

Worldwide Interoperability for Microwave Access (WiMAX)

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 802.16d](#) contained upgrades for the 2-11 GHz range.

In 2004, the original 802.16 standard, 16a, and 16d were combined into the massive [IEEE 802.16-2004](#) standard.

Uplink / downlink separation

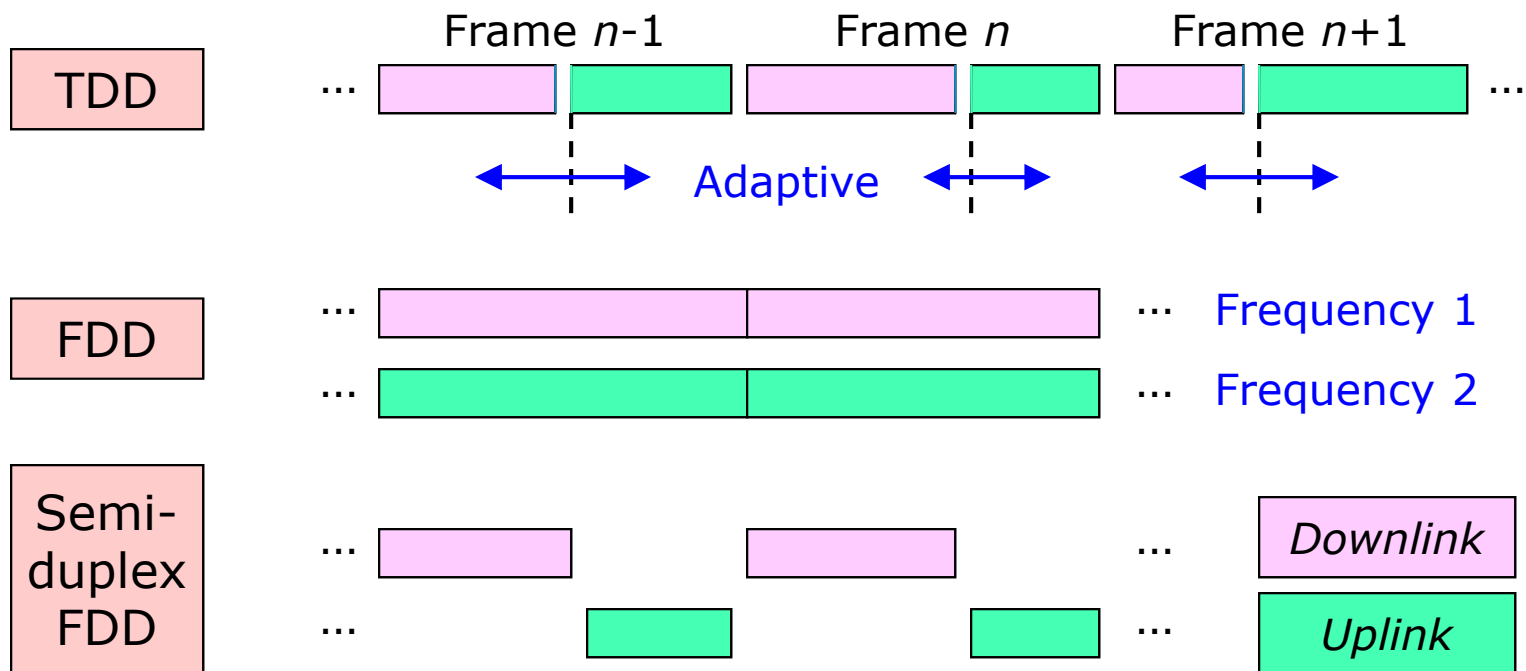
IEEE 802.16 offers both TDD (Time Division Duplexing) and FDD (Frequency Division Duplexing) alternatives.

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

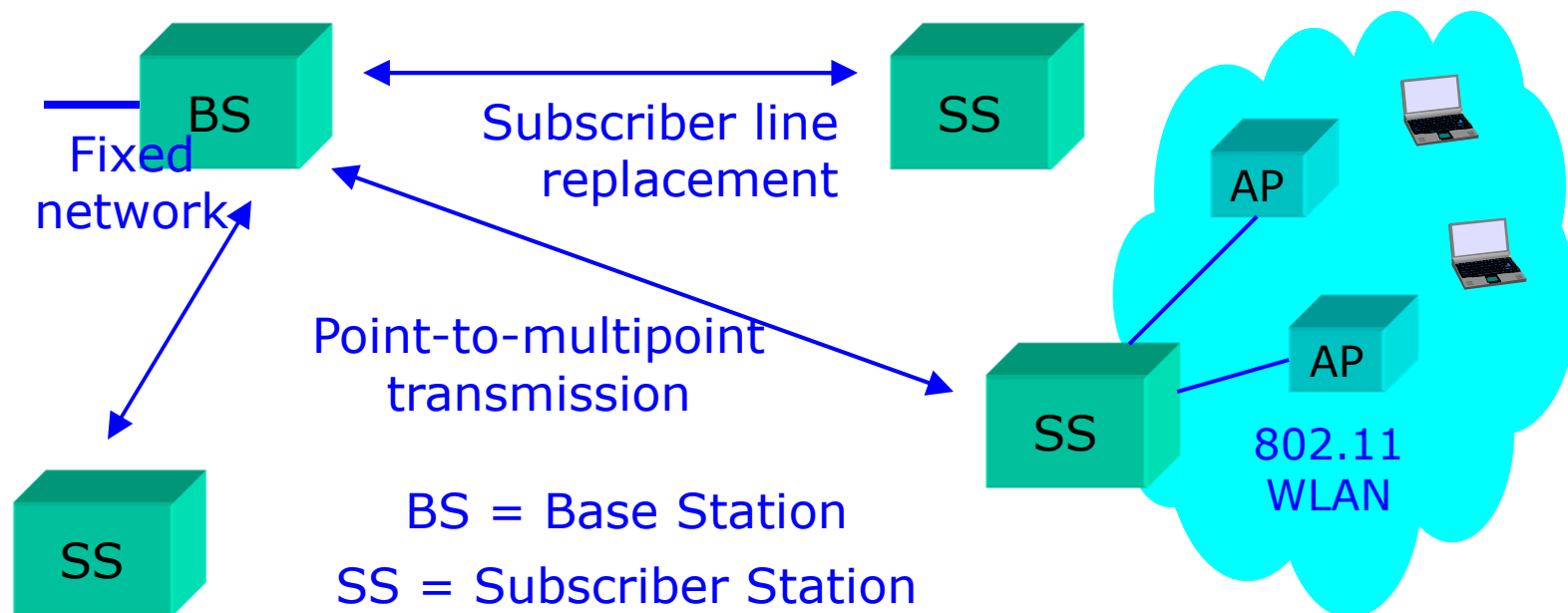


IEEE 802.16 PHY

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).

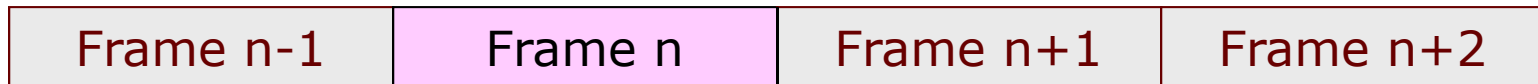
IEEE 802.16 basic architecture



Overall TDD frame structure (1)

