LTE

LTE

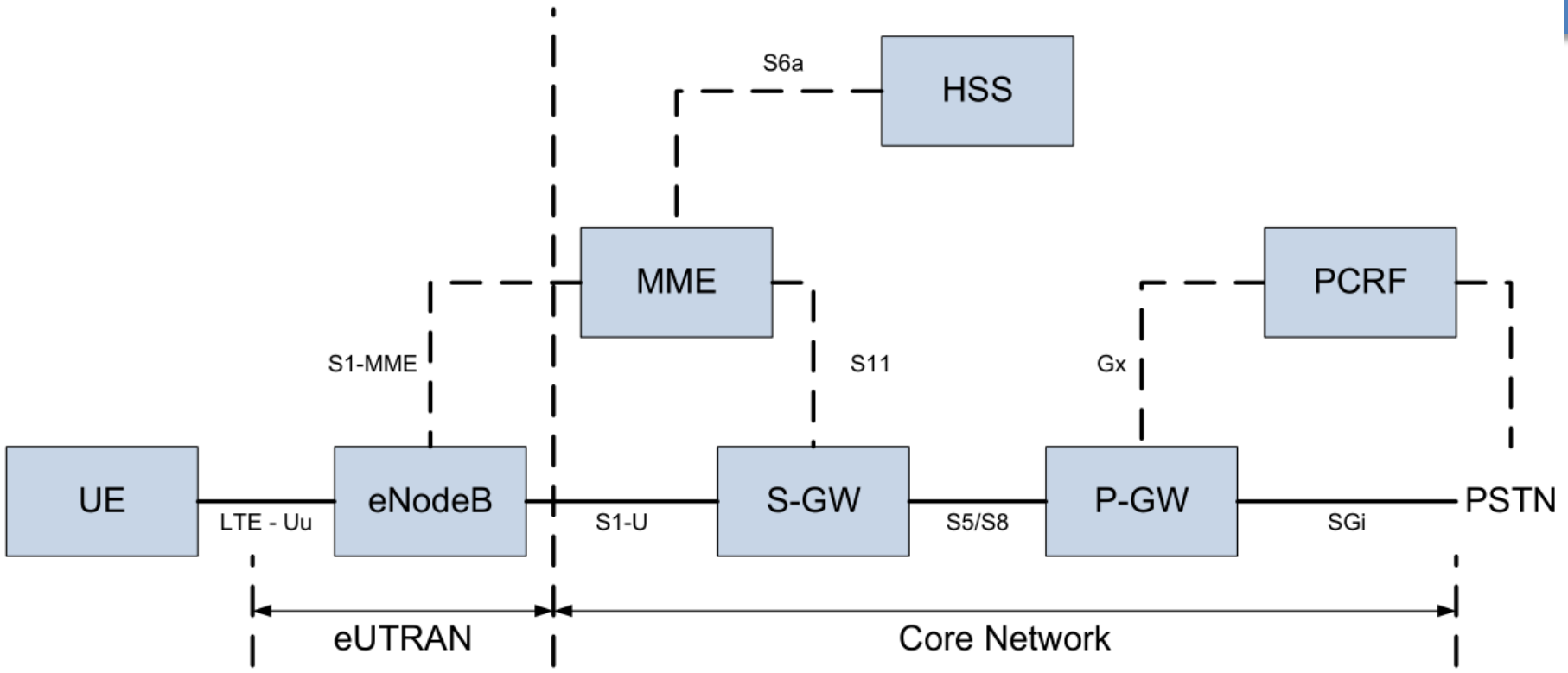
- LTE = Long Term Evolution
- 4G
  - Successor of 3G UMTS and CDMA2000
  - More successful than competing standards, e.g. WiMAX
  - Technologies of LTE have also been “back-ported” to UMTS in HSPA+, for example multiple antennas (MIMO)
  - More correctly: 4G starting from release 8, before: 3.9G
- Performance (in release 8 and 9):
  - Up to 300 Mbit/s downlink, 75 Mbit/s uplink
    - Much faster than UMTS/HSPA+: 28Mbit/s
  - 5-20ms latency

LTE

- Performance in UMTS/HSPA+ reached its limits
  - Higher transfer rates would have required higher chip rate → shorter chip duration → more sensitive to multipath fading
  - Latency in UMTS still high, partially because of old design of the core network (GPRS based network)

- LTE: Complete redesign of radio and core
  1. Again, a completely new radio interface (OFDM)
  2. Simplified IP-only network, with gateways to other networks (GSM, UMTS, CDMA2000,…).
     Only packet-switched, no circuit-switching.

