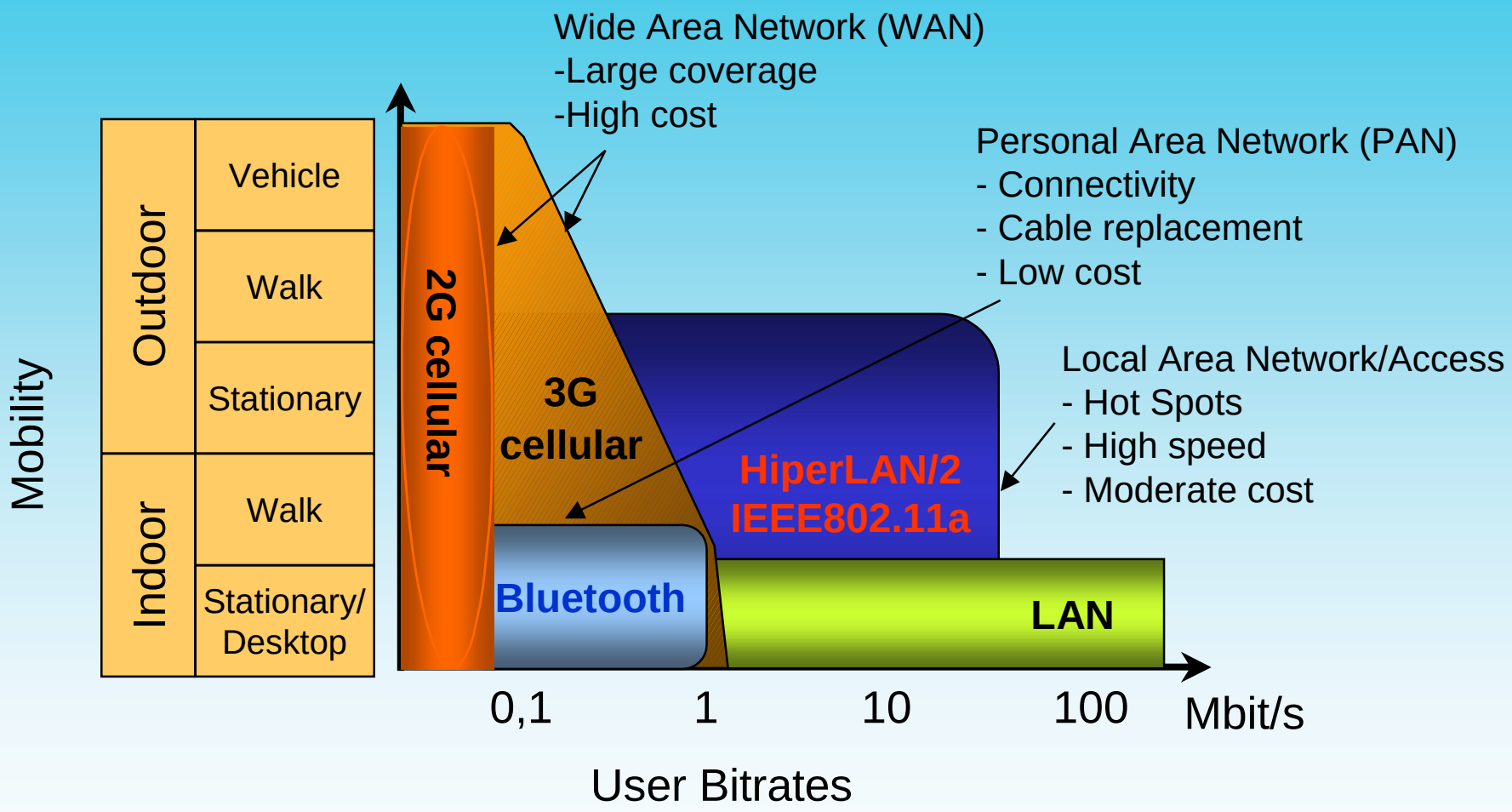
Wireless Communications Map

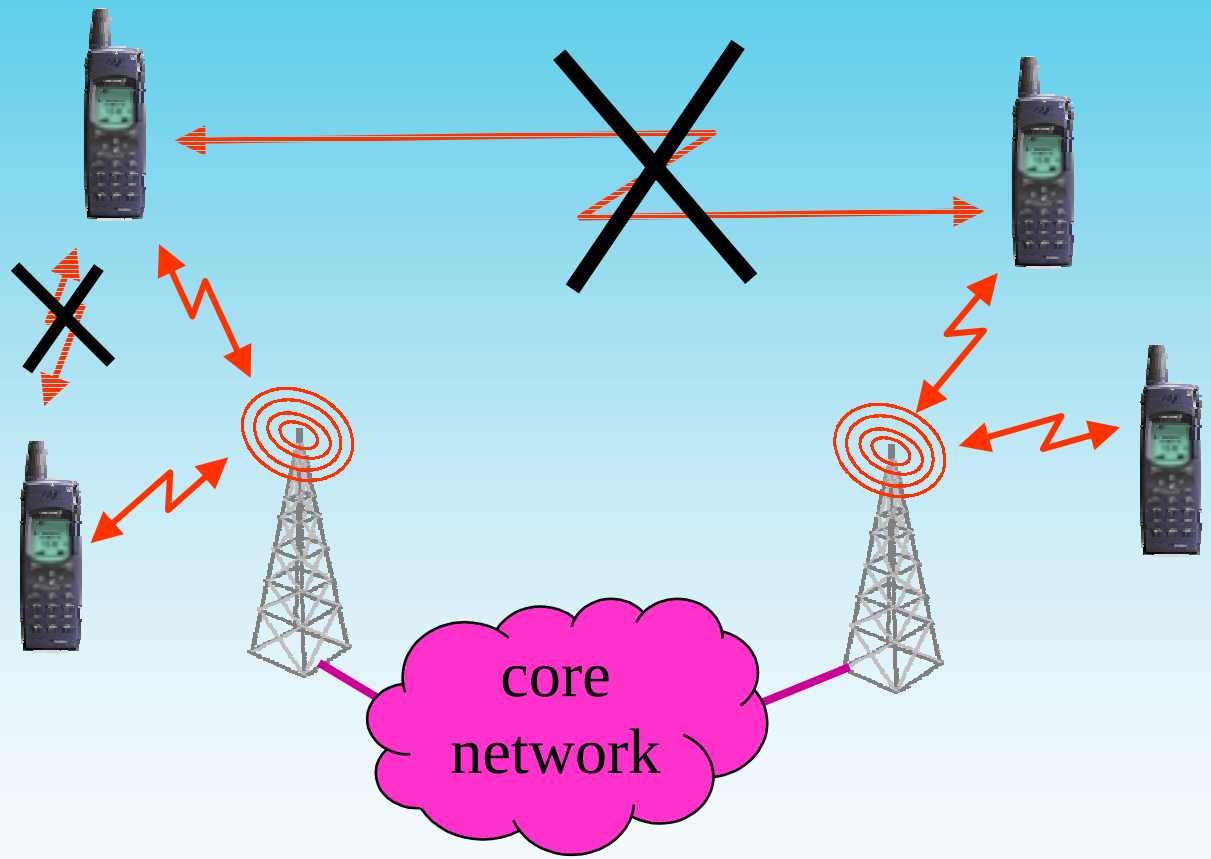
Type	Coverage	Data rate	Topology	Examples
Mobile	global	9.6kb/s ... 2Mb/s	Fixed AP-Infrastructur	GPRS, UMTS
FWA	1 ... 5km	155Mb/s	Fixed AP-Infrastructur	Hiperaccess, Hiperlink
Cord-less	100m ... 3km	600kb/s	Fixed AP-Infrastructur	DPRS
W-LAN	100m ... 200m	11Mb/s .. 54Mb/s	AP-oriented or Ad-hoc	802.11a/e/g, HiperLAN/2, MMAC
PAN	10m	1Mb/s ... 2Mb/s	Ad-hoc	Bluetooth
BAN	2-5 m	200kb/s ... 1Mb/s	Ad-hoc	Bluetooth

Wireless “Data” Solutions

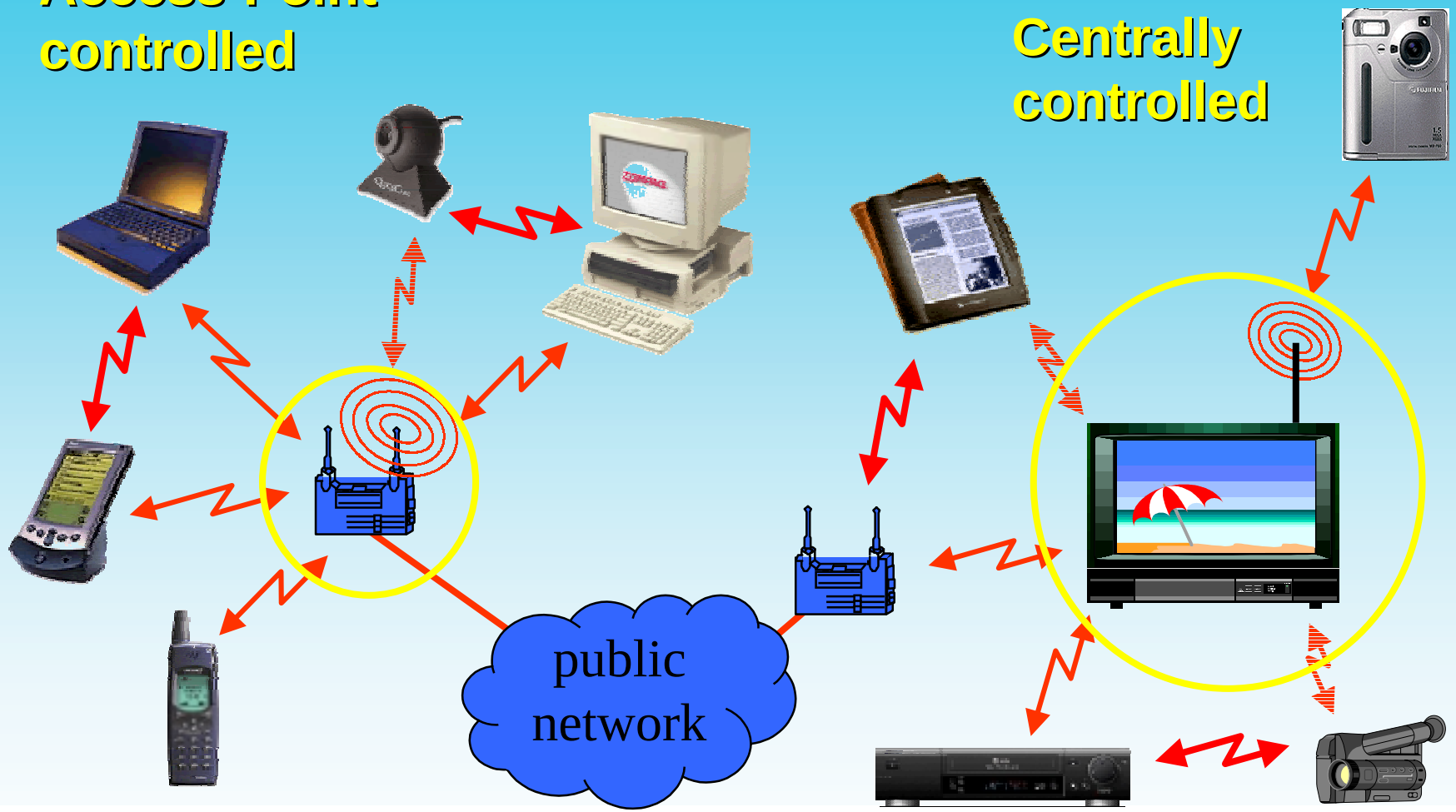


Networking Paradigms (1)

