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Introduction to Bluetooth

Kirsten Matheus

- The idea behind Bluetooth
- The problems when trying to realize the idea
- The solutions used in Bluetooth
- How well the solutions work

The Idea Behind Bluetooth

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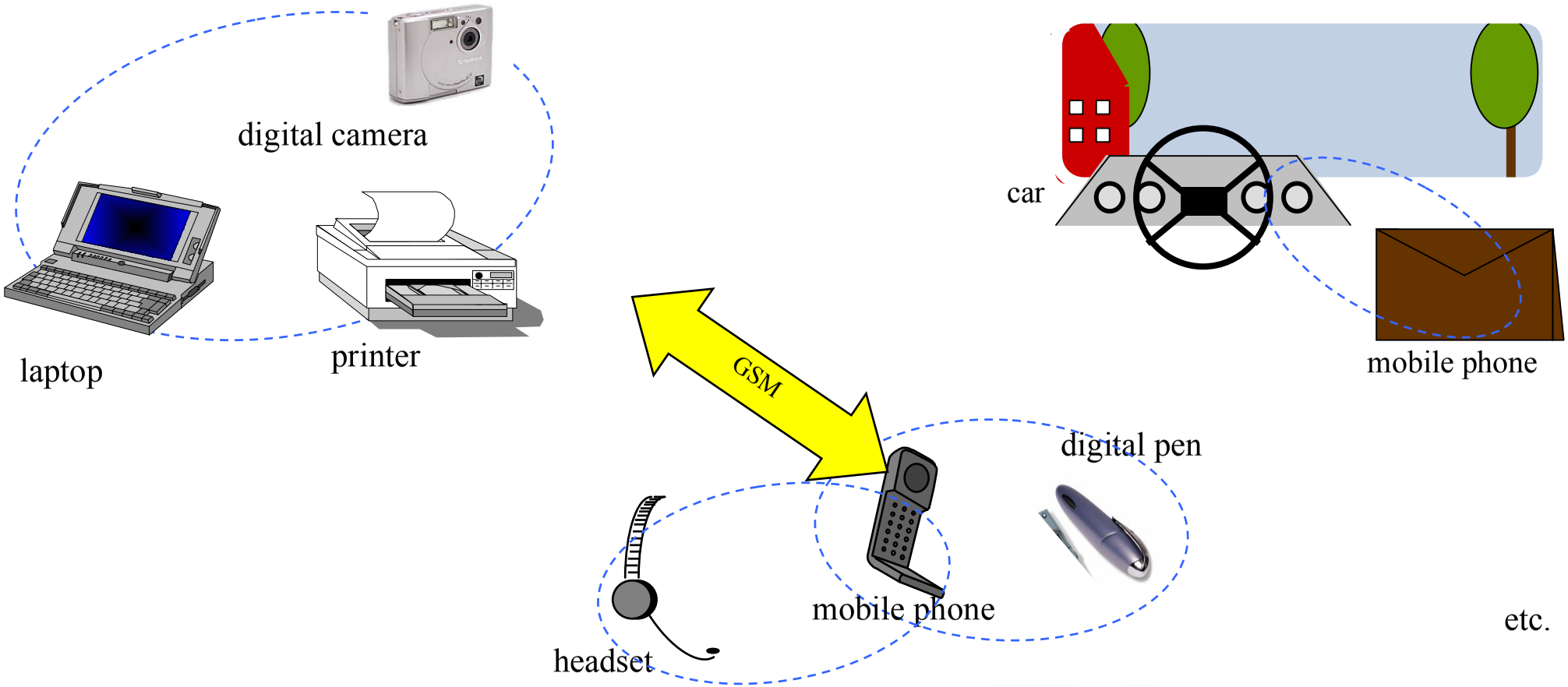
niversal, short range cable replacement

supports speech and data and can be used (almost) worldwide without the need of an infrastructure



Bluetooth has to

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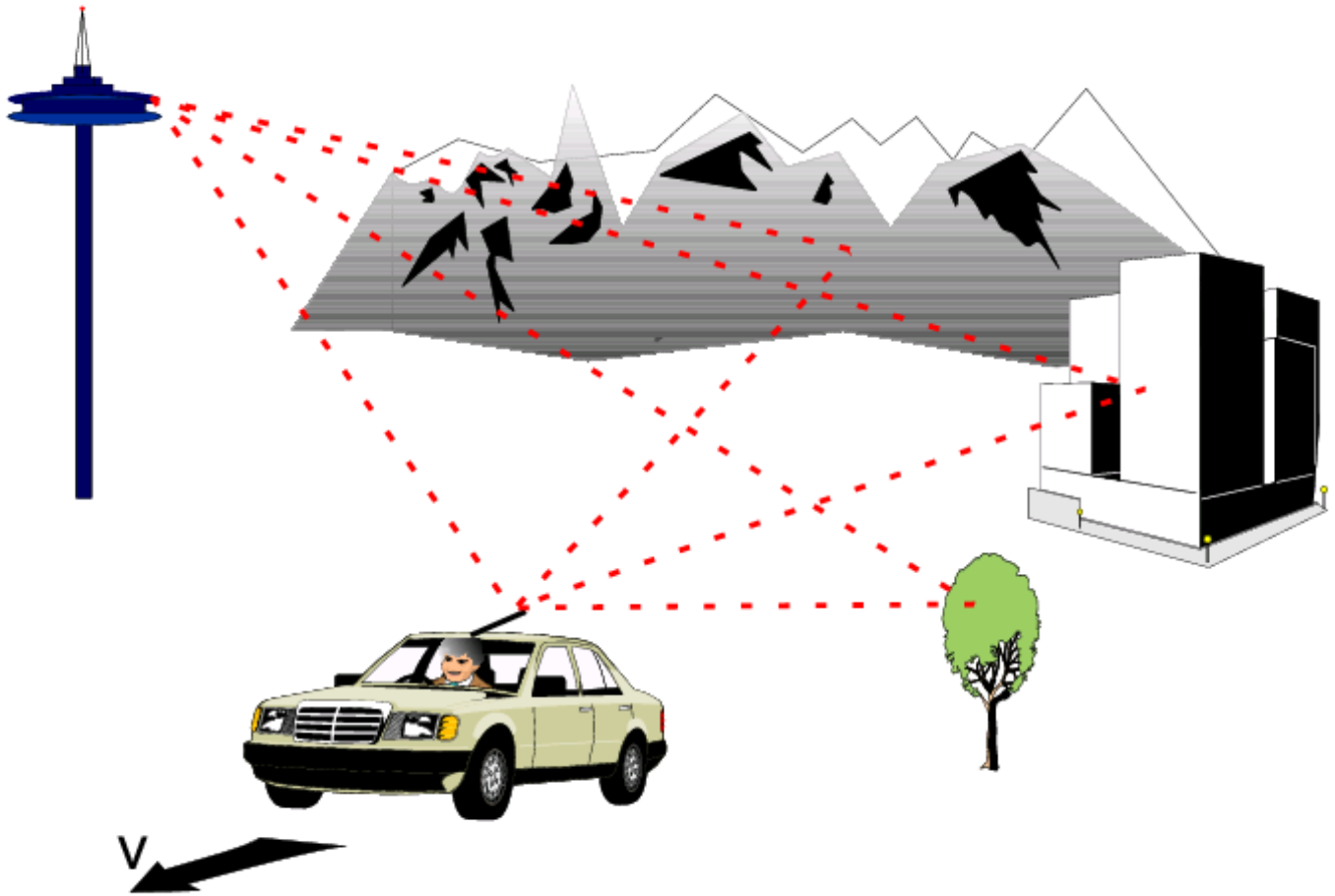
- **Function in the harsh conditions of the wireless transmission medium**
- **Widely us**
- **Compatib**



Measures to Ensure Distribution:

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- **Specification by industrial consortium**
  - ➔ Ericsson, IBM, Intel, Nokia and Toshiba founded the BT SIG in 1998
  - ➔ Fast because few partners mean fewer opinion that have to be agreed upon
- **Open to be used by anyone**
  - ➔ No fees for key patents
- **Technical side comparably cheap to realise**
  - ➔ Chip price today under 5$US
- **Placed in unlicenced frequency band (ISM at 2.4GHz)**
  - ➔ Almost worldwide deployment without the need to pay licence fees

Measures to Ensure Compatability:

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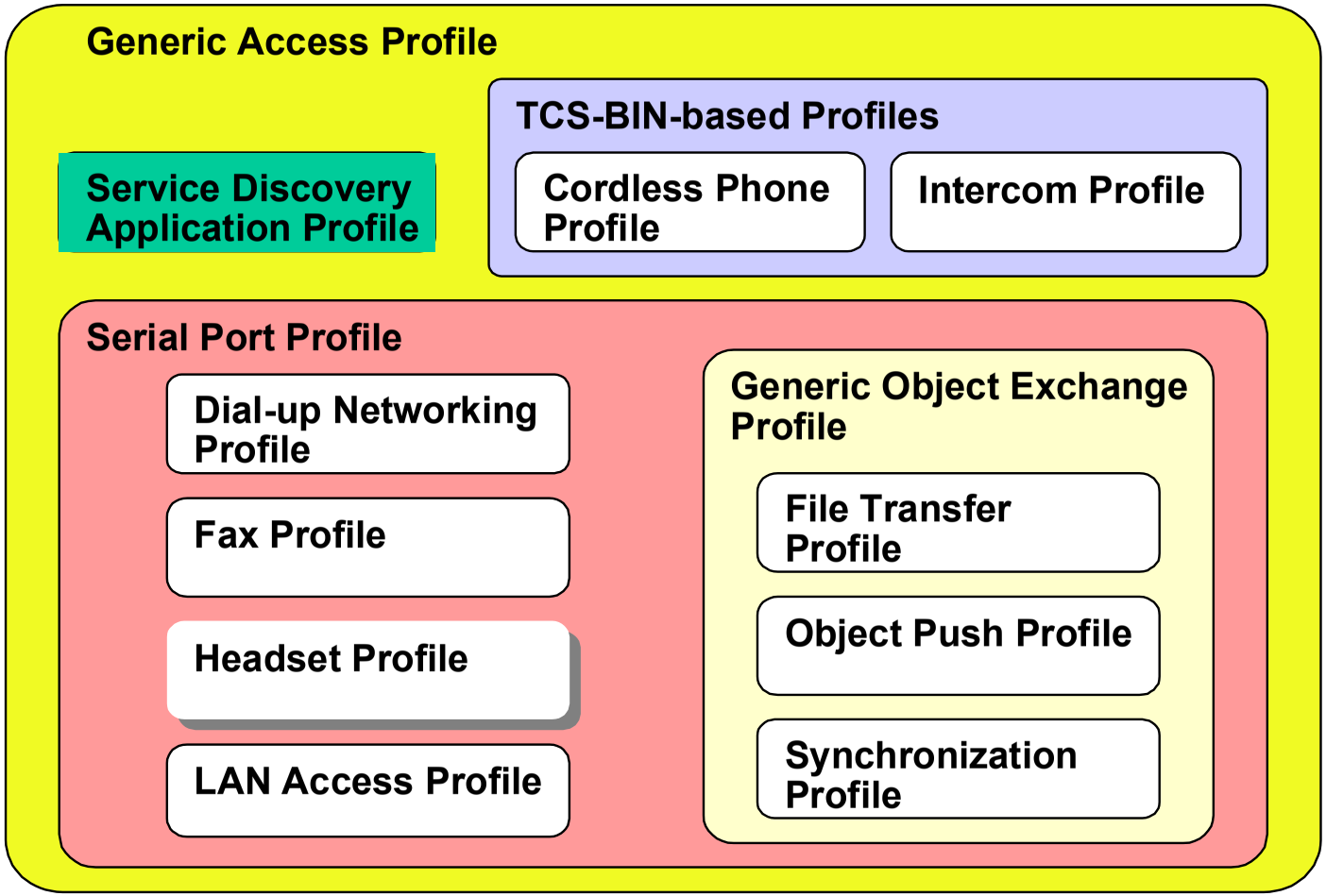
- Qualification procedure for every BT product
- Specific profiles for each application



Connection Set-up Example

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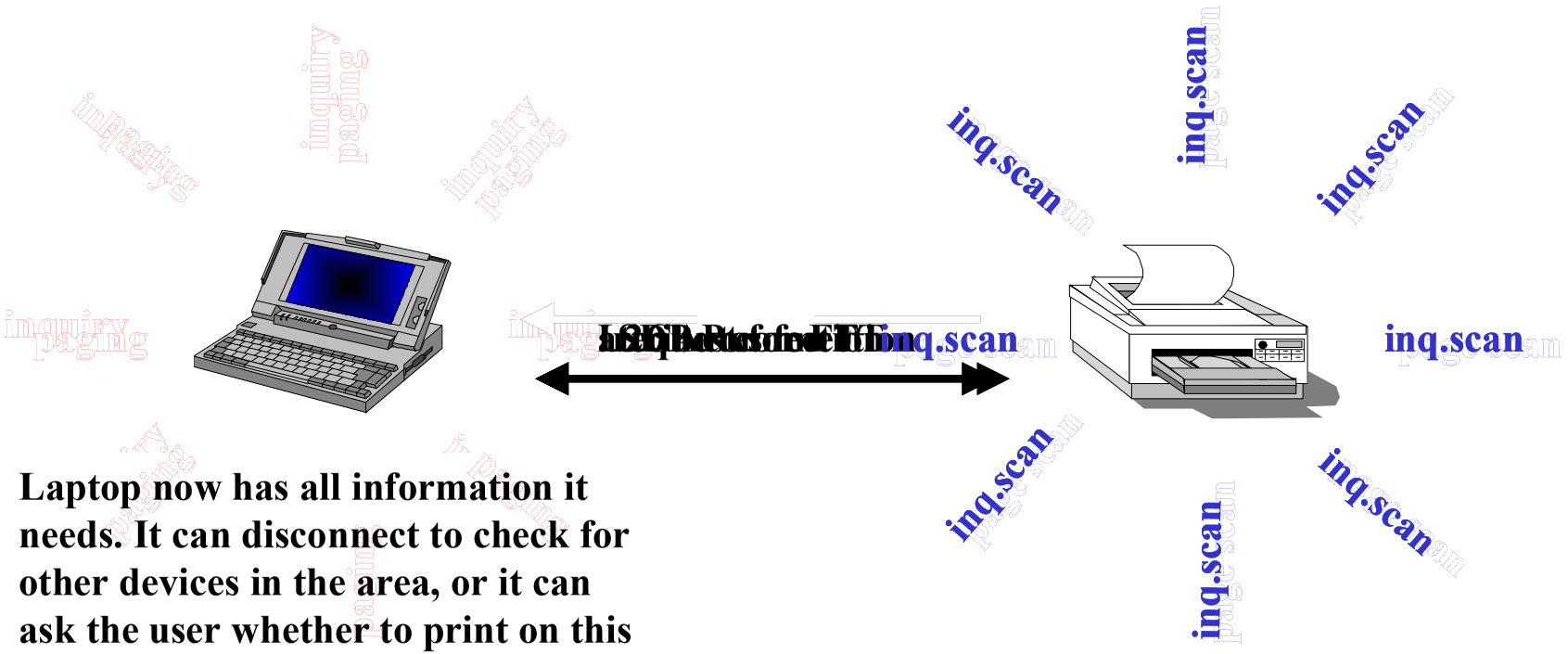

Laptop now has all information it needs. It can disconnect to check for other devices in the area, or it can ask the user whether to print on this printer or it can start the printing process

Technical Data

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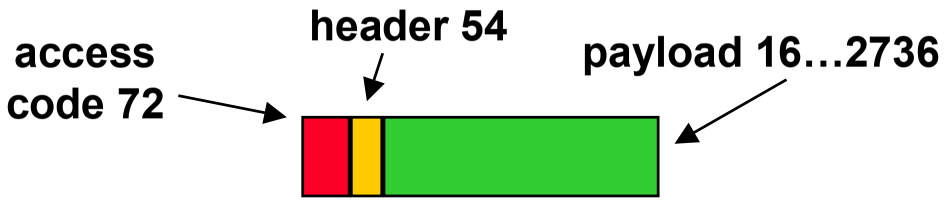
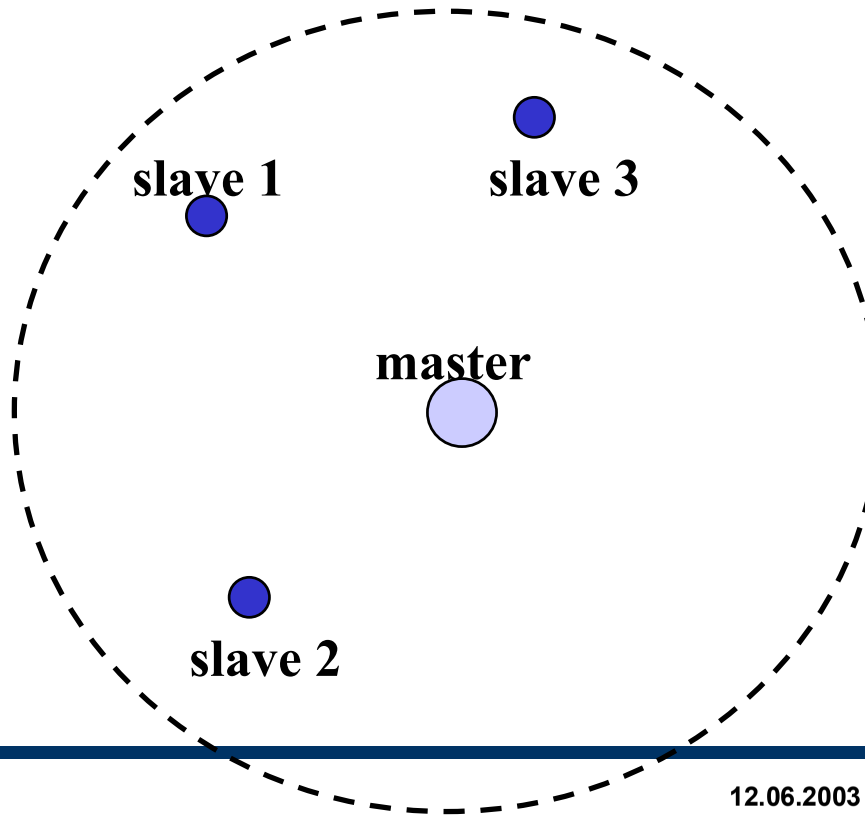


- Organized in packets
- GFSK modulated data at 1Mbps (1bit ≙ 1symbol)
- 79 carriers of 1MHz
- 1mW transmit power (100mW optional)
- Master/Slave concept (piconets)
  - ➔Organizes the piconet of
  - ➔up to 7 slaves
  - ➔Determines the hop sequence of
  - ➔FH/TDD-scheme