Evolved Packet System (EPS)

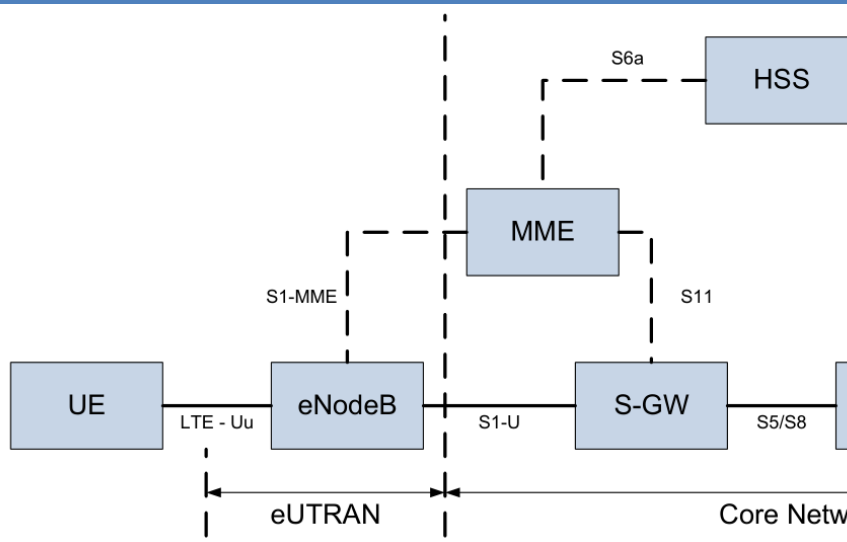


Source: Alexander Schill. TU Dresden

- UE = User Equipment (MS in GSM)
- HSS = Home Subscriber Server (HLR in GSM)
- eNodeB = Evolved Node B (BSS in GSM)
- E-UTRAN = Evolved UTRAN
- EPC = Evolved Packet Core (Network). Completely IP based.

eNodeB

- eNodeB = “evolved” Node B
- Does the job of
  - GSM: BSS
  - UMTS: Node B + RNC



- eNodeB can directly communicate with each other
  - Interference coordination: UE reports signal measurements from neighbor cells to its eNodeB; the node can contact the eNodeB of those cells
  - Handover: eNodeB can decide and prepare handover (without involvement of an MSC in GSM)