Infrastructure-based

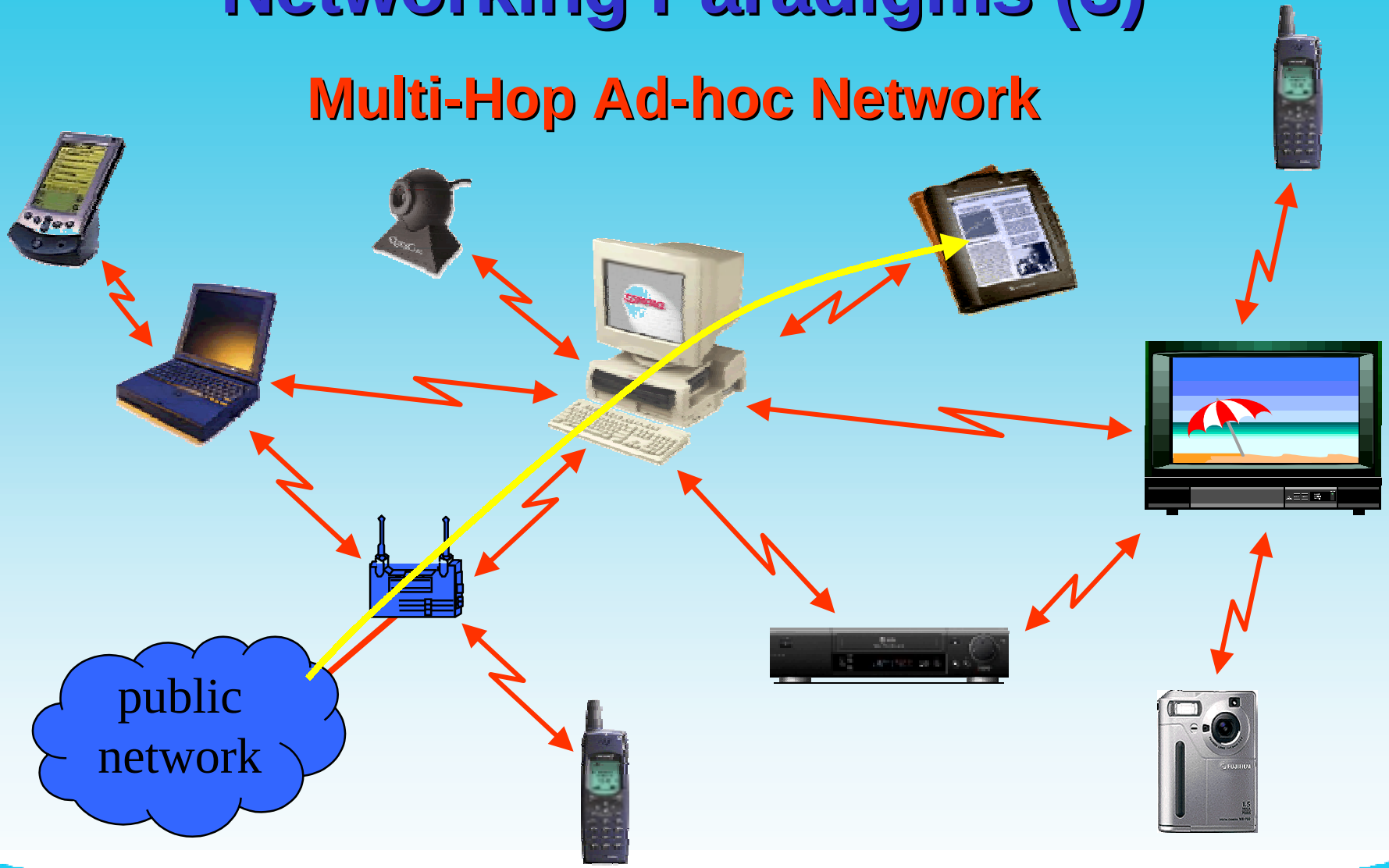


Networking Paradigms (2)



Networking Paradigms (3)

Multi-Hop Ad-hoc Network



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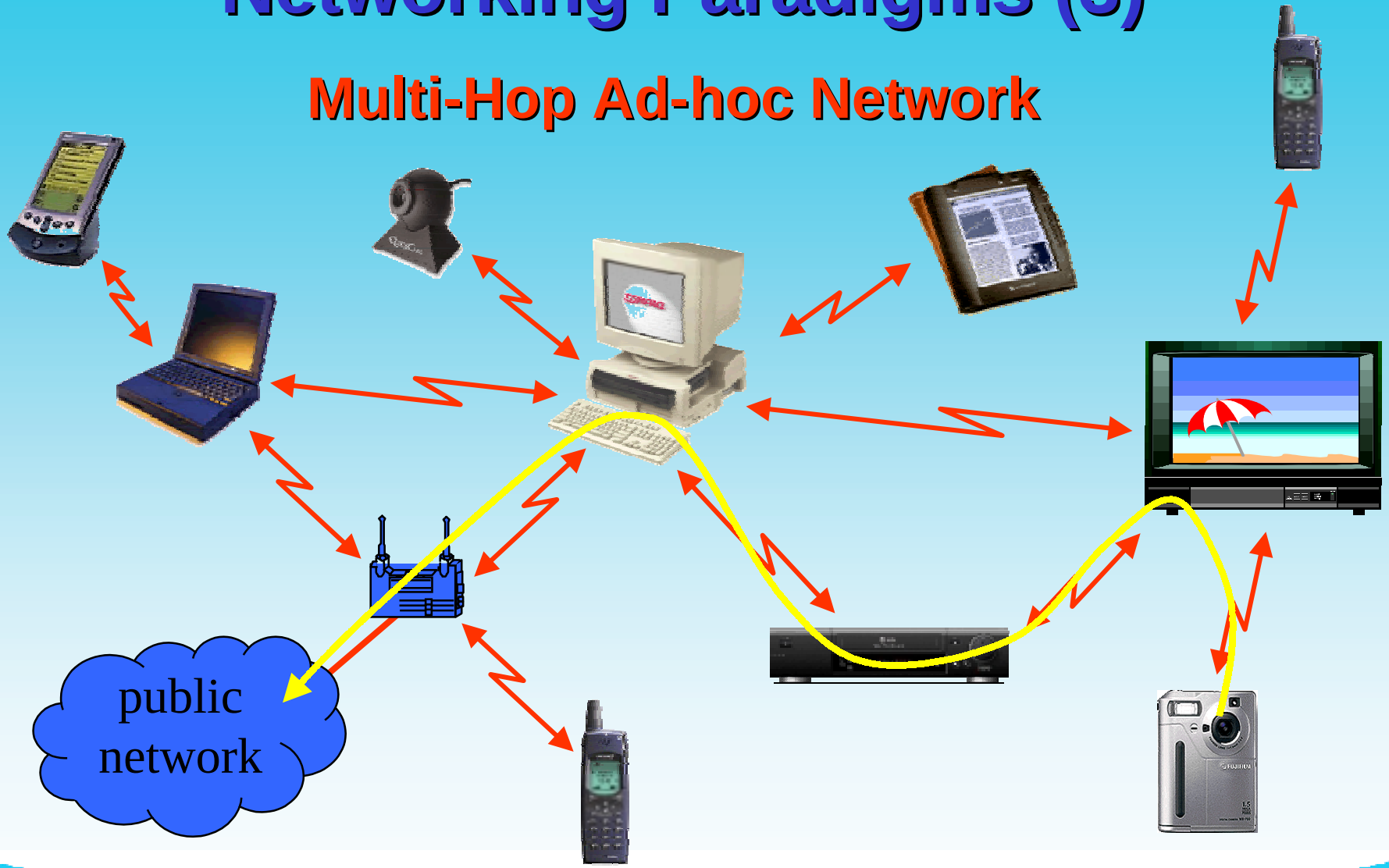

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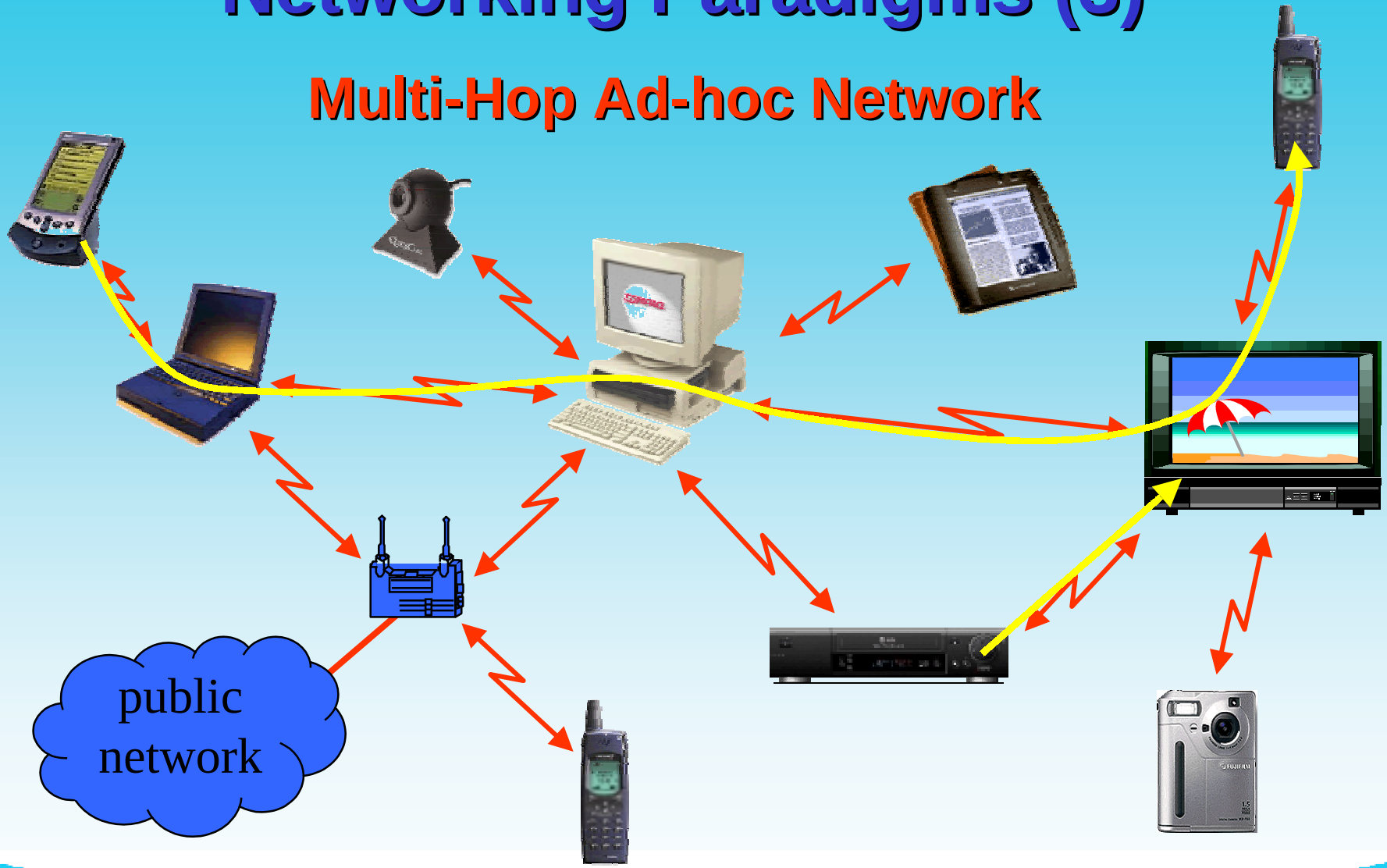

Home Networking Requirements

- **Ease of use (user convenience)**
  - plug'n'play, no user administration
  - ubiquity
  - infrastructure-less
- **Support of isochronous (A/V) and asynchronous traffic**
- **Quality-of-Service provision**
  - Bandwidth negotiation
  - Flexible handover mechanisms
  - Error correction capability
- **Low cost**

