Contents

IEEE 802.16

The standard IEEE 802.16 defines the air interface, including the MAC layer and multiple PHY layer options, for fixed Broadband Wireless Access (BWA) systems to be used in a Wireless Metropolitan Area Network (WMAN) for residential and enterprise use. IEEE 802.16 is also often referred to as WiMax. The WiMax Forum strives to ensure interoperability between different 802.16 implementations - a difficult task due to the large number of options in the standard.

IEEE 802.16 cannot be used in a mobile environment. For this purpose, IEEE 802.16e is being developed. This standard will compete with the IEEE 802.20 standard (still in early phase).

IEEE 802.16 standardization

The first version of the IEEE 802.16 standard was completed in 2001. It defined a single carrier (SC) physical layer for line-of-sight (LOS) transmission in the 10-66 GHz range.

IEEE 802.16a defined three physical layer options (SC, OFDM, and OFDMA) for the 2-11 GHz range.

IEEE 802.16c contained upgrades for the 10-66 GHz range.

IEEE 802.16d contained upgrades for the 2-11 GHz range.

In 2004, the original 802.16 standard, 16a, 16c and 16d were combined into the massive IEEE 802.16-2004 standard.

Uplink / downlink separation

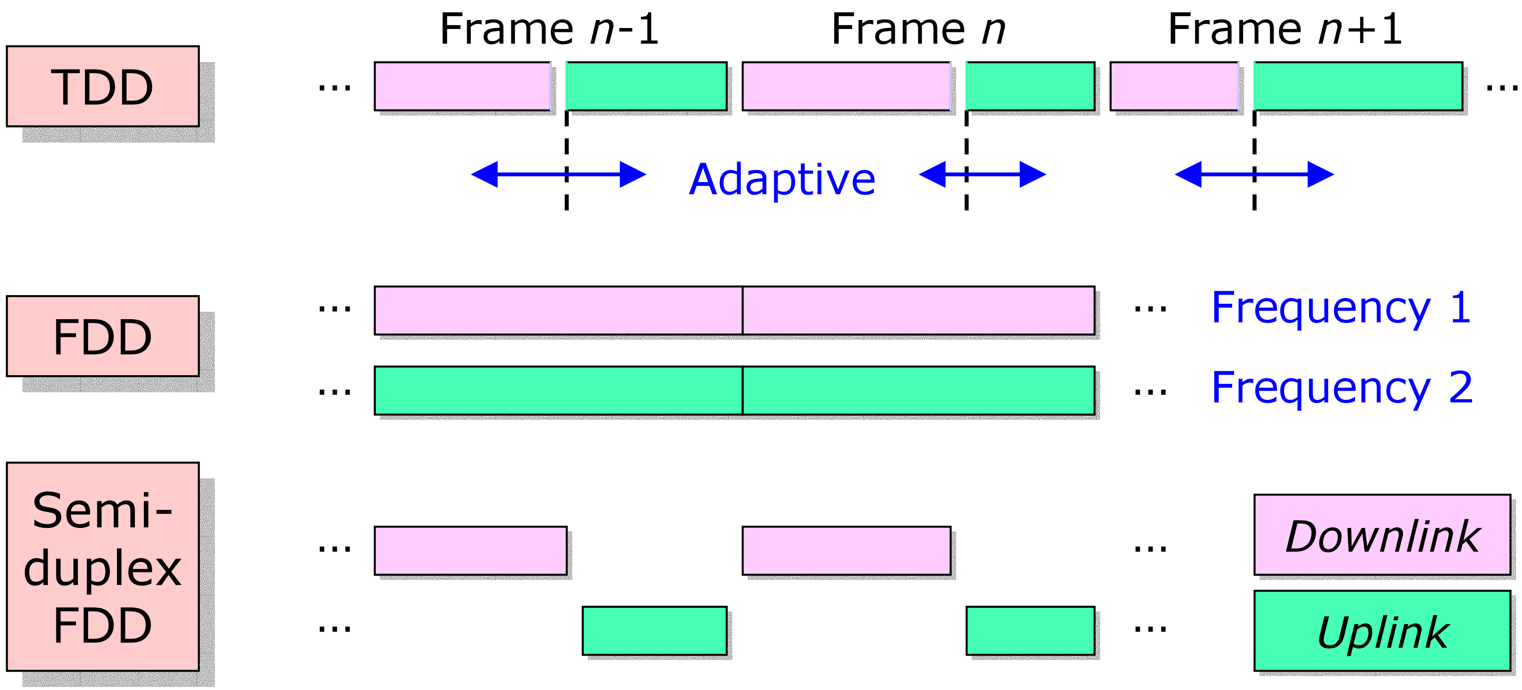
IEEE 802.16 offers both TDD (Time Division Duplexing) and FDD (Frequency Division Duplexing) alternatives.

Wireless devices should avoid transmitting and receiving at the same time, since duplex filters increase the cost:

- TDD: this problem is automatically avoided
- FDD: IEEE 802.16 offers semi-duplex operation as an option in Subscriber Stations.

(Note that expensive duplex filters are also the reason why IEEE 802.11 WLAN technology is based on CSMA/CA instead of CSMA/CD.)

Uplink / downlink separation

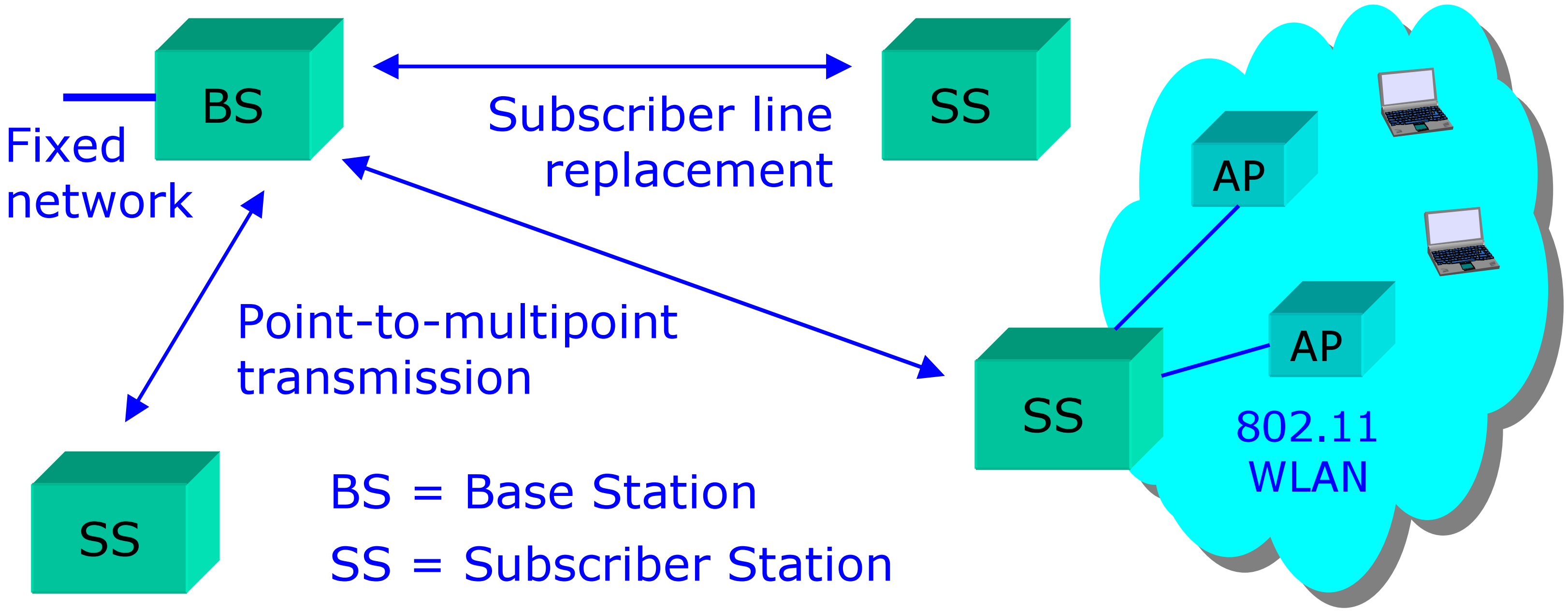


IEEE 802.16 PHY

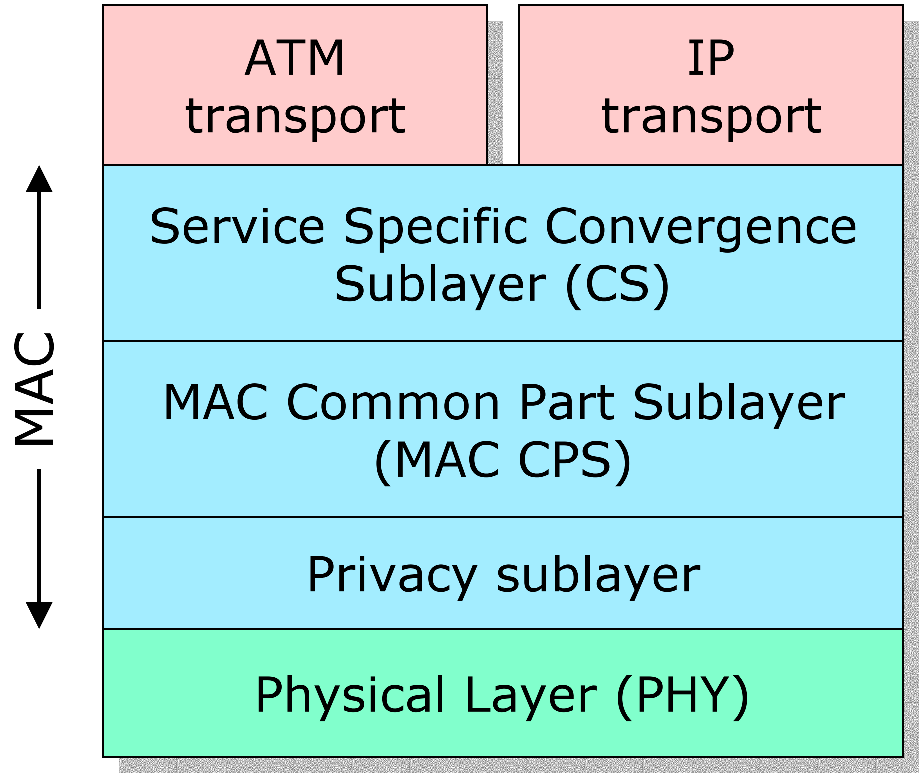
IEEE 802.16-2004 specifies three PHY options for the 2-11 GHz band, all supporting both TDD and FDD:

- WirelessMAN-SCa (single carrier option), intended for a line-of-sight (LOS) radio environment where multipath propagation is not a problem
- WirelessMAN-OFDM with 256 subcarriers (mandatory for license-exempt bands) will be the most popular option in the near future
- WirelessMAN-OFDMA with 2048 subcarriers separates users in the uplink in frequency domain (complex technology).