TDD/FH Channel

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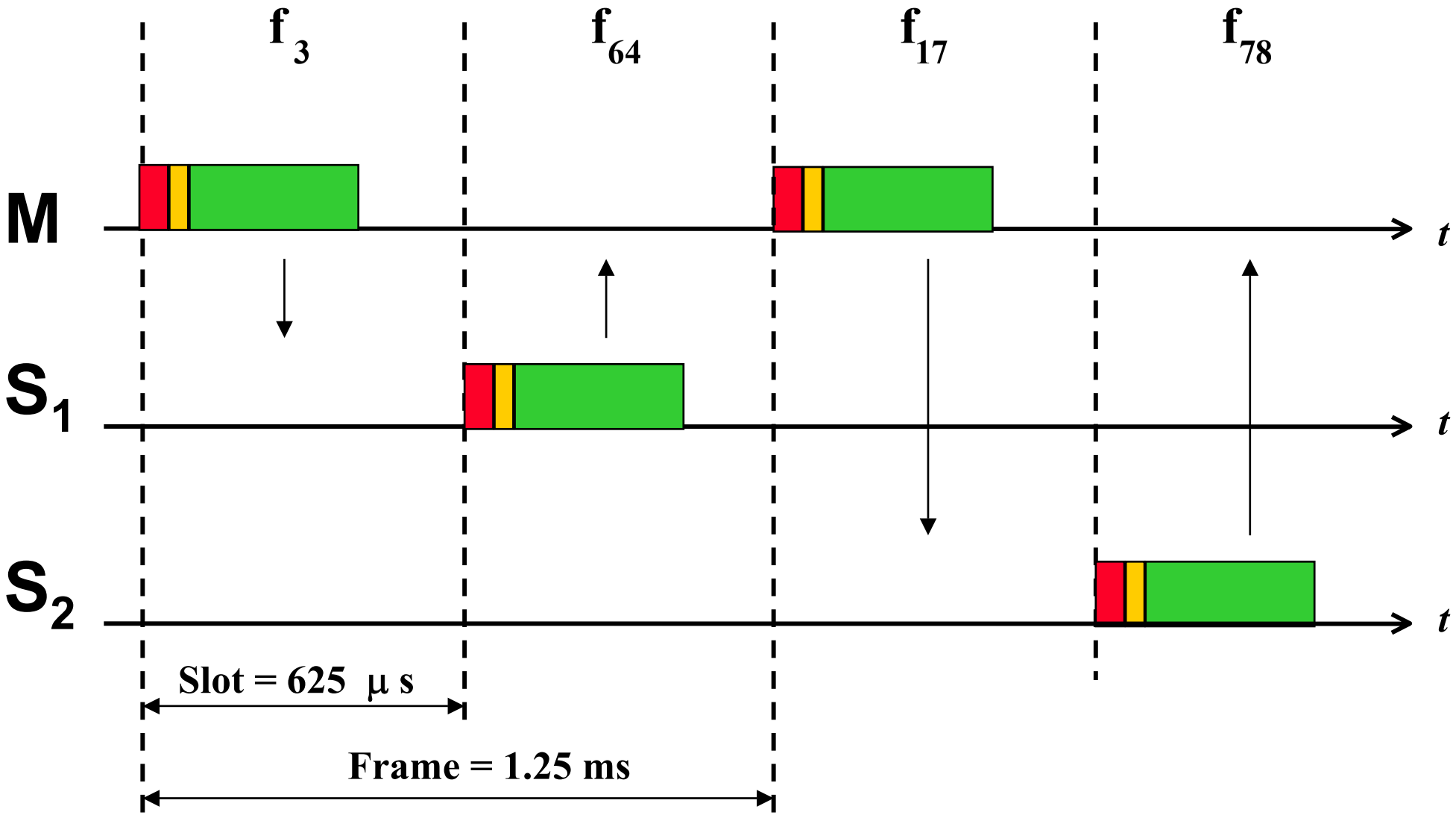

ACL Packets (for Data)

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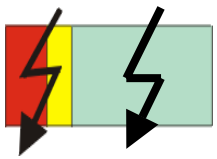
- (A)symmetric, asynchronous services
- Because data allows no bit errors, ARQ scheme
- Polling scheme for slaves
- Quality of data link:



Burst requires retransmission

Retransmitted bursts are counted in the burst failure rate BFR

Causes delay

Payload can be used with optional FEC coding (rate 2/3)

Up to 10% packet retransmissions ok

ACL Packet Types

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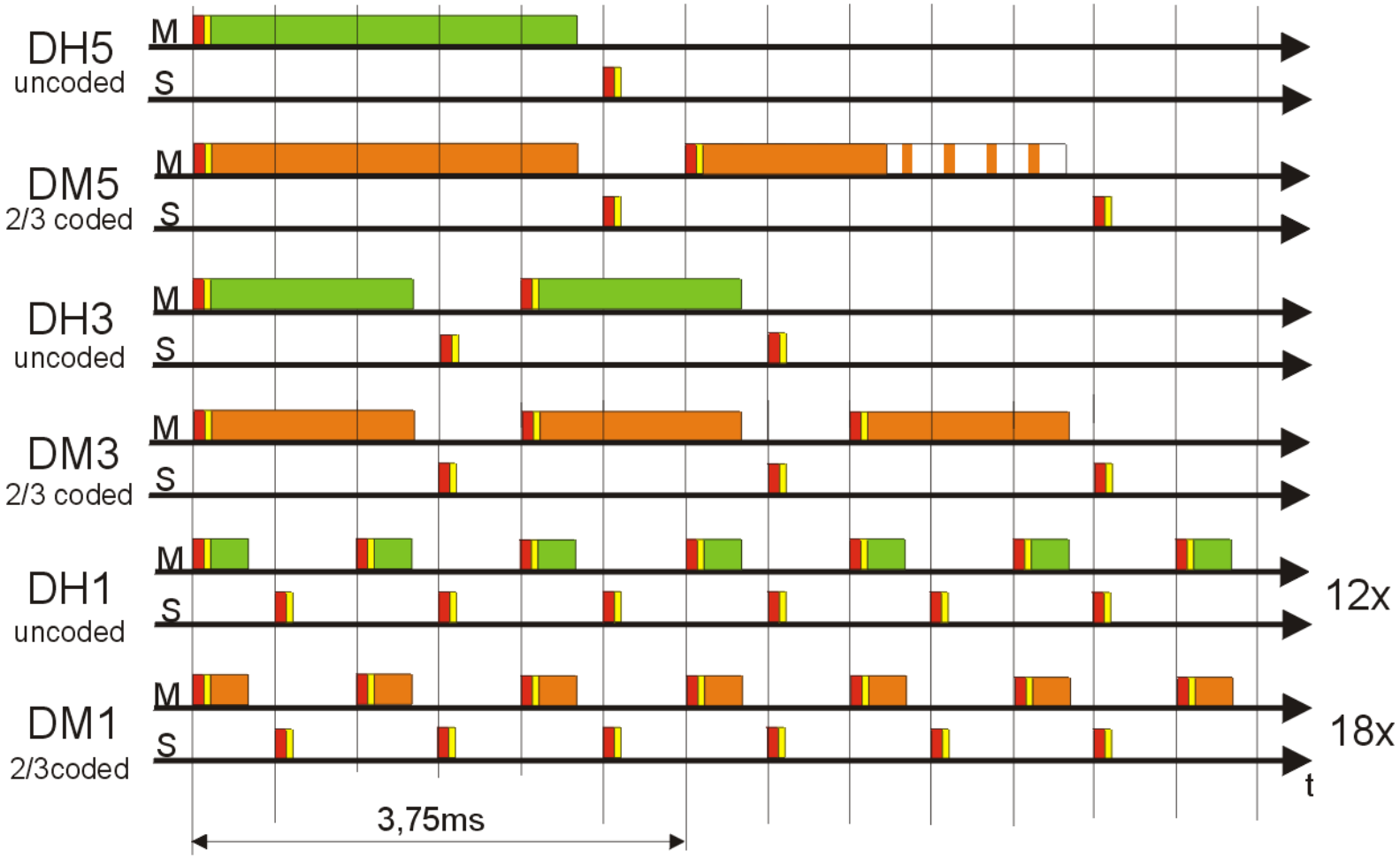

- short packets are less sensitive to interference
- have a smaller transmission rate

SCO Packets (for Speech)

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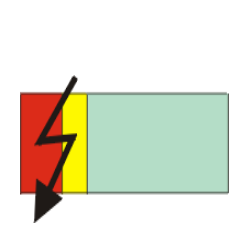
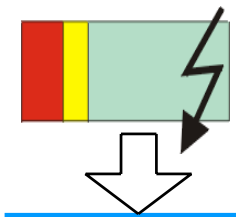
- Symmetric, synchronous services
- Speech allows no delay
- Slot reservation at fixed intervalls
- Speech quality:



Burst is replaced with a 01 bit pattern

Replaced bursts are counted in the frame erasure rate FER

Distorts the voice



Payload (incl. bit errors) is forwarded to the CVSD decoder

Bursts with too many bit errors are counted in the unsat. payload rate UPR

ACL:
Up to 10% packet retransmissions ok

Payload can be used with optional FEC coding

Combined in the unsat. burst rate FER+UPR=UBR

1-2% average UBR per link unacceptable

SCO Packet Types

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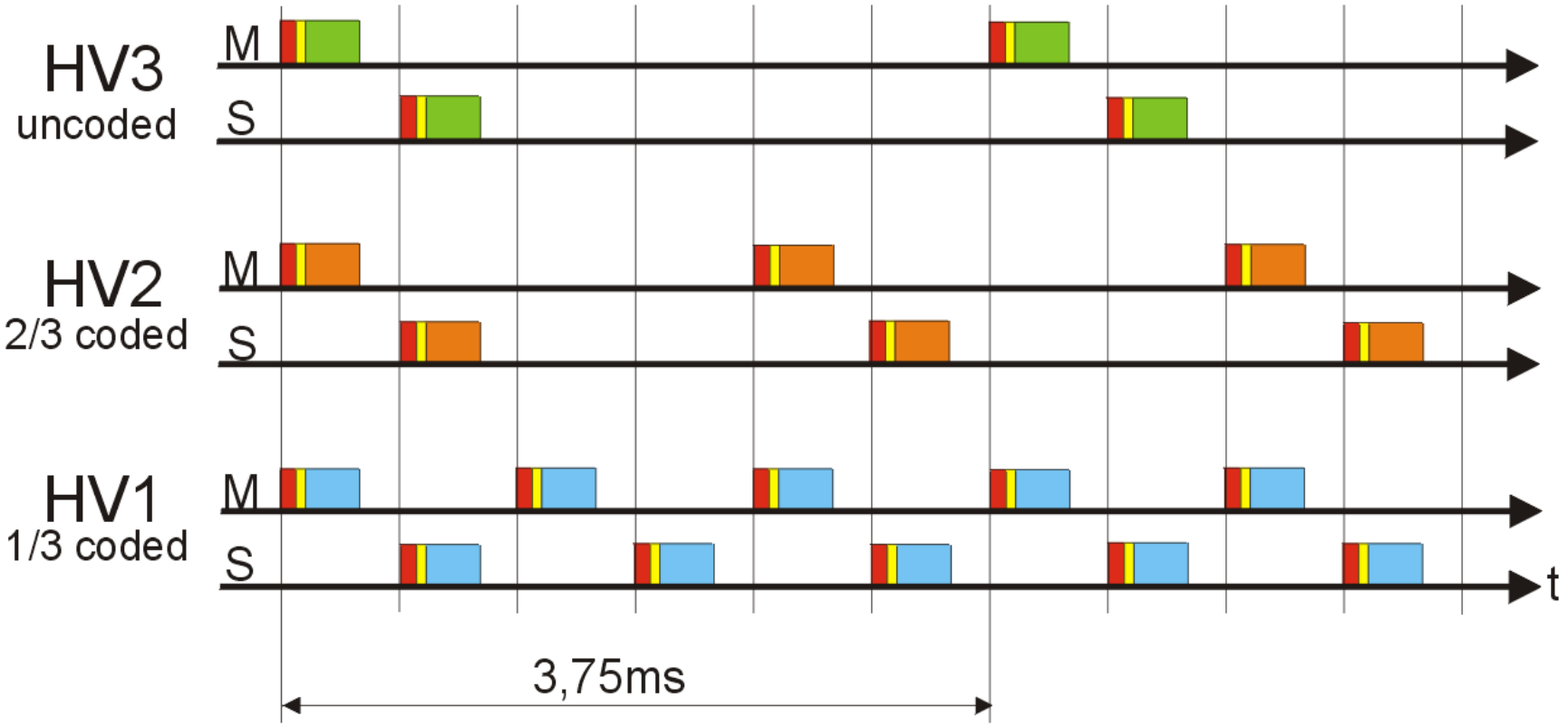

! HV1 causes three times and HV2 causes 1.5 times
! more interference than HV3 but only their
! payloads receives more protection

Packet Types in Overview

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	Type	FEC	symmetric	asymmetric traffic	
Data	DM1	2/3	108.8 kbit/s	108.8 kbit/s	108.8 kbit/s
	DM3	2/3	258.1 kbit/s	387.2 kbit/s	54.4 kbit/s
	DM5	2/3	286.7 kbit/s	477.8 kbit/s	36.3 kbit/s
	DH1	-	172.8 kbit/s	172.8 kbit/s	172.8 kbit/s
	DH3	-	390.4 kbit/s	585.6 kbit/s	86.4 kbit/s
	DH5	-	433.9 kbit/s	723.2 kbit/s	57.6 kbit/s
Speech	HV1	1/3	64 kbit/s		
	HV2	2/3	64 kbit/s		
	HV3	-	64 kbit/s		

Mixed Link Example

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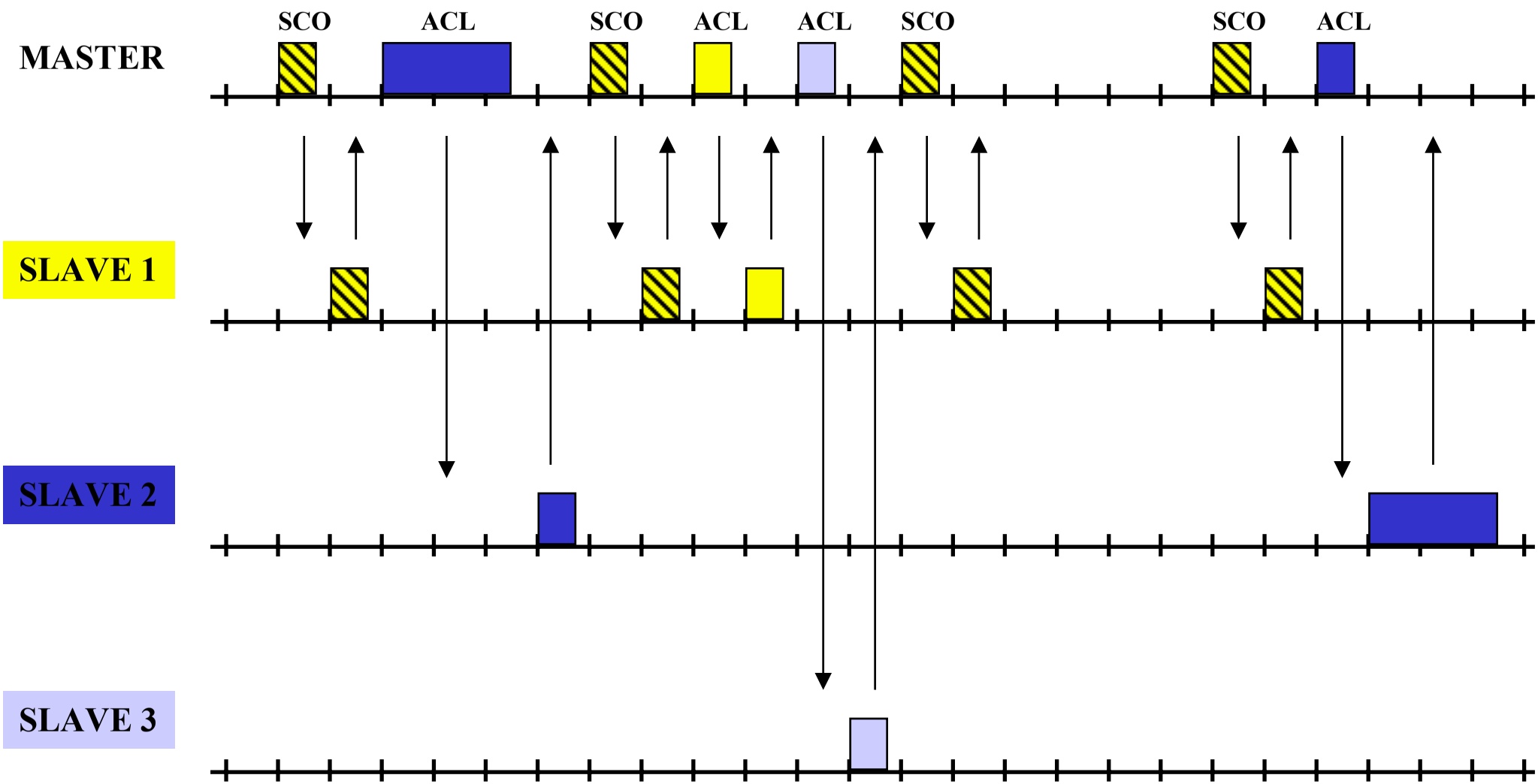

Interference Robustness

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To interfere with each other different devices have to be used:

- In the same location
- At the same time

} Depends on user scenario

- On the same frequency

Depends on specification

Other Bluetooth piconets
Microwave ovens
IEEE 802.11b WLAN
other

Interference Robustness

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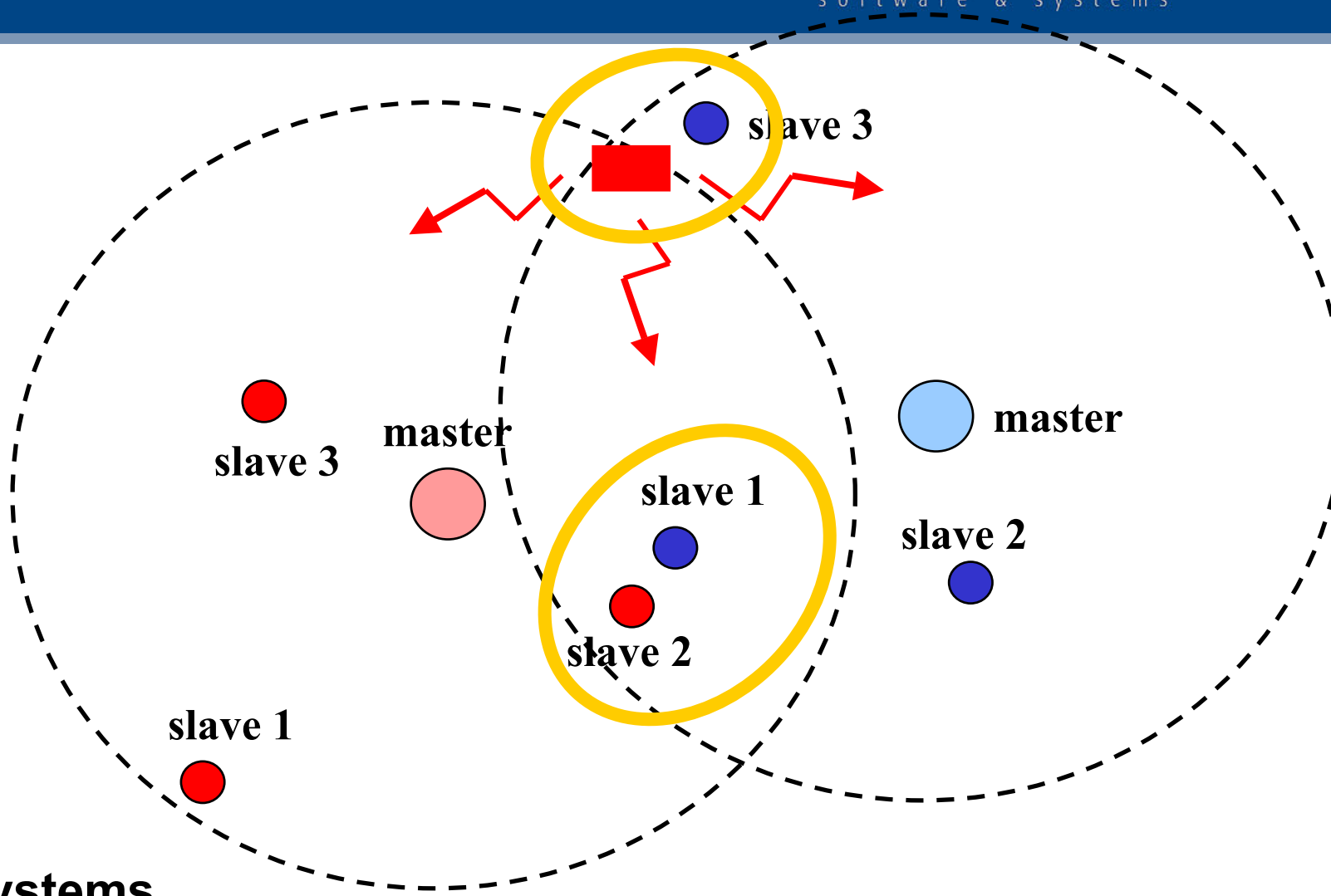