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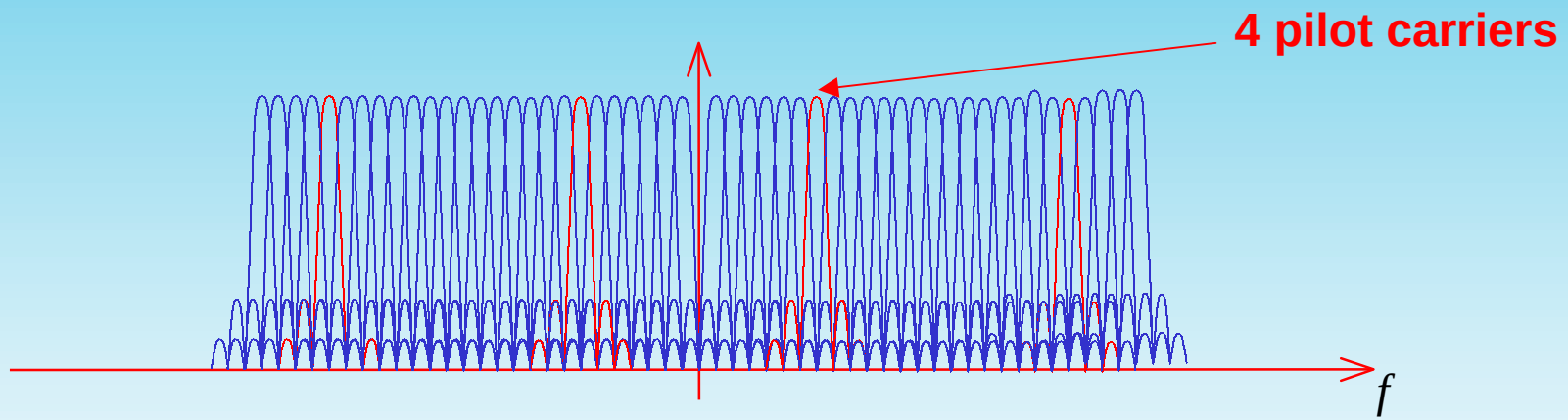
HiperLAN/2 Characteristics (1/2)

- **Single-Hop ad-hoc network**
- **Modulation technique: OFDM**
  - 48 out of 64 carriers used, 20 MHz channel grid

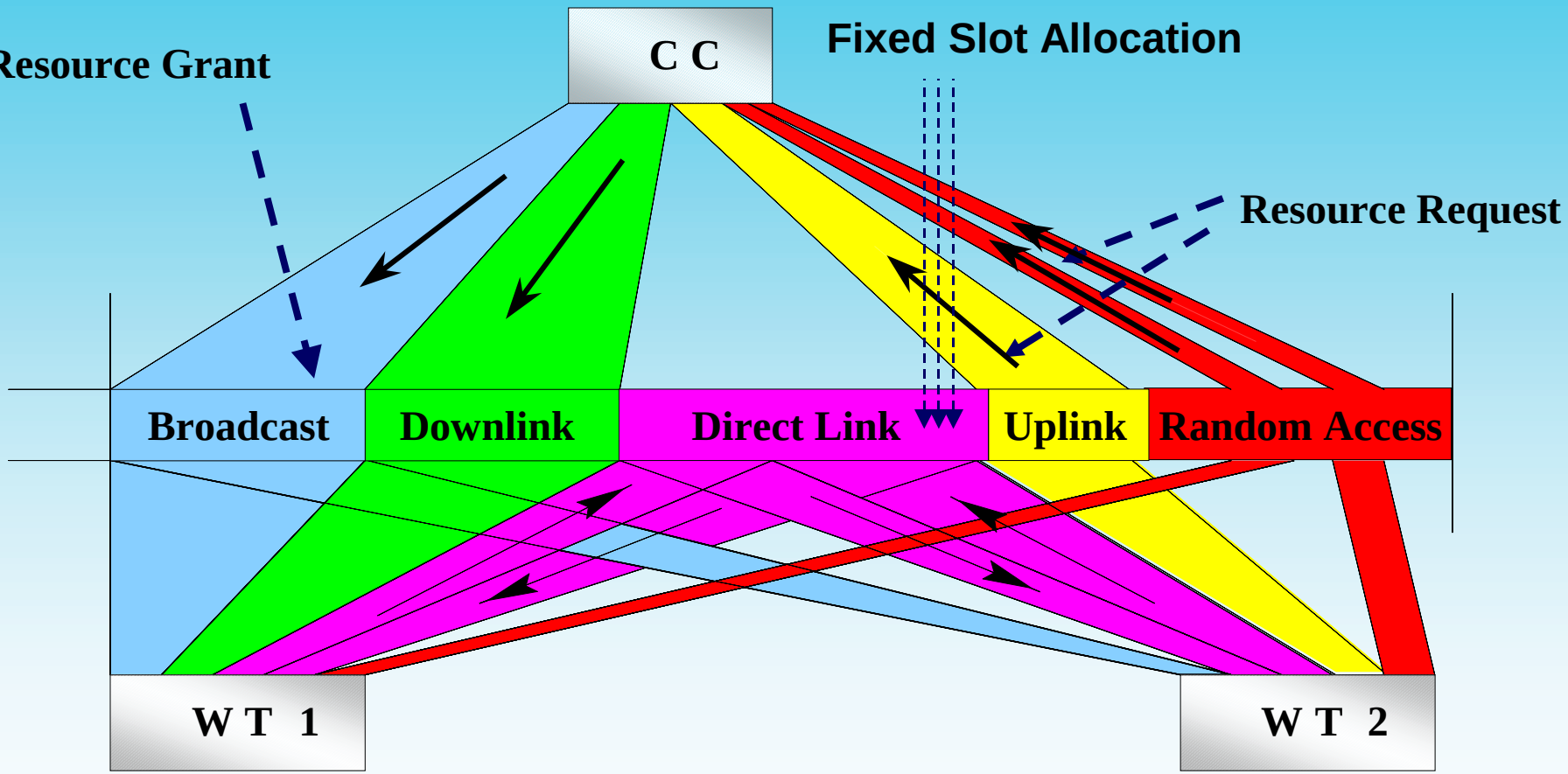


- **Flexible PHY mode selection**
  - BPSK, QPSK, QAM16 and QAM64
  - gross data rate from 6 to 54 Mbit/s

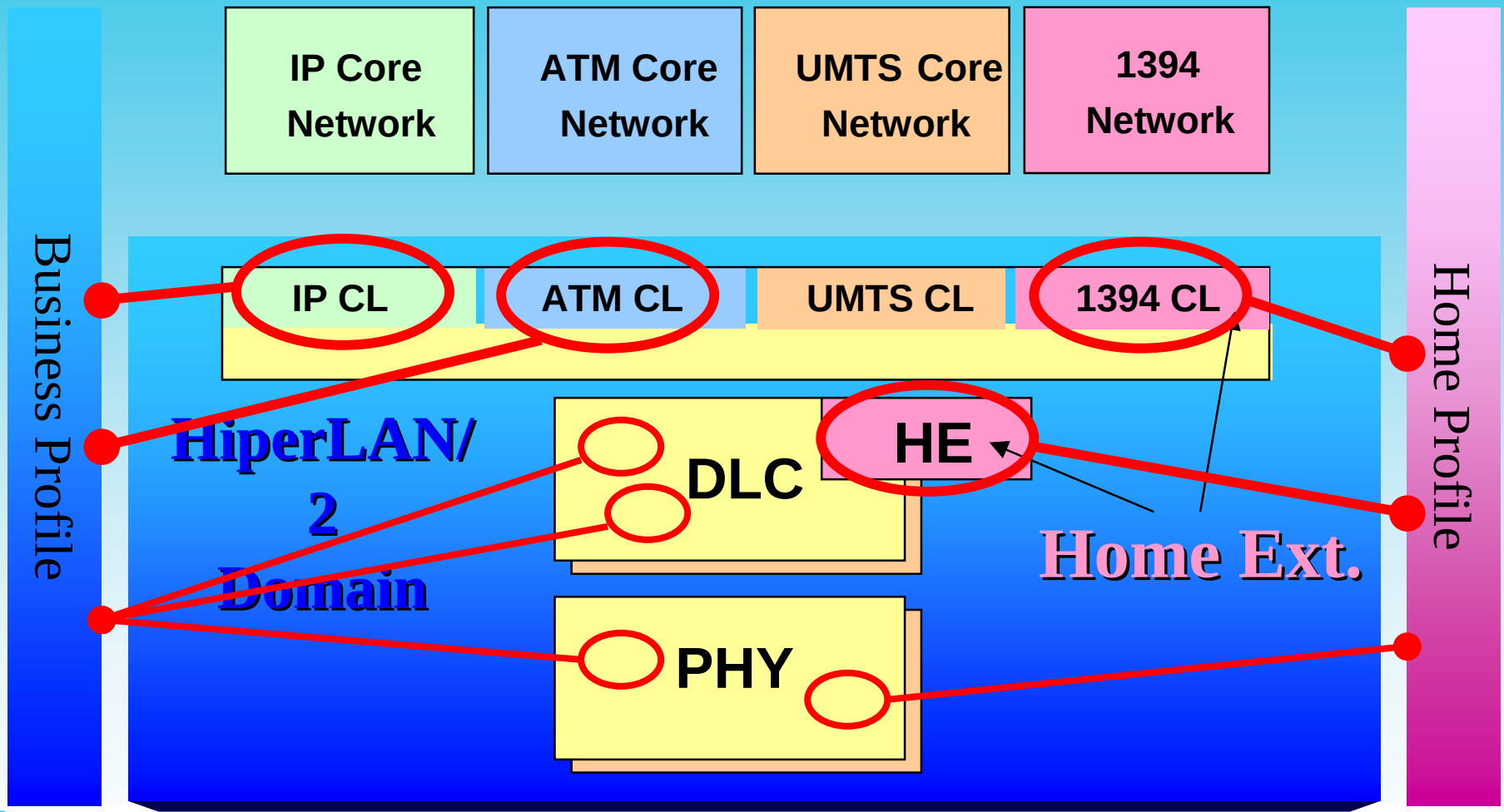
HiperLAN/2 Characteristics (2/2)

- **Time-Division Multiple-Access (TDMA) scheme**
  - Broadcast, up-link-, down-link and direct-link channels
  - Long and short channels (data and control)
  - Time-Division Duplex mode
- **Flexible error correction scheme**
  - PHY: convolutional FEC with adjustable code rate and ARQ
  - DLC: additional RS-based FEC scheme
- **Dynamic frequency selection**
- **Transmit power control**
- **Advanced power management**

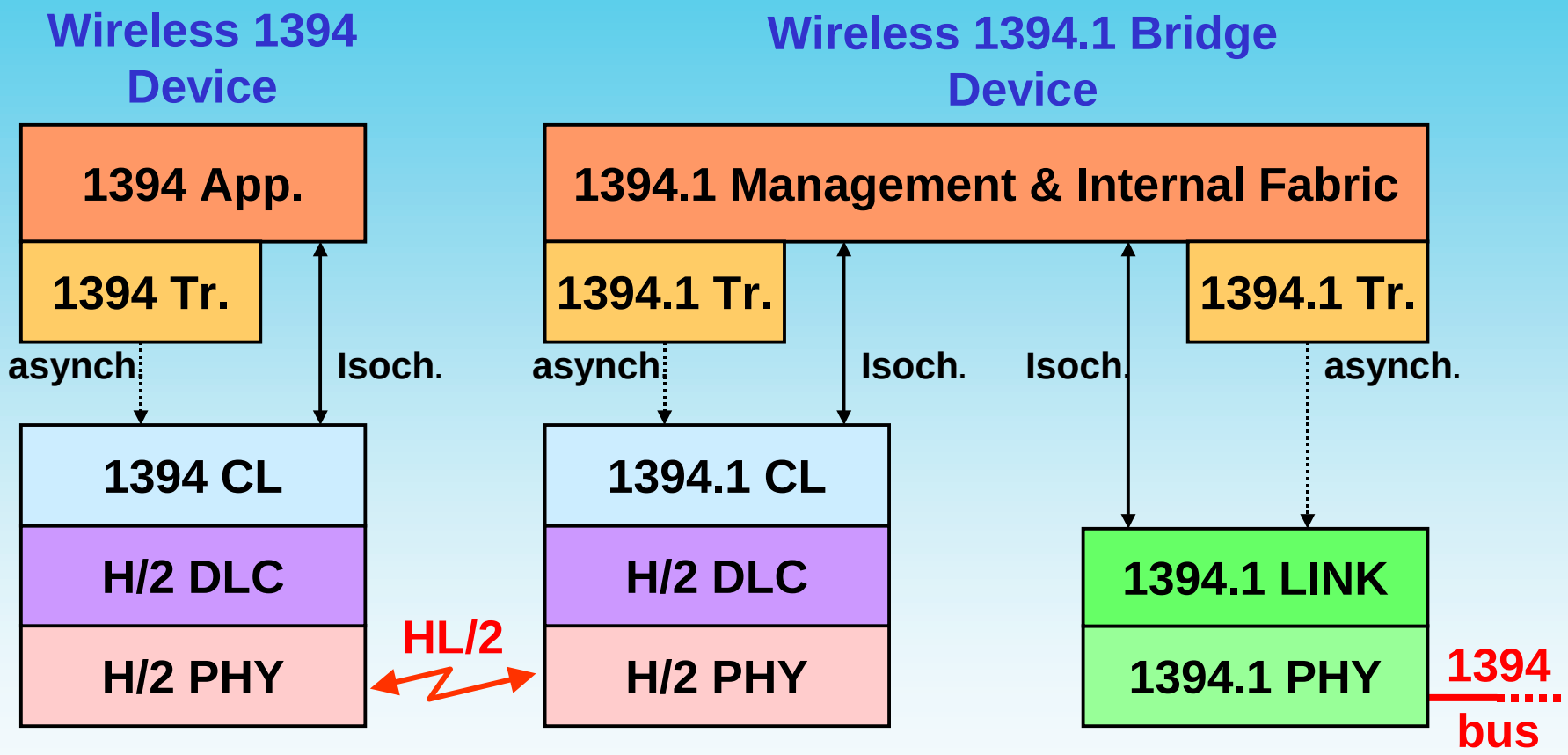
HiperLAN/2 Communication Frame incl. Home Extension features