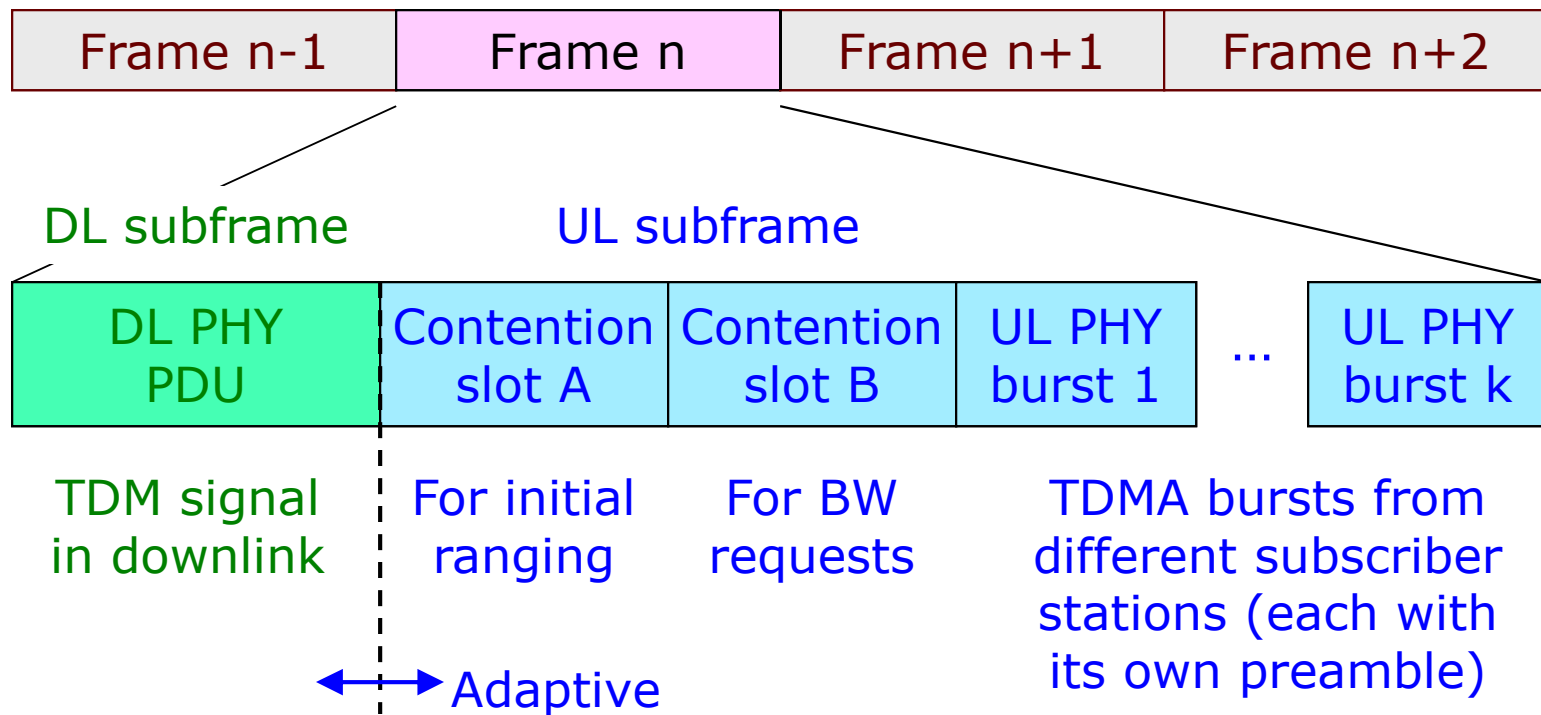
The following slides present the overall IEEE 802.16 frame structure for TDD.

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.

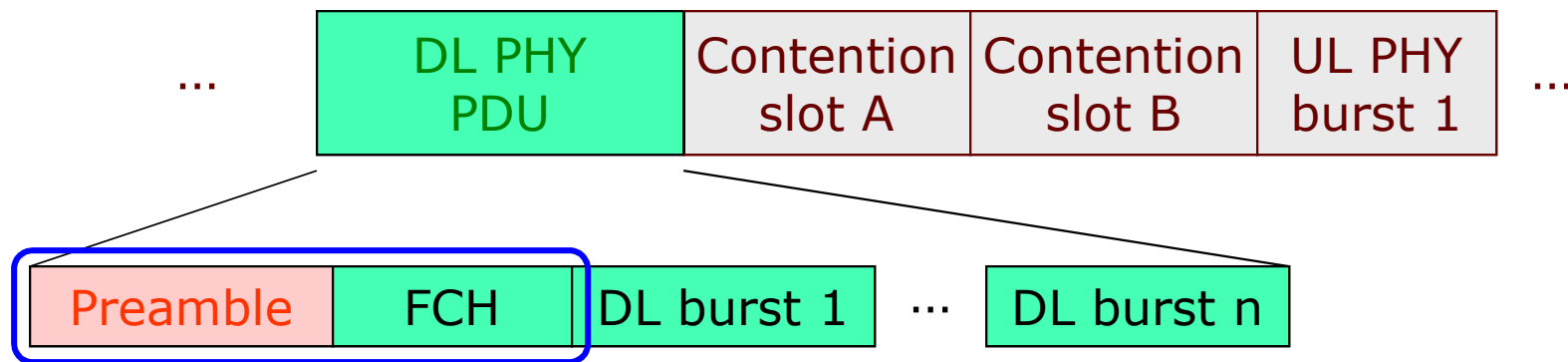


Frame length 0.5, 1 or 2 ms

Overall TDD frame structure (2)

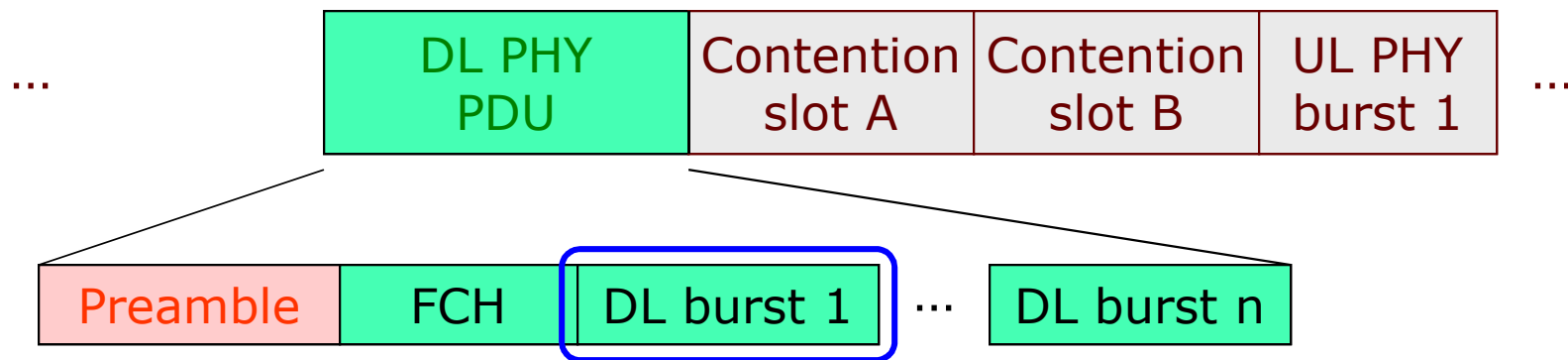


DL subframe structure (1)



