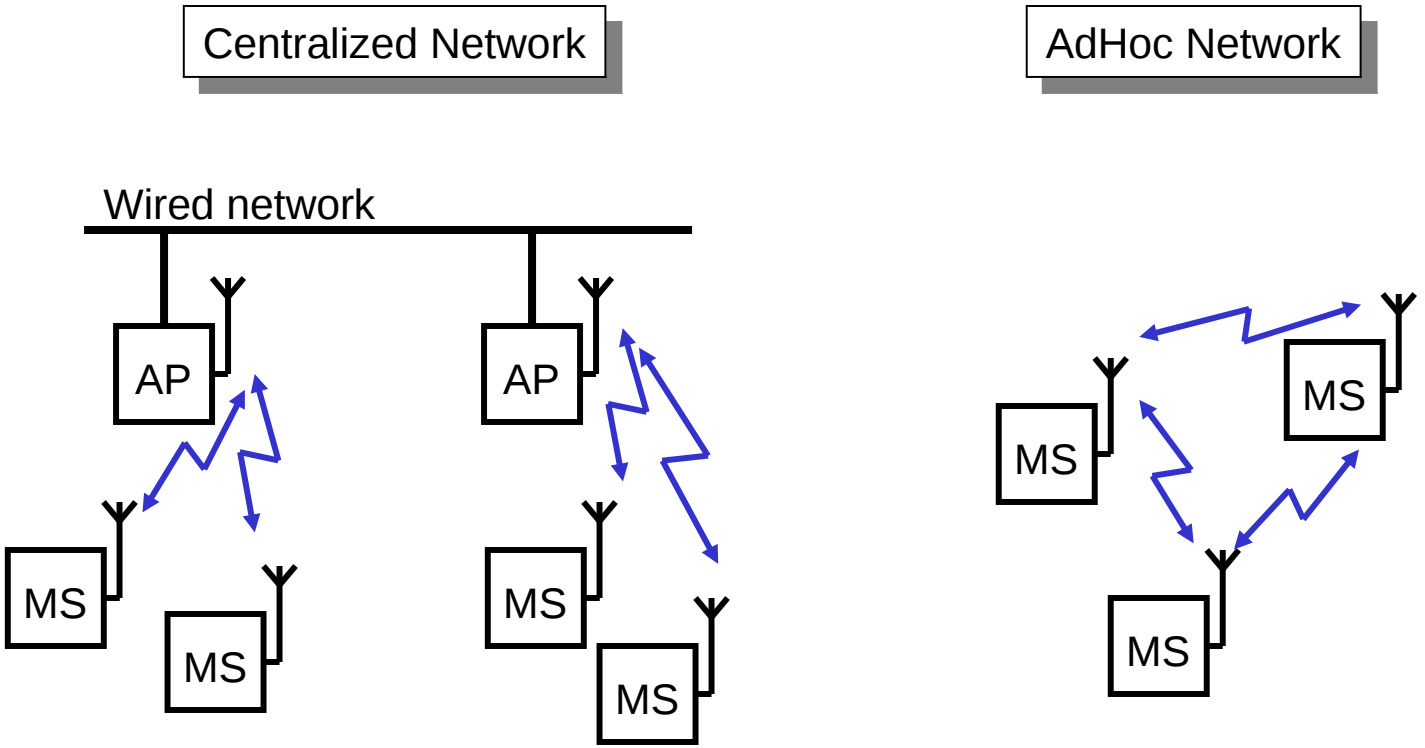
Lecture no: 12

Wireless LANs/data networks

Ove Edfors, Department of Electrical and Information Technology
Ove.Edfors@eit.lth.se

Centralized and AdHoc networks

Centralized and AdHoc Networks



Infrastructure and AdHoc Networks

- Some issues to consider:
  - Centralized networks
    - Integration with wired LAN
    - Network planning (access points)
    - Interoperability
    - Roaming and handover between access points
    - Security / authentication
    - Power management
  - AdHoc networks
    - Multi-hop and routing
    - Quality of service
    - Interoperability
    - Security / authentication
    - Power management

Error control and ARQ

Error-correcting and Error-detecting Codes

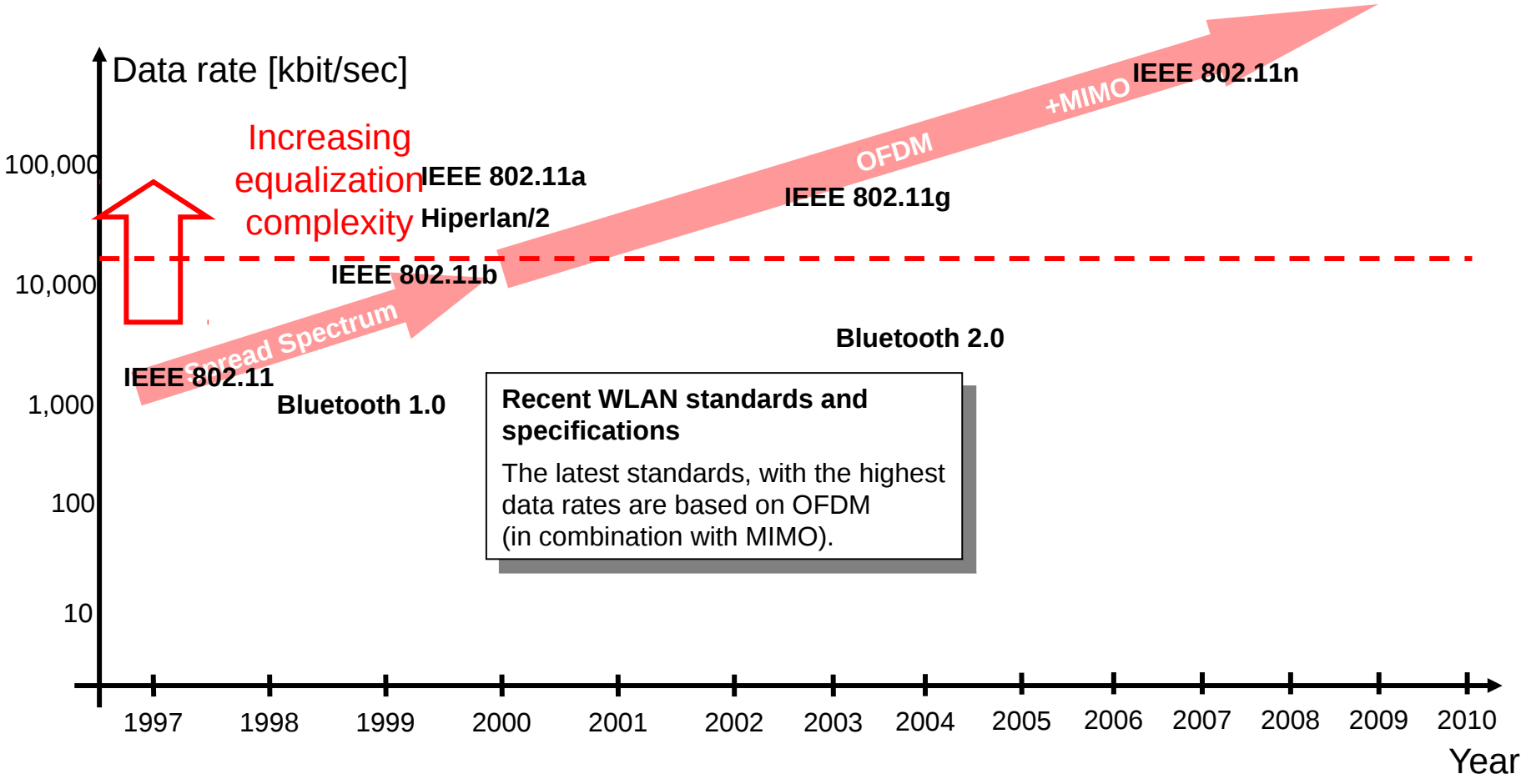
- In wireless systems we need error-correcting and error-detecting codes
- The quality of the wireless channel changes with time and we need to safeguard our data.
  - Data transmitted during a fading dip can (if the coding scheme is properly designed) be recovered by an error-correcting code.
- To reach very low error rates we need error detection to trap incorrectly decoded data.