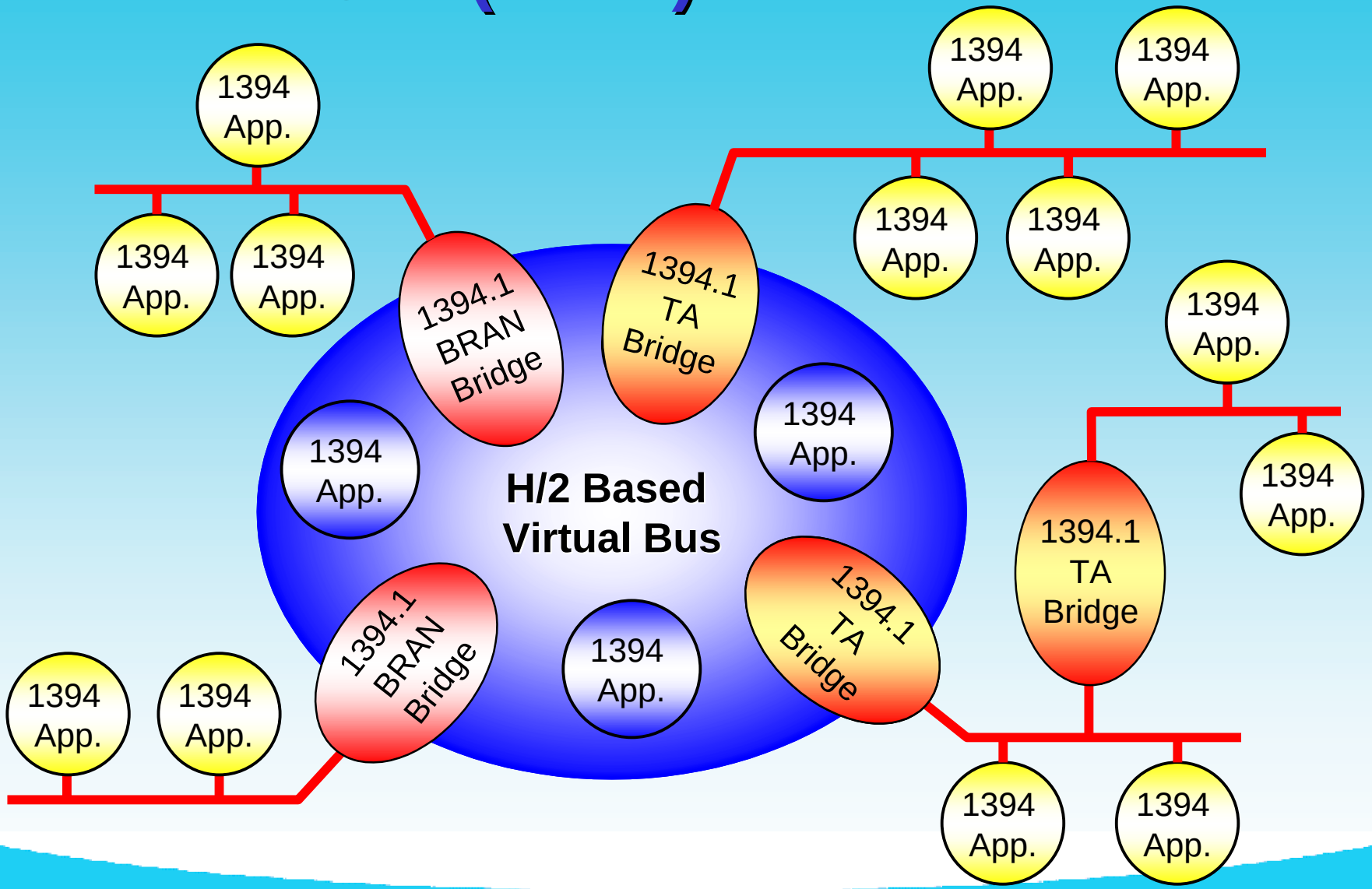
HiperLAN/2 Layer Architecture



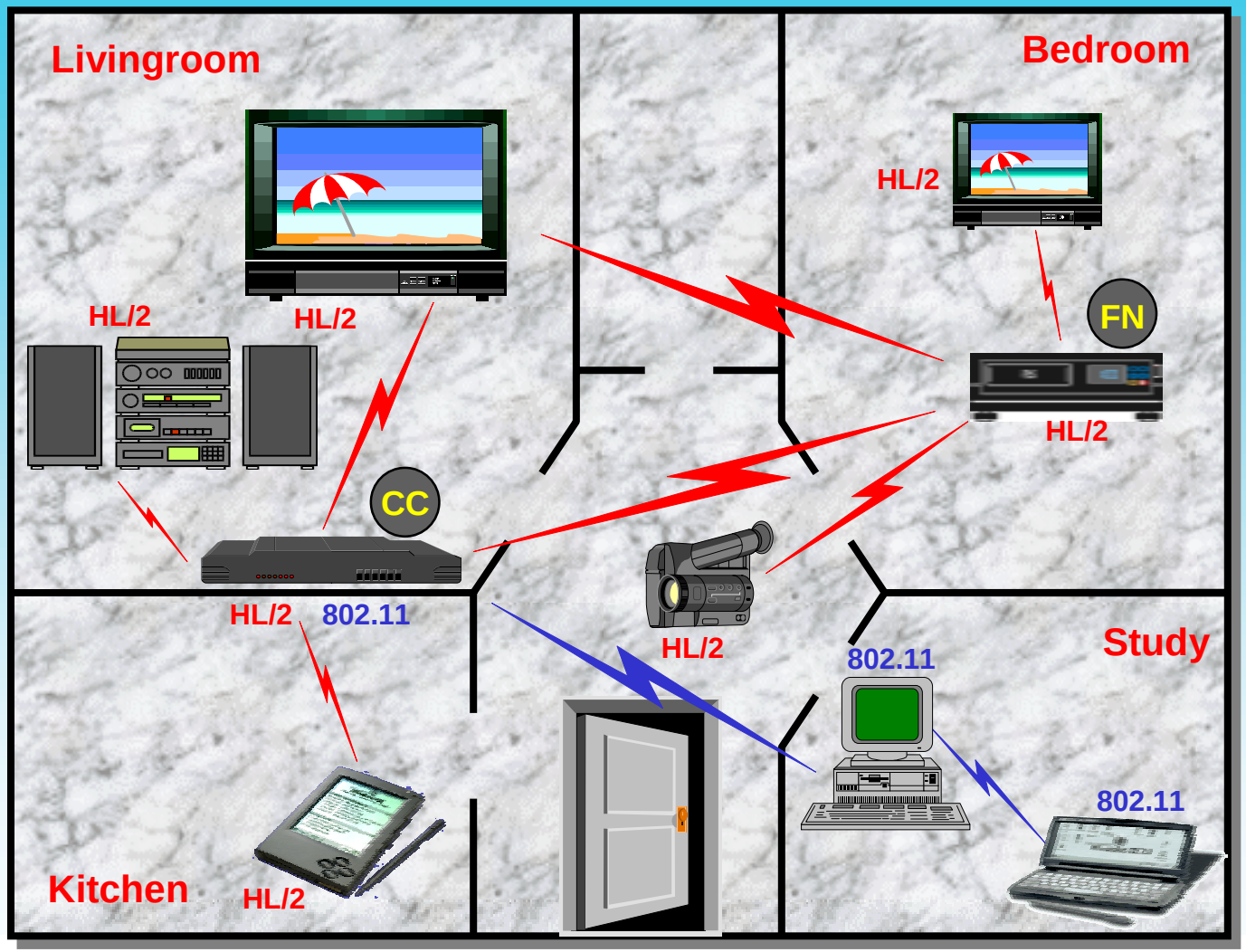
HiperLAN/2-based Wireless-1394 Architecture