IEEE 802.16 basic architecture



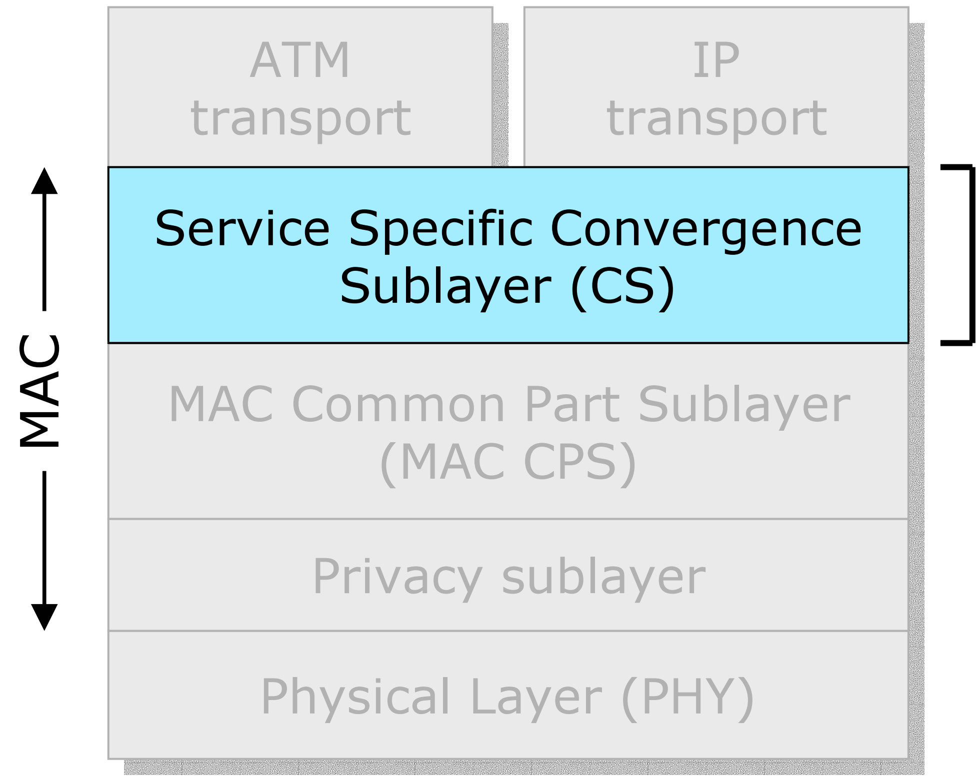
IEEE 802.16 protocol layering



Like IEEE 802.11, IEEE 802.16 specifies the Medium Access Control (MAC) and PHY layers of the wireless transmission system.

The IEEE 802.16 MAC layer consists of three sublayers.

IEEE 802.16 protocol layering

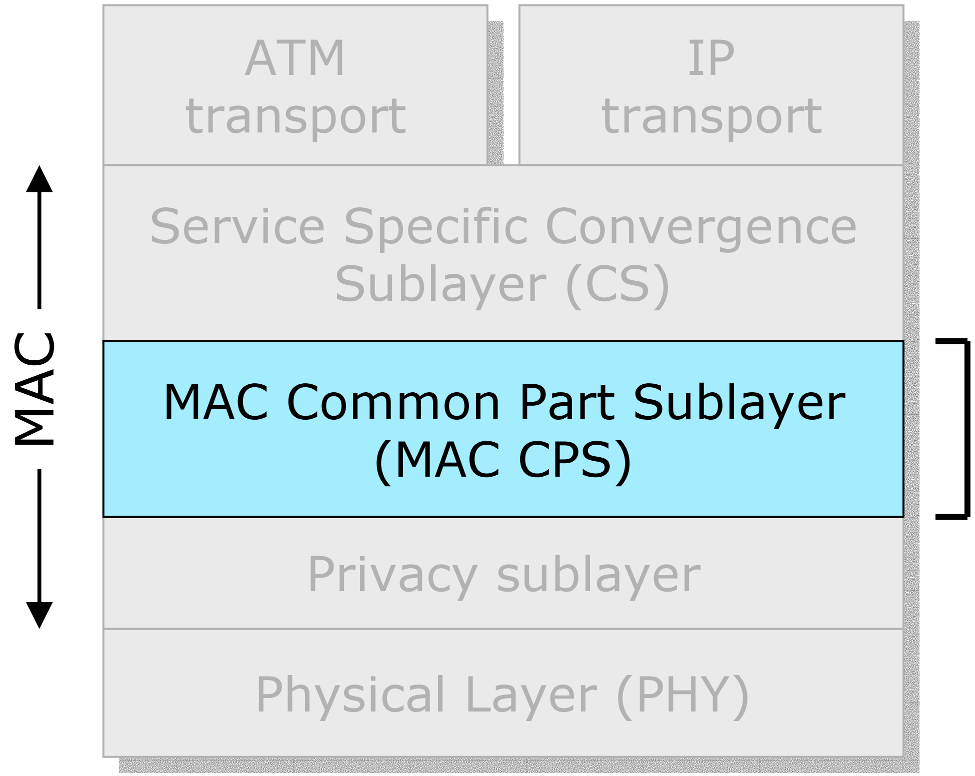


CS adapts higher layer protocols to MAC CPS.

CS maps data (ATM cells or IP packets) to a certain unidirectional connection identified by the Connection Identifier (CID) and associated with a certain QoS.

May also offer payload header suppression.

IEEE 802.16 protocol layering

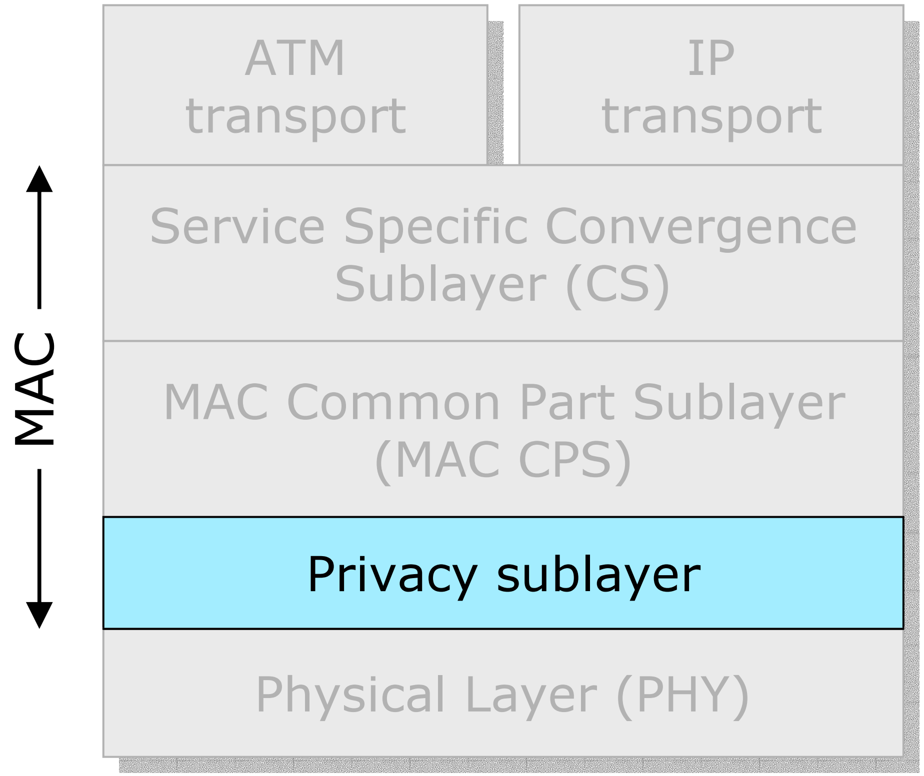


MAC CPS provides the core MAC functionality:

- System access
- Bandwidth allocation
- Connection control

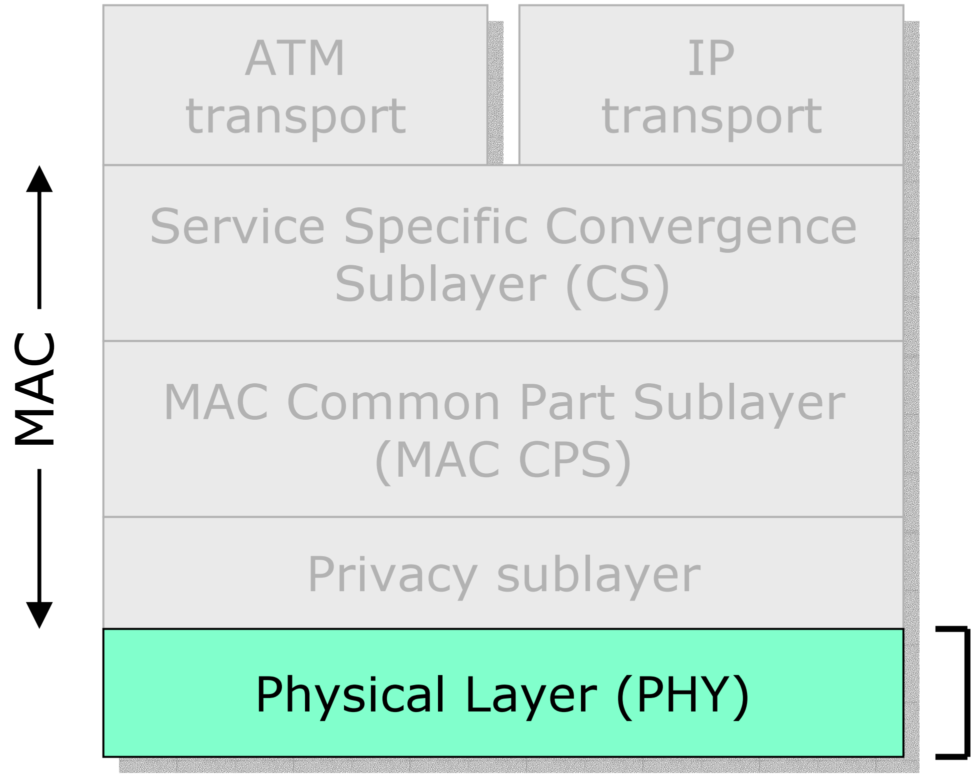
Note: QoS control is applied dynamically to every connection individually.