Automatic Repeat Request (ARQ)

- Using error-detection codes we can reduce the error rate by applying an ARQ scheme.
- ARQ is usually not an option for time critical data over ‘slow’ channels, such as real-time audio and video.
- For high efficiency, ARQ schemes for wireless channels need to be more intricate than the ones used on wired channels
  - This is due to the fading nature of wireless channels

Digital transmission in WLANs

Some WLANs

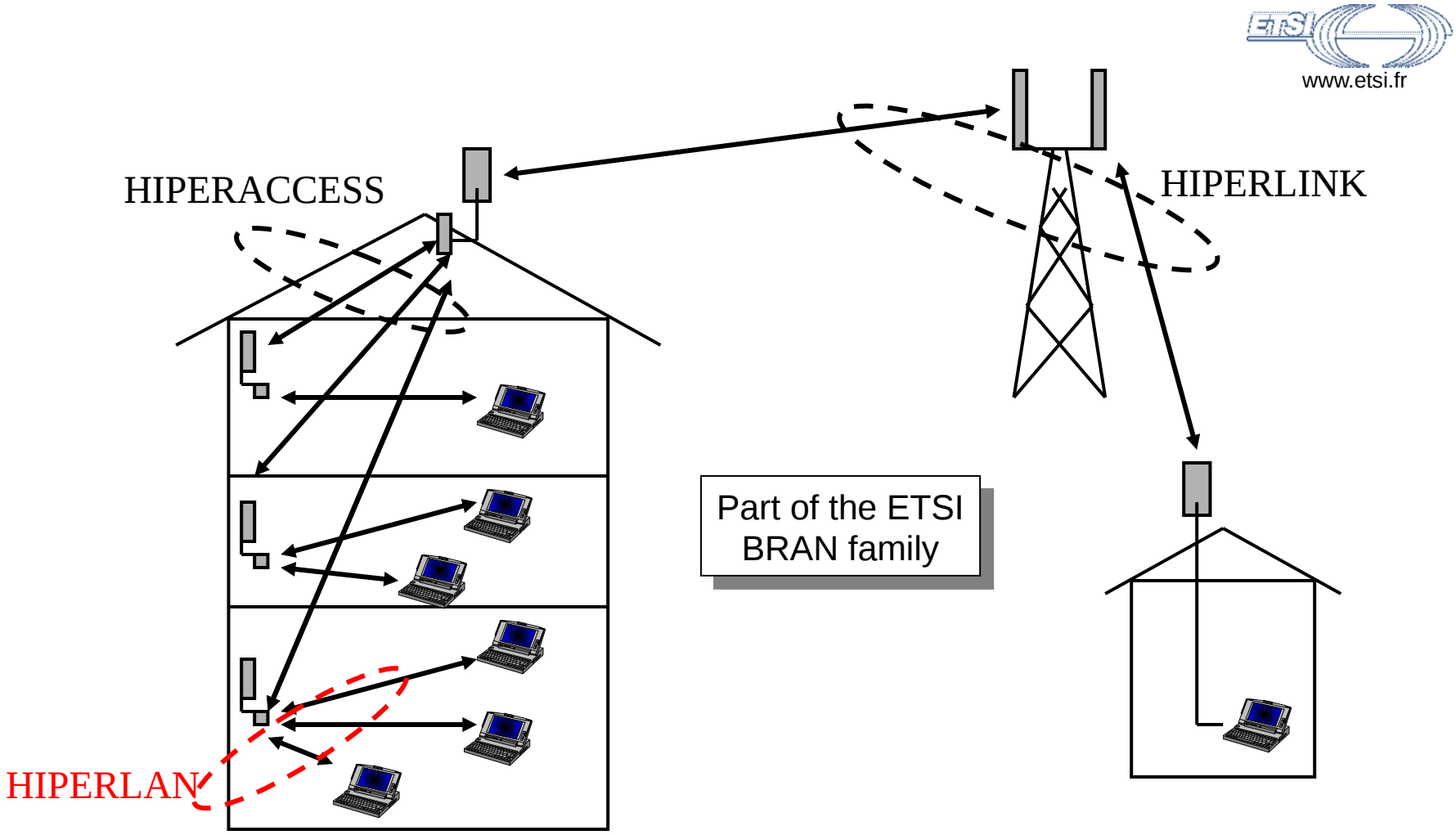

Data rate [kbit/sec]
100,000
10,000
1,000
100
10
Increasing equalization complexity
IEEE 802.11a
Hiperlan/2
IEEE 802.11b
Spread Spectrum
IEEE 802.11
Bluetooth 1.0
OFDM
+MIMO
IEEE 802.11n
IEEE 802.11g
Bluetooth 2.0
Recent WLAN standards and specifications
The latest standards, with the highest data rates are based on OFDM (in combination with MIMO).
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

Wireless LAN standards and specifications

Wireless LAN Standards and Specifications

- Some of the available standards and specifications
  - ETSI
    - HIPERLAN/2 (not used, but of historical importance)
  - IEEE
    - 802.11
    - 802.11a
    - 802.11b
    - 802.11g
    - 802.11n
  - BlueTooth SIG
    - BlueTooth