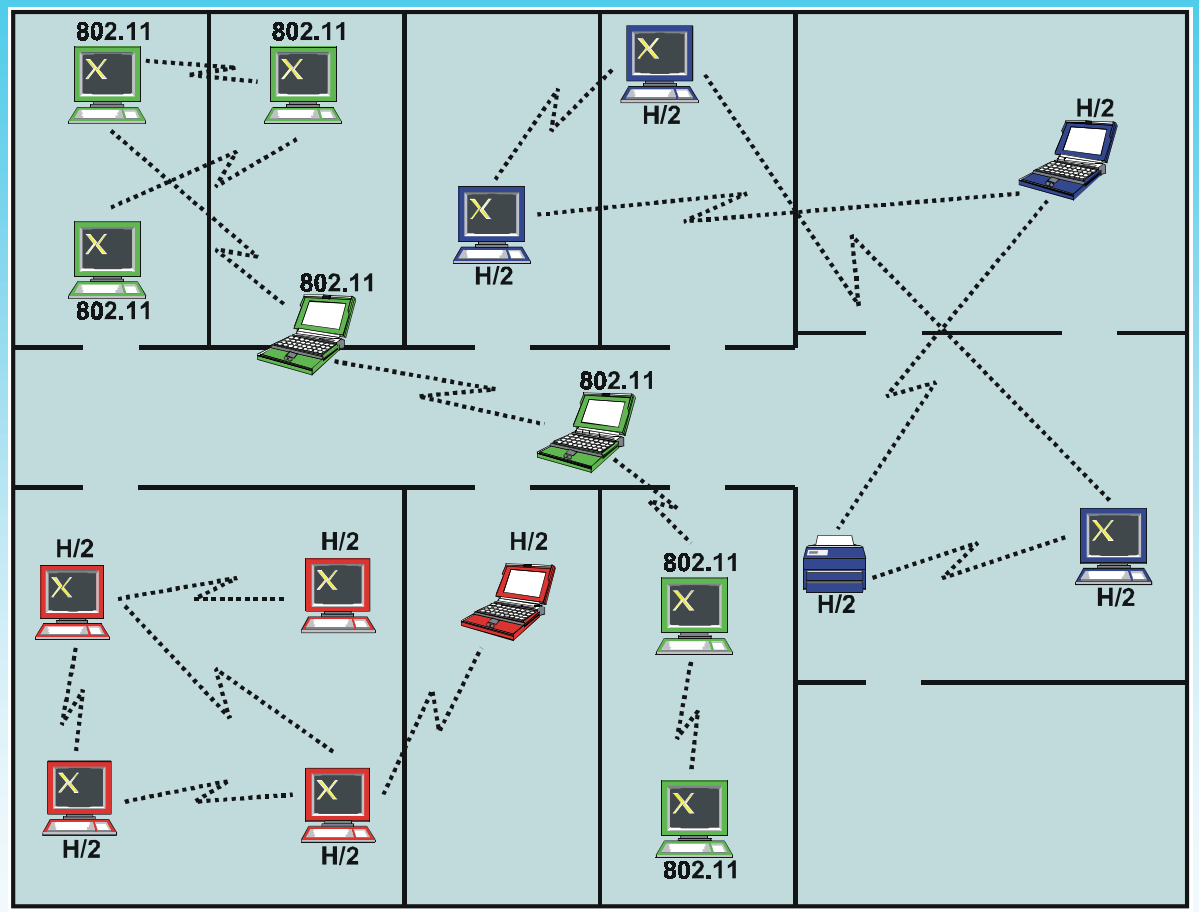
W-IEEE1394 (Leaf-) Bus Architecture

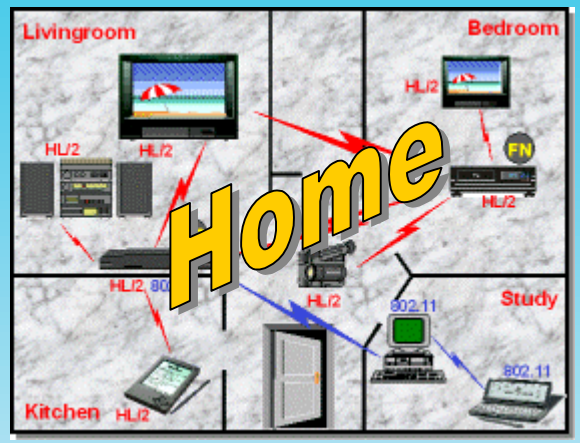


The Wirelessly Networked Home

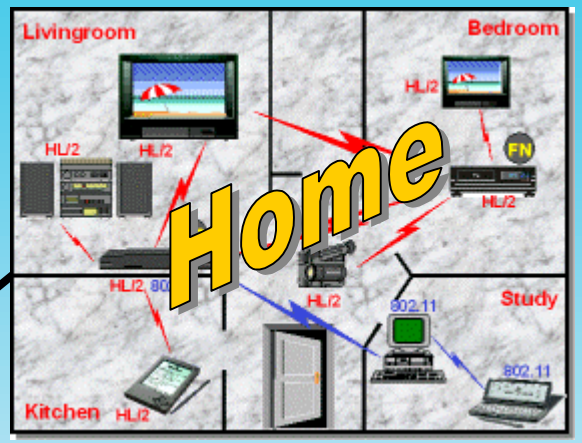


Office empowered by Wireless LAN

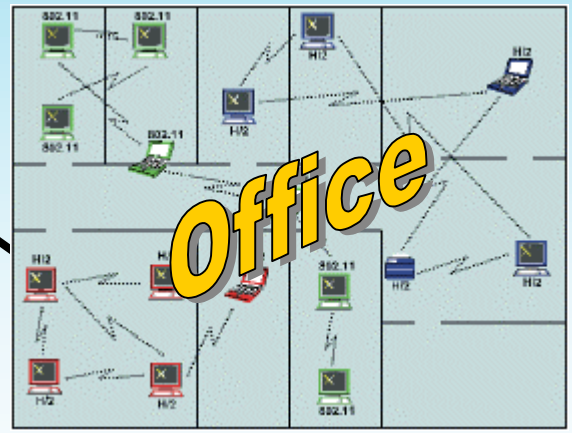




HiperLAN/2 - Ubiquitous Wireless Access



Internet



HiperLAN/2 vs. HN-Requirements

- **Ease of use (user convenience)**
  - ✔ Auto-configuration built-in
  - ✔ Advanced power management (e.g. absence mode)
- **Support of isochronous (A/V) and asynchronous traffic**
  - ✔ Fixed slot assignment, fixed capacity agreement
- **Quality-of-Service provision**
  - ✔ Time-division multiple-access scheme
  - ✔ Scheduled bandwidth assignment
- **Low cost**
  - ✔ Scheduling avoids excessive buffering requirements

HiperLAN/2 – Status & Next Steps

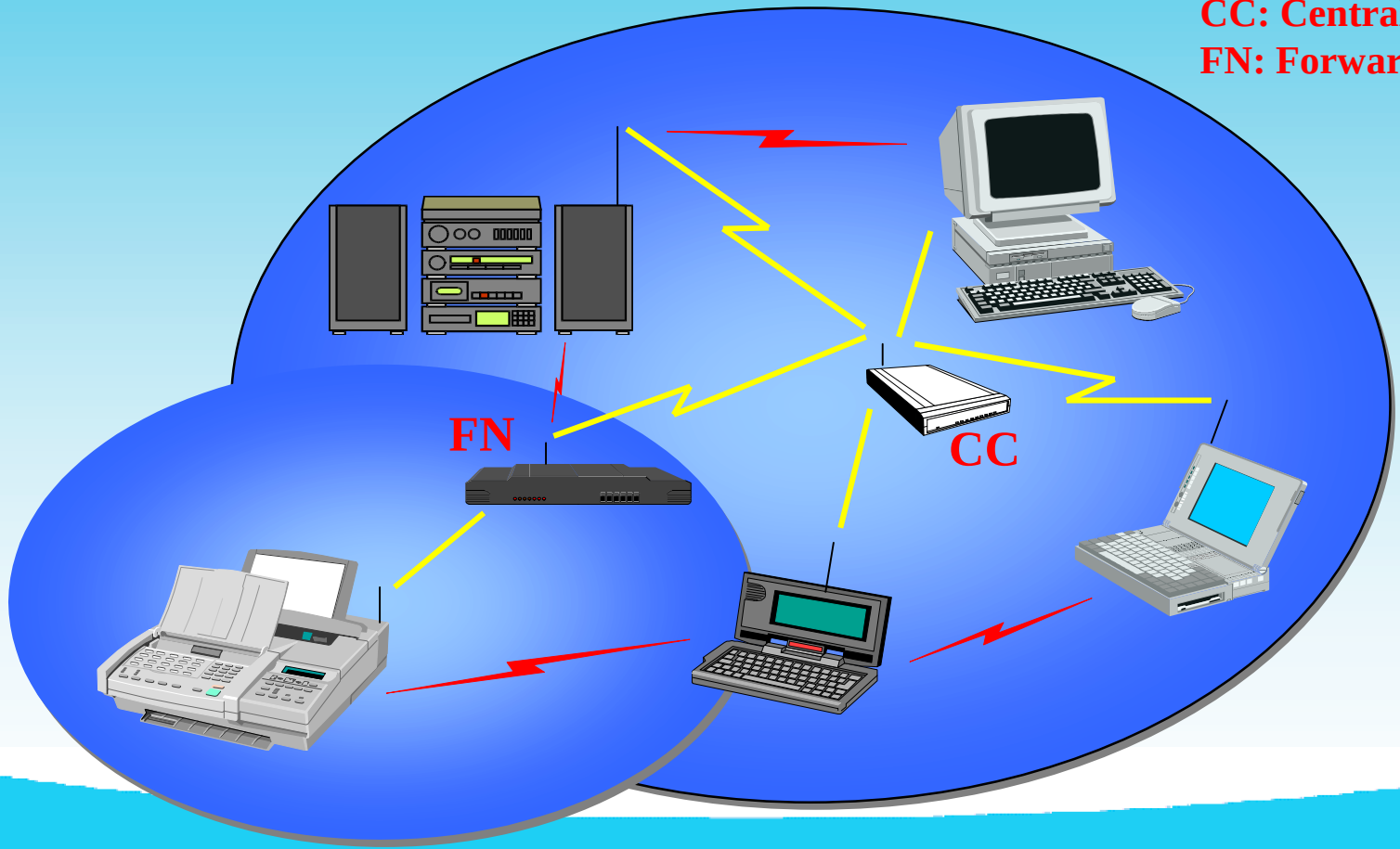
- **HiperLAN/2 basic specification and home extension released**
- **Business and home profiles standardized**
- **First HiperLAN/2 products announced for 2001**

- **Extension towards a multi-hop ad-hoc network**
  - Forwarding nodes to accommodate far-out terminals
  - Cluster bridges for inter-subnet-communication
- **Unification in the 5 GHz band**
  - Coexistence and Interworking
  - **5WING**: 5 GHz Wireless LAN Next Generation Study Group

HiperLAN/2 “Next Generation” (1/2)

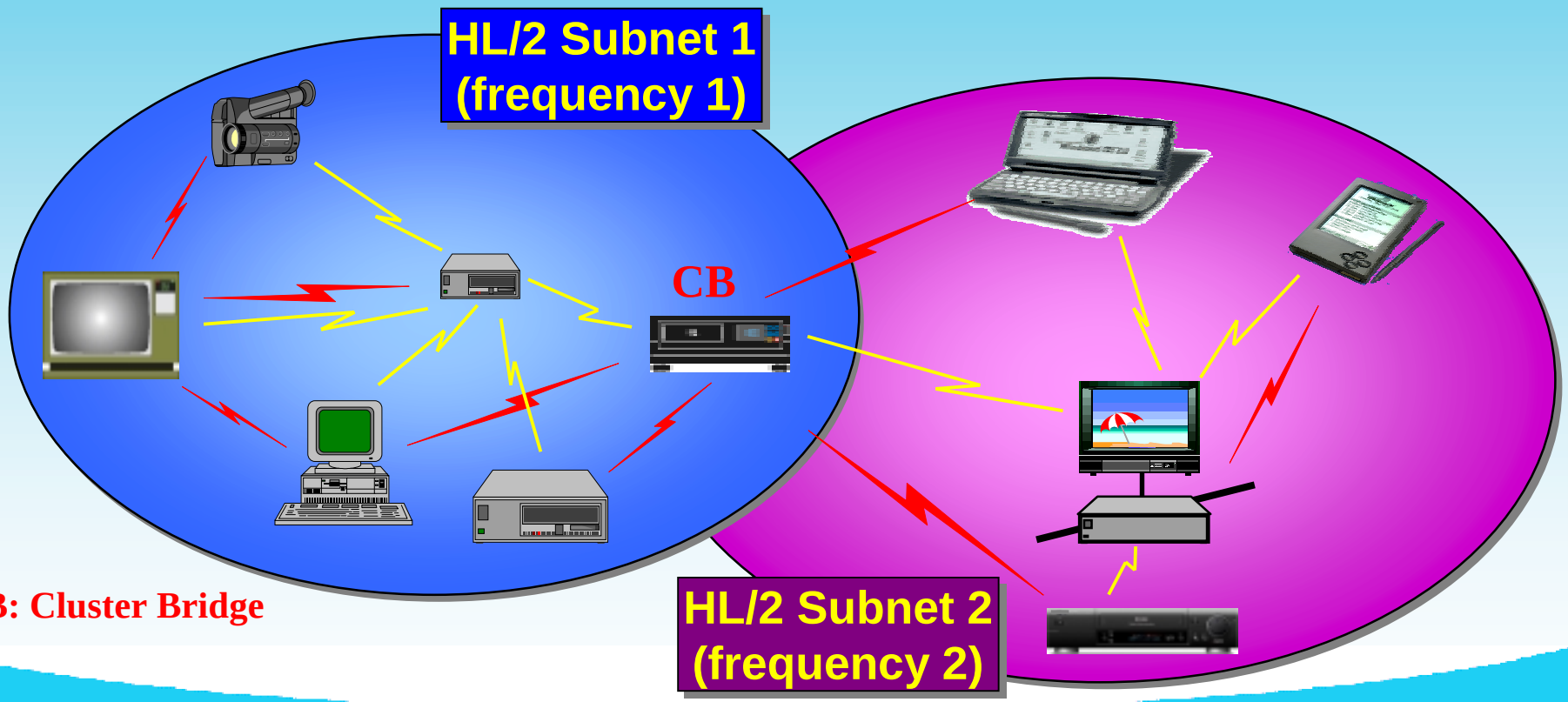
- **Multi-Hop topology for extension of coverage area**
  - Solution to the “hidden node” problem

CC: Central Controller
FN: Forwarding Node



HiperLAN/2 “Next Generation” (2/2)