IEEE 802.16 protocol layering



The privacy sublayer provides authentication, key management and encryption.

IEEE 802.16 protocol layering



IEEE 802.16 offers three PHY options for the 2-11 GHz band:

- WirelessMAN-SCa
- WirelessMAN-OFDM
- WirelessMAN-OFDMA

WiMAX

The WiMax (Worldwide Interoperability for Microwave Access) certification program of the WiMax Forum addresses compatibility of IEEE 802.16 equipment

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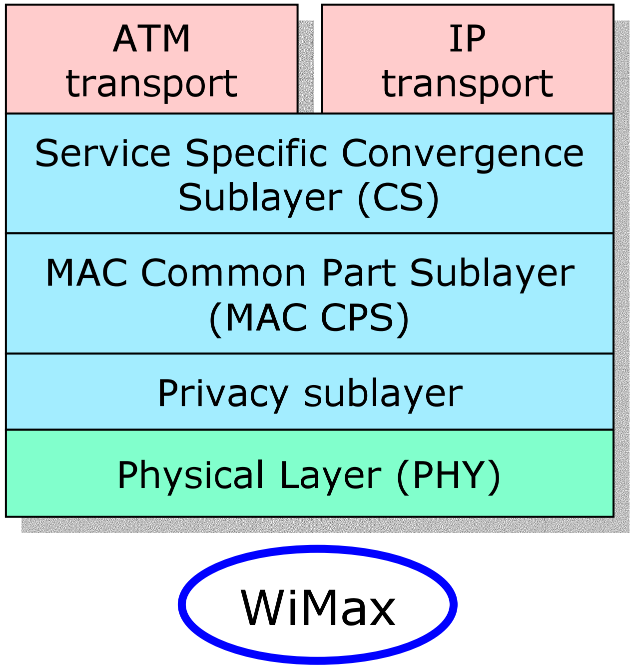
WiMax ensures interoperability of equipment from different vendors.



Overall TDD frame structure (1)

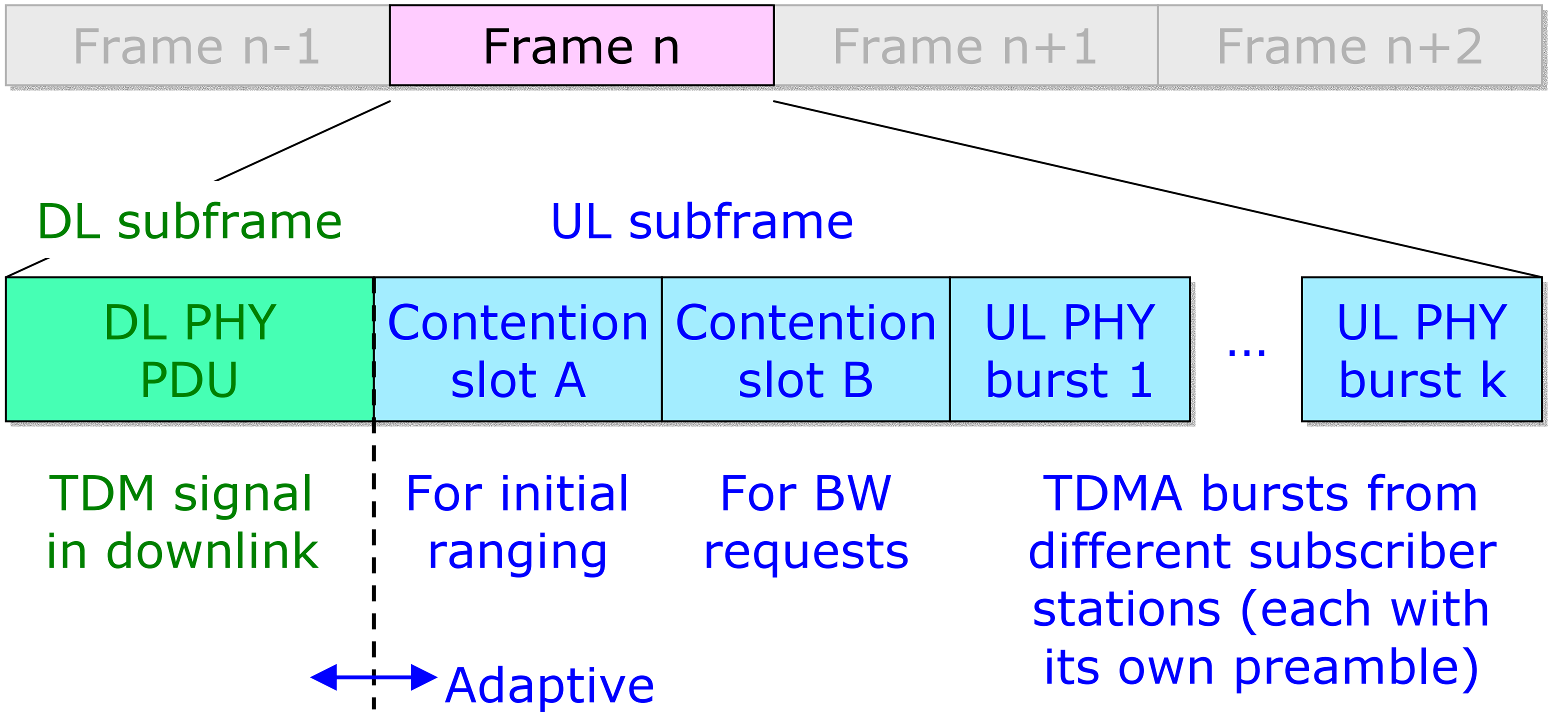
The following slides present the overall IEEE 802.16 frame structure for TDD.

It is assumed that the PHY option is WirelessMAN-OFDM, since this presumably will be the most popular PHY option (in the near future). The general frame structure is applicable also to other PHY options, but the details may be different.

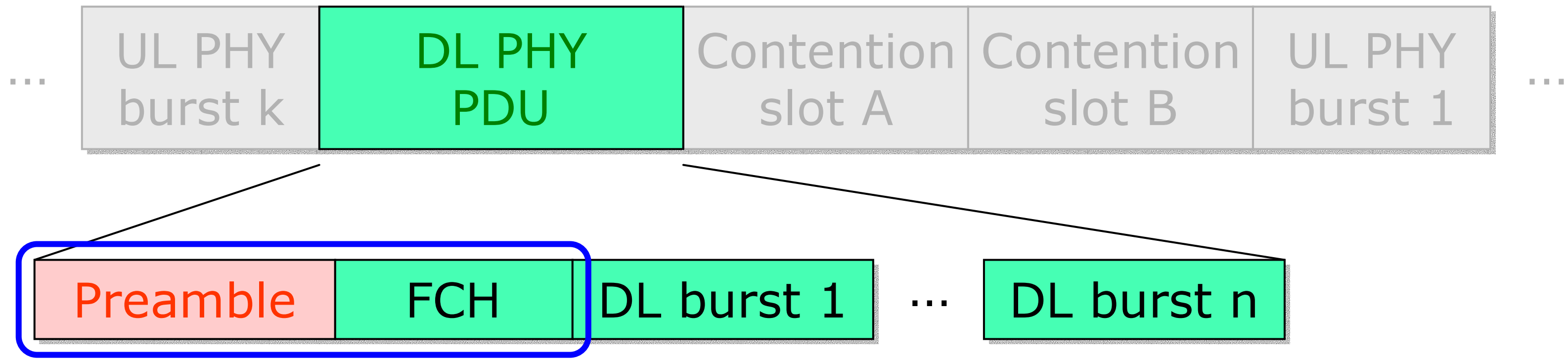
Frame n-1	Frame n	Frame n+1	Frame n+2

Frame length 0.5, 1 or 2 ms

Overall TDD frame structure (2)

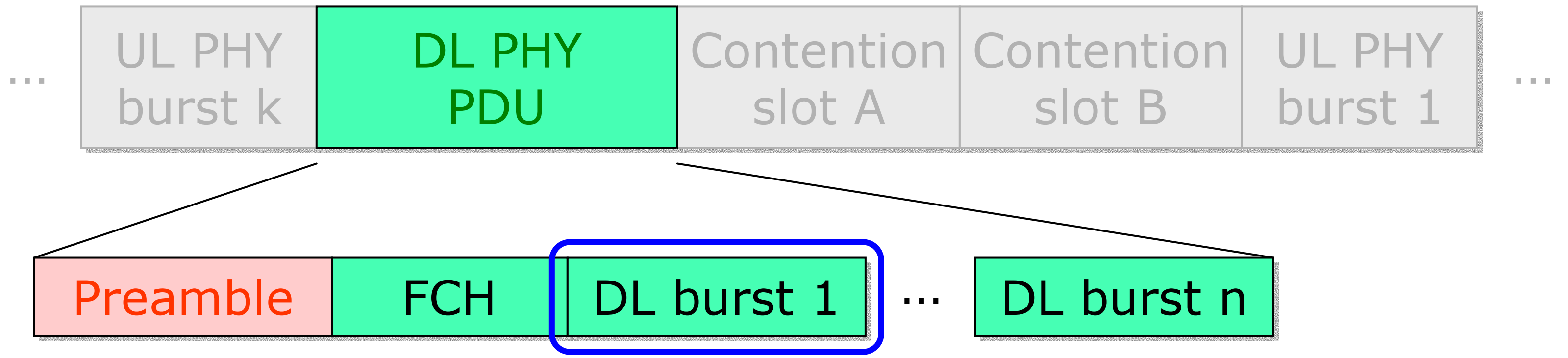


DL subframe structure (1)