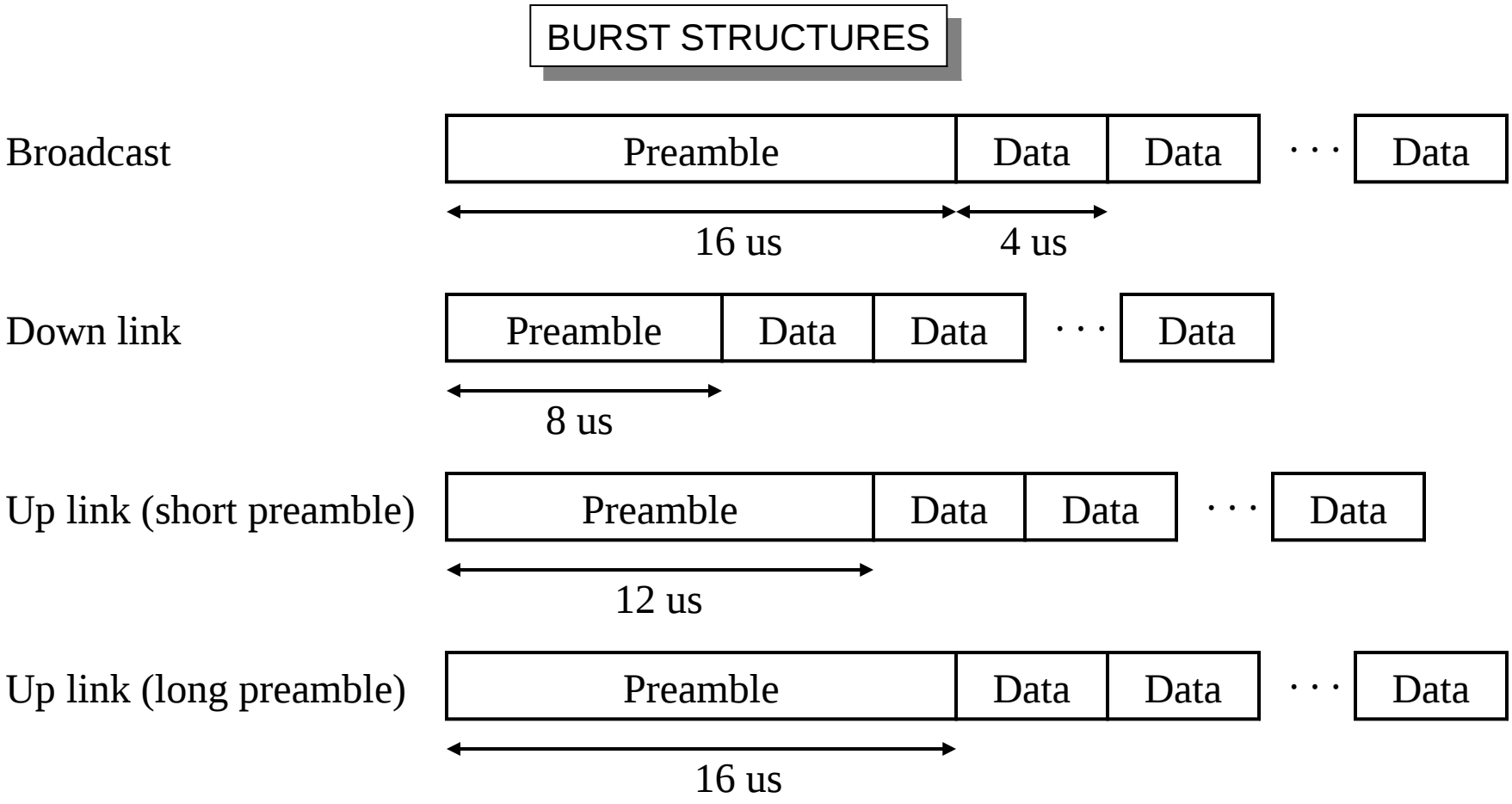
ETSI - HIPERLAN/2



ETSI - HIPERLAN/2

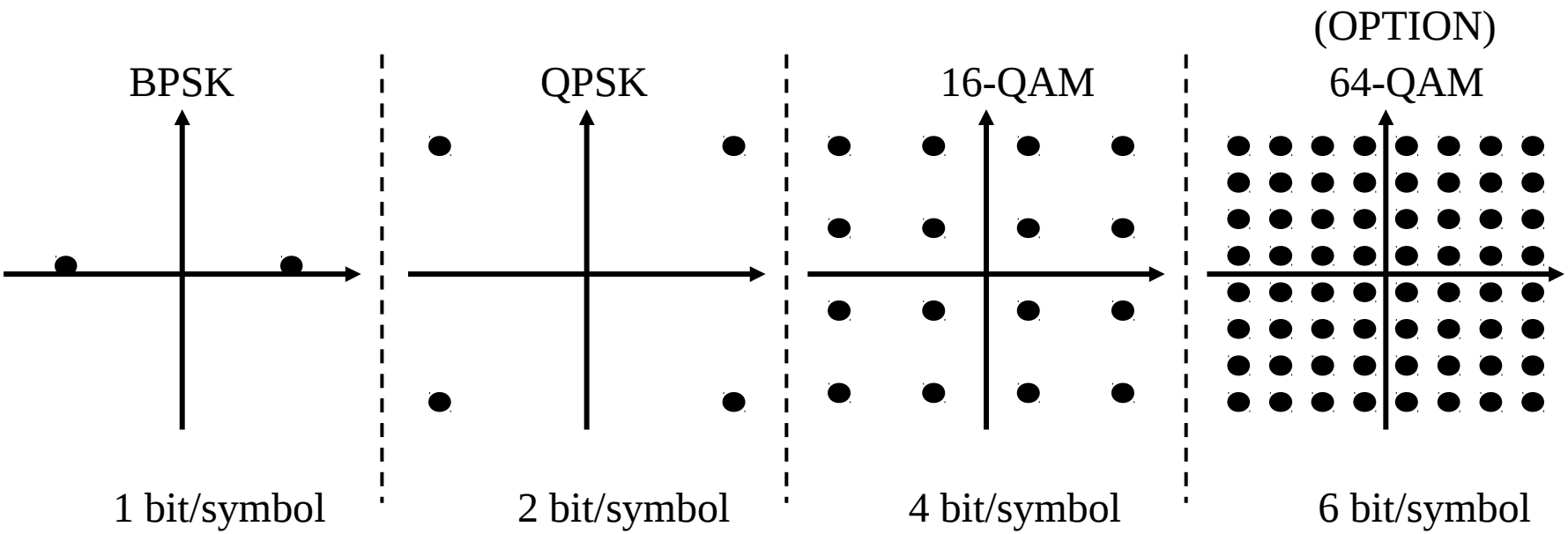
- Digital transmission
  - OFDM (multicarrier) with sampling rate 20 MHz
  - 5.150-5.350 GHz & 5.470-5.725 GHz
  - 48 data carriers + 4 pilot carriers
  - Carrier spacing 0.3125 MHz
  - Symbol length 4 us (0.8 us cyclic prefix)
  - Range < 150 m.
  - TDMA/TDD
- Syncronization
  - Broadcast (base => all). Preamble 16 us.
  - Downlink (base => terminal). Preamble 8 us.
  - Uplink (teminal => base). Short preamble 12 us and long preamble 16 us.

ETSI - HIPERLAN/2



ETSI - HIPERLAN/2

SIGNAL CONSTELLATIONS



ETSI - HIPERLAN/2

TRANSMISSION MODES

Sig.const	Code	Databit/symbol	Data rate
BPSK	1/2	24	6 Mbit/s
BPSK	3/4	36	9 Mbit/s
QPSK	1/2	48	12 Mbit/s
QPSK	3/4	72	18 Mbit/s
16QAM	9/16	108	27 Mbit/s
16QAM	3/4	144	36 Mbit/s
64QAM	3/4	216	54 Mbit/s

IEEE - 802.11

- 802.11-1997
  - PHY layer
    - diffused infrared - in baseband
    - DSSS and FHSS (50 hops/sec) in 2.4 GHz ISM band
    - 1 and 2 Mbps data rate
  - MAC layer
    - Two network architectures: Infrastructure Network and Ad-Hoc Network
    - Primary services: Data transfer, Association, Reassociation, Authentication, Privacy, and Power Management
  - MISSING
    - AP-to-AP coordination for roaming, Data frame mapping, Confomance test

www.ieee.org

IEEE - 802.11

- 802.11a-1999 (supplement to 802.11-1997)
  - New PHY (and MAC) layer for 802.11
  - 5 GHz band
  - Essentially the same physical layer (OFDM) as HIPERLAN/2
  - 6-54 Mbps data rate

- 802.11b-1999 (supplement to 802.11-1997)
  - New PHY (and MAC) layer for 802.11
  - 2.4 GHz band
  - DSSS based physical layer
  - 11 Mbps data rate

IEEE - 802.11

- 802.11g-2003 (supplement to 802.11-1997)
  - Same PHY layer as 802.11a
  - 2.4 GHz band
  - New MAC layer
  - 6-54 Mbps data rate

- 802.11n-2009
  - Up to 500 Mbit/sec
  - Proposal based on MIMO technology
  - Developed beyond 500 Mbit/sec in 802.11ac