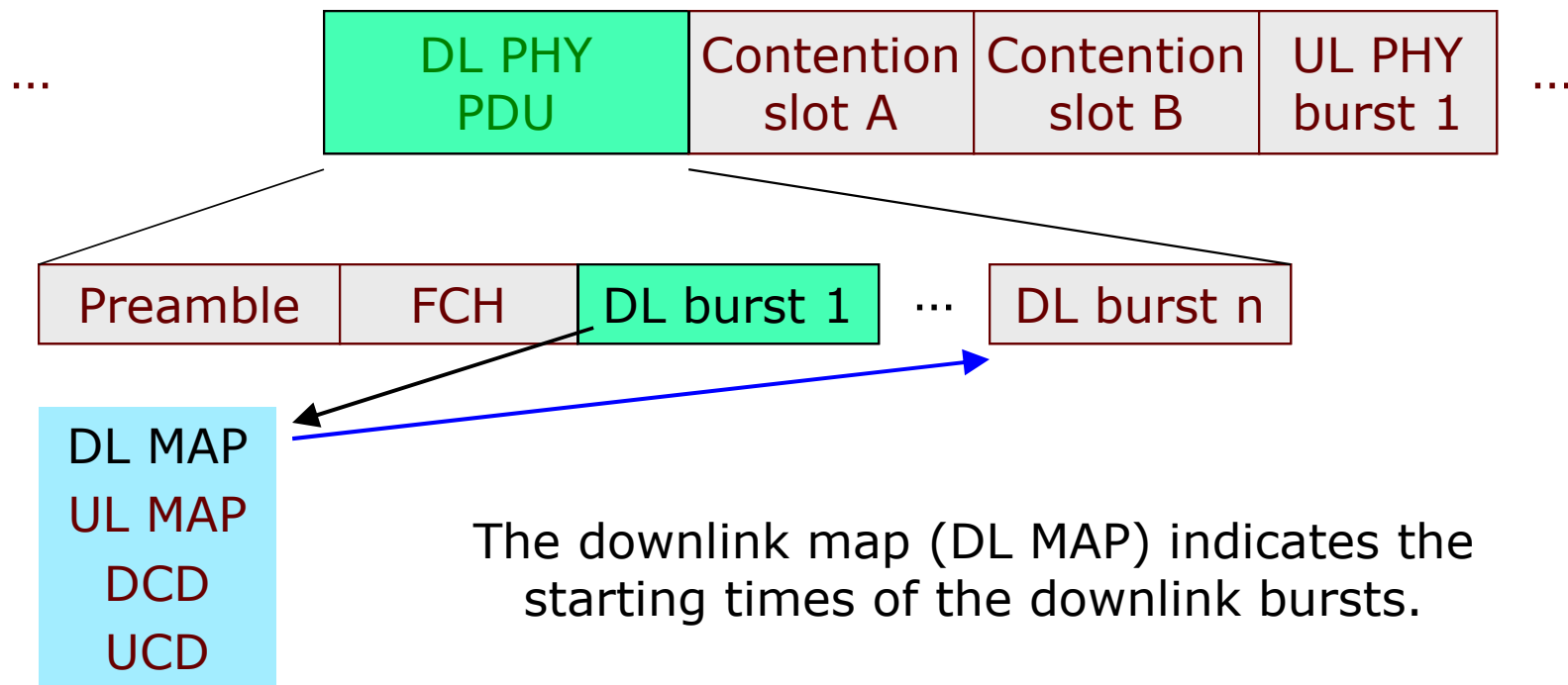
The DL subframe starts with a **preamble** (necessary for frame synchronization and equalization) and the **Frame Control Header (FCH)** that contains the location and burst profile of the first DL burst following the FCH. **The FCH is one OFDM symbol long and is transmitted using BPSK modulation.**

DL subframe structure (2)

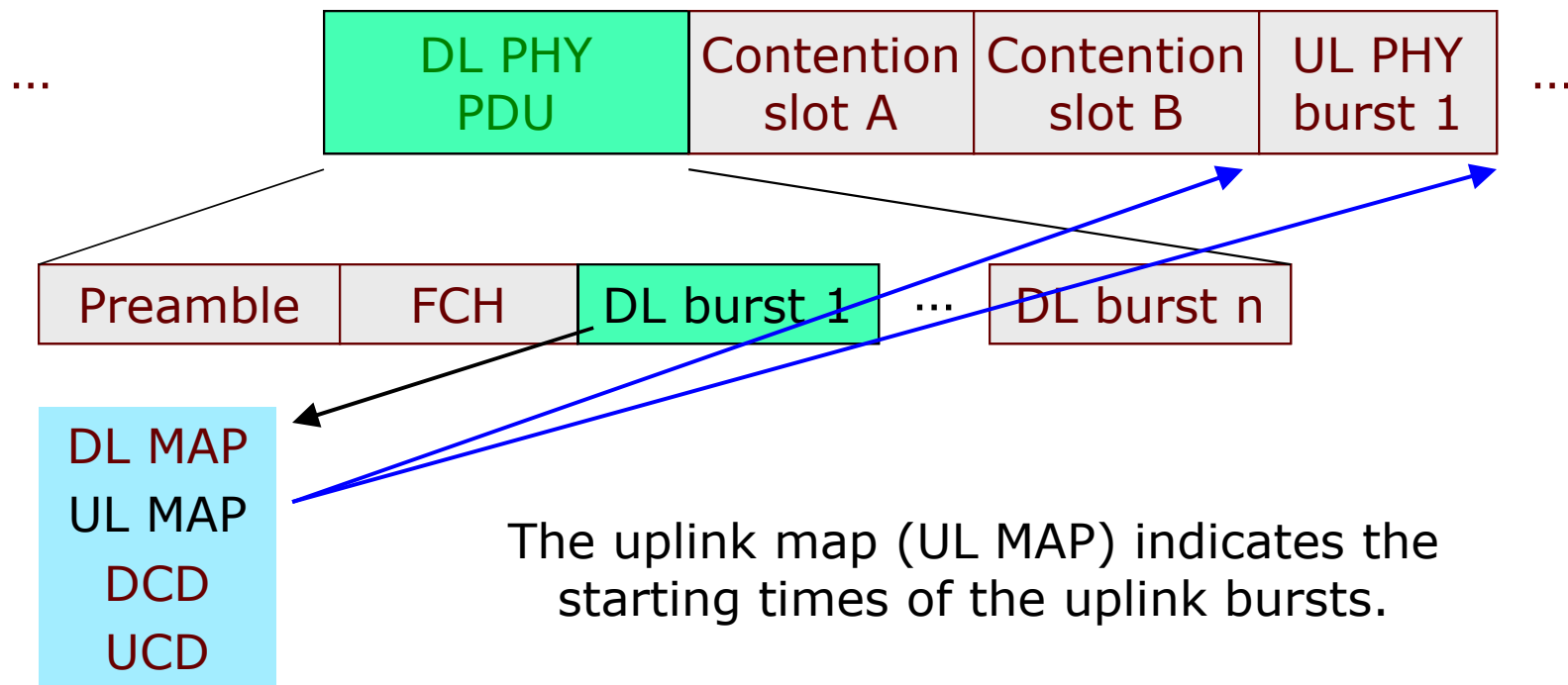


The first burst in downlink contains the downlink and uplink maps (DL MAP & UL MAP) and downlink and uplink channel descriptors (DCD & UCD). These are all contained in the first MAC PDU of this burst. The burst may contain additional MAC PDUs.

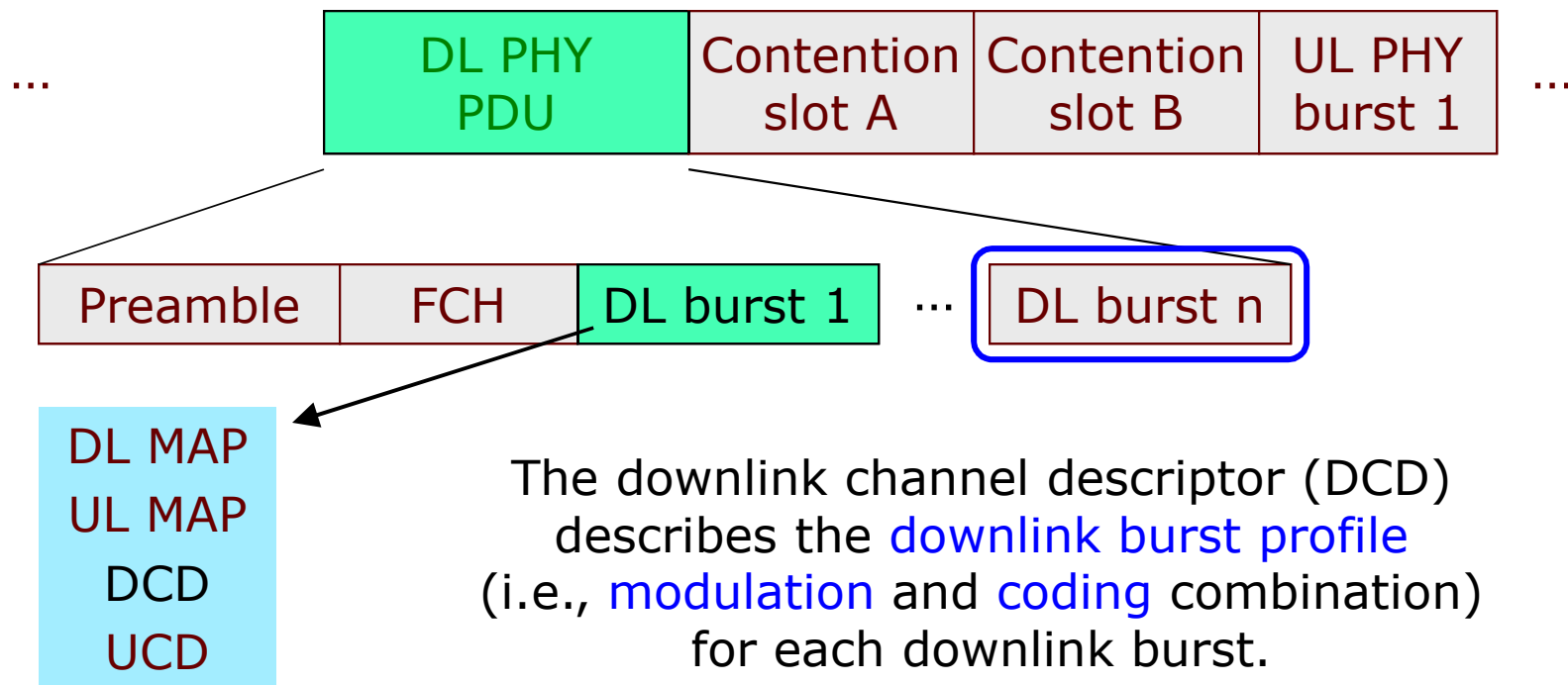
DL subframe structure (3)