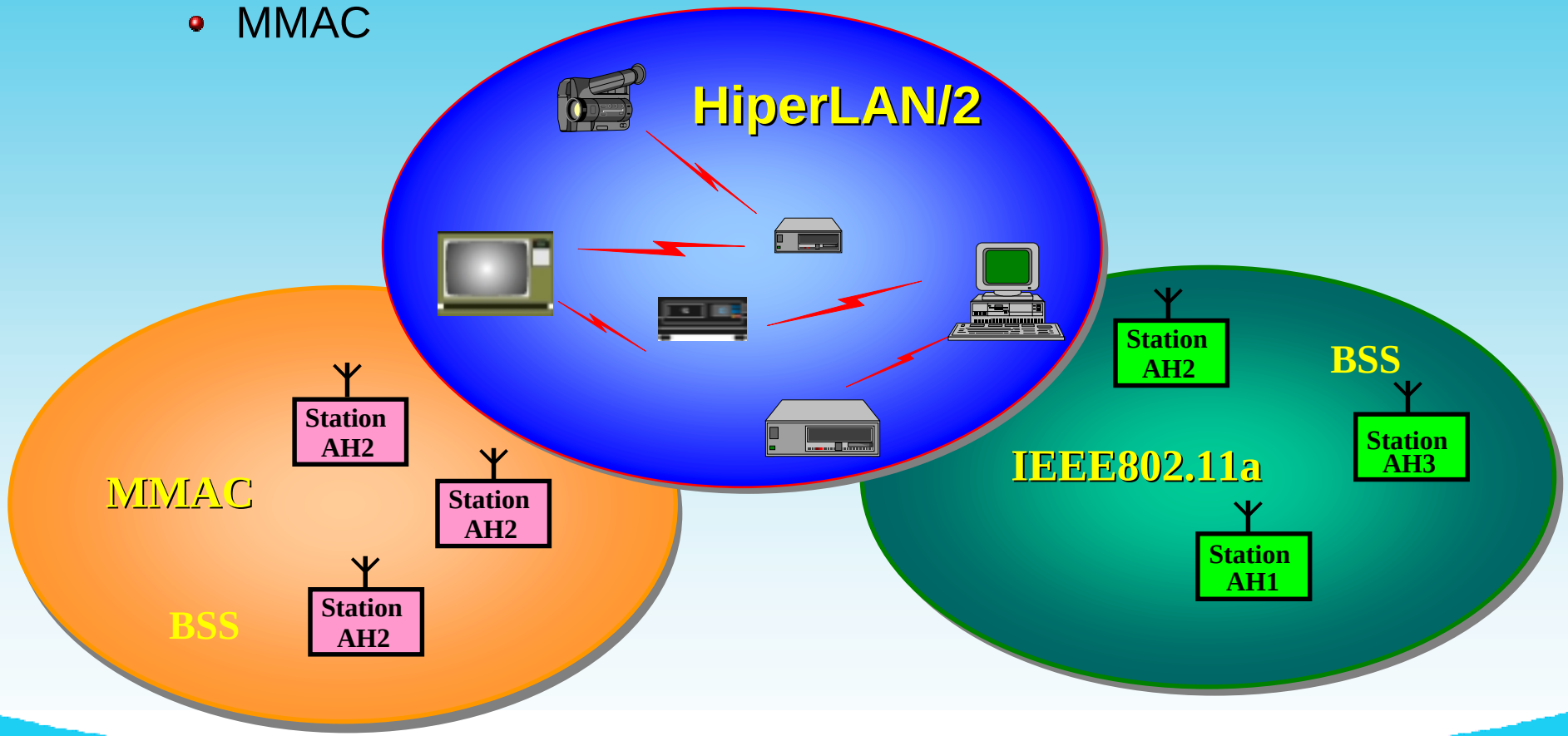
- **Multi-Hop topology for inter-subnet communication**
  - centralized approach for maximum QoS support
  - routing strategies and auto-configuration



CB: Cluster Bridge

5 GHz Standards

- **Co-existence and interworking solutions**
  - IEEE802.11a and its derivatives, IEEE802.15/.16
  - MMAC



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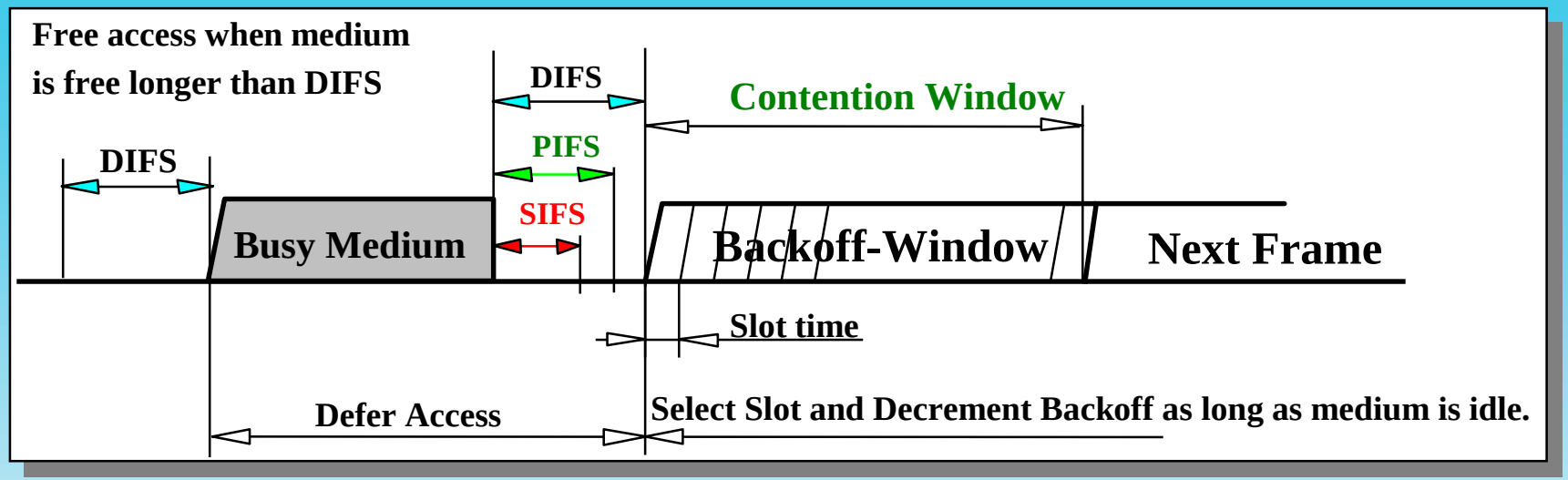
802.11 Basics

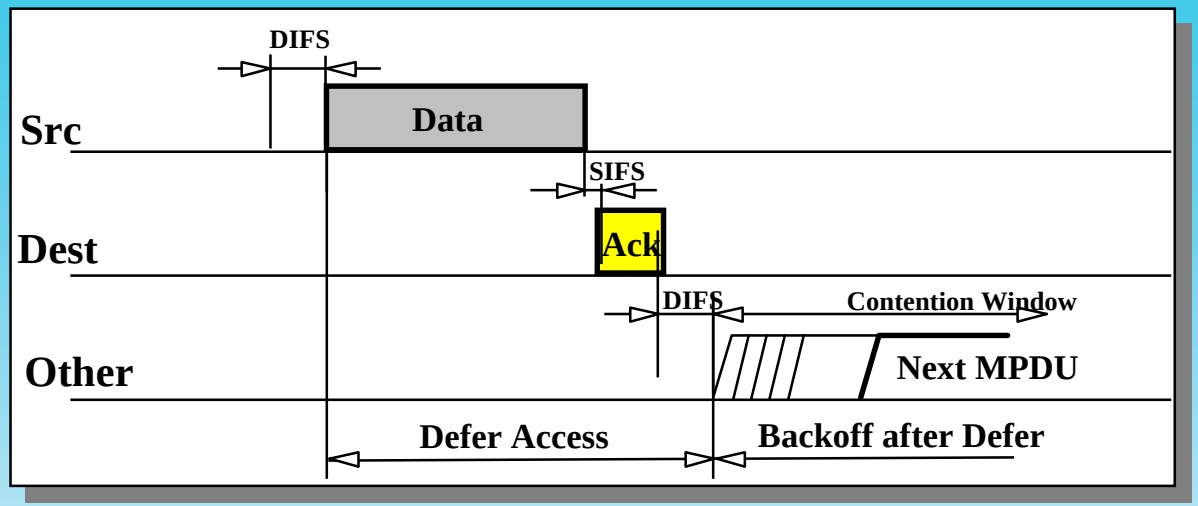
- **CSMA/CA, started as „Wireless Ethernet“**
- **Hidden Node provision by RTS/CTS in 802.11-1999 (“legacy“)**
- **DCF for basic access, and PCF for QoS**
- **Poor QoS only, but under discussion at Task Group “e” (TGe) for new 802.11e**
  - Enhanced DCF
  - Hybrid CF, HCF
  - DFS for overlapping BSSs (moved to TGh)
  - Still Legacy PCF
- **DFS and TPC will allow introduction in European regulatory domains, under discussion at TGh**

Random Access with CSMA



- Stations are waiting for medium to become free.
- Select random back-off after a defer, resolving contention to avoid collisions.
- Exponential back-off window increases for retransmissions.

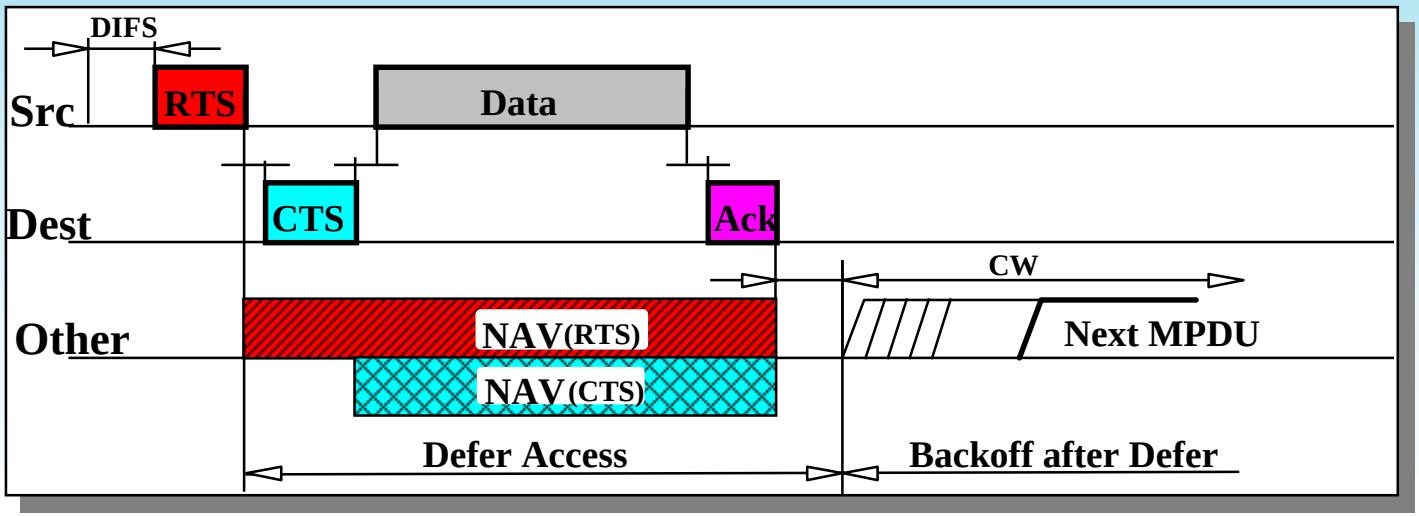
CSMA/CA + ACK protocol



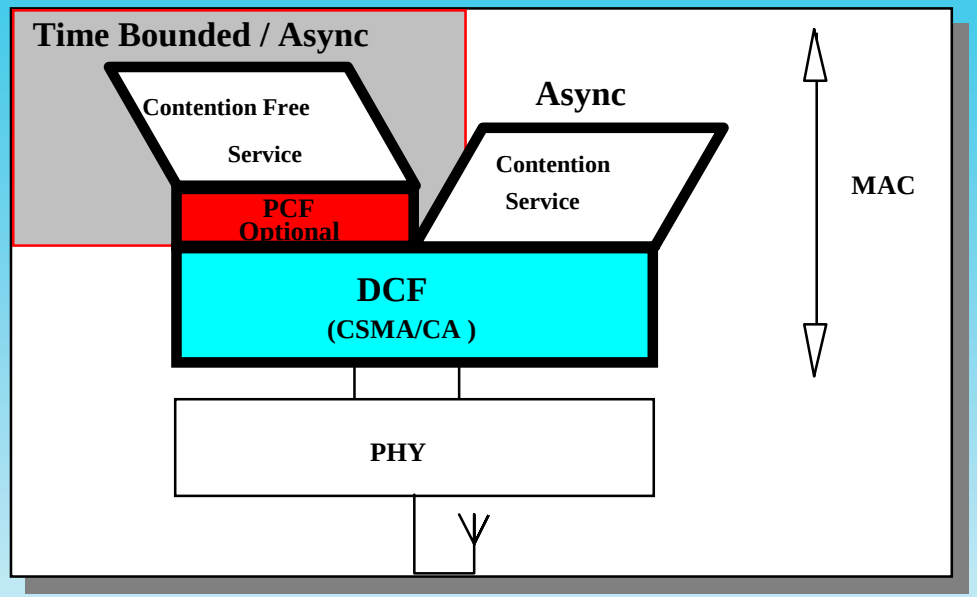
- Defer access based on Carrier Sense.
- CCA from PHY and Virtual Carrier Sense state.
- Direct access when medium is sensed free longer than DIFS, otherwise defer and backoff.
- Receiver of directed frames returns an ACK