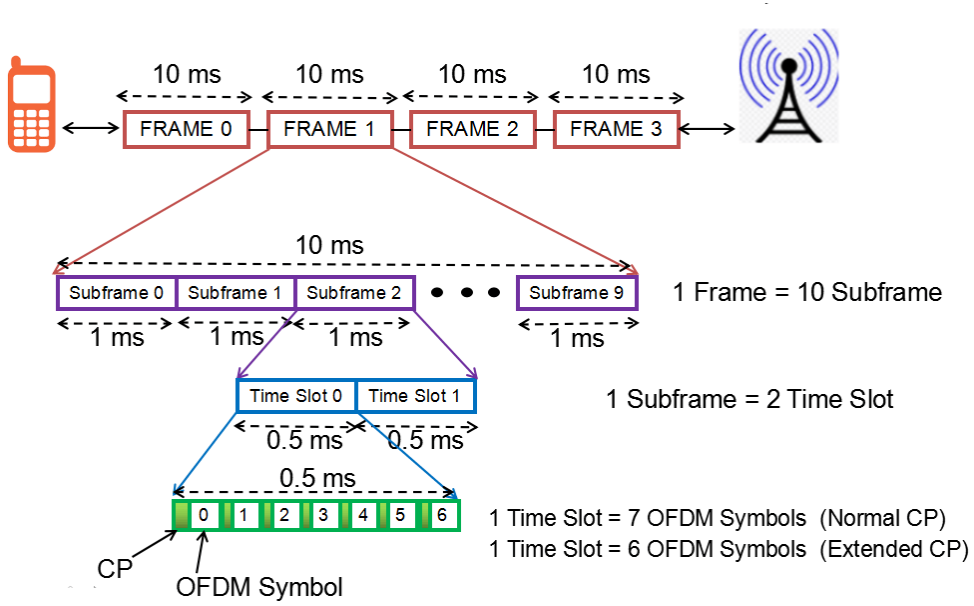
LTE Radio Interface

LTE Frequencies

- LTE 800
  - 791-862 MHz
  - Frequency band originally used by TV stations
  - Divided into 5 MHz blocks assigned to different operators
- LTE 2600
  - 2500-2570 and 2620-2690 MHz
  - Again, blocks of 5 MHz
- In general, higher frequencies have a smaller propagation range. LTE 2600 is used in large cities with many (small) cells
- When GSM is switched off, LTE can also use the GSM frequencies (900 and 1800 MHz)

Frame structure

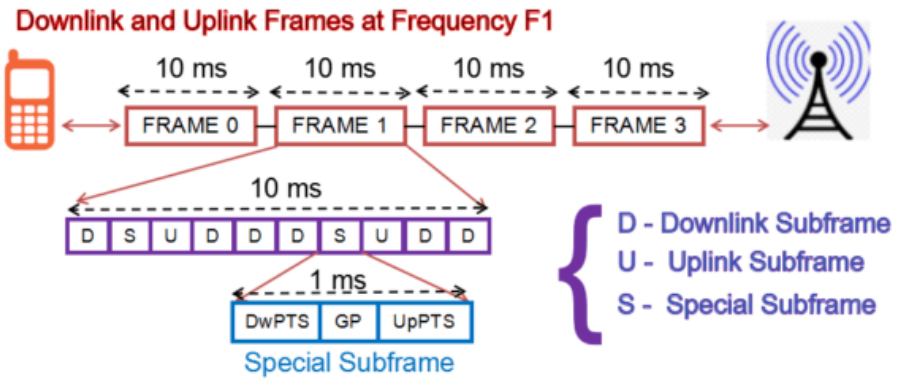
- Data is distributed over a large number of 15kHz subcarriers
- Sub-carriers are assigned in “resource blocks” of 12 carriers (=12×15kHz=180kHz) for 0.5ms (= 1 slot) to a UE
- 1 slot = 7 symbols
- 2 slots = subframe
- 10 subframes = 1 frame



Source: keysight.com

Duplexing with TDD

- TDD = Time Division Duplexing
  - Device switches between sending and receiving