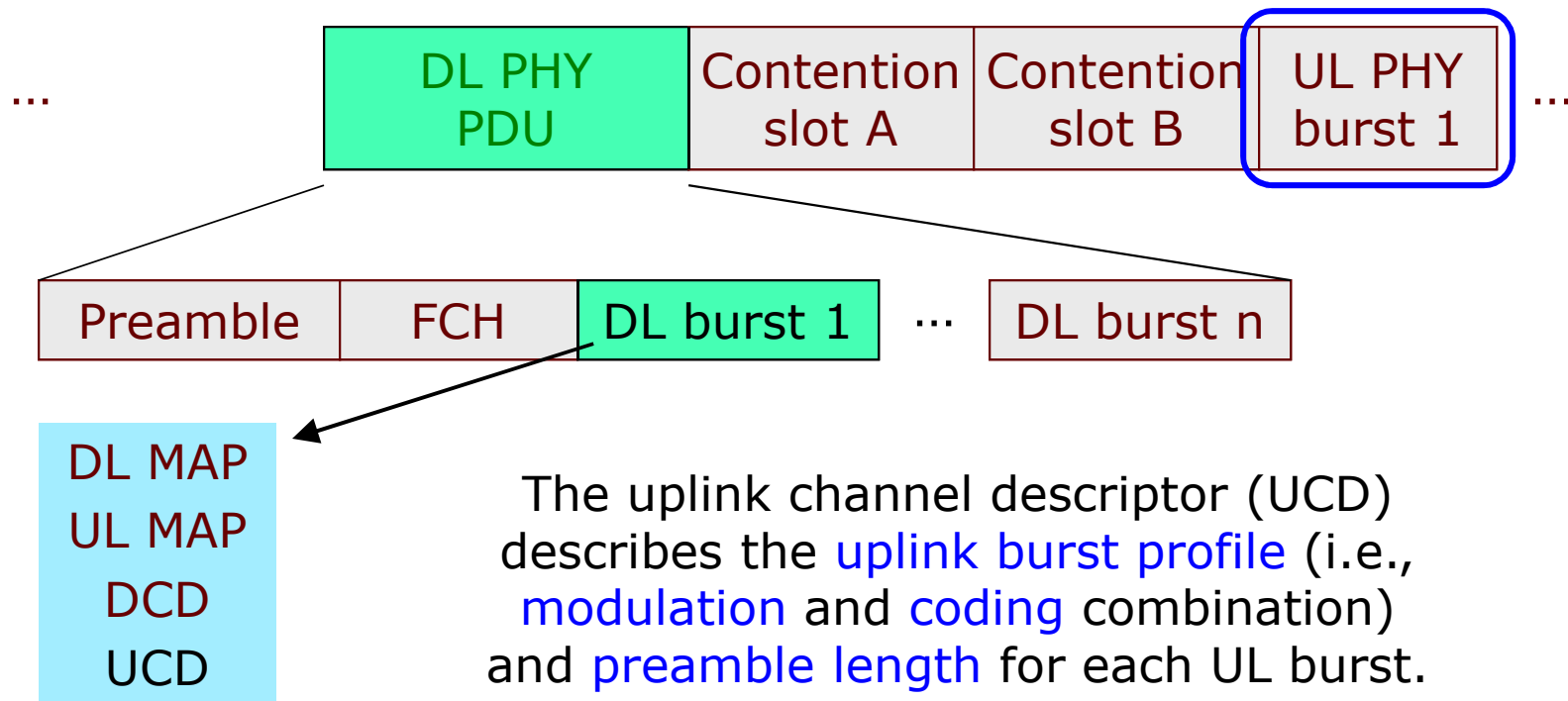
DL subframe structure (4)



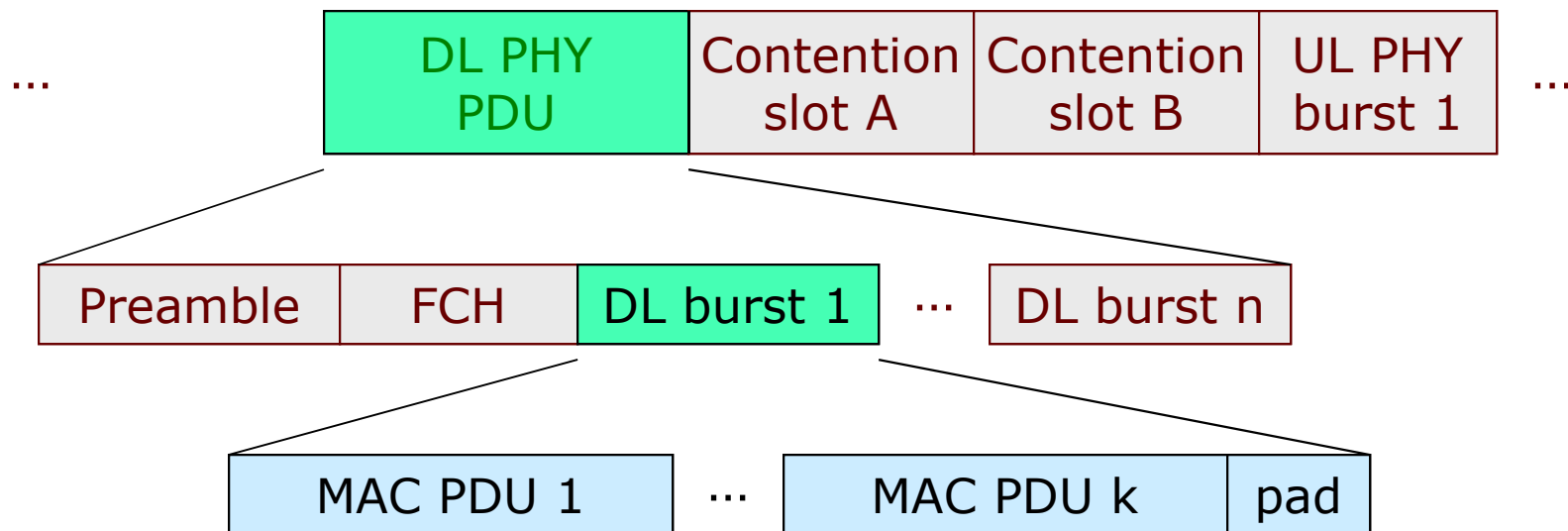
DL subframe structure (5)



DL subframe structure (6)