- not like cellular systems
- blocking, adjacent channel effects
- hit or miss (interference)

Interference in Cellular Systems

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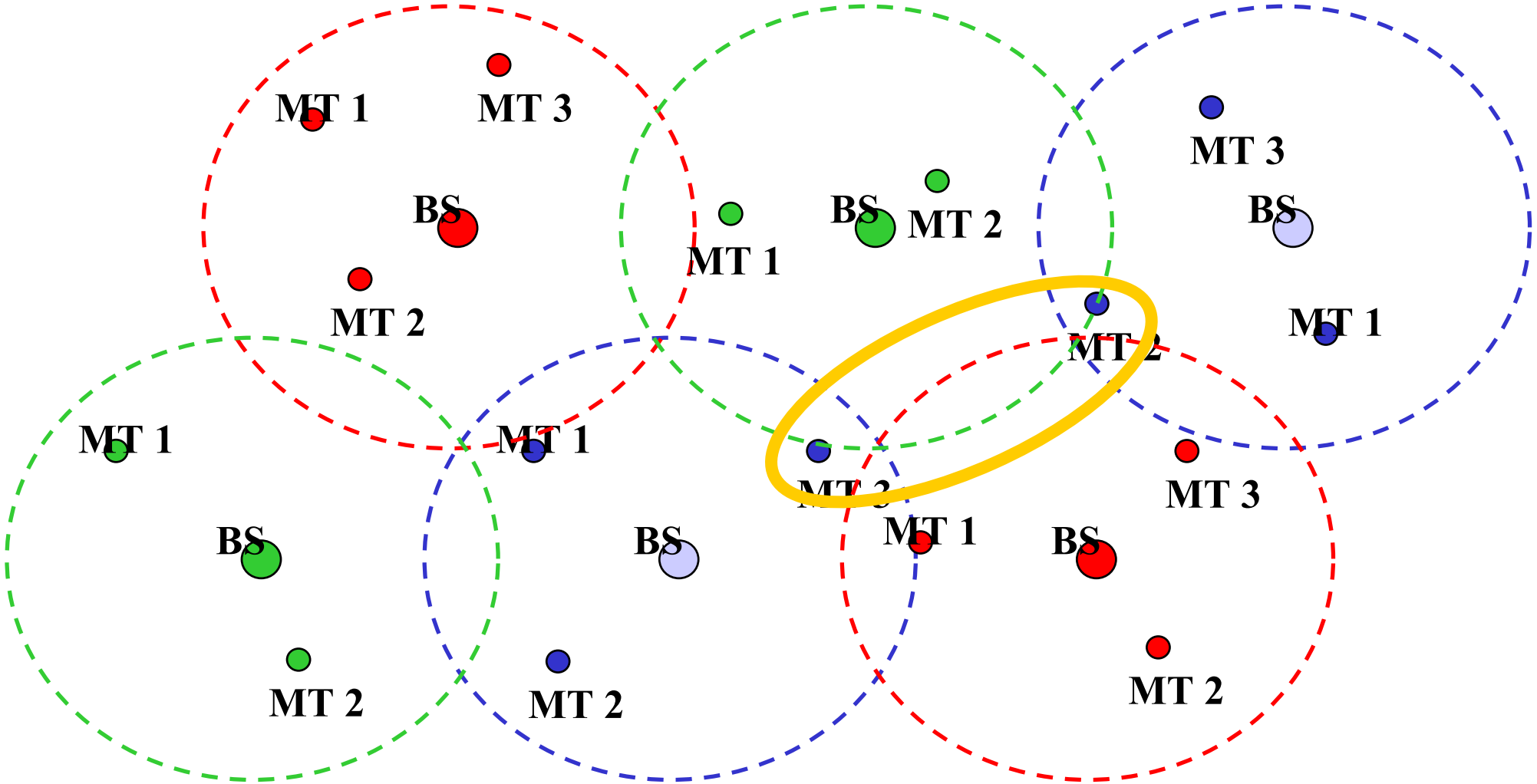

➔Minimum distance to next co-channel interferer

Performance in Case of Bluetooth interference

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- **Radio Network Simulations** (in MATLAB)
  - ➔ Many simultaneous BT connections

- **Propagation Model**
  - ➔ Distant dependent fading
  - ➔ Shadowing
  - ➔ Multipath fading

- **Traffic Models**
  - ➔ Www-traffic (av.generated data 33.2kbps)

- **Positioning Model**
  - ➔ 10m by 20m room
  - ➔ Uniform distribution of masters
  - ➔ Slaves at av. 2m to master in 2-dim Gaussian distribution

Performance in Case of Bluetooth Interference (contd)

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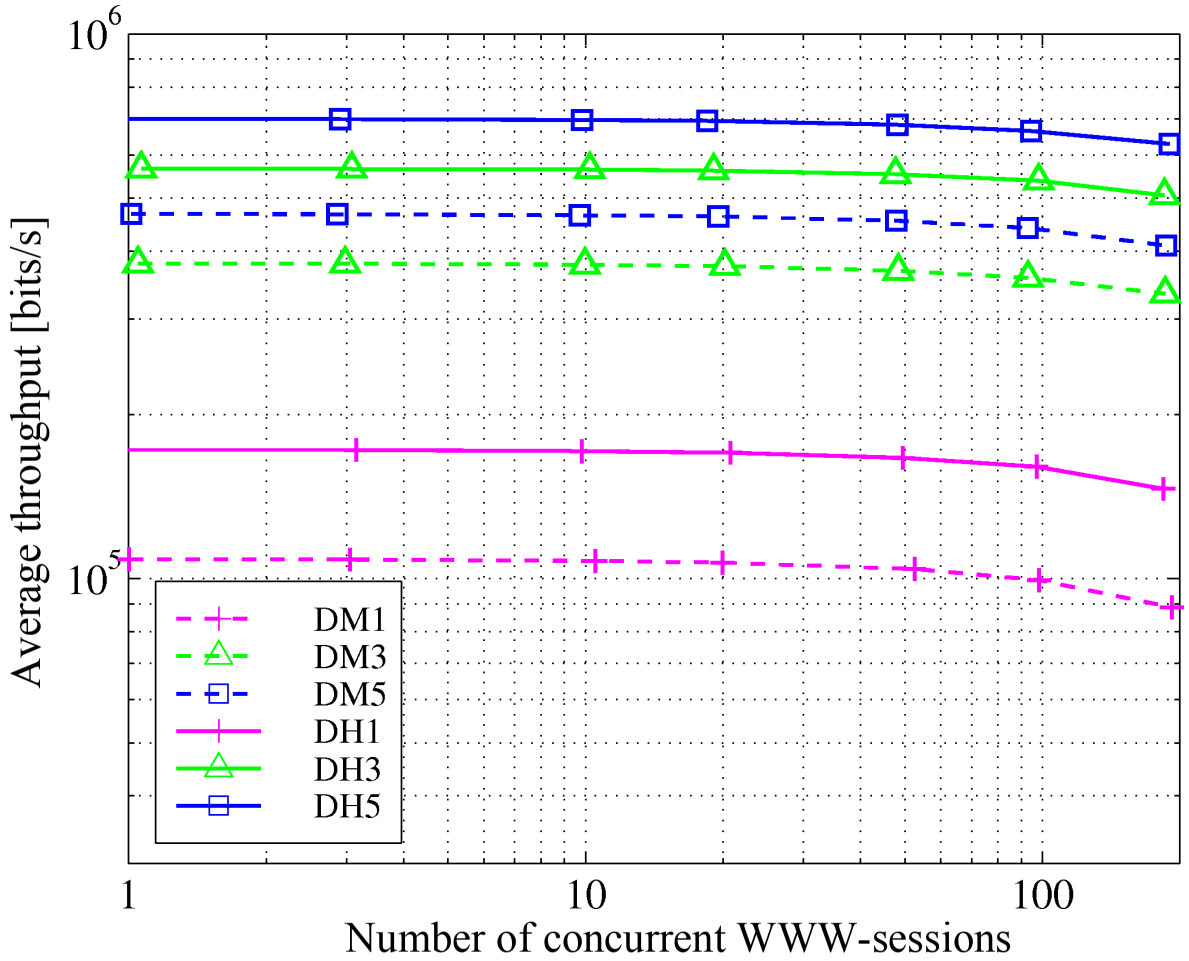