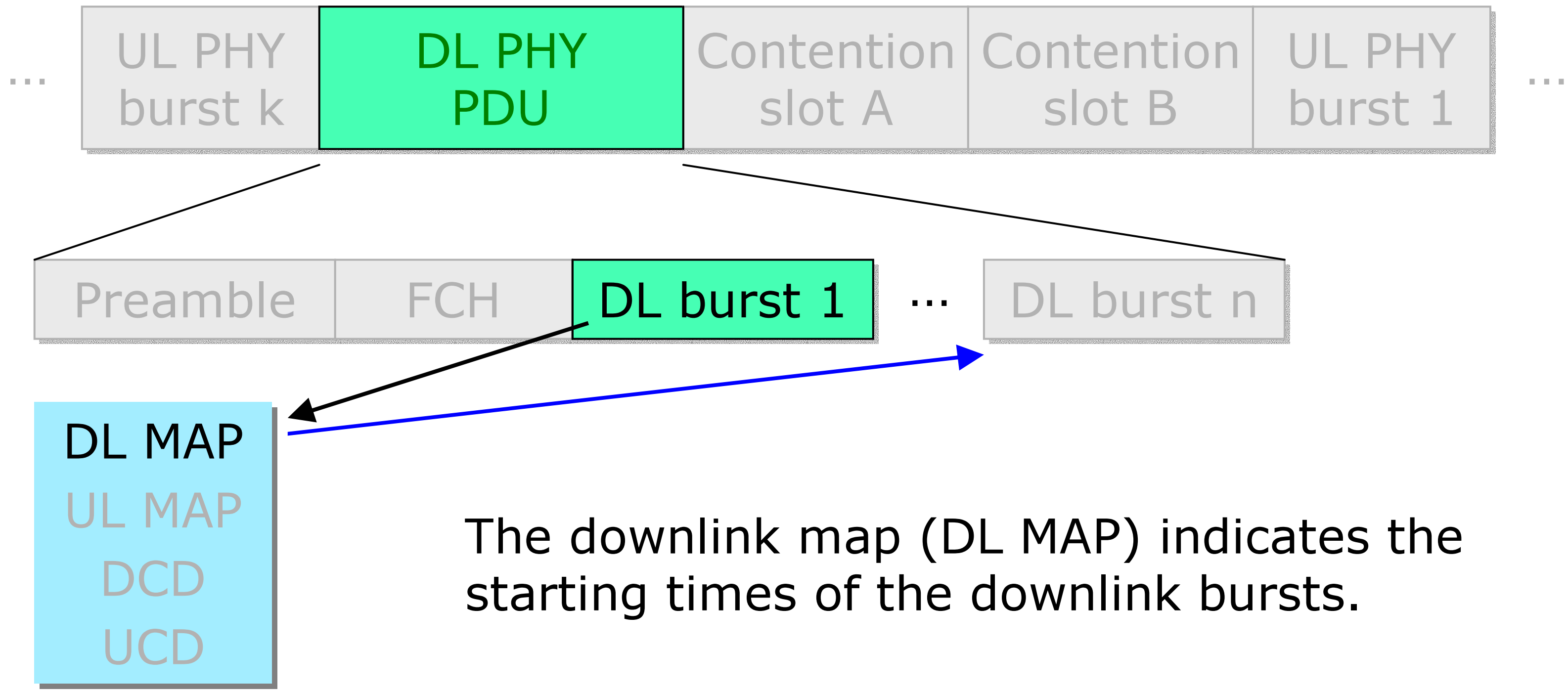
The DL subframe starts with a preamble (necessary for frame synchronization and equalization) and the Frame Control Header (FCH) that contains the location and burst profile of the first DL burst following the FCH. The FCH is one OFDM symbol long and is transmitted using BPSK modulation.

DL subframe structure (2)



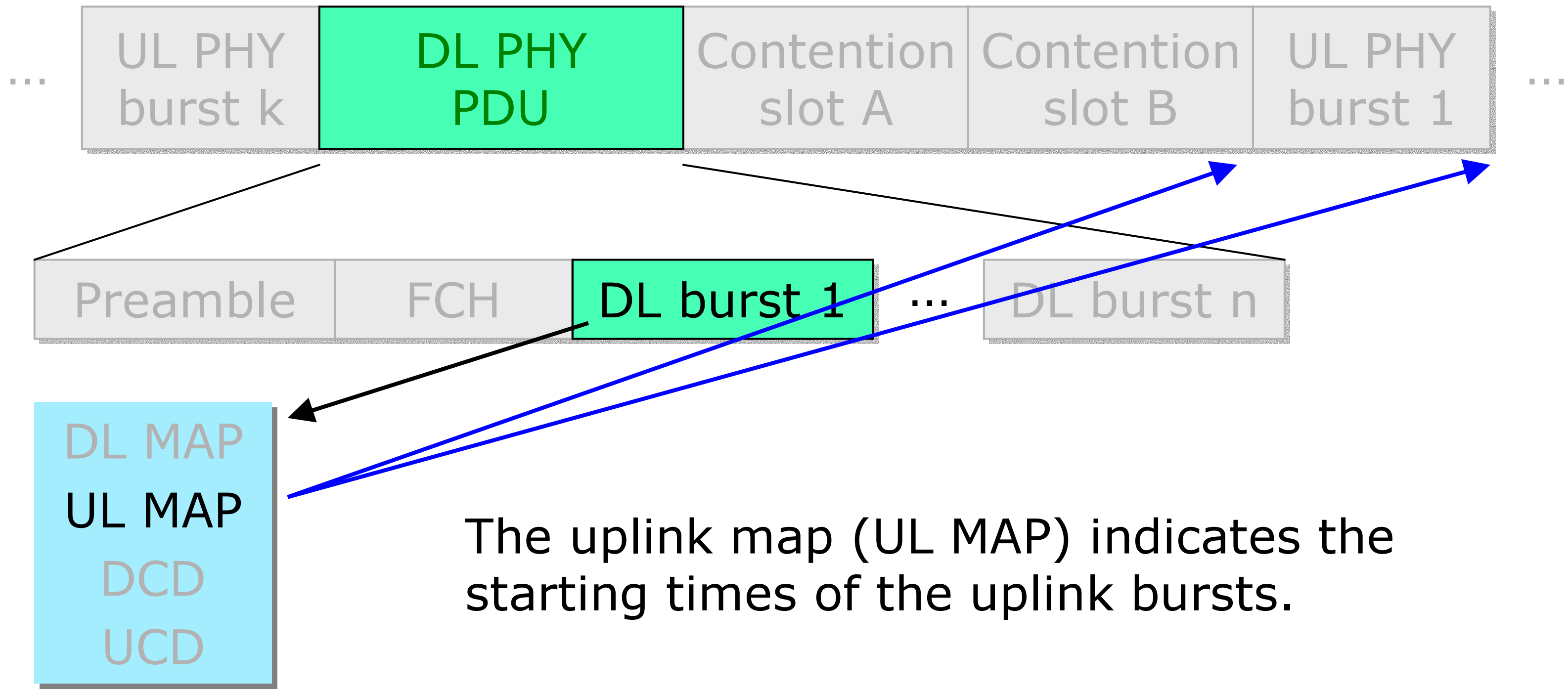
The first burst in downlink contains the downlink and uplink maps (DL MAP & UL MAP) and downlink and uplink channel descriptors (DCD & UCD). These are all contained in the first MAC PDU of this burst. The burst may contain additional MAC PDUs.

DL subframe structure (3)



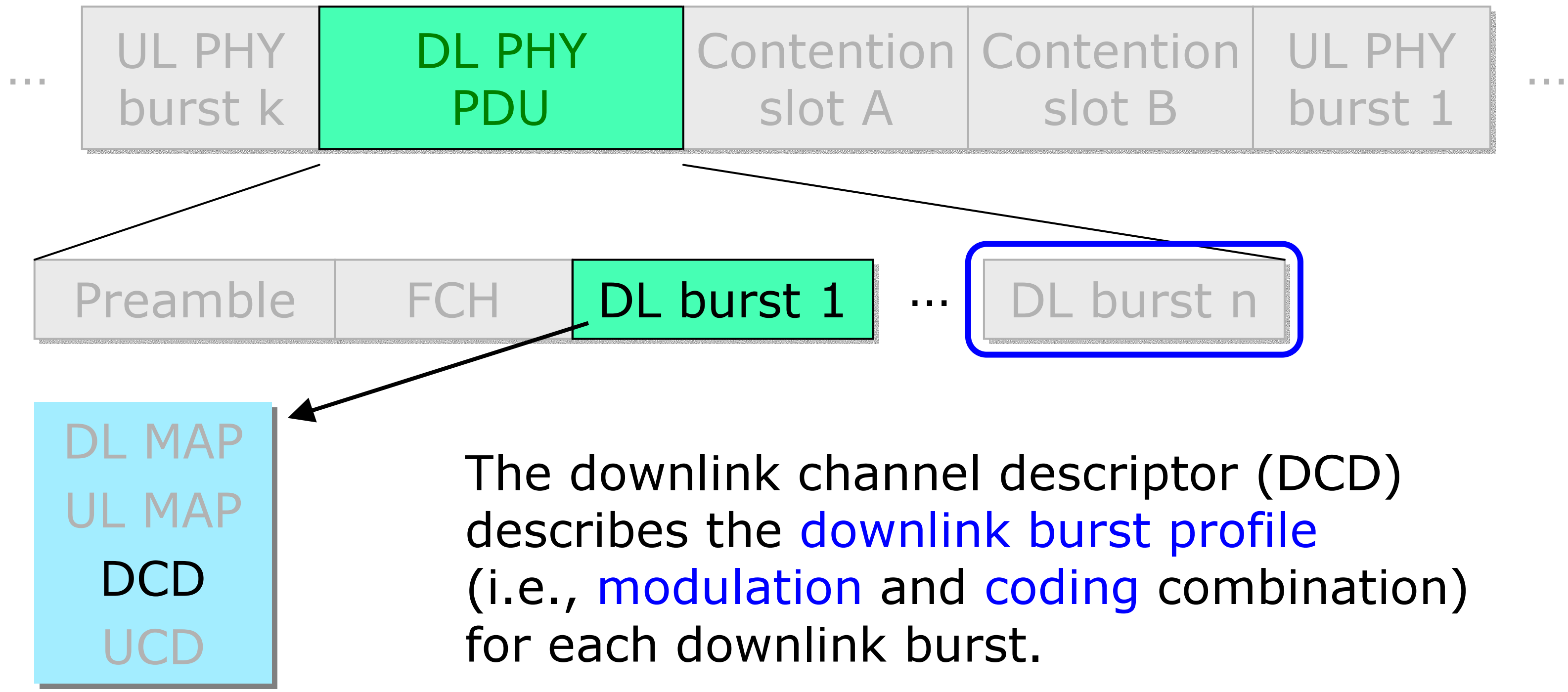
The downlink map (DL MAP) indicates the starting times of the downlink bursts.

