Long Term Evolution (LTE) and LTE-Advanced (LTE-A)

LTE: Long Term Evolution

- Standardized by 3GPP (3rd Generation Partnership Project).
- 3GPP is a partnership of 7 regional standards organizations.
  - ARIB (Japan)
  - ATIS (USA)
  - CCSA (China)
  - ETSI (Europe)
  - TTA (South Korea)
  - TTC (Japan)
  - TSDSI (India)*

*Joined on Jan. 1, 2015

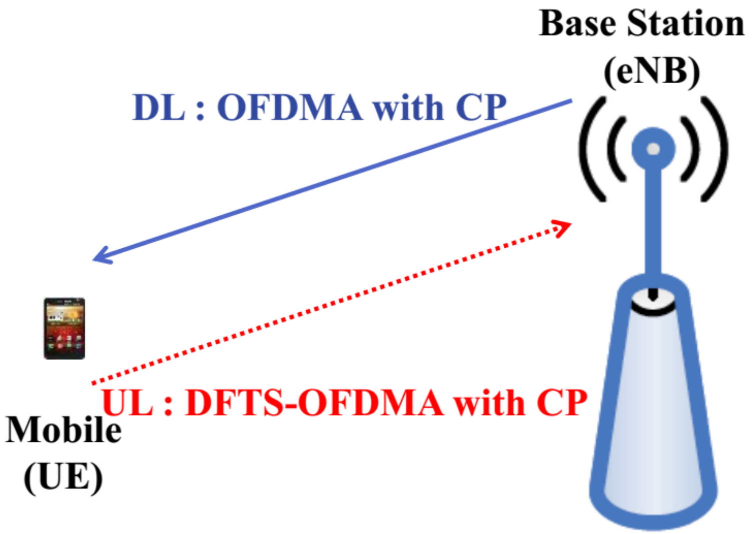
3GPP Evolution

- Release 99 (2000): UMTS/WCDMA
- Rel. 5 (2002): HSDPA
- Rel. 6 (2005): HSUPA
- Rel. 7 (2007) and beyond: HSPA+
- Long Term Evolution (LTE)
  - 3GPP work on the Evolution started in November 2004.
  - Standardized in the form of Rel. 8 (Dec. 2008).
- LTE-Advanced (LTE-A)
  - More bandwidth (up to 100 MHz) and backward compatible with LTE.
  - Standardized in the form of Rel. 10 (Mar. 2011).
  - Meets IMT-Advanced requirements.

LTE Introduction

- Long Term Evolution (LTE) is the next step forward in cellular 3G services.
- It provides for an uplink speed of up to 50 megabits per second (Mbps) and a downlink speed of up to 100 Mbps.
- Bandwidth will be scalable from 1.25 MHz to 20 MHz.
- LTE is also expected to improve spectral efficiency in 3G networks

LTE-Basic Terminologies



DL (Downlink), **UL** (Uplink), **CP** (Cyclic Prefix)

eNB (e Node B), **UE** (User Equipment)

DFTS-OFDMA (DFT Spread OFDMA) : also called as **SC-FDMA** (Single Carrier FDMA)