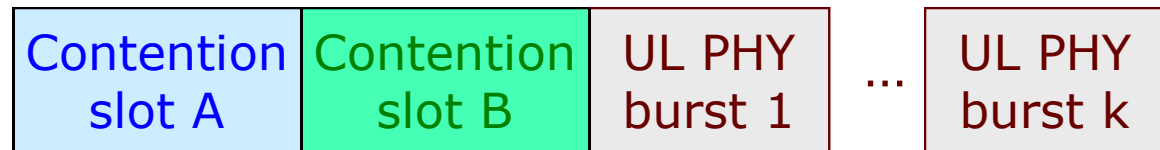


DL subframe structure (10)



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

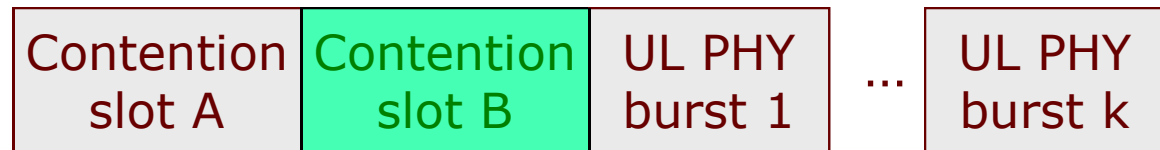
UL subframe structure (1)



The uplink subframe starts with a contention slot that offers subscriber stations the opportunity for sending **initial ranging messages** to the base station (for timing and power control adjustments).

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

UL subframe structure (2)

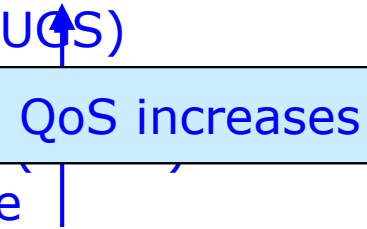


The usage of **bandwidth request messages** in this contention slot (and **response messages** in downlink bursts) offers a mechanism for achieving extremely flexible and dynamical operation of IEEE 802.16 systems.

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.

Four service classes

The IEEE 802.16 MAC layer defines four service classes:

- Unsolicited Grant Service (UGS)
 - Real-time Polling Service (rtPS)
 - Non-real-time Polling Service (nrtPS)
 - Best Effort (BE) service
- 
- A light blue rectangular box with a black border containing the text "QoS increases". A vertical blue line with an upward-pointing arrow at the top connects the box to the "UGS" text in the list above.

The **scheduling** algorithms needed for implementing the three first types of services are **implemented in the BS** (while allocating uplink bandwidth to each SS) and are **not defined in the 802.16 standard**. Each SS negotiates its service policies with the BS at the connection setup time.

Unsolicited grant service (UGS)

UGS
rtPS
nrtPS
BE

UGS offers fixed size grants on a real-time periodic basis, which eliminates the overhead and latency of SS requests and assures that grants are available to meet the flow's real-time needs. The BS provides fixed size bursts in the uplink at periodic intervals for the service flow. The burst size and other parameters are negotiated at connection setup.

Typical UGS applications: E1/T1 links (containing e.g. delay-sensitive speech signals), VoIP (without silence suppression).

Real-time Polling Service (rtPS)

UGS
rtPS
nrtPS
BE

The Real-time Polling Service (rtPS) is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as VoIP (with silence suppression) or streaming video.

This service offers real-time, periodic, unicast request opportunities, which meet the flow's real-time needs and allow the SS to specify the size of the desired uplink transmission burst. This service requires more request overhead than UGS, but supports variable grant sizes for optimum data transport efficiency.

Non-real-time Polling Service (nrtPS)

UGS
rtPS
nrtPS
BE

The Non-real-time Polling Service (nrtPS) is designed to support non-real-time service flows that require variable size bursts in the uplink on a regular (but not strictly periodic) basis.

Subscriber stations contend for bandwidth (for uplink transmission) during contention request opportunities. The availability of such opportunities is guaranteed at regular intervals (on the order of one second or less) irrespective of network load.

Best Effort (BE) service

UGS
rtPS
nrtPS
BE

The Best Effort service is intended to be used for best effort traffic where no throughput or delay guarantees are provided.

Subscriber stations contend for bandwidth (for uplink transmission) during contention request opportunities. The availability of such opportunities depends on network load and is not guaranteed (in contrast to nrtPS).

Radio Link Control in IEEE 802.16

The main task of Radio Link Control (RLC) in IEEE 802.16 systems is to provide **dynamic changing** of UL and DL **burst profiles** on a **per-connection** and **per-frame** basis, depending on **radio channel characteristics** and **QoS requirements**.

As an example, RLC provides signaling for **initial access (ranging)** and **bandwidth allocation** in the downlink direction:

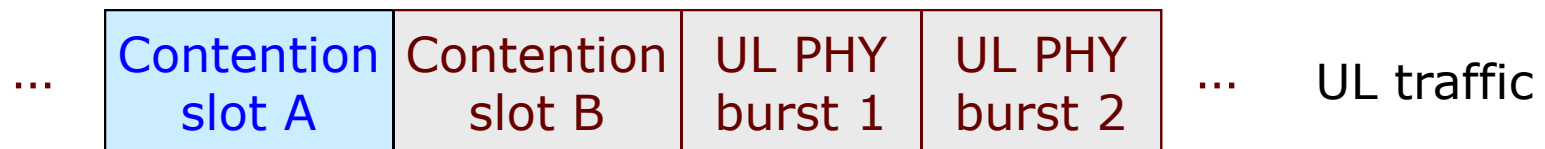
- Ranging request (RNG-REQ) from SS to BS
- Ranging response (RNG-RSP) from BS to SS
- Bandwidth requests (DBPC-REQ) from SS to BS
- Bandwidth confirmation (DBPC-RSP) from BS to SS

Initial access (initial ranging)

RNG-REQ
RNG-RSP
DBPC-REQ
DBPC-RSP

During initial access, the SS sends a **ranging request message** in the contention slot reserved for this purpose, among others indicating which kind of DL burst profile should be used.

Note: There is the possibility of collision since other subscriber stations also send ranging request messages in this contention slot.

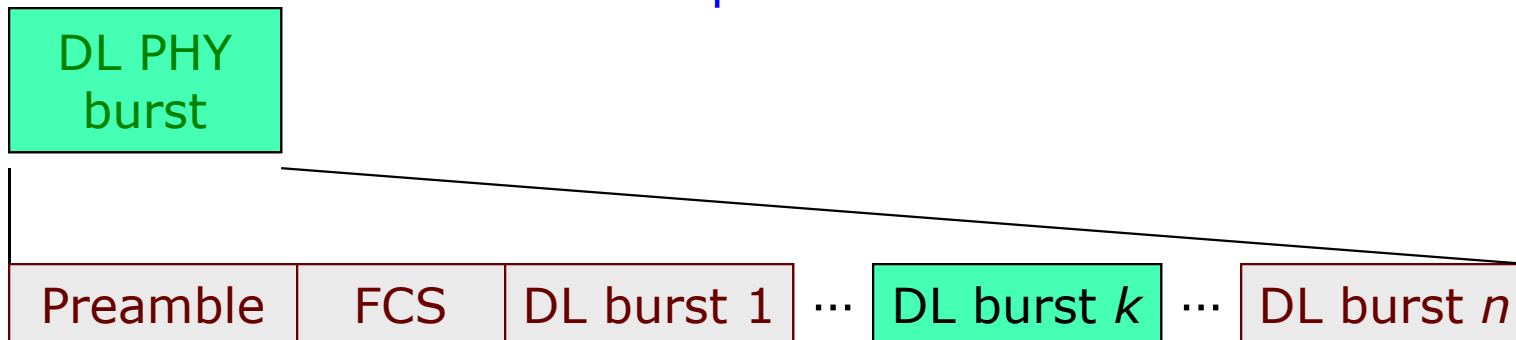


Initial access (initial ranging)

RNG-REQ
RNG-RSP
DBPC-REQ
DBPC-RSP

In response to the RNG-REQ message, the BS returns a **ranging response message** in a DL burst with a sufficiently robust burst profile.