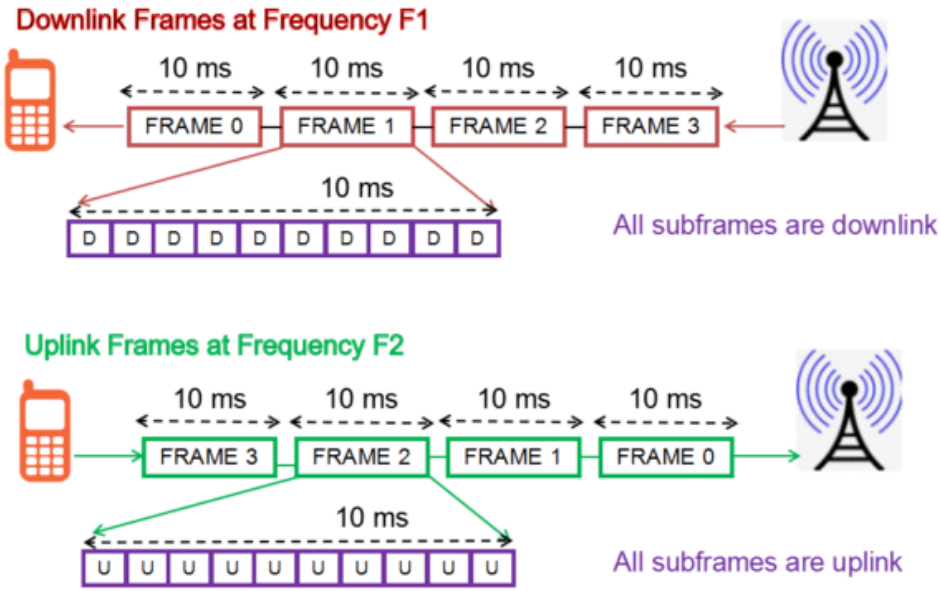
Source: www.techplayon.com

  - Attractive for operators when license fees for frequency bands are expensive. Used in China
  - The ratio uplink to downlink subframes can be configured

Configuration	3GPP release	Downlink to uplink switch point periodicity (ms)	Subframe number										Number of subframes / frame		
			0	1	2	3	4	5	6	7	8	9	D [DL]	U [UL]	S [SSF]
0	8	5	D	S	U	U	U	D	S	U	U	U	2	6	2
1	8	5	D	S	U	U	D	D	S	U	U	D	4	4	2