IEEE 802.11 – a bigger family

- IEEE 802.11 - The original 1 Mbit/s and 2 Mbit/s, 2.4 GHz RF and IR standard
- IEEE 802.11a - 54 Mbit/s, 5 GHz standard (1999, shipping products in 2001)
- IEEE 802.11b - Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)
- IEEE 802.11d - international (country-to-country) roaming extensionsNew countries
- IEEE 802.11e - Enhancements: QoS, including packet bursting
- IEEE 802.11F - Inter-Access Point Protocol (IAPP)
- IEEE 802.11g - 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)
- IEEE 802.11h - 5 GHz spectrum, Dynamic Channel/Frequency Selection (DCS/DFS) and Transmit Power Control (TPC) for European compatibility
- IEEE 802.11i (ratified 24 June 2004) - Enhanced security
- IEEE 802.11j - Extensions for Japan
- IEEE 802.11k - Radio resource measurements
- IEEE 802.11n - Higher throughput improvements
- IEEE 802.11p - WAVE - Wireless Access for the Vehicular Environment (such as ambulances and passenger cars)
- IEEE 802.11r - Fast roaming
- IEEE 802.11s - Wireless mesh networking
- IEEE 802.11T - Wireless Performance Prediction (WPP) - test methods and metrics
- IEEE 802.11u - Interworking with non-802 networks (e.g., cellular)
- IEEE 802.11v - Wireless network management

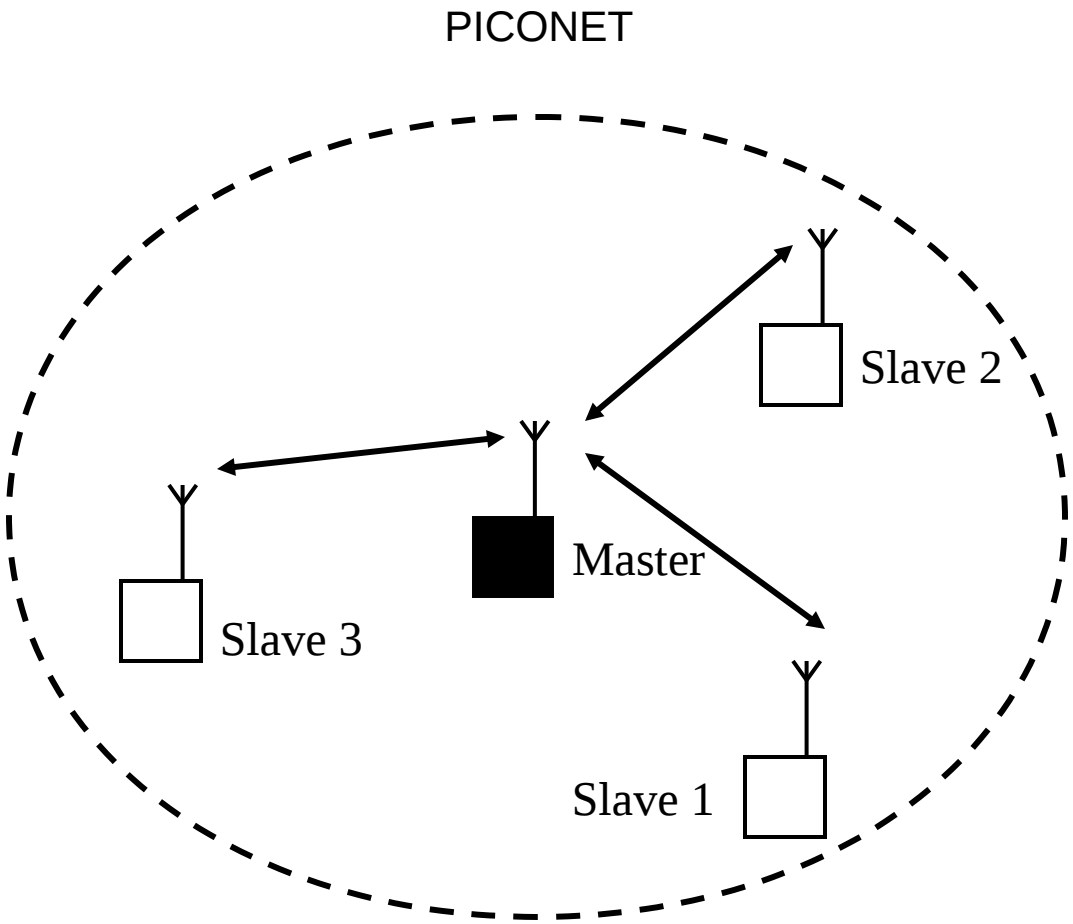
... and more!

Bluetooth Special Interest Group - Bluetooth

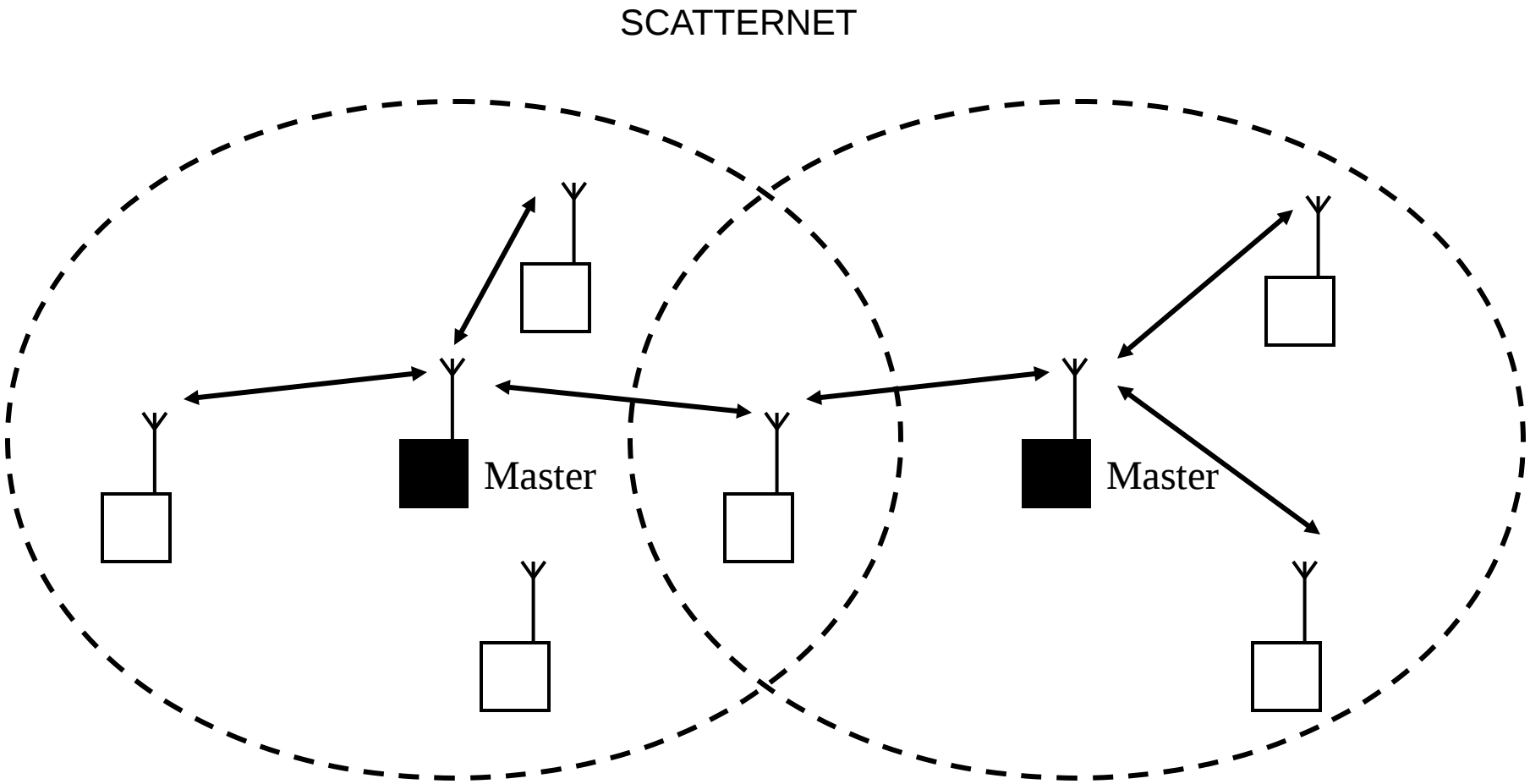
Bluetooth™
www.bluetooth.com

- FHSS in the 2.4 GHz band
  - max 1600 hops/sec (much faster than IEEE 802.11 FHSS)
  - 1 MHz channels
  - 79 frequency channels
- Modulation
  - Version 1.x
    - GFSK (BT=0.5)
    - 1 Mbps (raw)
  - Version 2.x
    - Additionally differential 4PSK and 8PSK
    - 2 & 3 Mbps
- Range
  - 10 cm -- 10 m (for Class 2)