At 100 concurrent WWW-sessions only 5% throughput degradation

Performance in Case of Microwave Oven Interference

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Interference of microwave oven depends on:

- **Type (residential or commercial)**
- **Oven brand**
- **Oven load**
- **Position of the receiver towards the oven (in front of window worst radiation)**
- **Distance between receiver and oven**

Performance in Case of Microwave Oven Interference (contd)

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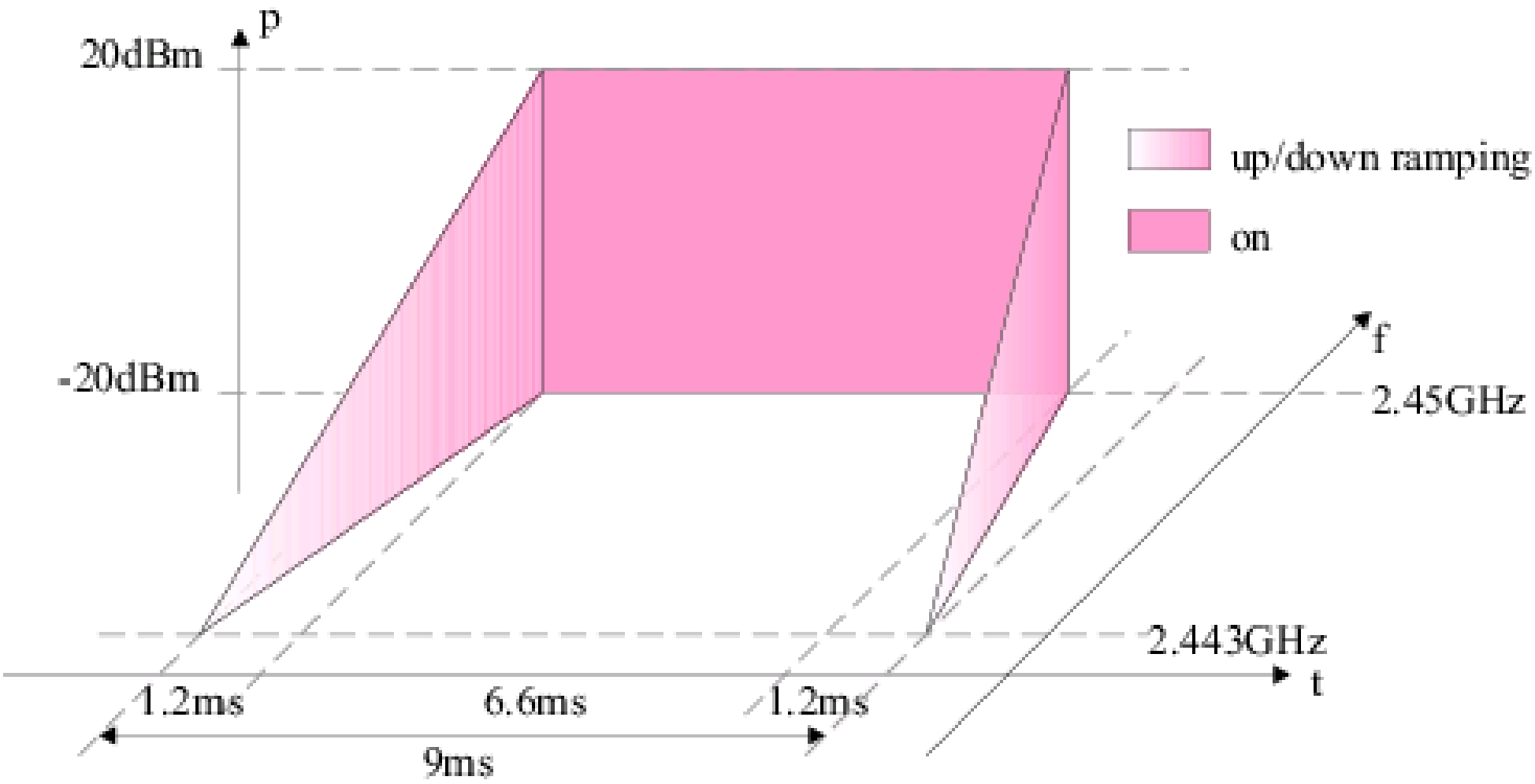

Performance in Case of Microwave Oven Interference (contd)

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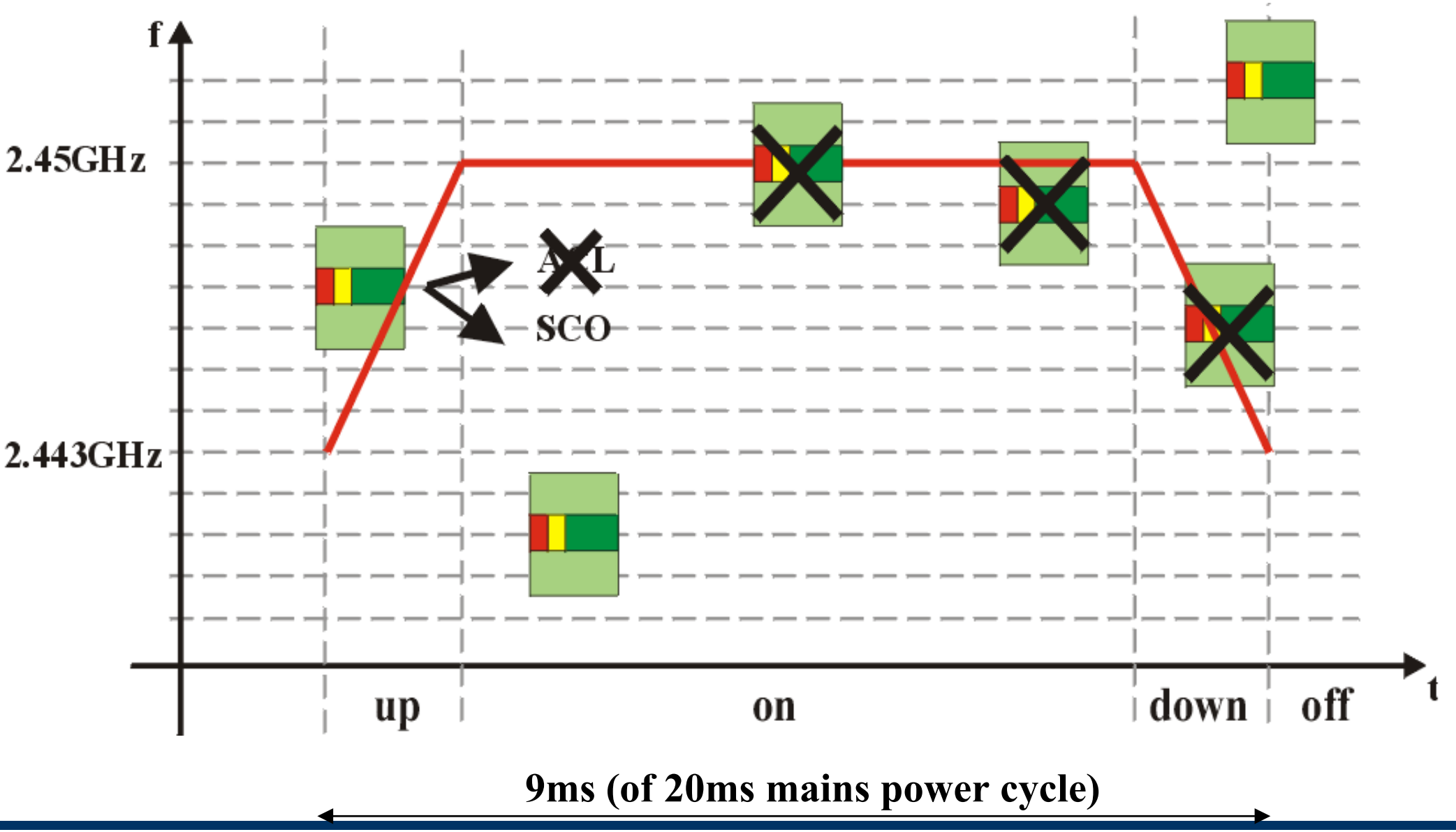

Performance in Case of Microwave Oven Interference (contd)

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Simulation Parameters:

- Distance of BT to microwave oven
- Distance between BT units

➔ As expected: The closer the Bluetooth units to each other and the further away they are from the microwave oven the better

➔ Data (ACL) transmission is uncritical

➔ Speech (SCO) transmission

- Not critical in PAN environments
- Degradations will occur only at unfavourable distance ratios
- Even then the degradation is smooth and
- Comprehensibility remains