“Hidden Node” Provisions

- Duration field in RTS and CTS frames distribute Medium Reservation information which is stored in a Network Allocation Vector (NAV).
- Defer on either NAV or "CCA" indicating medium busy.
- Use of RTS / CTS is optional.

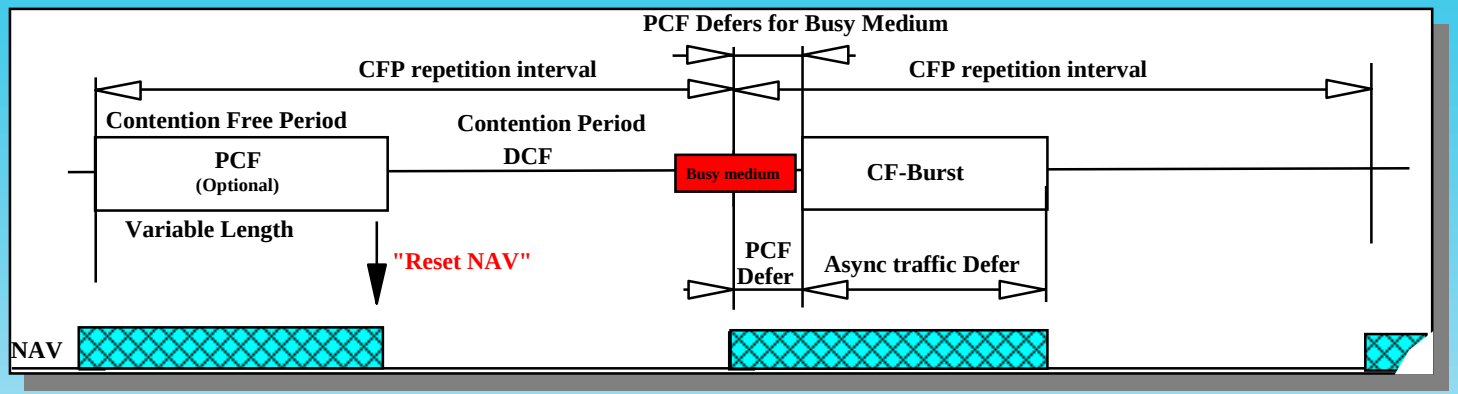


Point Coordination Function, PCF



- Contention Free Service uses Point Coordination Function (PCF) on a DCF Foundation.
- PCF can provide lower transfer delay variations to support Time Bounded Services.
- PCF will be replaced by HCF in 802.11e

PCF: Contention Free operation

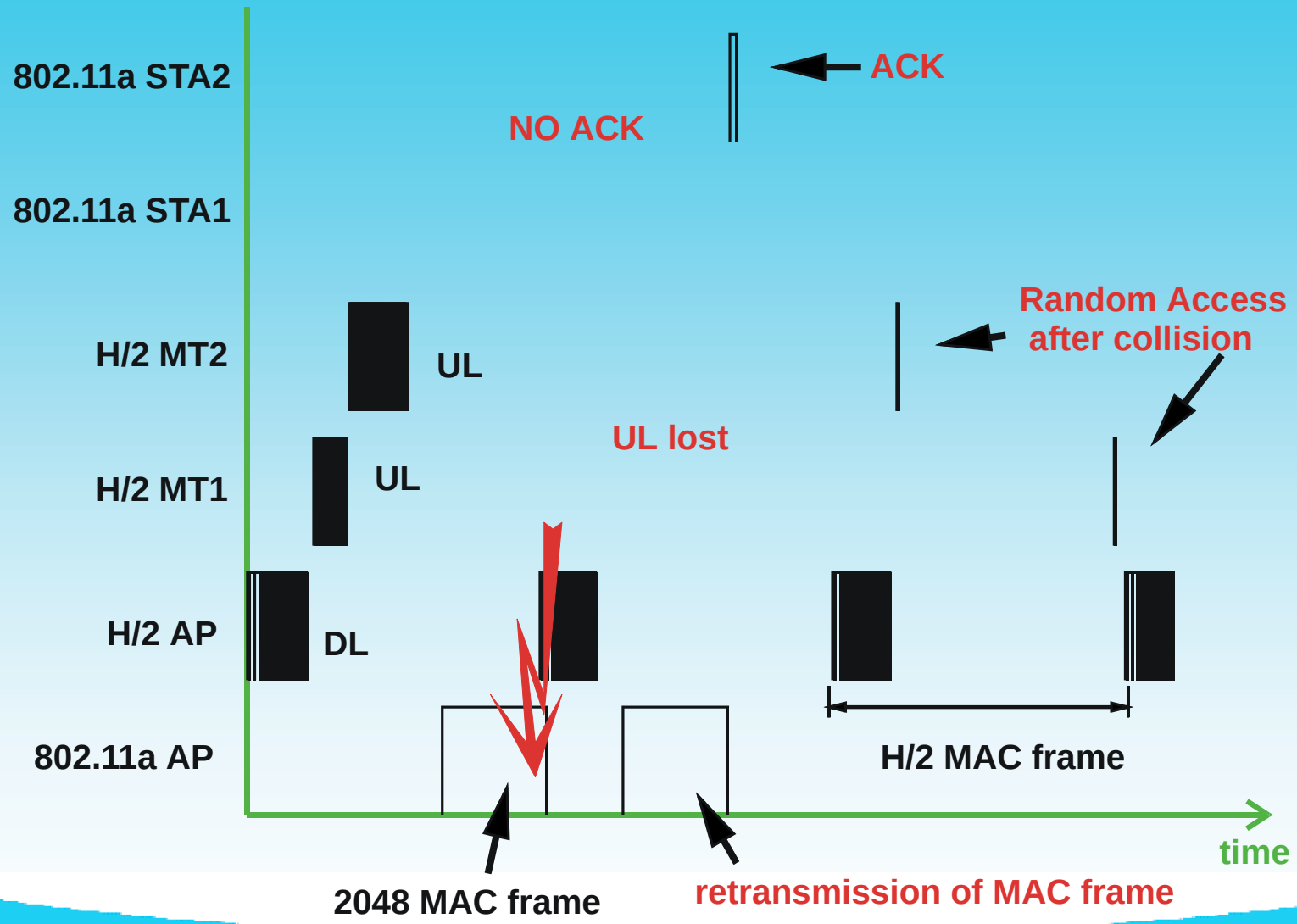


- **Alternating Contention Free and Contention operation under PCF control.**
- **NAV prevents Contention traffic until reset by the last PCF transfer.**
  - Variable length of Contention Free period per interval.
- **In legacy 802.11-1999, PCF and DCF defer to each other causing PCF Burst start variations. Enhanced Stations (ESTAs) of 802.11e will not cause beacon delays.**

New Priority schemes: EDCF and HCF

- **Enhanced DCF (EDCF)**
  - Enhanced STAs (ESTAs) strictly obey TXOPs
  - No Tx extension across TBTT, no beacon delays
  - Arbitration IFS rather than DIFS allows different traffic category
- **Hybrid Coordination Function (HCF)**
  - HCF frame exchange sequences in CFP and CP
  - Hybrid Coordinater (HC) may generate CFP
  - Highest Priority due to PIFS
  - Suffers from overlapping QBSSs
- **Controlled Contention Interval (CCI)**
  - Used for requesting TXOPs
  - CCI is similar to random access phase in HiperLAN/2

Mutual Interference with HiperLAN/2



IEEE 802.11a vs. HiperLAN/2

ISO/IEC 8802-11

"a wireless LAN utilizing carrier sense multiple access with collision avoidance (CSMA/CA) as the access method"

- fully de-central Distributed Coordination Function
- listen-before-talk
- short signaling bursts reduce collision
- Point Coordinator cannot share the spectrum in Contention Free Period
- Point Coordination Function poorly defined
- hidden station problem does exist
- exposed station problem does exist

nice: **fair resource sharing**
bad: **PCF is wasting resources**

ETSI BRAN HiperLAN/2

"a standard for a high speed radio communication system where a centralized mode is used to operate as an access network via a fixed access point"

- direct mode enables the ad-hoc operation
- the central controller is dynamically selected
- an Access Point Transcv. (APT) requires one frequency exclusively
- QoS support only if no other system around
- hidden station problem does exist
- exposed station problem does exist

nice: **QoS support, low overhead**
bad: **no resource sharing**

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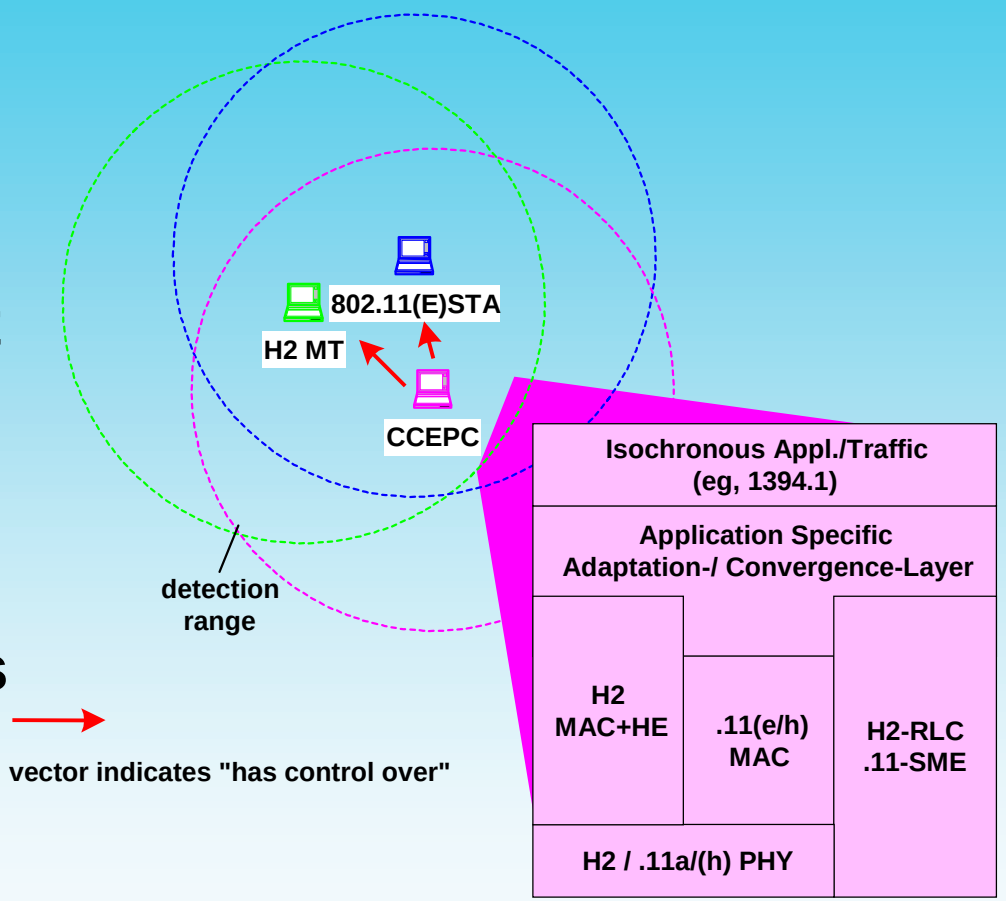
Interworking Scenario