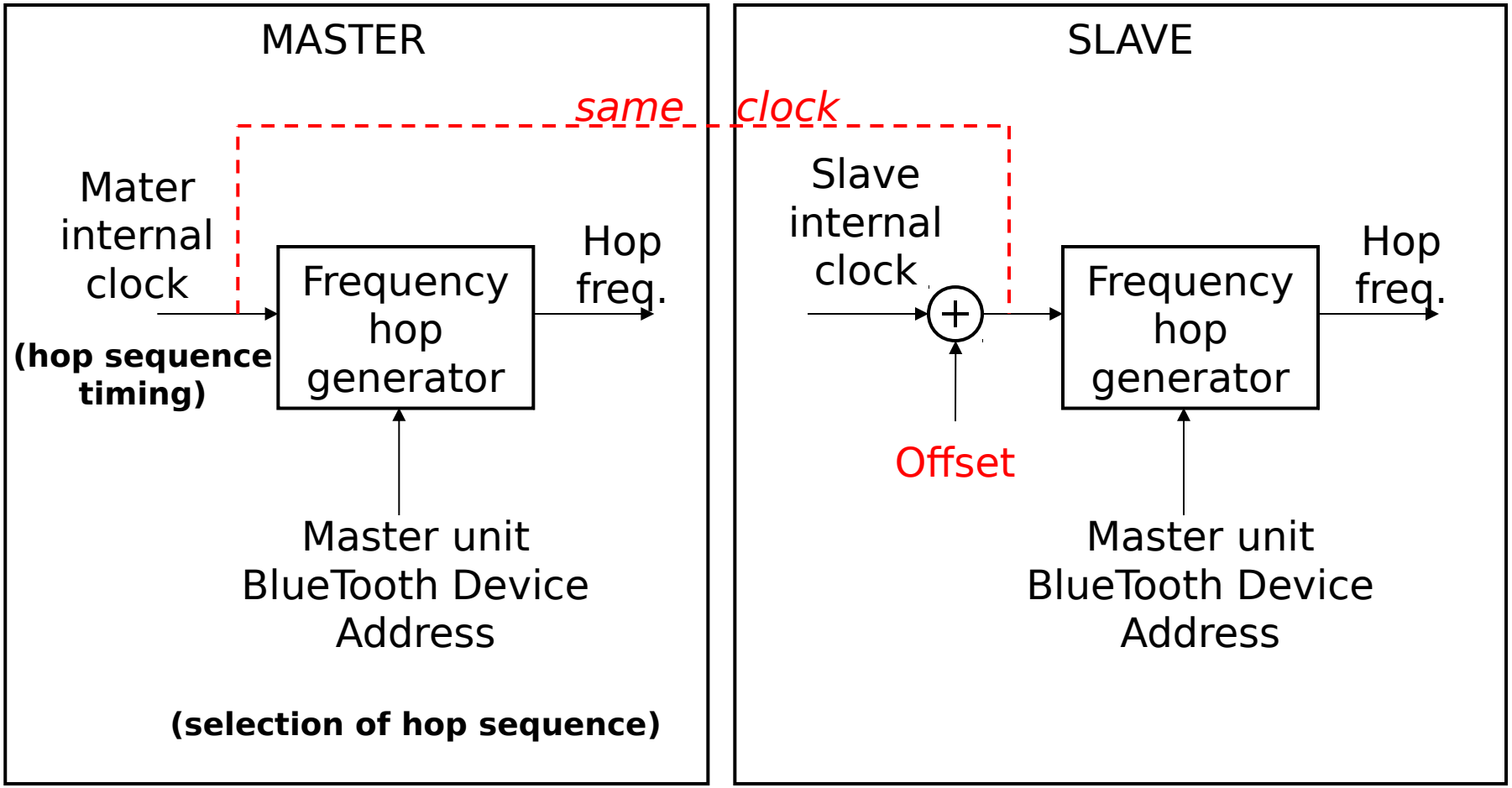
Bluetooth Special Interest Group - Bluetooth



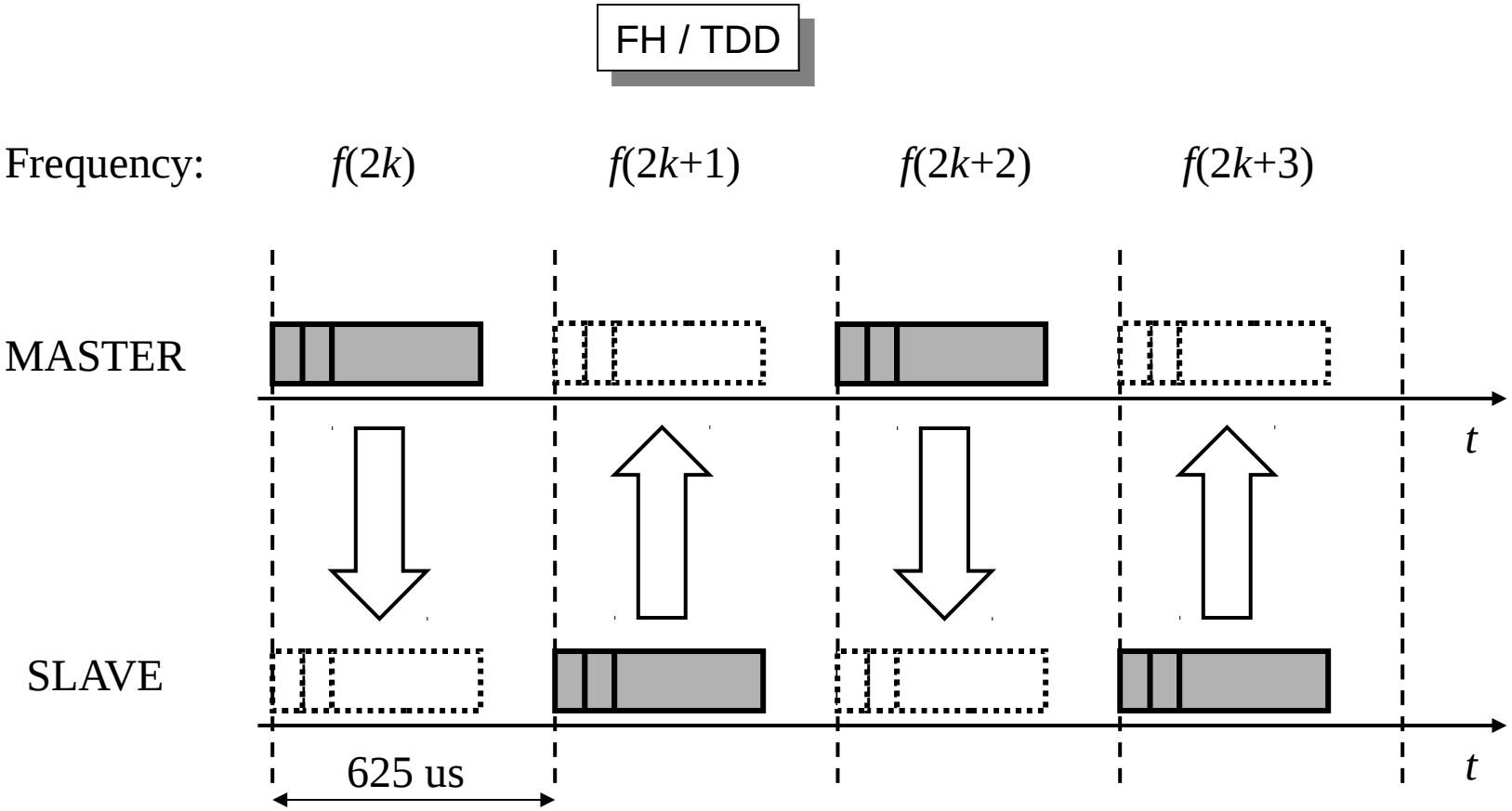
Bluetooth Special Interest Group - Bluetooth