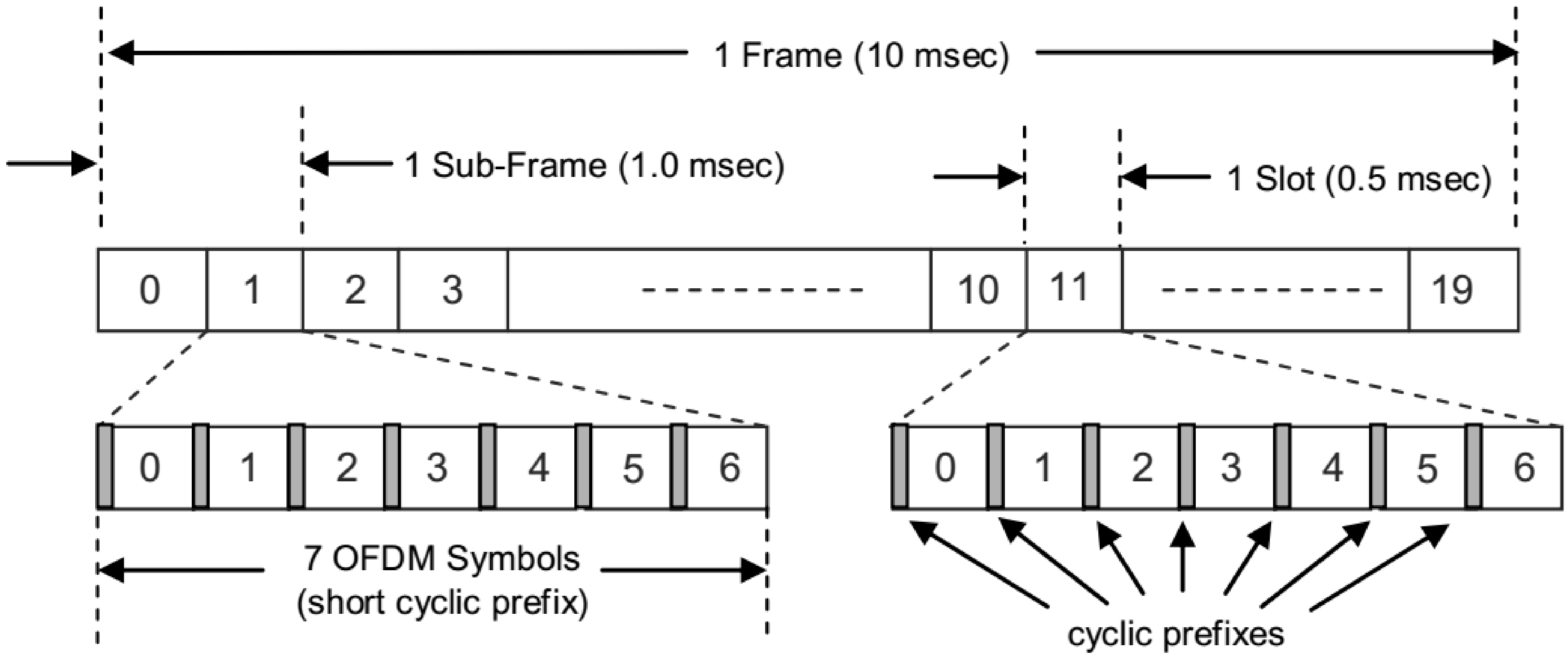
(Reference : p7, 3GPP TS 36.201 V8.3.0 (2009-03))

OFDMA

- OFDMA is employed as the multiplexing scheme in the LTE downlink.
- OFDMA is an excellent choice of multiplexing scheme for the 3GPP LTE downlink.
- In OFDMA, users are allocated a specific number of subcarriers for a predetermined amount of time.
- These are referred to as physical resource blocks (PRBs) in the LTE specifications.
- PRBs thus have both a time and frequency dimension. Allocation of PRBs is handled by a scheduling function at the 3GPP base station (eNodeB).