Performance in Case of IEEE 802.11b Interference

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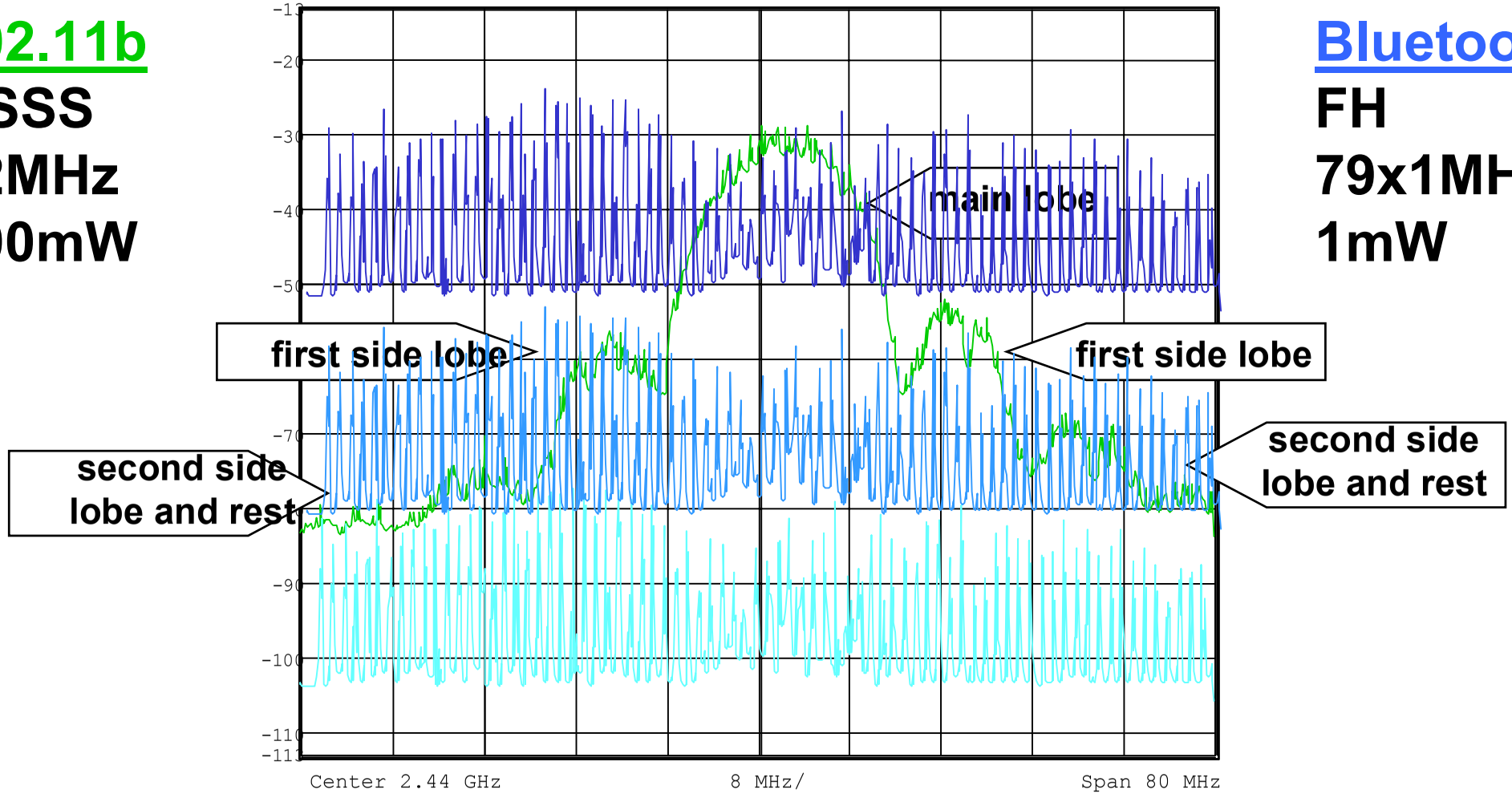
802.11b
DSSS
22MHz
100mW



Bluetooth
FH
79x1MHz
1mW

In principle overlap, actual impact (of 802.11b on BT or of BT on 802.11b) depends on location of units

Performance in Case of IEEE 802.11b Interference (contd)

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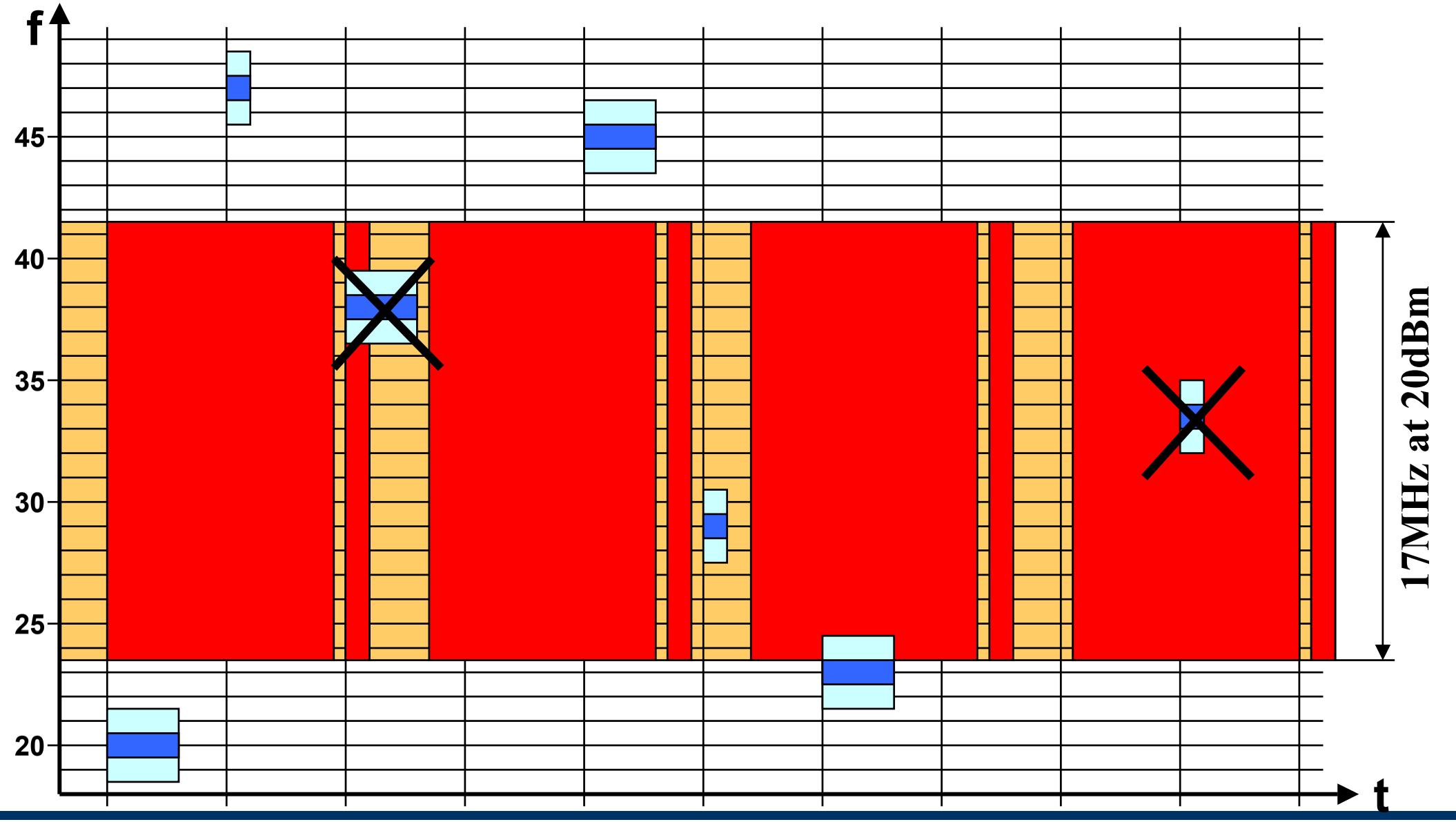

Performance in Case of IEEE 802.11b Interference (contd)

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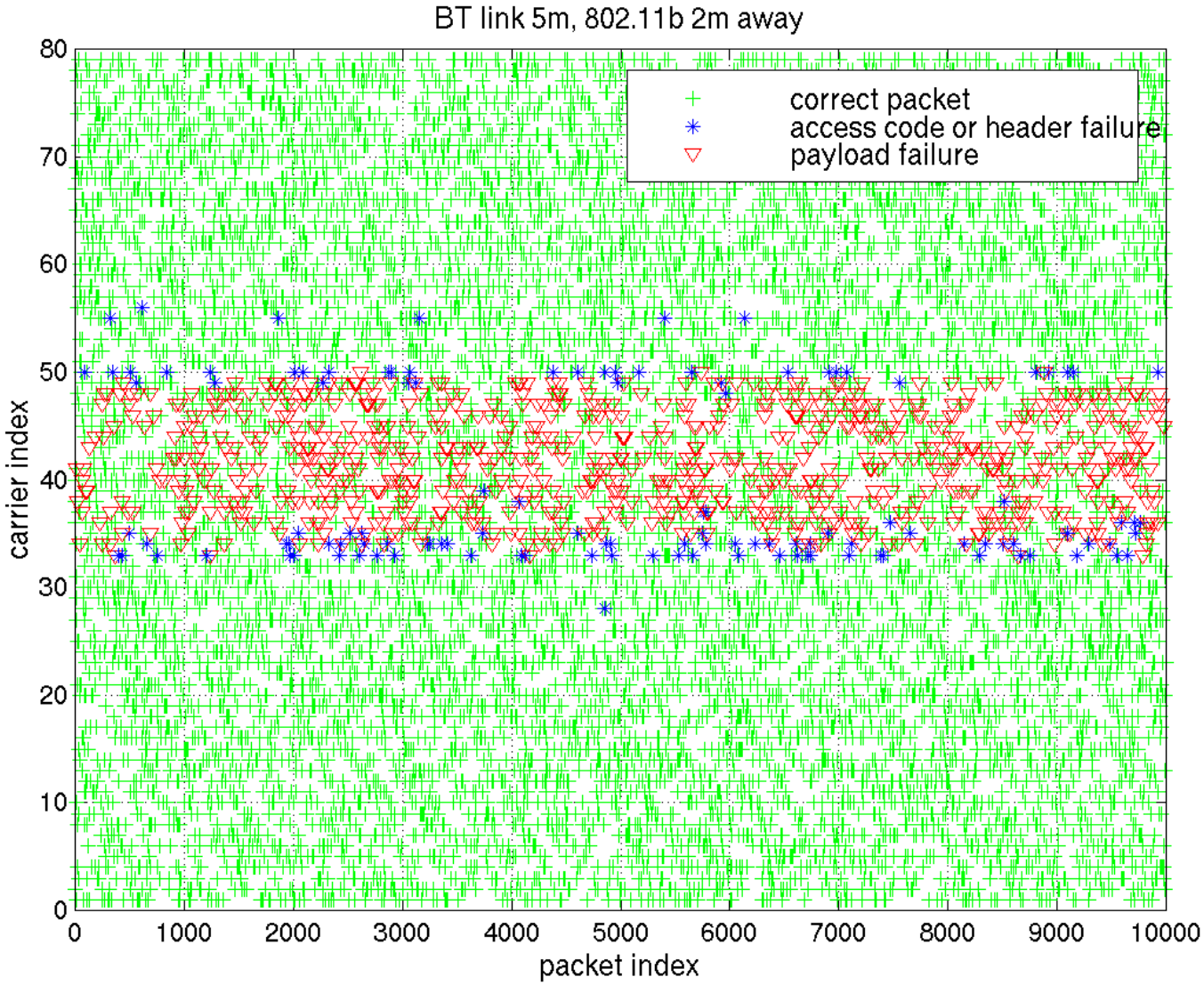