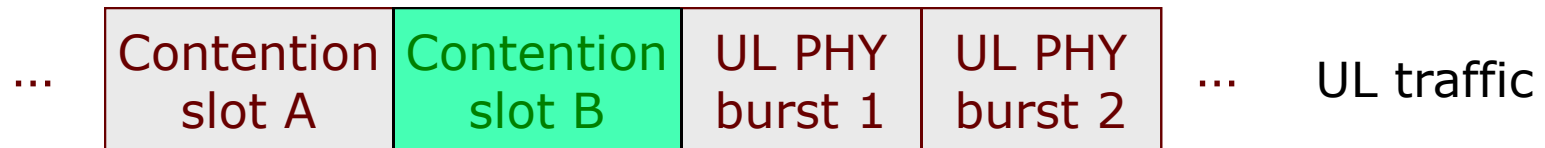
This message includes the **timing advance** value for correct alignment of bursts in UL, as well as **UL power control** information.



DL burst profile change

RNG-REQ
RNG-RSP
DBPC-REQ
DBPC-RSP

The SS continuously measures the radio channel quality. If there is a need for change in DL burst profile, the SS sends a **DL burst profile change request message** in the contention slot reserved for this purpose, indicating the desired new DL burst profile.

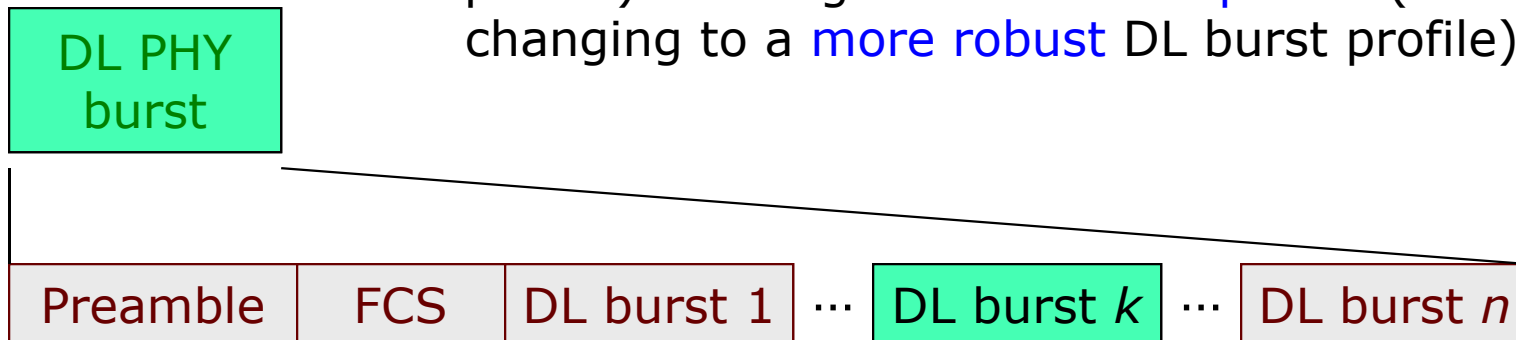


DL burst profile change

RNG-REQ
RNG-RSP
DBPC-REQ
DBPC-RSP

In response to the DBPC-REQ message, the BS returns a **DL burst profile change response message** confirming the new burst profile.

This is done in a DL burst with the **old burst profile** (when changing to a **less robust** DL burst profile) or using the **new burst profile** (when changing to a **more robust** DL burst profile).

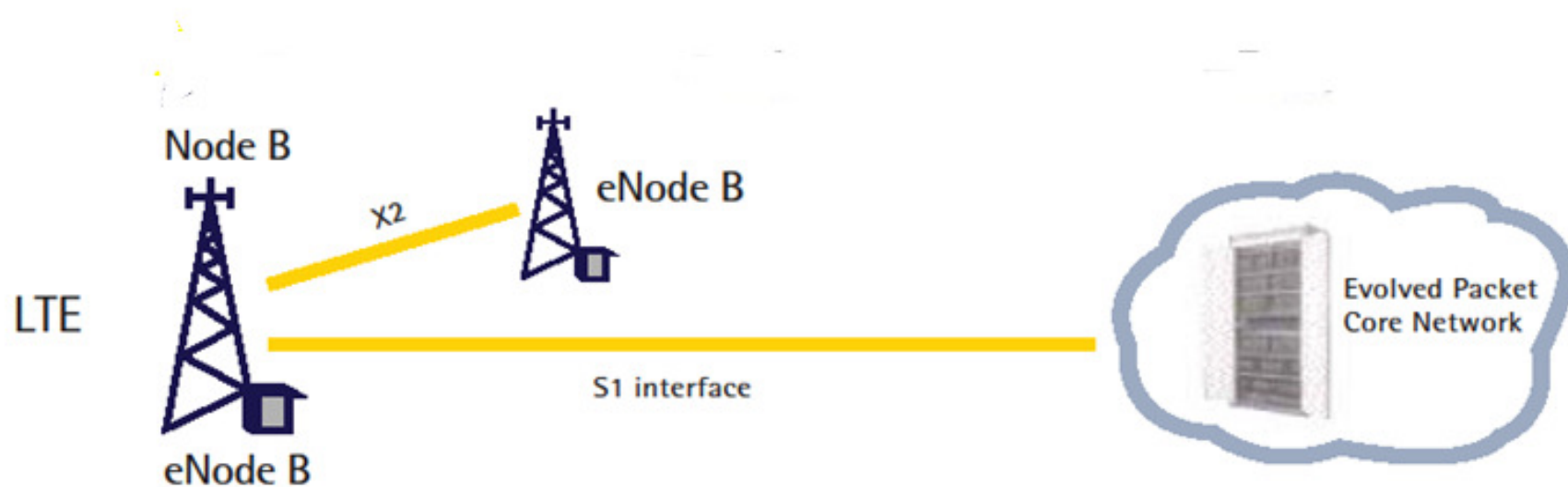


An Introduction of 3GPP Long Term Evolution (LTE)