DL subframe structure (4)



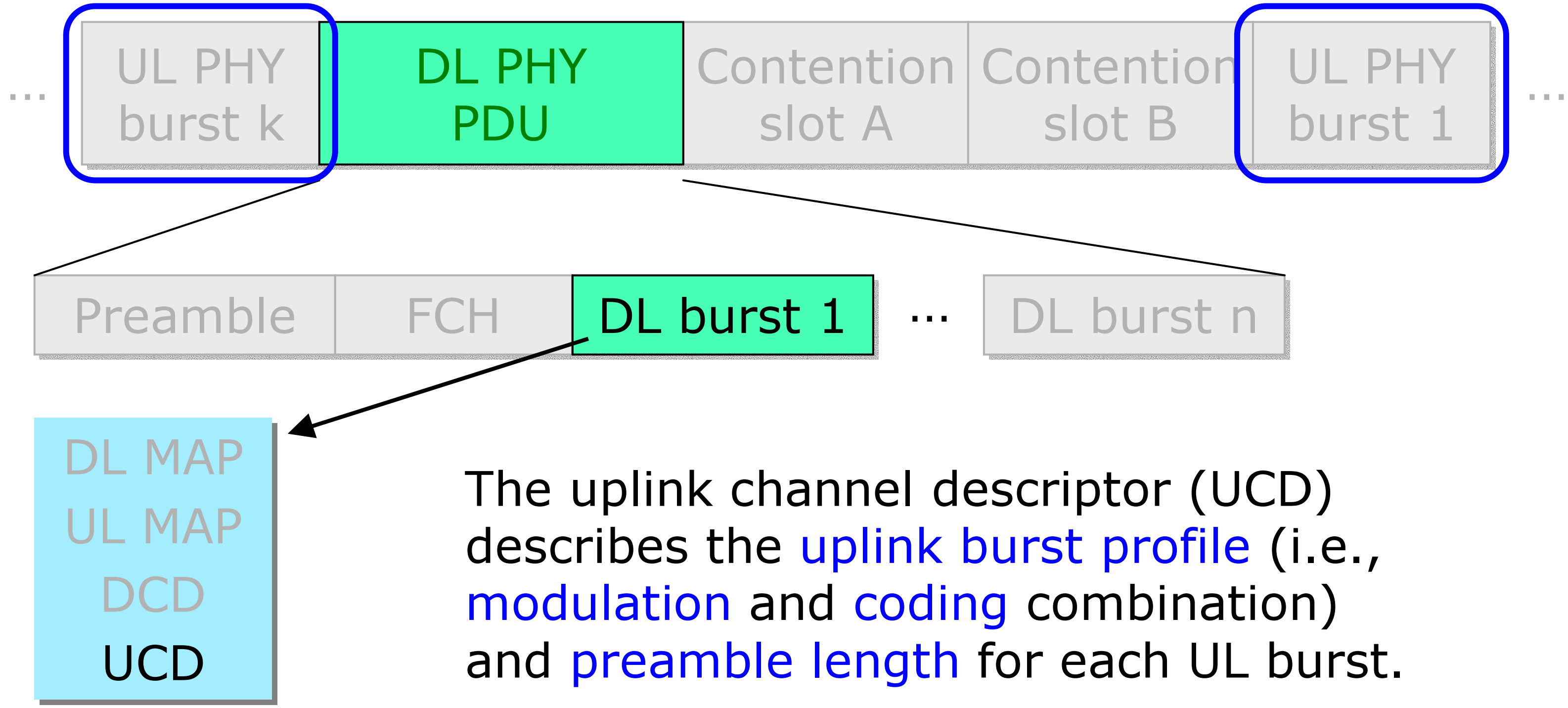
The uplink map (UL MAP) indicates the starting times of the uplink bursts.

DL subframe structure (5)



The downlink channel descriptor (DCD) describes the downlink burst profile (i.e., modulation and coding combination) for each downlink burst.

DL subframe structure (6)



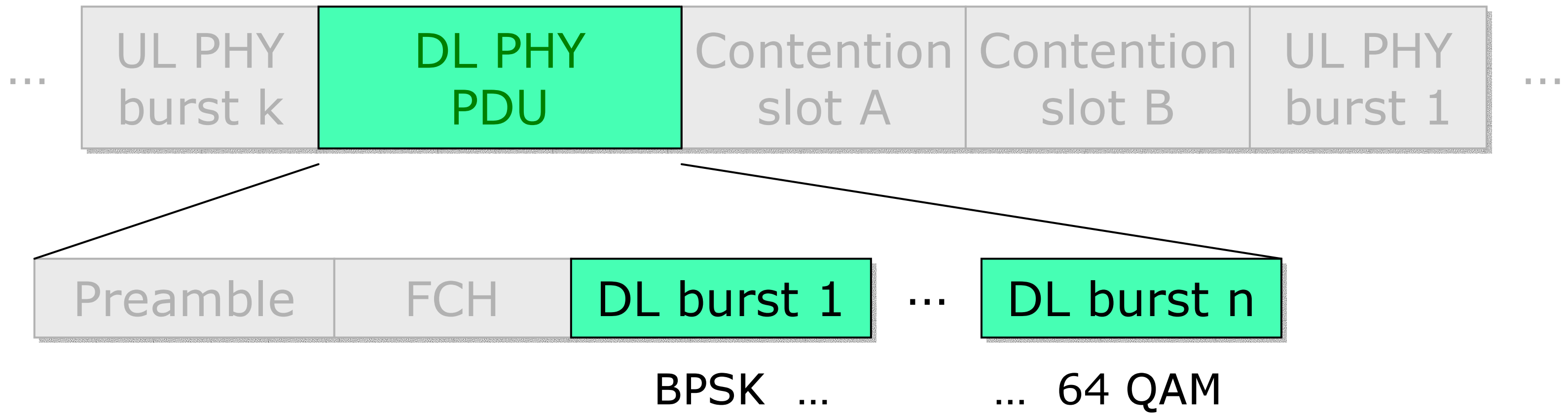
The uplink channel descriptor (UCD) describes the uplink burst profile (i.e., modulation and coding combination) and preamble length for each UL burst.

Modulation and coding combinations

Modulation	Coding rate	Info bits / subcarrier	Info bits / symbol	Peak data rate (Mbit/s)
BPSK	1/2	0.5	88	1.89
QPSK	1/2	1	184	3.95
QPSK	3/4	1.5	280	6.00
16-QAM	1/2	2	376	8.06
16-QAM	3/4	3	568	12.18
64-QAM	2/3	4	760	16.30
64-QAM	3/4	4.5	856	18.36

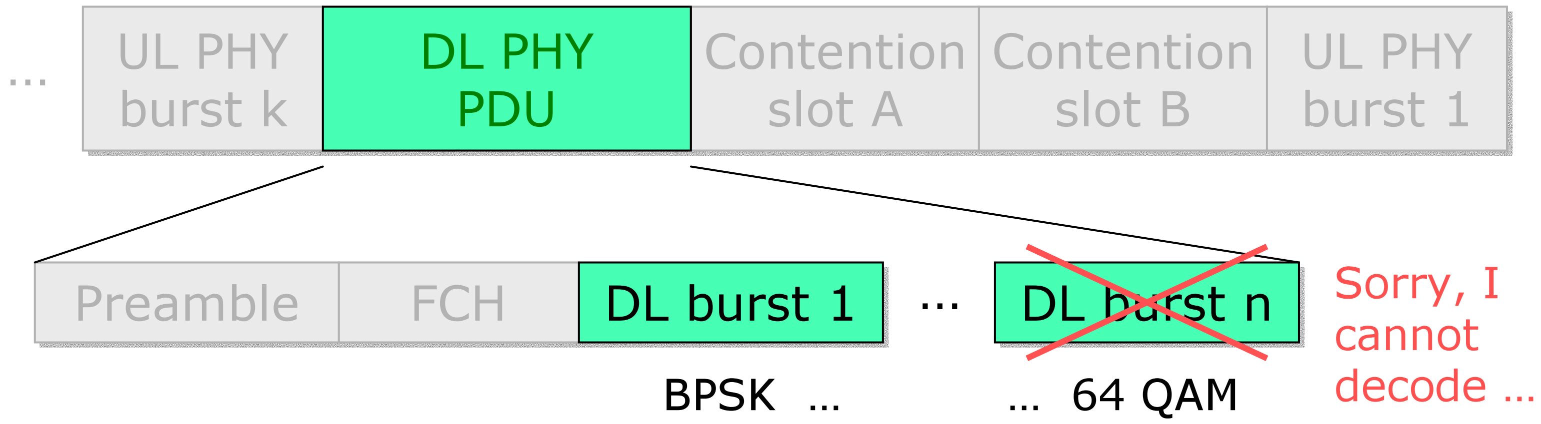
Depends on chosen bandwidth (here 5 MHz is assumed)

DL subframe structure (7)



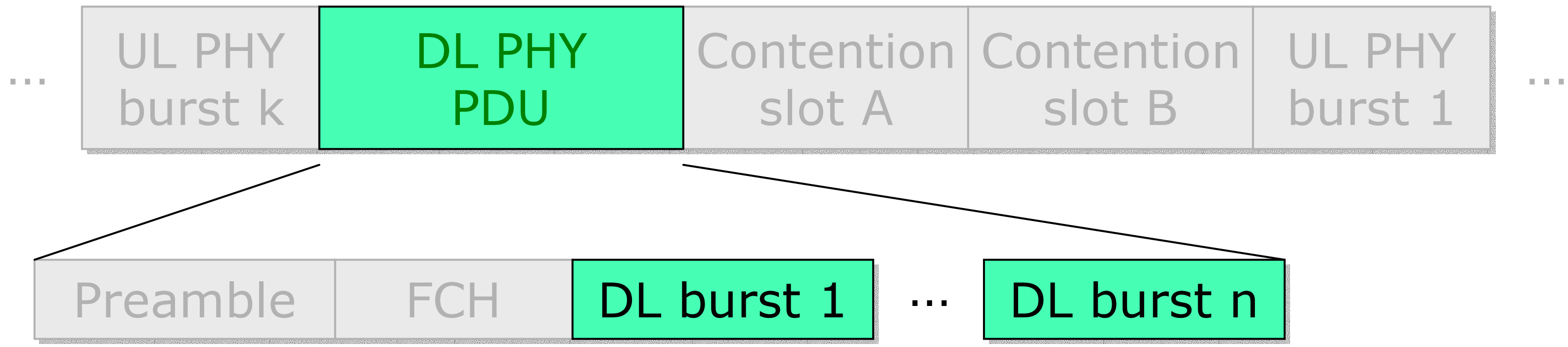
Downlink bursts are transmitted in order of decreasing robustness. For example, with the use of a single FEC type with fixed parameters, data begins with BPSK modulation, followed by QPSK, 16-QAM, and 64-QAM.