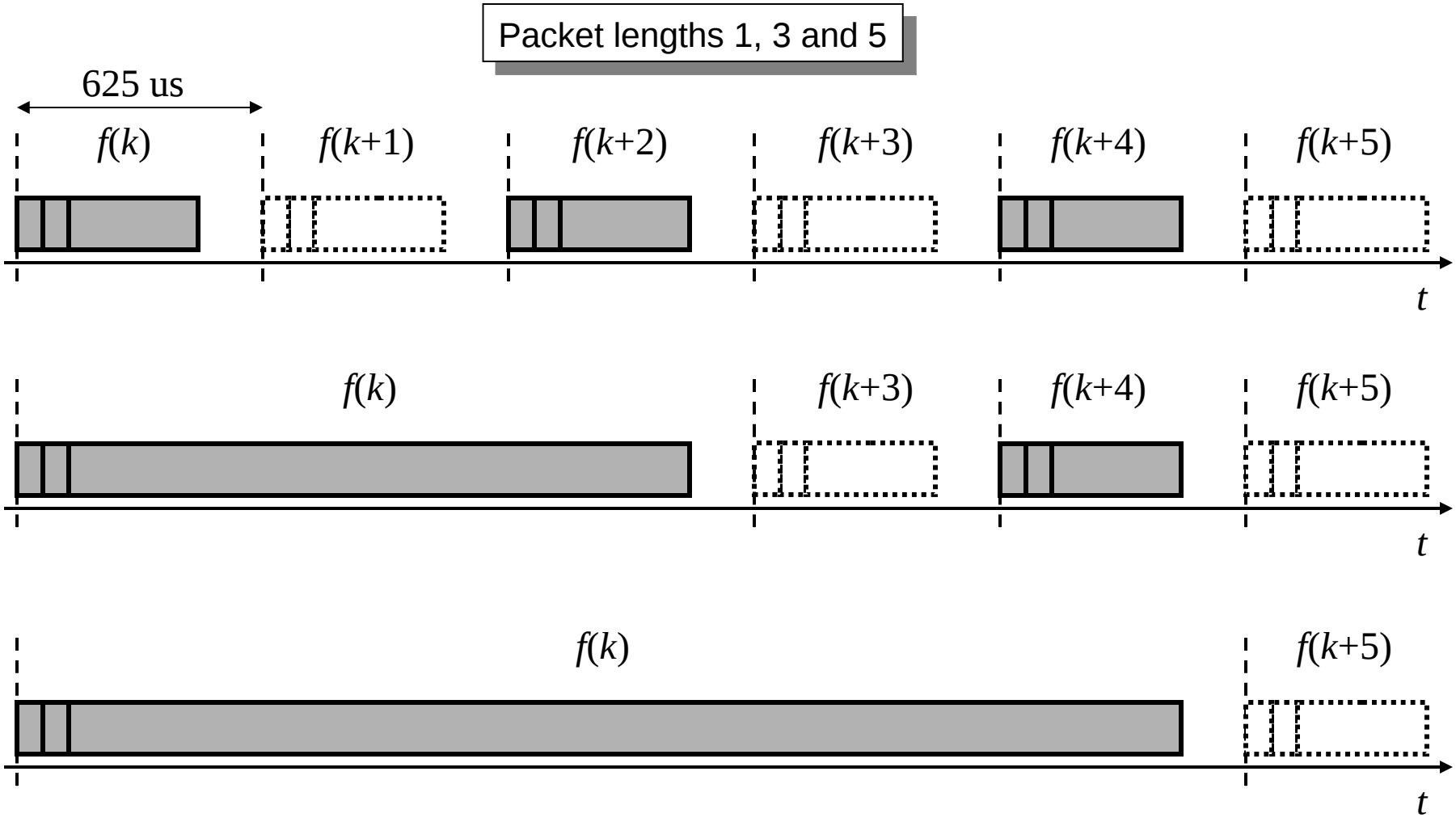
Bluetooth Special Interest Group - Bluetooth



Bluetooth Special Interest Group - Bluetooth



Bluetooth Special Interest Group - Bluetooth



Bluetooth Special Interest Group - Bluetooth

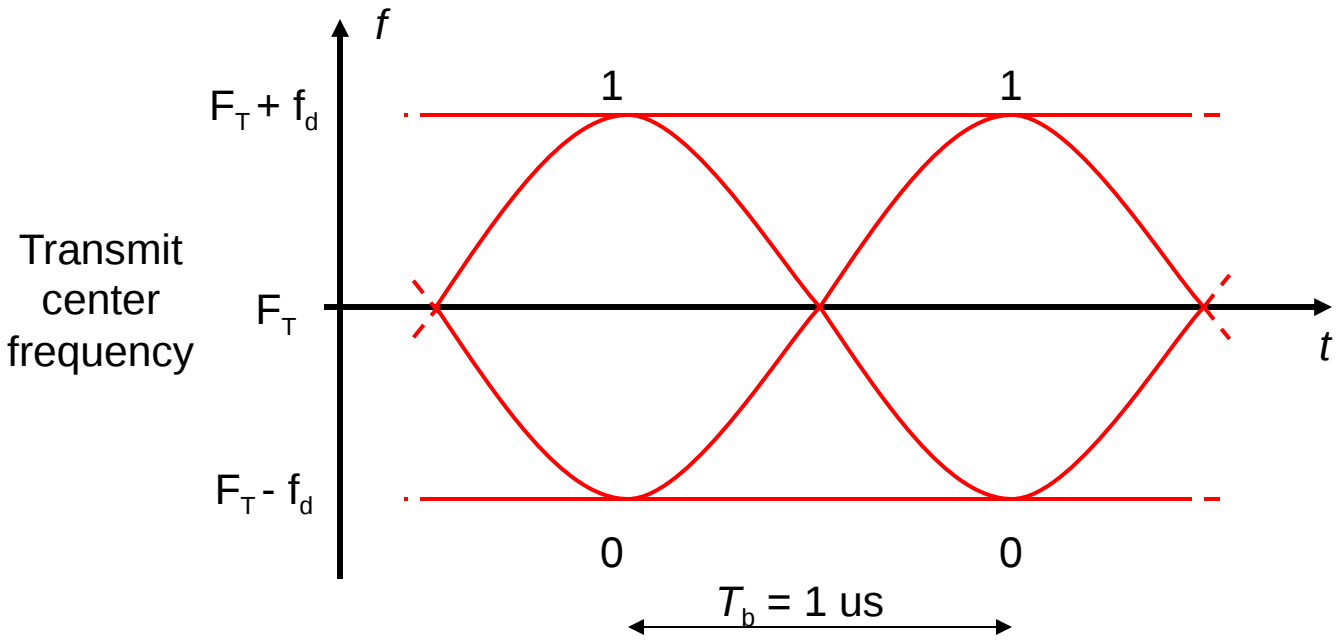
Modulation

Gaussian-filtered Frequency Shift Keying (GFSK) [c.f. GMSK]

$BT_b = 0.5$ → B = 500 kHz

Mod.index = 0.32 (+/-3%)

Bitrate 1 Mbit/sec (+/-1ppm) → f_d = 320/2 kHz = 160 kHz (+/-3%)



Bluetooth Special Interest Group - Bluetooth

- Synchronous connection oriented (SCO)
  - Synchronous transmission
  - Symmetric data rate
  - Reserved time slots
  - Intended for voice
  - No retransmission
- Asymmetric connection less (ACL)
  - Asynchronous transmission
  - Used for asymmetric communication
  - Retransmission used (Go-back-1 ARQ)

These are the basic packet types.