2	8	5	D	S	U	D	D	D	S	U	D	D	6	2	2
3	8	10	D	S	U	U	U	D	D	D	D	D	6	3	1
4	8	10	D	S	U	U	D	D	D	D	D	D	7	2	1
5	8	10	D	S	U	D	D	D	D	D	D	D	8	1	1
6	8	5	D	S	U	U	U	D	S	U	U	D	3	5	2

Duplexing with FDD

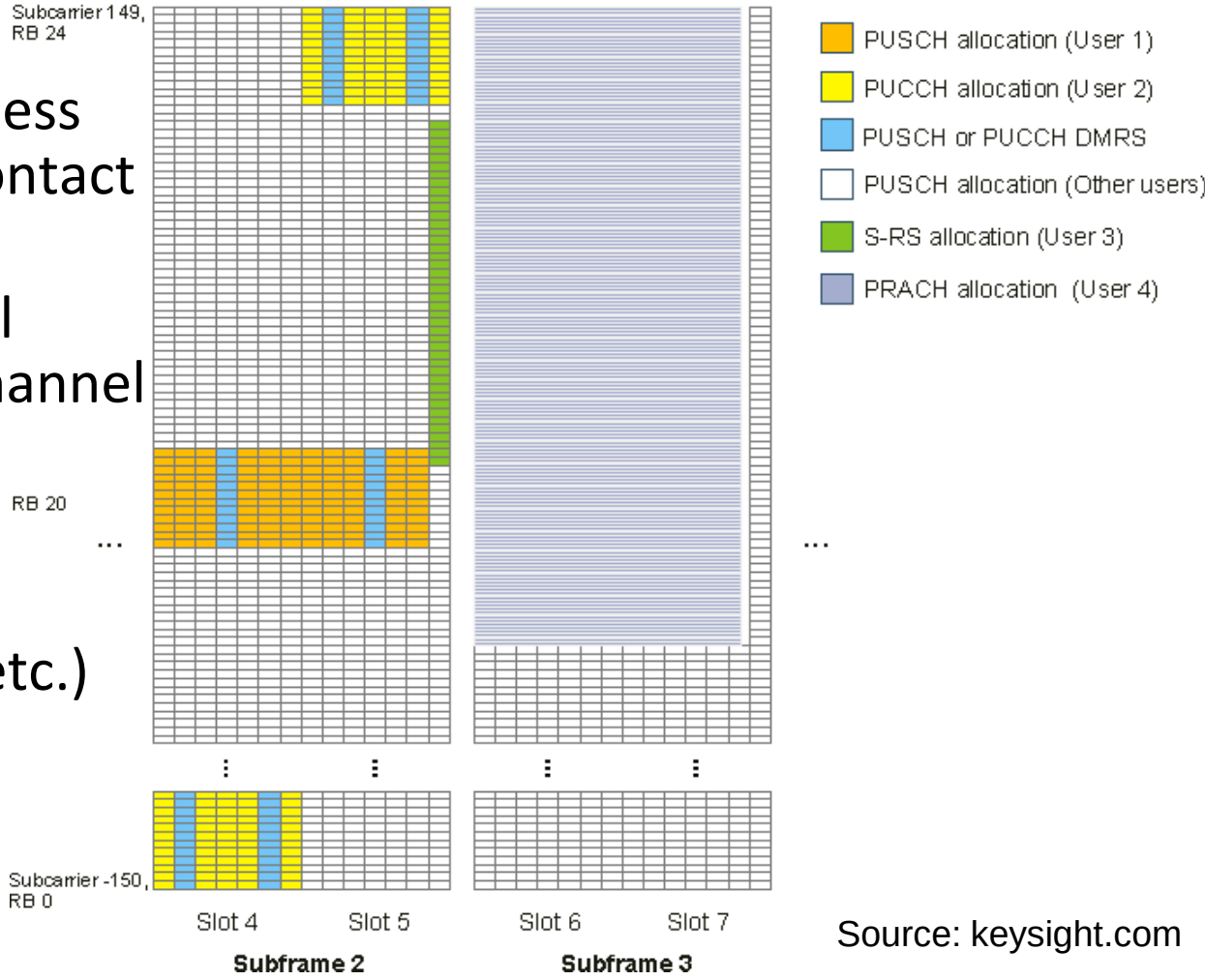
- FDD = Frequency Division Duplexing
  - Different frequencies for downlink and uplink
  - Less sensitive too timing variations than TDD (for example when user is moving in a car)
  - Mainly used in Europe, USA, Japan, South Korea