DL subframe structure (8)



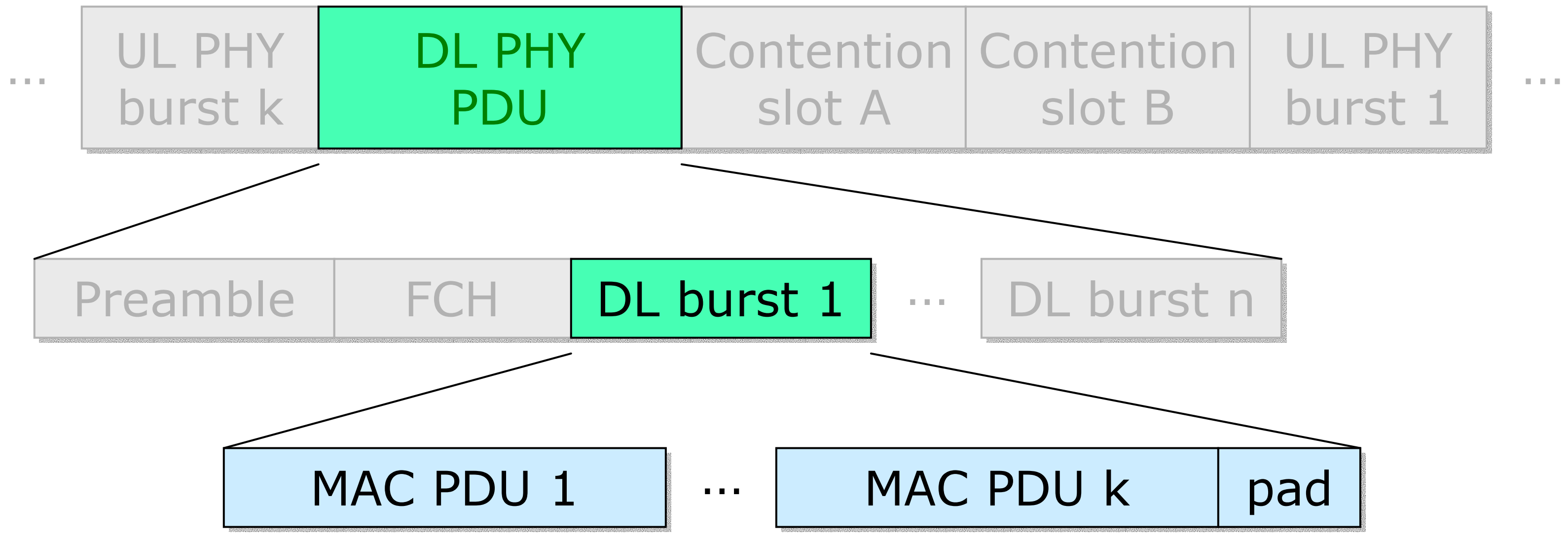
A subscriber station (SS) listens to all bursts it is capable of receiving (this includes bursts with profiles of equal or greater robustness than has been negotiated with the base station at connection setup time).

DL subframe structure (9)



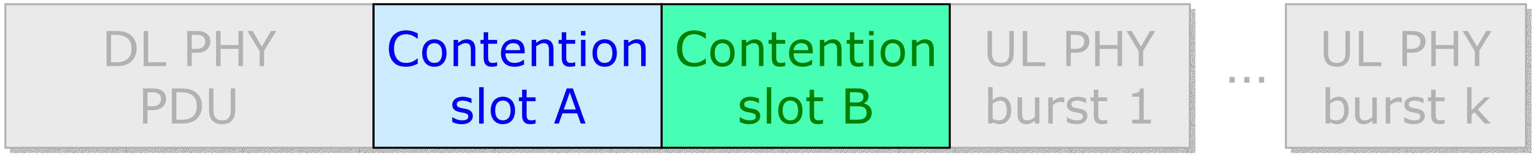
A subscriber station (SS) does not know which DL burst(s) contain(s) information sended to it, since the Connection ID (CID) is located in the MAC header, not in the DL PHY PDU header.

DL subframe structure (10)



IEEE 802.16 offers concatenation of several MAC PDUs within a single transmission burst.

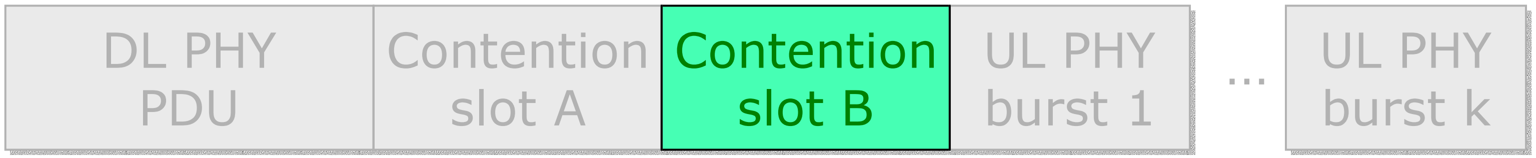
UL subframe structure (1)



The uplink subframe starts with a contention slot that offers subscriber stations the opportunity for sending initial ranging messages to the base station (corresponding to RACH operation in GSM).

A second contention slot offers subscriber stations the opportunity for sending bandwidth request messages to the base station.

UL subframe structure (2)

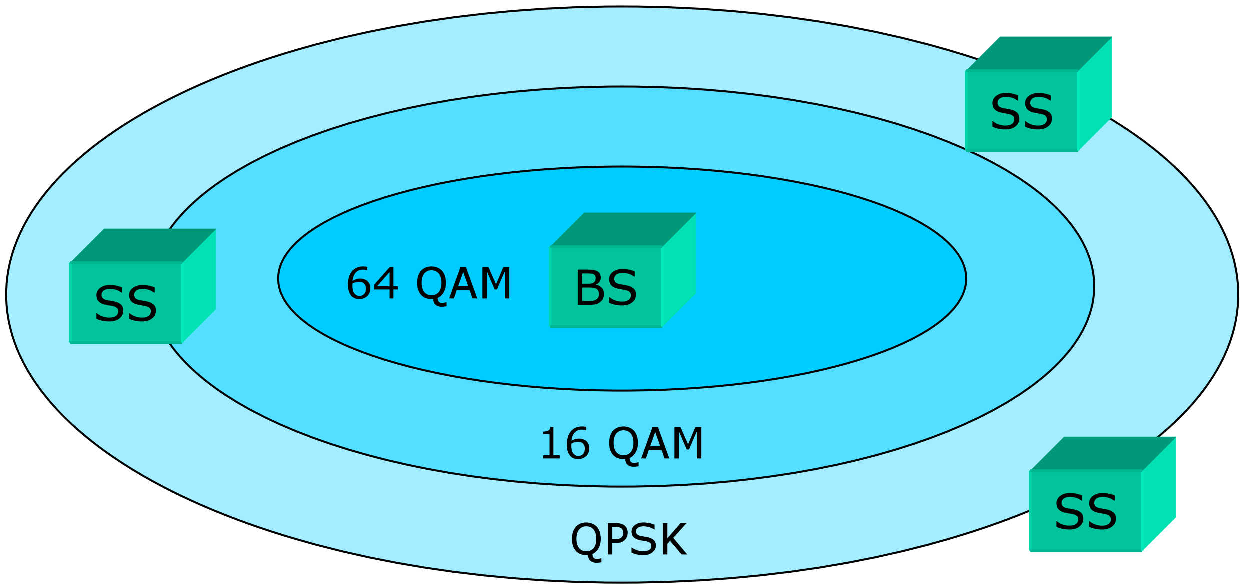


The usage of bandwidth request messages in this contention slot (and response messages in downlink bursts) offers a mechanism for achieving extremely flexible and dynamical operation of IEEE 802.16 systems.

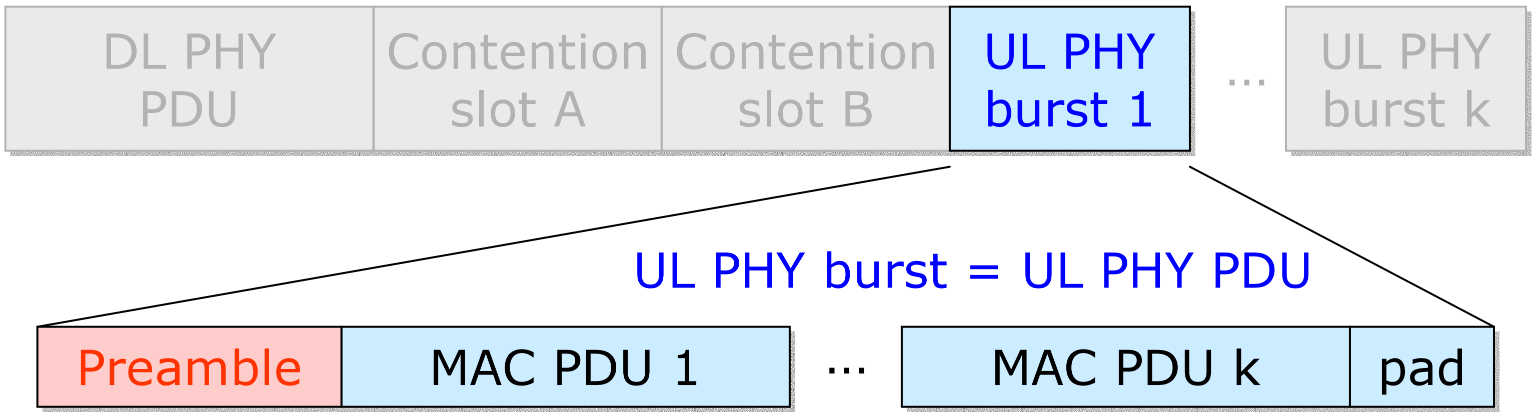
Bandwidth (corresponding to a certain modulation and coding combination) can be adaptively adjusted for each burst to/from each subscriber station on a per-frame basis.