Bluetooth evolution

- Bluetooth has evolved to newer versions, e.g.
  - Version 2.0 + EDR
    - Main feature: (optional) higher data rate (3 Mbit/sec)
  - Version 2.1 + EDR
    - Main feature: secure simple pairing of devices
  - Version 3.0 + HS
    - Main feature: up to 24 Mbit/sec by using 802.11 MAC/PHY
  - Version 4.0 (Smart)
    - Includes classic Bluetooth, Bluetooth high speed and Bluetooth low energy (previously Wibree)

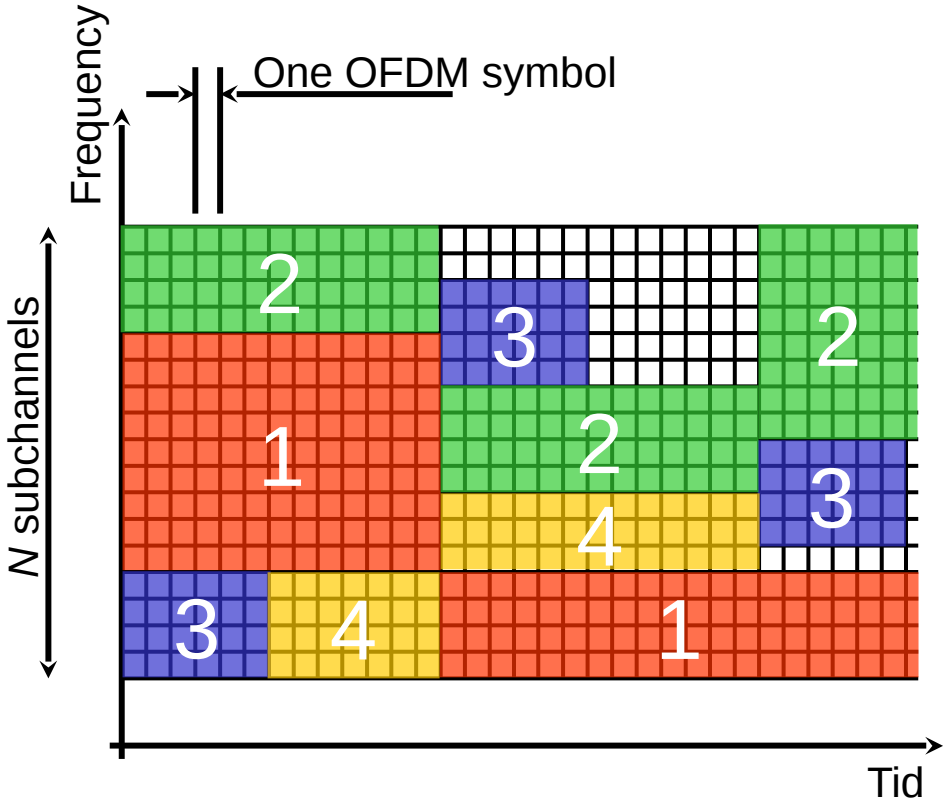
A few words about WiMAX

OFDM based multiple access

- Traditional multiple access based on sharing resources in time (TDMA), frequency (FDMA) or code (CDMA).
- The two-dimensional time-frequency grid of OFDM opens up for a more advanced sharing of the resourses.
- One such system was developed for the ETSI starndardization ”contest” in 1997 when WCDMA was adopted. Similar systems can be found in the LTE (log-term evolution) in 3GPP.
- Another variation on the theme is found in the WiMAX (IEEE802.16 systems).

OFDM based multiple access (cont.)

- In OFDM we can place transmission blocks in an arbitrary pattern in time and frequency:



Example:
Four users with different access patterns.

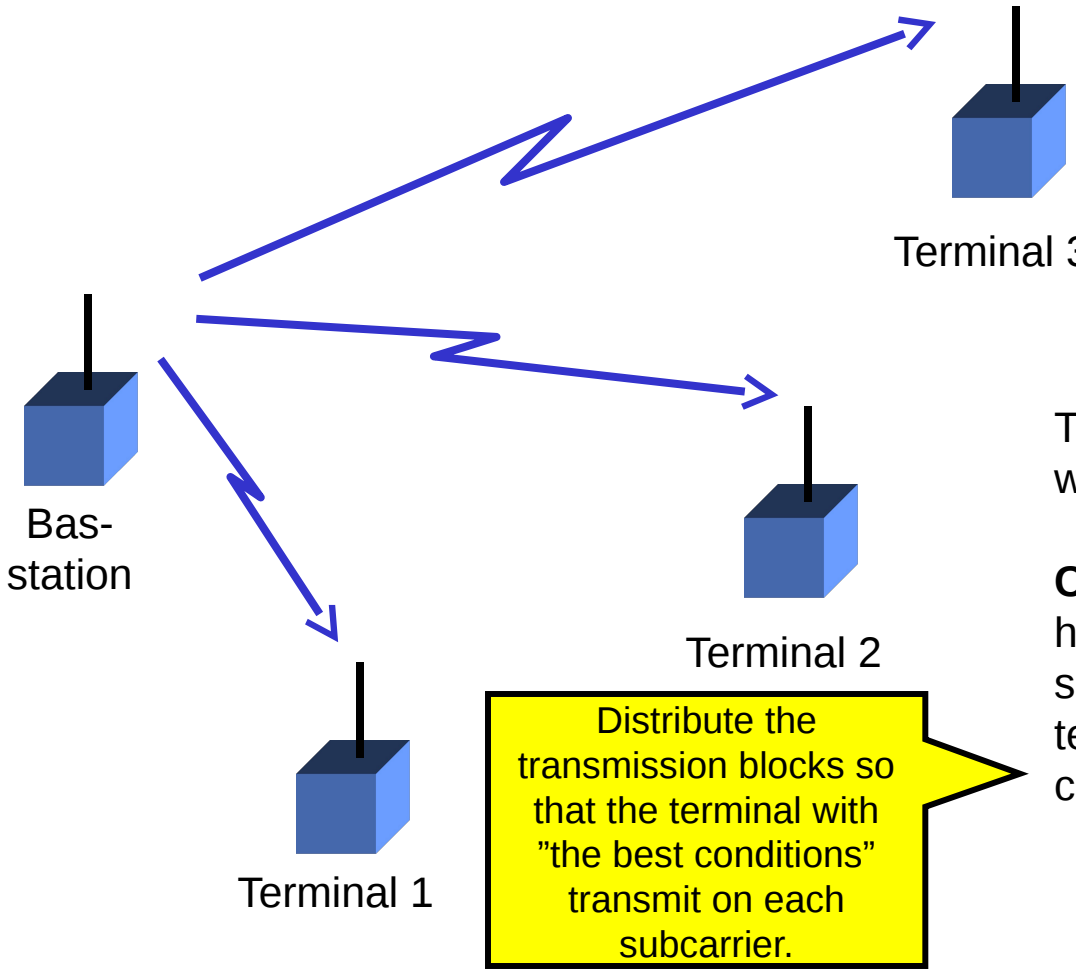
Variable data rate.