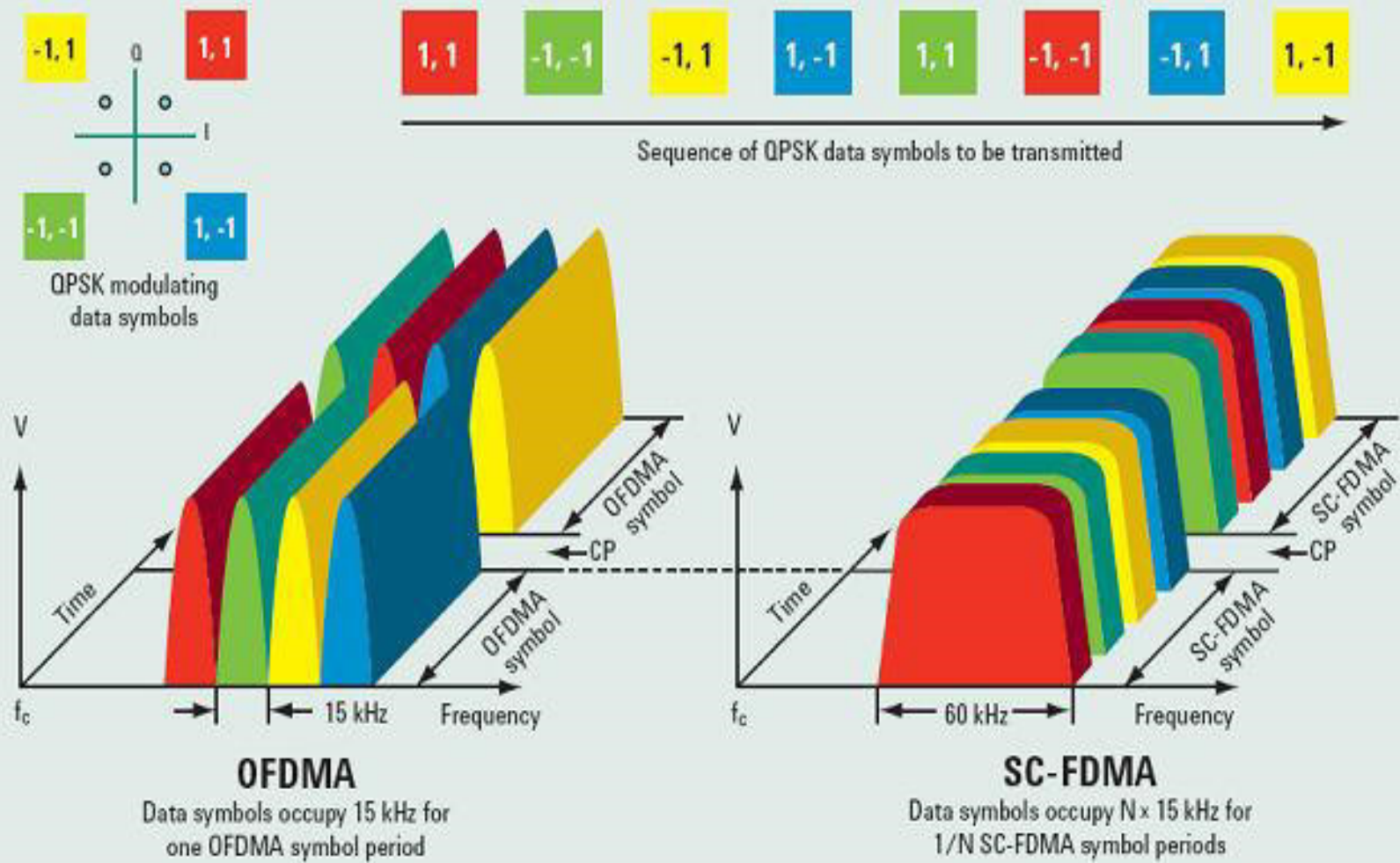
LTE Basic Concepts

- LTE employs Orthogonal Frequency Division Multiple Access (OFDMA) for downlink data transmission and **Single Carrier FDMA (SC-FDMA)** for uplink transmission
- **SC-FDMA** is a new single carrier multiple access technique which has similar structure and performance to OFDMA
- A salient advantage of SC-FDMA over OFDM is the low Peak to Average Power (PAP) ratio : Increasing battery life

LTE Architecture

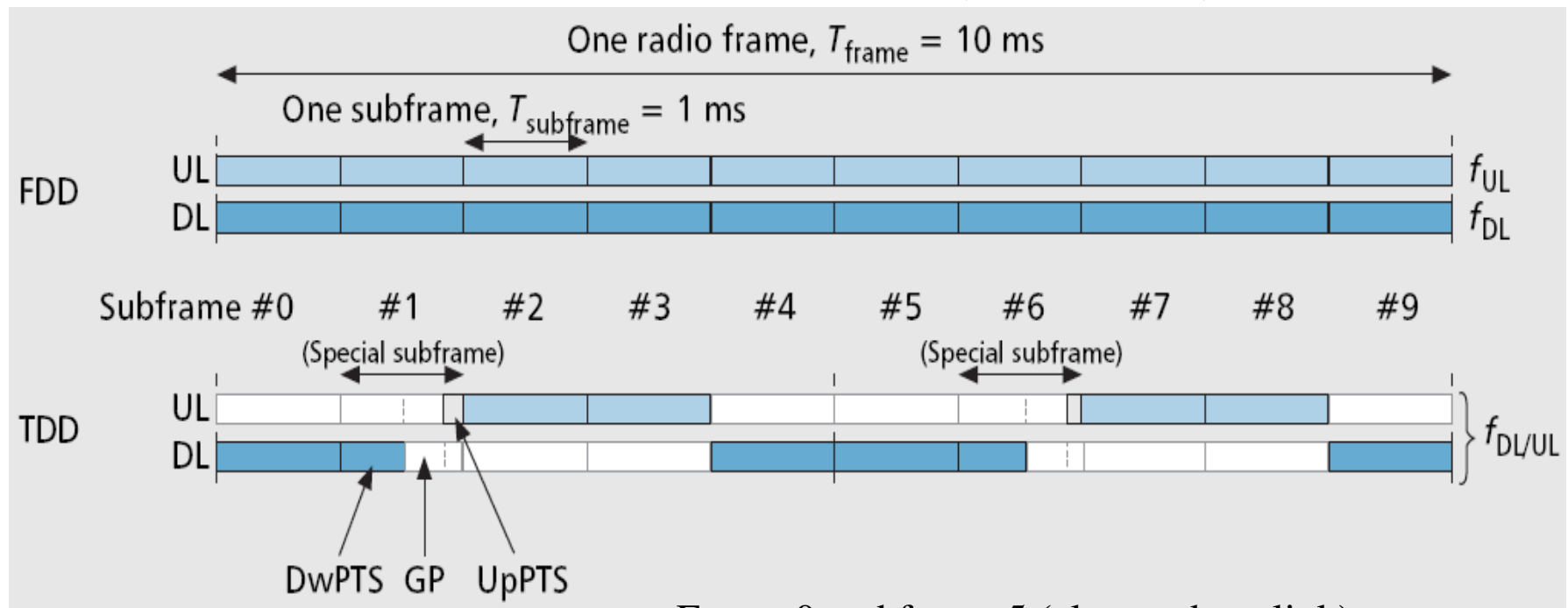


LTE Uplink (SC-FDMA)



Generic Frame Structure

- Allocation of physical resource blocks (PRBs) is handled by a scheduling function at the 3GPP base station: Evolved Node B (eNodeB)