Example: Efficiency vs. robustness trade-off

Large distance => high attenuation => low bit rate



UL subframe structure (3)



Preamble in each uplink burst.

IEEE 802.16 offers concatenation of several MAC PDUs within a single transmission burst also in uplink.

MAC PDU structure

6 bytes	0 - 2041 bytes	4 bytes
MAC Header	MAC Payload	CRC-32

Two MAC header formats:

1. Generic MAC header (HT=0)

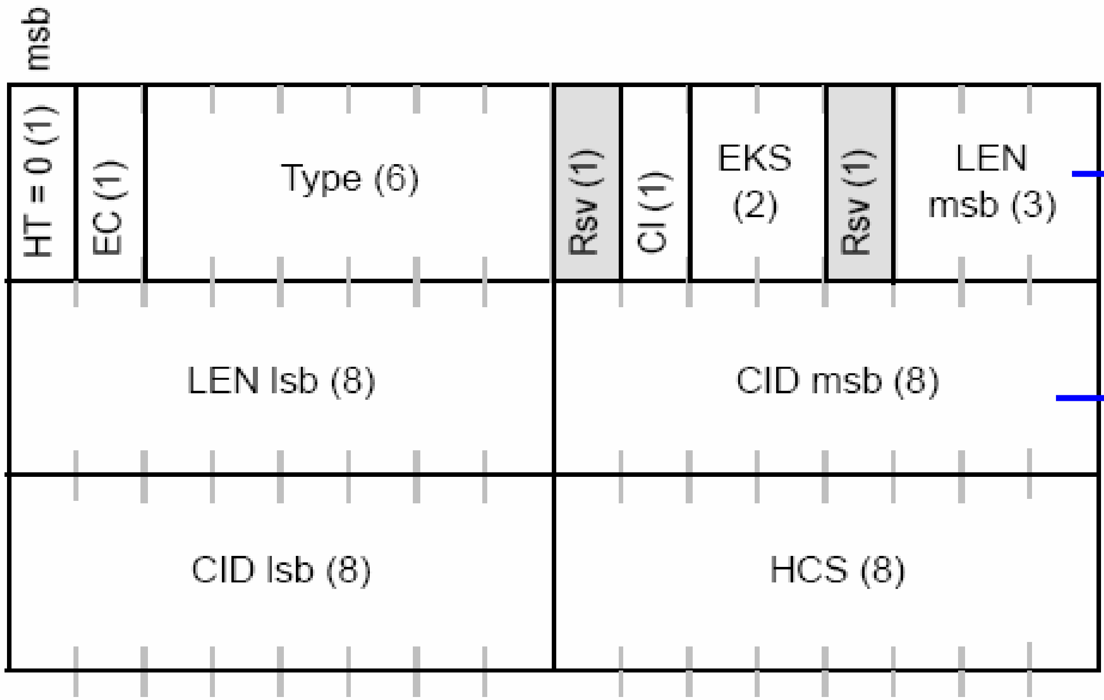
2. Bandwidth request header (HT=1)

MAC payload contains management message or user data

No MAC payload, no CRC

For error control

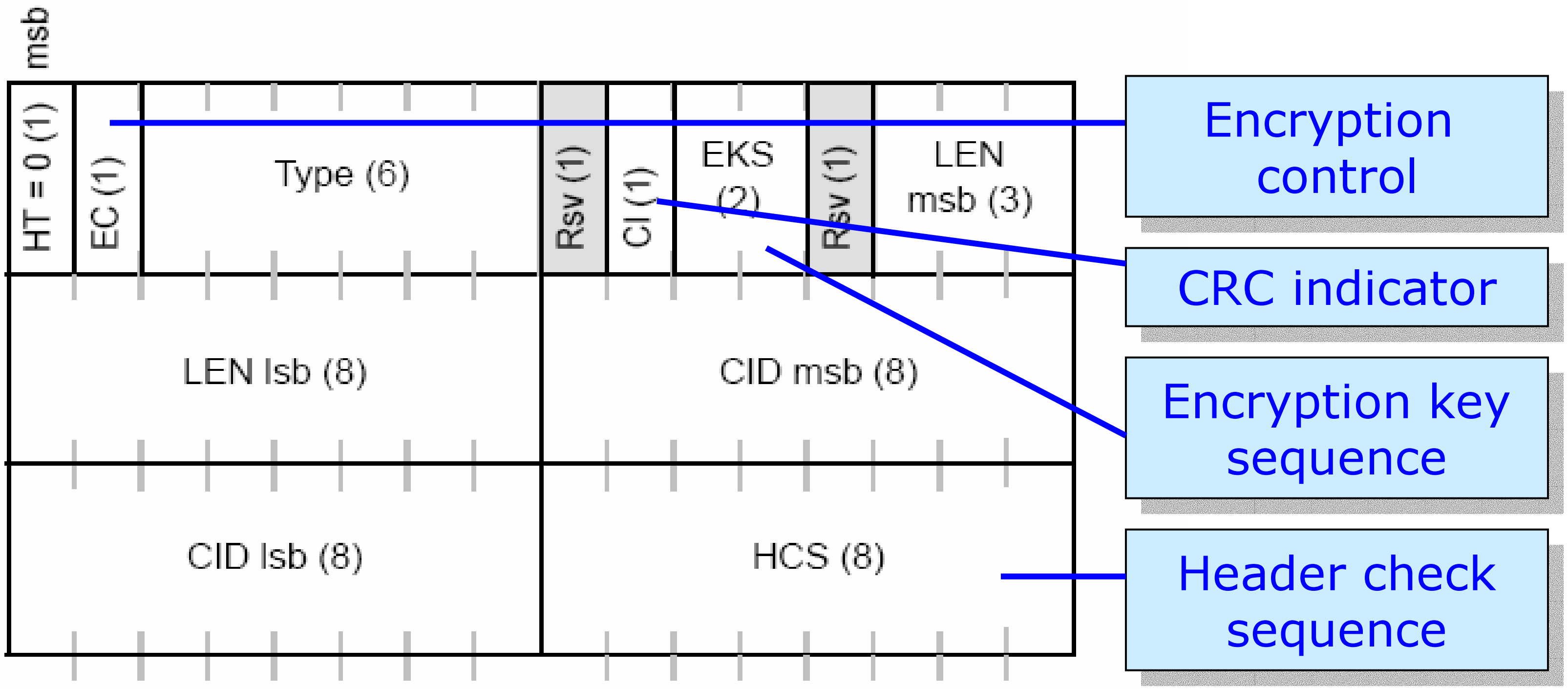
Generic MAC header (1)



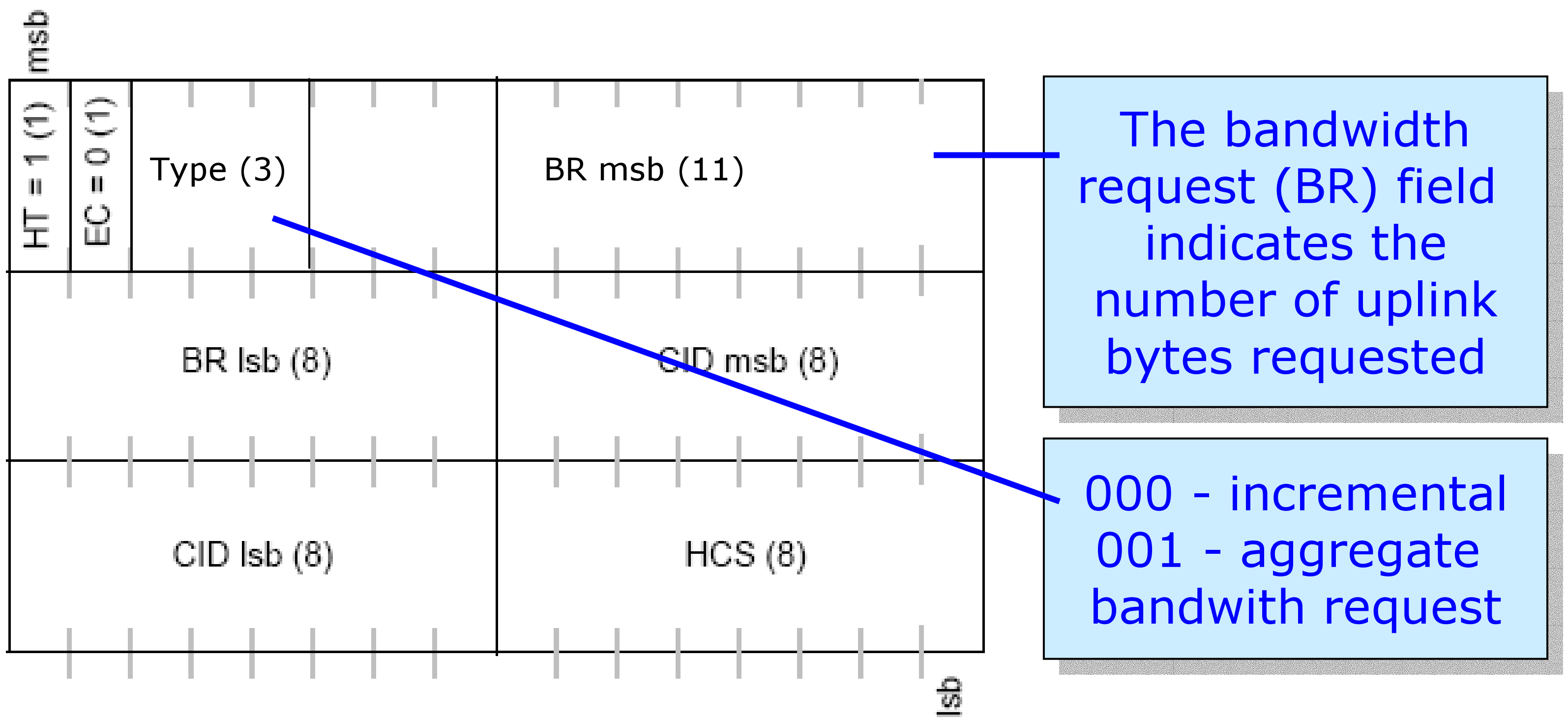
Length of MAC PDU in bytes (incl. header)

Connection ID (CID) is in MAC header!