Source: www.techplayon.com

Example allocation of Uplink

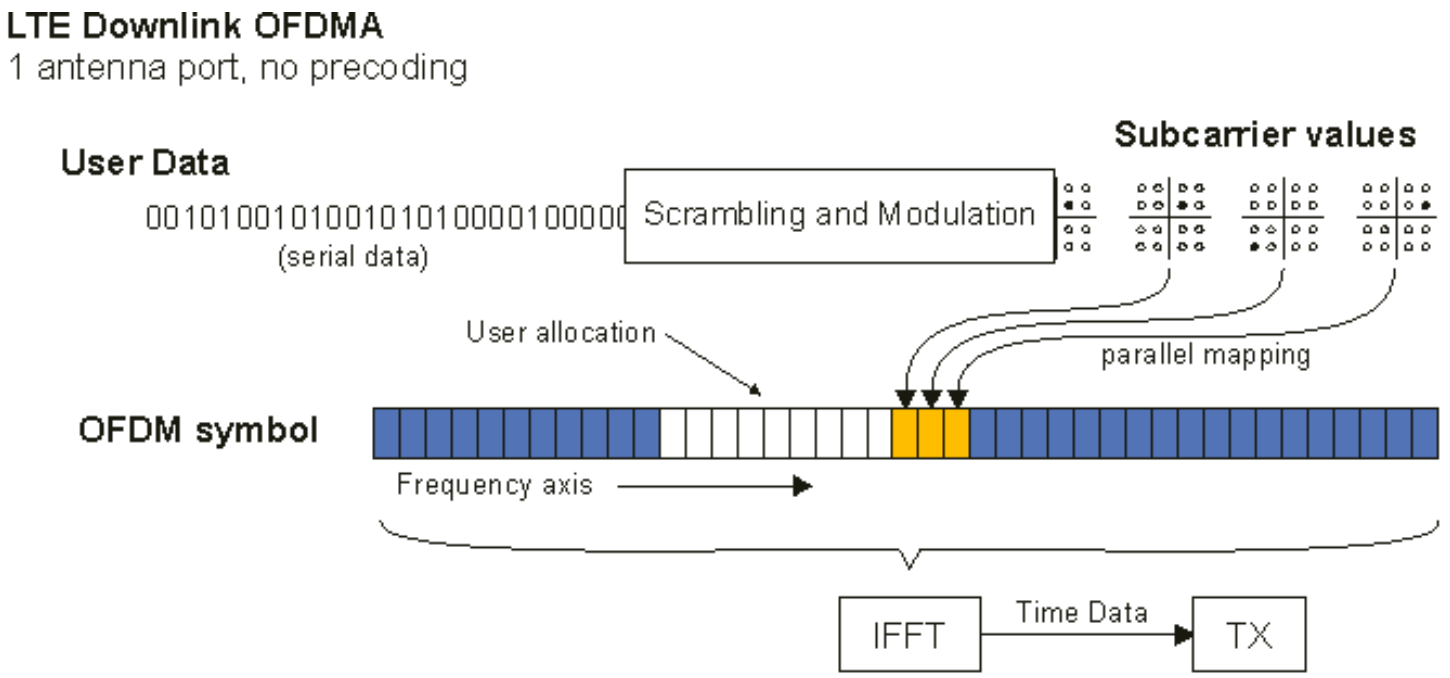
- PUCCH = physical uplink control channel = control messages (channel quality info, ACKs, resource requests, ...)
- PUSCH = uplink data
- PRACH = random access channel to initiate contact to base station
- SRS= reference signal for UE to measure channel characteristics
- (Downlink also has broadcast channels etc.)