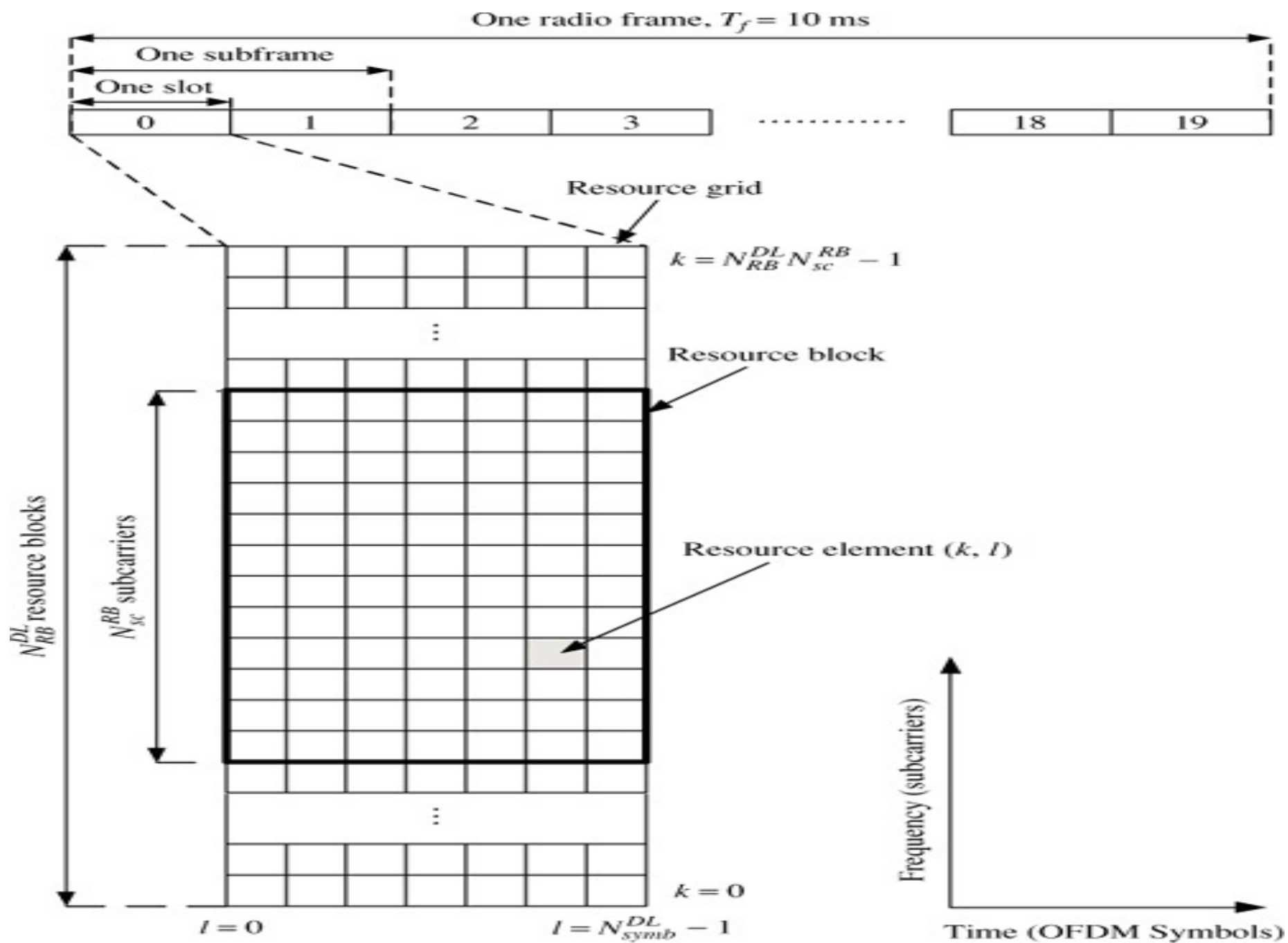


Frame 0 and frame 5 (always downlink)

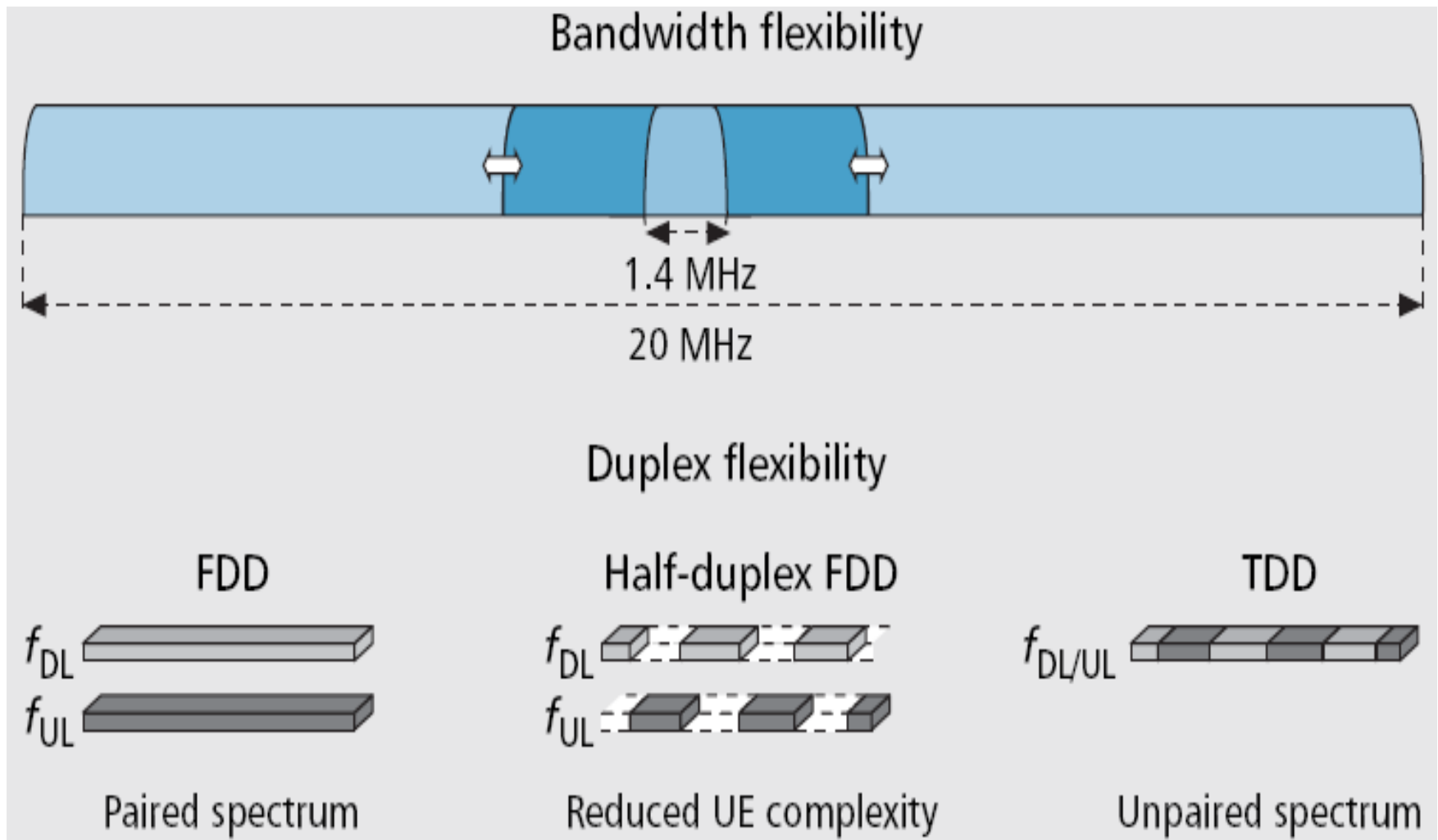
SR is a special Physical Layer message for UE to ask Network to send UL Grant (DCI Format 0) so that UE can transmit PUSCH. Once SR is transmitted and eNB receives it, eNB should send UL Grant(DCI 0) and UE has to send PUSCH in response to the UL Grant.

Resource Blocks for OFDMA

- One frame is 10 ms consisting of 10 subframes
- One subframe is 1ms with 2 slots
- One slot contains N Resource Blocks ($6 < N < 110$)
 - The number of downlink resource blocks depends on the transmission bandwidth.
- One Resource Block contains M subcarriers for each OFDM symbol
 - The number of subcarriers in each resource block depends on the subcarrier spacing Δf
- The number of OFDM symbols in each block depends on both the Cyclic Prefix length and the subcarrier spacing.



LTE Spectrum (Bandwidth and Duplex) Flexibility



LTE Downlink Channels

- The LTE radio interface, various "channels" are used. These are used to segregate the different types of data and allow them to be transported across the radio access network in an orderly fashion.

LTE Downlink Physical Channels

Physical Downlink Shared Channel (PDSCH)

- Carries the DL-SCH and PCH
- QPSK, 16-QAM, and 64-QAM Modulation

Physical Downlink Control Channel (PDCCH)

- Informs the UE about the resource allocation of PCH and DL-SCH, and Hybrid ARQ information related to DL-SCH
- Carries the uplink scheduling grant
- QPSK Modulation

Physical Hybrid ARQ Indicator Channel (PHICH)

- Carries Hybrid ARQ ACK/NAKs in response to uplink transmissions.
- QPSK Modulation

LTE Downlink Physical Channels

Physical Broadcast Channel (PBCH)

- The coded BCH transport block is mapped to four sub-frames within a 40 ms interval. 40 ms timing is blindly detected, i.e. there is no explicit signalling indicating 40 ms timing
- Each sub-frame is assumed to be self-decodable, i.e. the BCH can be decoded from a single reception, assuming sufficiently good channel conditions.
- QPSK Modulation

Physical Multicast Channel (PMCH)

- Carries the MCH
- QPSK, 16-QAM, and 64-QAM Modulation

LTE Uplink Physical Channels

Physical Radio Access Channel (PRACH)

- Carries the random access preamble
- The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences.

Physical Uplink Shared Channel (PUSCH)

- Carries the UL-SCH
- QPSK, 16-QAM, and 64-QAM Modulation

Packet Uplink Control Channel (PUCCH)

- Carries Hybrid ARQ ACK/NAKs in response to downlink transmission
- Carries Scheduling Request (SR)
- Carries CQI reports
- BPSK and QPSK Modulation