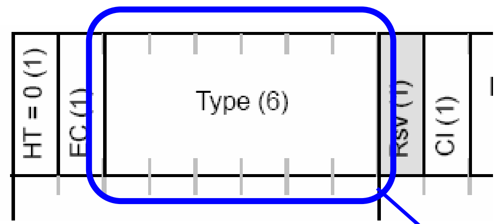
Generic MAC header (2)



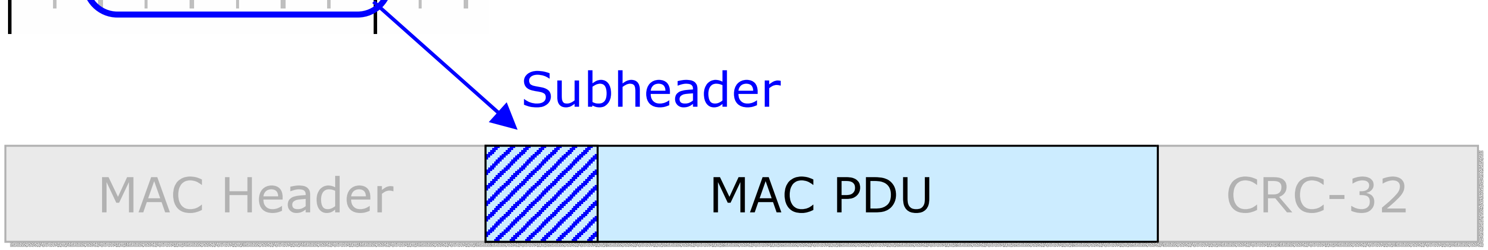
Bandwidth request header



Significance of Type field



This field indicates if (and what kind of) MAC subheader(s) is (are) inserted in the PDU payload after the MAC header.

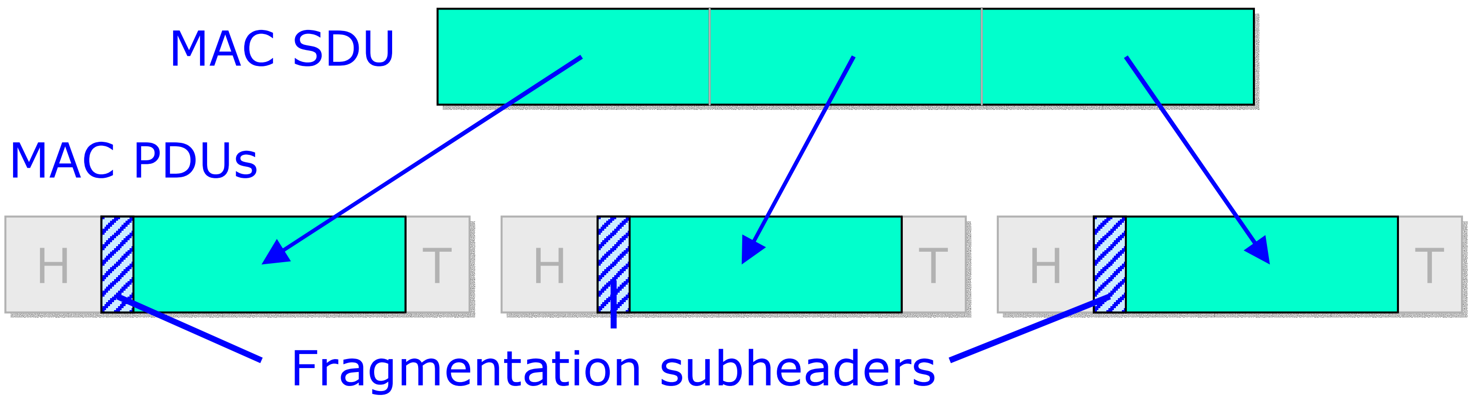


MAC subheaders are used for:

a) Fragmentation
b) Packing
c) Grant management

Fragmentation

Fragmentation is the process by which a MAC SDU is divided into one or more MAC PDUs. This process allows efficient use of available bandwidth relative to the QoS requirements of a connection's service flow.



Fragmentation subheader (1 byte) format

Number values my be outdated

Syntax	Size
Fragmentation subheader () {	
FC	2 bits
FSN	3 bits
reserved for CS use	3 bits
}	

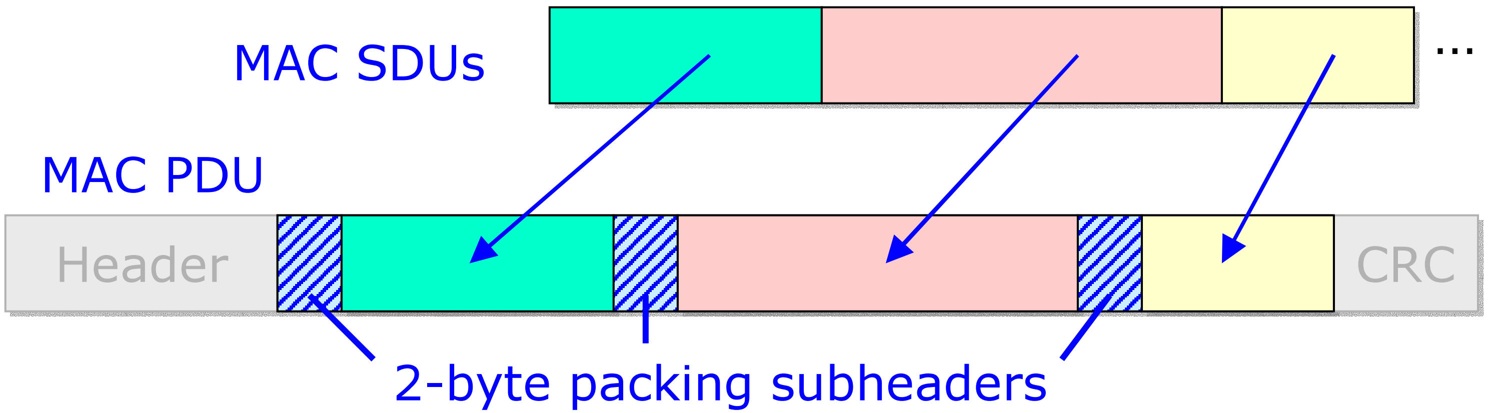
Fragmentation Sequence Number (modulo 8)

Fragmentation Control

00 – no fragmentation
01 – last fragment
10 – first fragment
11 – middle fragment

Packing

Packing means that several MAC SDUs are carried in a single MAC PDU. When packing variable-length MAC SDUs, a packing subheader is inserted before each MAC SDU.



Packing subheader (2 byte) format

Number values my be outdated

Syntax	Size
Packing sub-header () {	
FC	2 bits
FSN	3 bits
Length	11 bits
}	

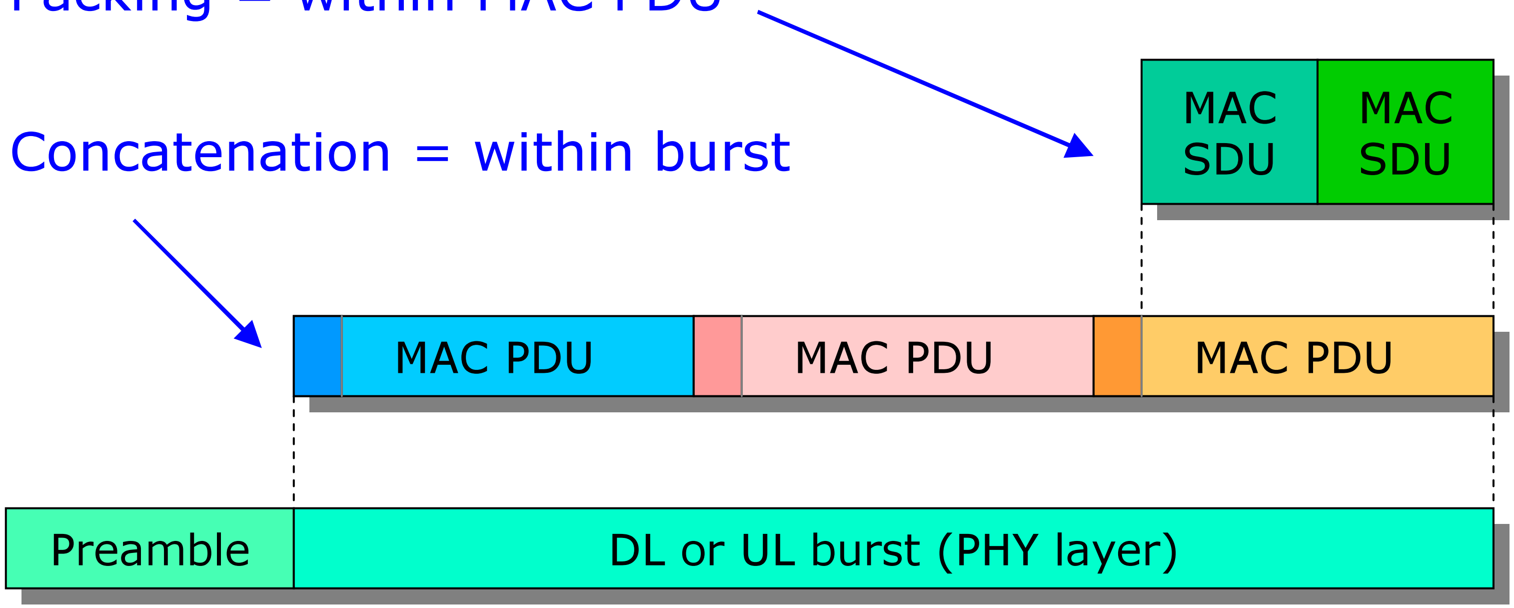
This enables simultaneous fragmentation and packing

Length (in bytes) of the MAC SDU or SDU fragment, including the two byte packing subheader

Difference between concatenation & packing

Packing = within MAC PDU

Concatenation = within burst



Fragmentation & packing

If fragmentation or packing is enabled for a connection, it is always the transmitting entity (base station in downlink or subscriber station in uplink) that decides whether or not to fragment/pack.

Fragmentation and packing can be done at the same time (see packing subheader structure). In this way the channel utilisation can be optimised.