- Infrastructure based
- CC: Central Controller HiperLAN/2 HE
- (E)PC: Enhanced Point Coordinator
- H2 and 802.11(e) time sharing is coordinated by beacons and TxOPs

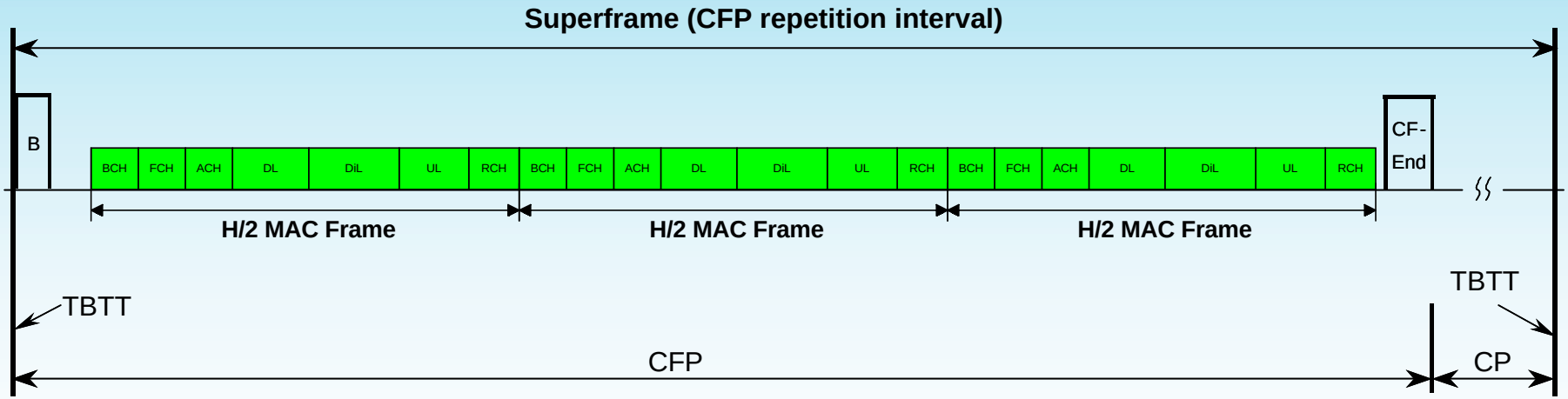


TGe will define QoS for 802.11e

- As part of the upcoming 802.11e MAC, the beacon can be transmitted at the TBTT all the time.
- ESTAs will not transmit their frames during the CP if they cannot finish their transmission before the next TBTT.
- Coordinator allocates transmission opportunities (TxOPs)
- Within the limits of each TXOP, decisions regarding what to transmit are made locally by the MAC entity at the ESTA.

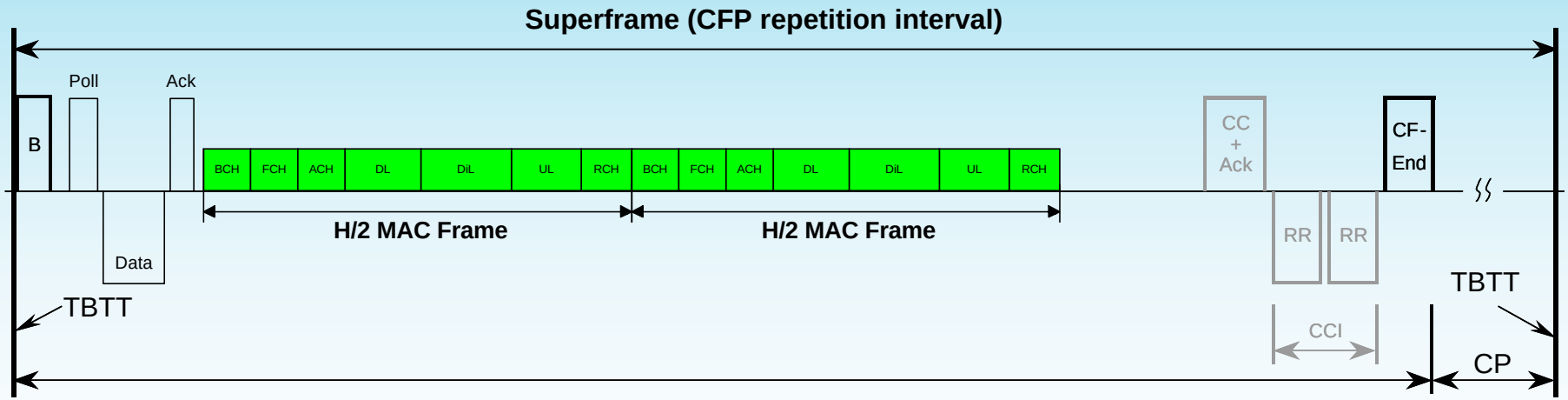
Legacy: CCEPC coordinates HiperLAN/2

- **HiperLAN/2 MAC frames within CFP, not CP**
- **Time sharing: CFP: HiperLAN/2 – CP: 802.11**
- **Superframe with CFP and CP, based on time units (1024us)**
  - H/2 will not start right after beacon
- **Beacon delays due to legacy devices**



TGe: CCEPC coordinates the both modes

- CCEPC can initiate HiperLAN/2 at any time during CFP
- TxOPs allow periods for HiperLAN/2 and 802.11 CF-traffic within CFP
- Length of CP is defined by CCEPC



CCEPC characteristics

- **For interworking and sharing:**
  - H2 → time division, absence mode
  - 802.11 → beacon, CFP
- **For isochronous traffic, QoS:**
  - TGe→ transmission opportunities, fixed periods for HiperLAN/2 MAC frames
  - TGh → DFS reduces interference from BSS and alien (legacy) devices
- **Interworking Solutions operate with legacy terminals, but Dual-MAC Access Points**

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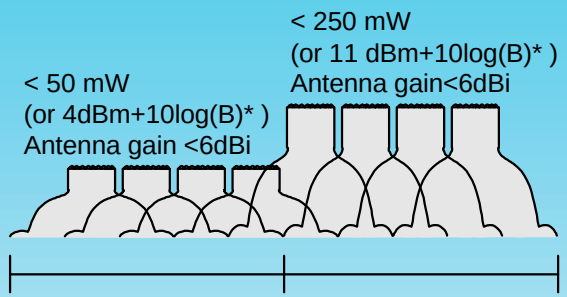
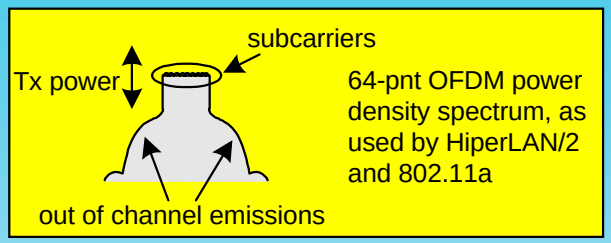
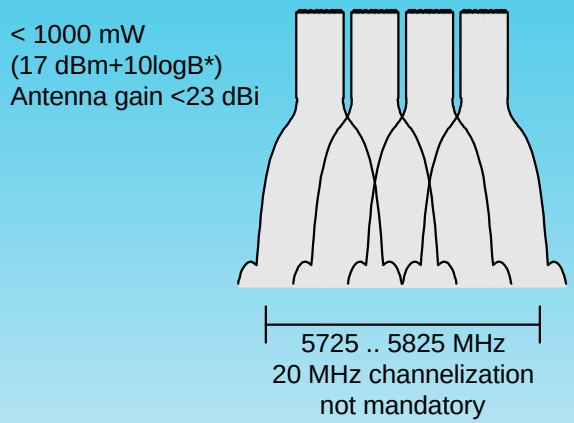
Spectrum Allocation at 5 GHz

U-NII Regulations, U.S.A.



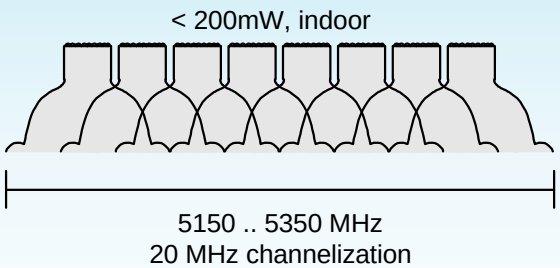


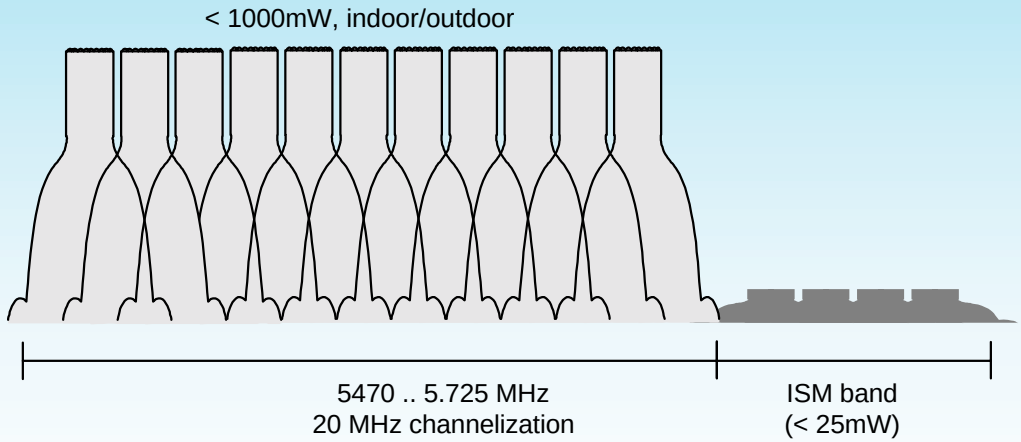
Higher antenna gain permitted with corresponding reduction of Tx output power.
*) B = 26 dB emission bandwidth.



European Regulations: License Exempt (Unlicensed)

Wireless LANs must use full spectrum range in order to share the spectrum with radar systems: dynamic channel/frequency selection and power control





Game Theory may be the Solution

- De-central coordination of resource sharing is crucial
- Cognitive Software Radio is opening new fields of research
- Interworking (fictious play) is often not possible
- System behaviour is rational, however
- Nash Equilibrium solutions and related work may not represent the real world scenarios?
- Most promising: learning from observation, adaptive strategies, evolution

Example: The Prisoner's Dilemma

social optimum

Nash Equilibrium

	don't confess	confess
don't confess	3,3 *both players spend only short time in prison: cooperative, social optimum*	0,4 *player two witnesses against one*
confess	4,0 *player one witnesses against two*	1,1 *three years both* *Nash Equilibrium*

The Evolution of Cooperation

- **Fundamental statement: cooperative players operating in a cooperative environment perform most successful**
- **Social science: experiments by Axelrod**
  - act fair and nice, allow cooperation first of all
  - act provokable and irritable when opponent does not cooperate
  - act forgiving after striking back
- **how to convince the others to play specific strategies without communication?**

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Conclusions and Outlook

- **Mature standards do exist in the 5 GHz band**
  - regional differentiation
  - evolution history
  - objectives and properties
- **Economics demand reduction of multitude**
- **Options to go for:**
  - co-existence (short-term solution for H2 and 802.11a)
  - inter-working (efficiency?)
  - unification (“best of both worlds”, backward compatibility?)
  - next generation wireless LAN (5WING) (long-term solution)
- **Diverging forces: technology, economy, politics**