Has some similarities to CDMA, since the data rate is variable.

OFDM based multiple access (cont.)

- Pros:
  - We can get variable bandwidth/data rate by changing the transmission block sizes. (BOD – bandwidth on demand)
  - By using several smaller transmission blocks spaced in frequency we can exploit frequency diversity even at low data rates.
  - The nice orthogonality properties of OFDM can give high data rates especially in the down-link.
- Cons:
  - Difficult to use in the up-link since all terminals need to be very well synchronized if we want to maintain orthogonality.

OFDM – advanced scheduling



Terminals at different positions will have different channels.

Conclusion: If one terminal has a fading dip at a certain subcarrier, then some other terminal may have good conditions at this subcarrier.

IEEE 802.16 Wireless MAN / WiMax

www.wimaxforum.org

	802.16	802.16a HiperMAN	802.16-2004	802.16e-2005
Launched	Dec. 2001	Jan. 2003 (802.16a)	June 2004	Dec. 2005
Frequency band	10-66 GHz	< 11 GHz	< 11 GHz	< 6 GHz
Radio environment	Only LOS	Non-LOS	Non-LOS	Non-LOS and mobile
Bit rates	32-134 Mbps	<= 75 Mbps	<= 75 Mbps	<= 15 Mbps
	802.16	**802.16a HiperMAN**	**802.16-2004**	**802.16e-2005**

IEEE 802.16 Wireless MAN / WiMax

A few sOFDMA (scalable OFDMA) parameters in WiMax

Parameters	Values			
System Channel Bandwidth (MHz)	1.25	5	10	20
Sampling Frequency (F_p in MHz)	1.4	5.6	11.2	22.4
FFT Size (N_{FFT})	128	512	1024	2048
Number of Sub-Channels	2	8	16	32
Sub-Carrier Frequency Spacing	10.94 kHz			
Useful Symbol Time ($T_b = 1/f$)	91.4 microseconds			
Guard Time ($T_g = T_b/8$)	11.4 microseconds			
OFDMA Symbol Duration ($T_s = T_b + T_g$)	102.9 microseconds			
Number of OFDMA Symbols (5 ms Frame)	48			

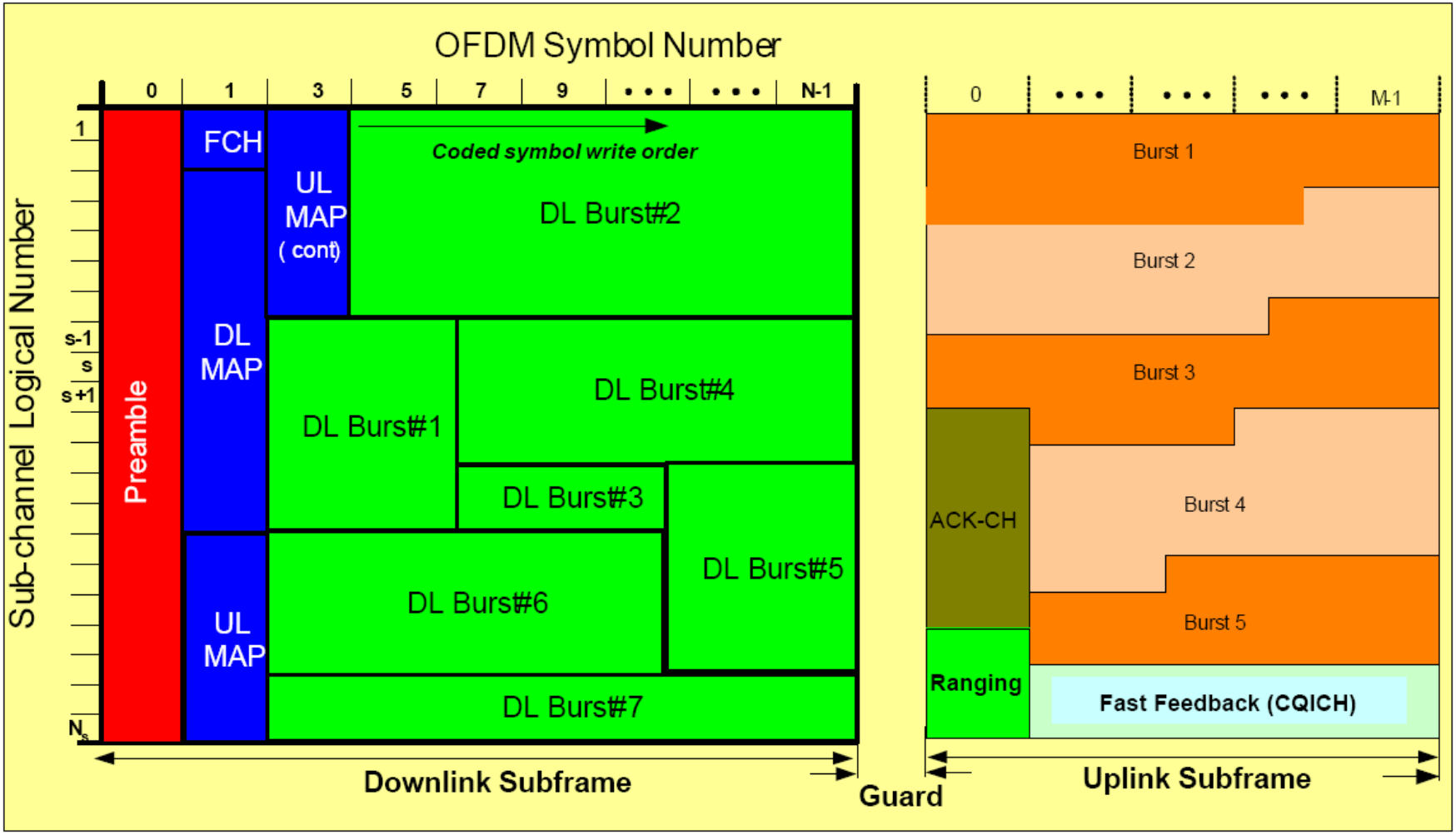
[from www.wimaxforum.org]

Scalable OFDMA means that the number of OFDM subcarriers (N_{FFT}) changes with the bandwidth so that the distance (in Hz) between subcarriers remain constant. This is favourable when implementing transmitters and receivers.

IEEE 802.16 Wireless MAN / WiMax

WiMax OFDMA frame structure

[from www.wimaxforum.org]



IEEE 802.16 Wireless MAN / WiMax

Modulation and coding

		DL	UL
Modulation		QPSK, 16QAM, 64QAM	QPSK,16QAM, *64QAM*
Code Rate	CC	1/2, 2/3, 3/4, 5/6	1/2, 2/3, *5/6*
	CTC	1/2, 2/3, 3/4, 5/6	1/2, 2/3, *5/6*
	Repetition	x2, x4, x6	x2, x4, x6

[from www.wimaxforum.org]

CC - Convolutional Code
CTC - Convolutional Turbo Code

3GPP – Long Term Evolution

LTE basic transmission principles (OFDMA) show strong similarities with WiMAX … but they are entirely different animals in many other respects.

LEARN MORE:

ETTN15 Modern Wireless Systems - LTE and Beyond