Source: keysight.com

LTE radio interface: Downlink

- LTE downlinks use OFDMA (Orthogonal Frequency Division Multiple Access)
- Data from the physical channels is modulated and then mapped to the 12 subcarriers of the resource block assigned to the UE



Source: keysight.com

LTE radio interface: Downlink (2)

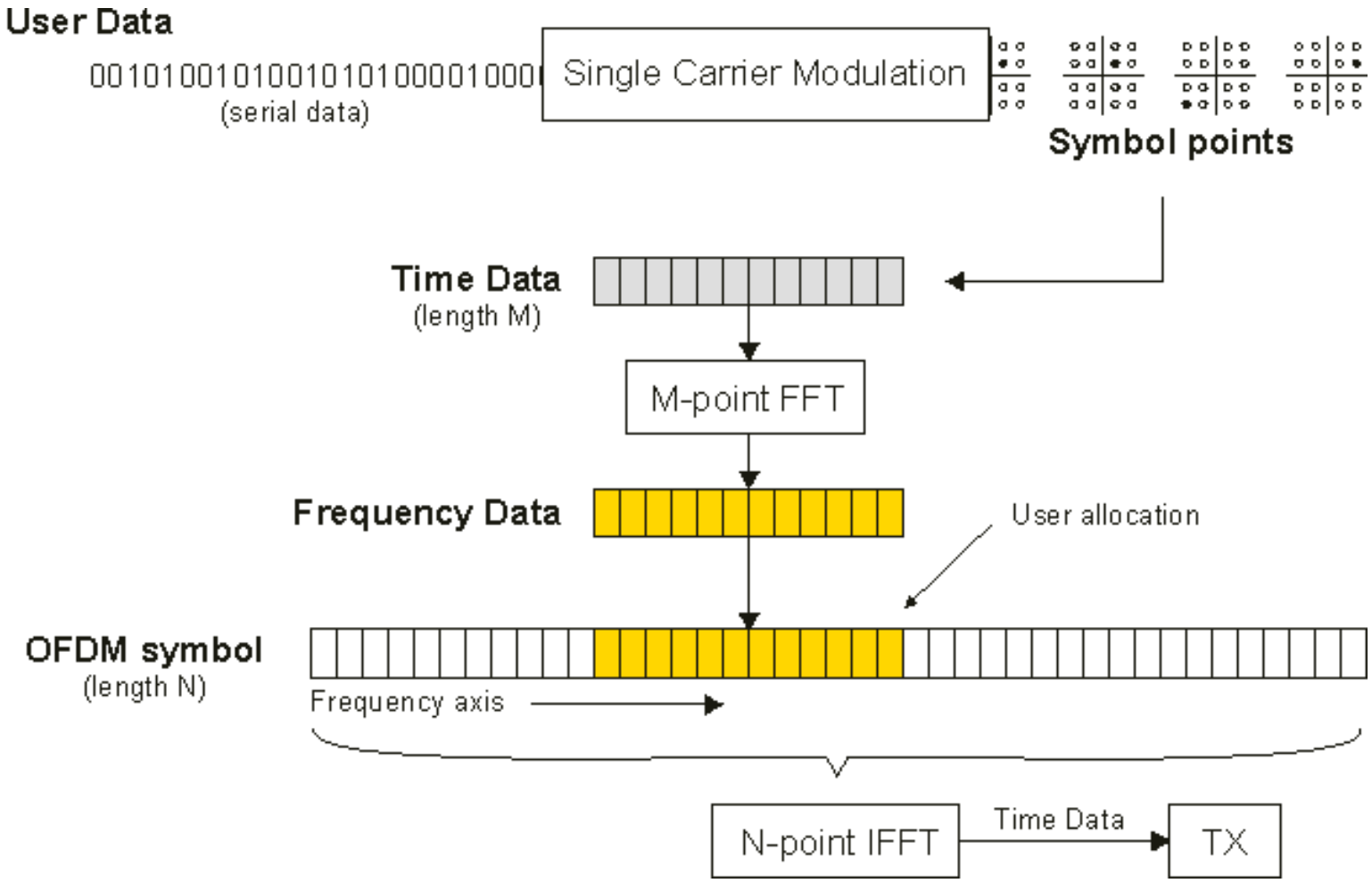
- Advantage of OFDMA:
  - More robust against narrowband interferences that affect only a few subcarriers:
    Unlike UMTS, a disturbed subcarrier can be reconstructed because it is very narrow
  - Subcarriers can be modulated independently depending on channel conditions. Some subcarriers may carry higher bit rates than others.
    - Phase Shift Keying with 4 different shifts (QPSK)
    - 16/64 QAM (combination of amplitude and phase shift keying resulting in 16/64 different symbols)
- Disadvantage of OFDMA:
  - More coding work for the sender
  - High variation of power levels

  → Requires expensive amplifiers

LTE radio interface: Uplink

- OFDMA is good for powerful base stations, but not for small+cheap mobile phones
- In LTE, the uplink uses SC-FDMA (Single Carrier FDMA)
  - Similar to OFDMA, but the 12 sub-carriers of the resource block are treated like one big carrier
  - Peak-To-Average-Power Ratio (PAPR) of the resulting signal is smaller than with OFDM → More energy-efficient, but uplink rate is lower than downlink rate

SC-FDMA



Source: keysight.com

LTE User Equipment Categories (Release 8+9)

Category		1	2	3	4	5
Peak data rate Mbit/s	DL	10	50	100	150	300
	UL	5	25	50	50	75
RF bandwidth		20 MHz				
Modulation		QPSK, 16QAM				QPSK, 16QAM, 64QAM
2 Rx diversity		Assumed in performance requirements				
2x2 MIMO		Not supported	Mandatory			
4x4 MIMO		Not supported				Mandatory

Source: Alexander Schill. TU Dresden

LTE Advanced (LTE-A)

- Compatible with LTE
- Pico and Femto cells for crowded areas
- Carrier aggregation: bundling of frequency carriers
  - LTE: UE can use up to 20MHz
  - LTE-A: UE can use several 20MHz blocks (carriers)
- New categories (releases 10-13)
  - Cat 6: 300MBit/s down, 2x2 MIMO, max. 2 carriers
  - ...
  - Cat 17: 25000MBit/s down, 8x8 MIMO, max. 32 carriers (640 MHz)