Performance in Case of IEEE 802.11b Interference (contd)

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- Voice
  - → Audible degradations unless BT-link <0.5m
- Data
  - → Up to 5m BT-link PLR always smaller than 20%
  - → PLR<10% for BT-link<2m and more than 5m distance to WLAN

Future Developments

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- **Bluetooth Specification 1.2**
  - → Improvements and additions to Spec. 1.1
  - → Adaptive Frequency Hopping
  - → Improvements of voice link
  - → QoS
  - → Further profiles (Hands-free, SIM-access etc)
- **Bluetooth Version 2.0**
  - → High rate mode with 10-fold throughput
  - → Downward compatible

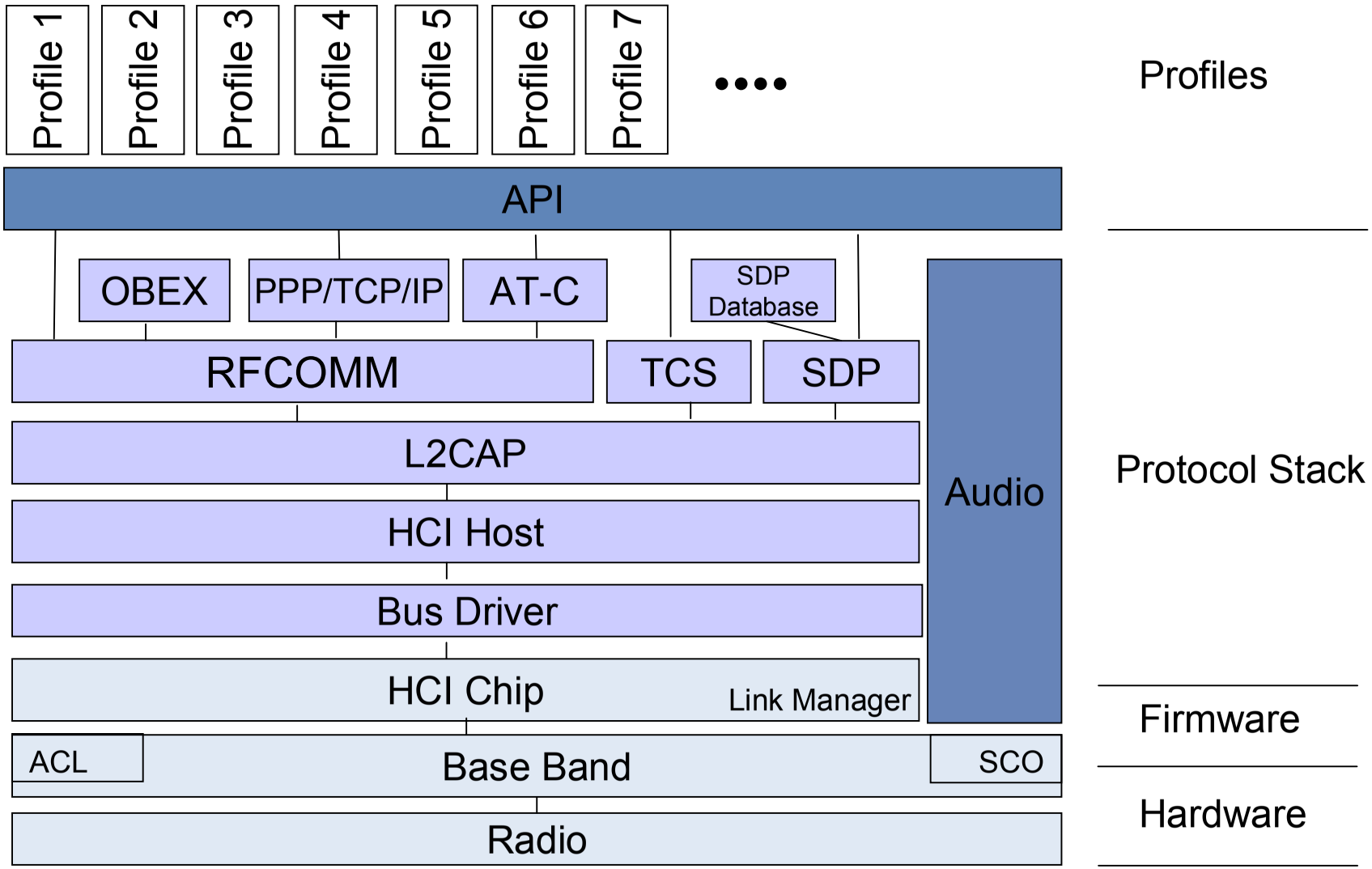
Summary

- The idea and basic principles behind Bluetooth
  - → Universal cable replacement
  - → Compatibility and world wide deployment feasable
- Master/Slave concept
- FH/TDD
- Different conceptions of speech and data quality
- Interference Robustness
  - → Bluetooth to Bluetooth
  - → Microwave oven to Bluetooth
  - → IEEE 802.11b to Bluetooth
- Future Developments

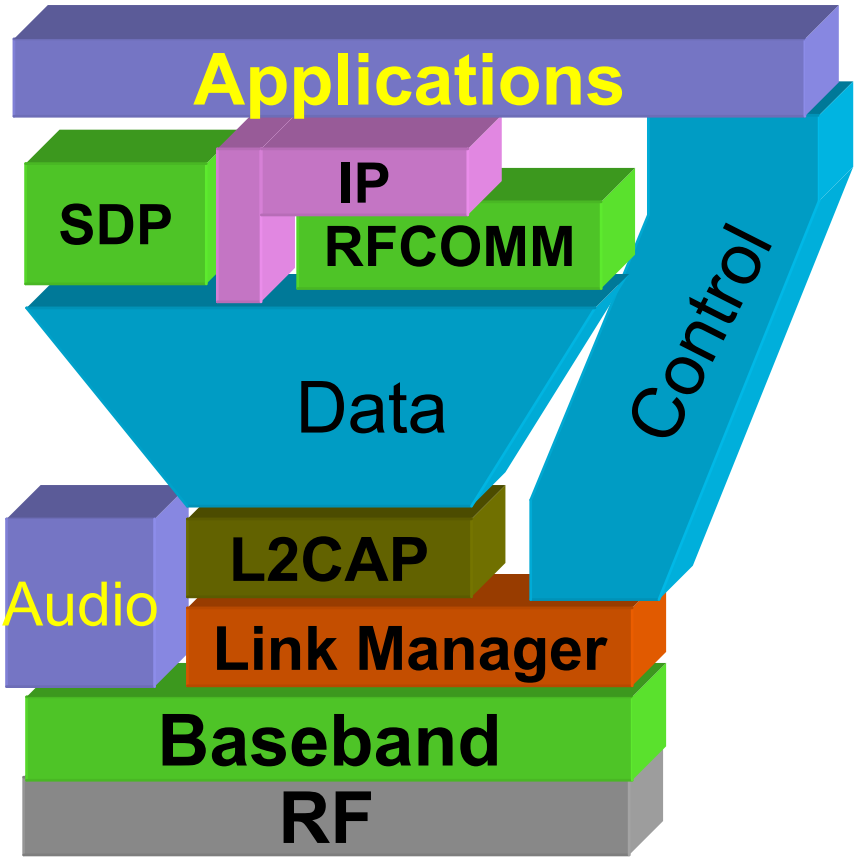
Kommunikationscharakteristika der Dienste:

Dienst	Charakteristik	Anforderung
Telefonie	**Sprachübertragung**	**64Kbit/s; isochron**
SIM Zugriff	**Signalisierung**	**Semiechtzeit**
Flashen der Steuergerät-SW	**Daten upload**	**Hohe Datensicherheit (Fehlerbehebung)**
Infotainment	**Streaming**	**Semiechtzeit**
Datenübertragung	**File Transfer**	**Hohe Datensicherheit (Fehlerbehebung)**

Bluetooth Protokolle und Profiles



System Architecture



The Radio, Baseband and Link Manager are on firmware. The higher layers could be in software. The interface is then through the Host Controller (firmware and driver)
The HCI interfaces defined for Bluetooth are UART, RS232 and USB.

Bluetooth Protocol Stack

Bluetooth defined Profiles

Profile dependencies