LTE Generic Frame Structure

Figure 2.3.2-1 LTE Generic Frame Structure



Bandwidth distribution

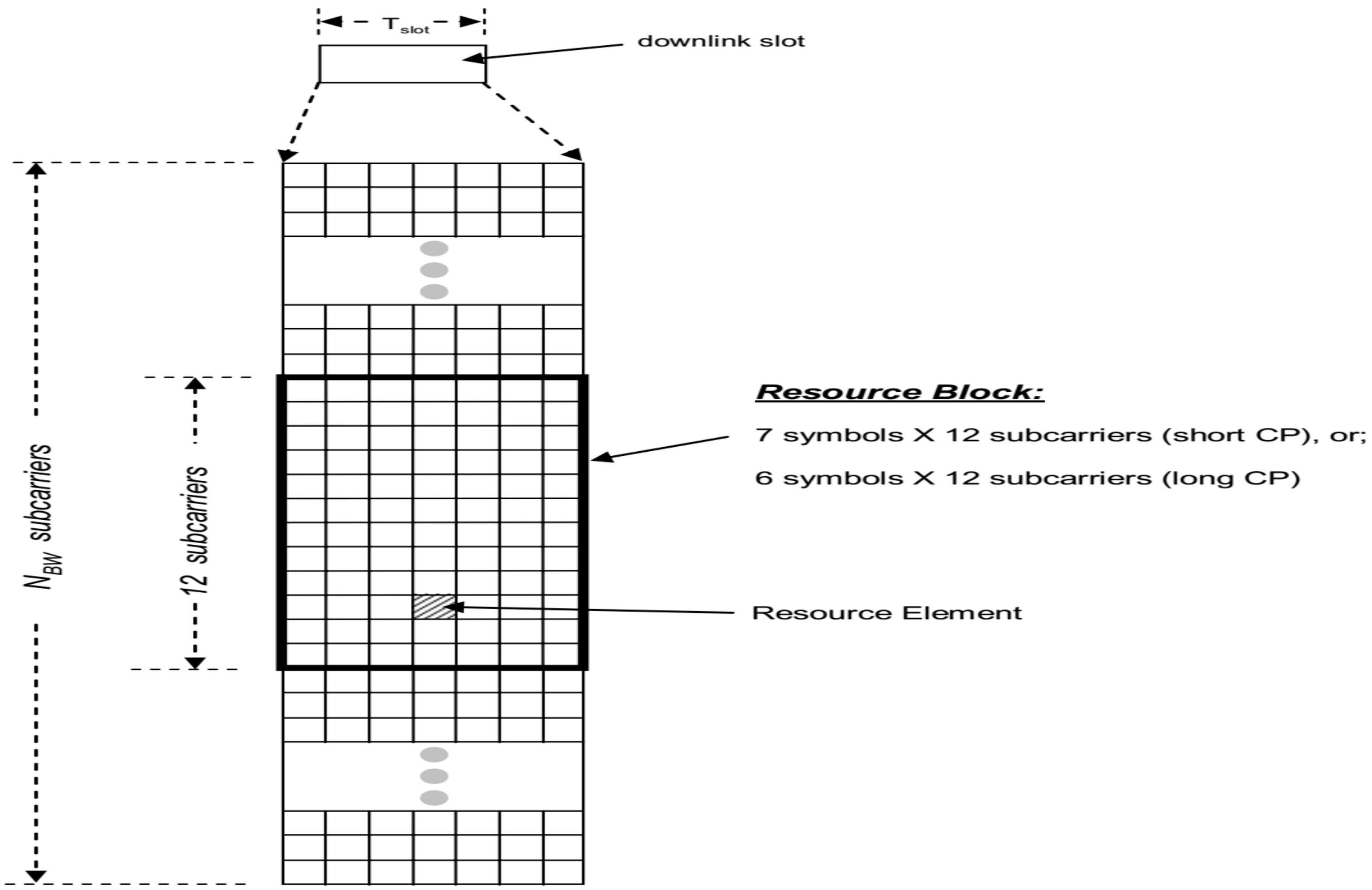
Table 2.3.2-1 Available Downlink Bandwidth is Divided into Physical Resource Blocks

Bandwidth (MHz)	1.25	2.5	5.0	10.0	15.0	20.0
Subcarrier bandwidth (kHz)	15					
Physical resource block (PRB) bandwidth (kHz)	180					
Number of available PRBs	6	12	25	50	75	100

- The total number of available subcarriers depends on the overall transmission bandwidth of the system. The LTE specifications define parameters for system bandwidths from 1.25 MHz to 20 MHz as shown in Table 2.3.2-1.
- A PRB is defined as consisting of 12 consecutive subcarriers for one slot (0.5 msec) in duration.
- A PRB is the smallest element of resource allocation assigned by the base station scheduler.

Downlink resource grid

Figure 2.3.2-2 Downlink Resource Grid

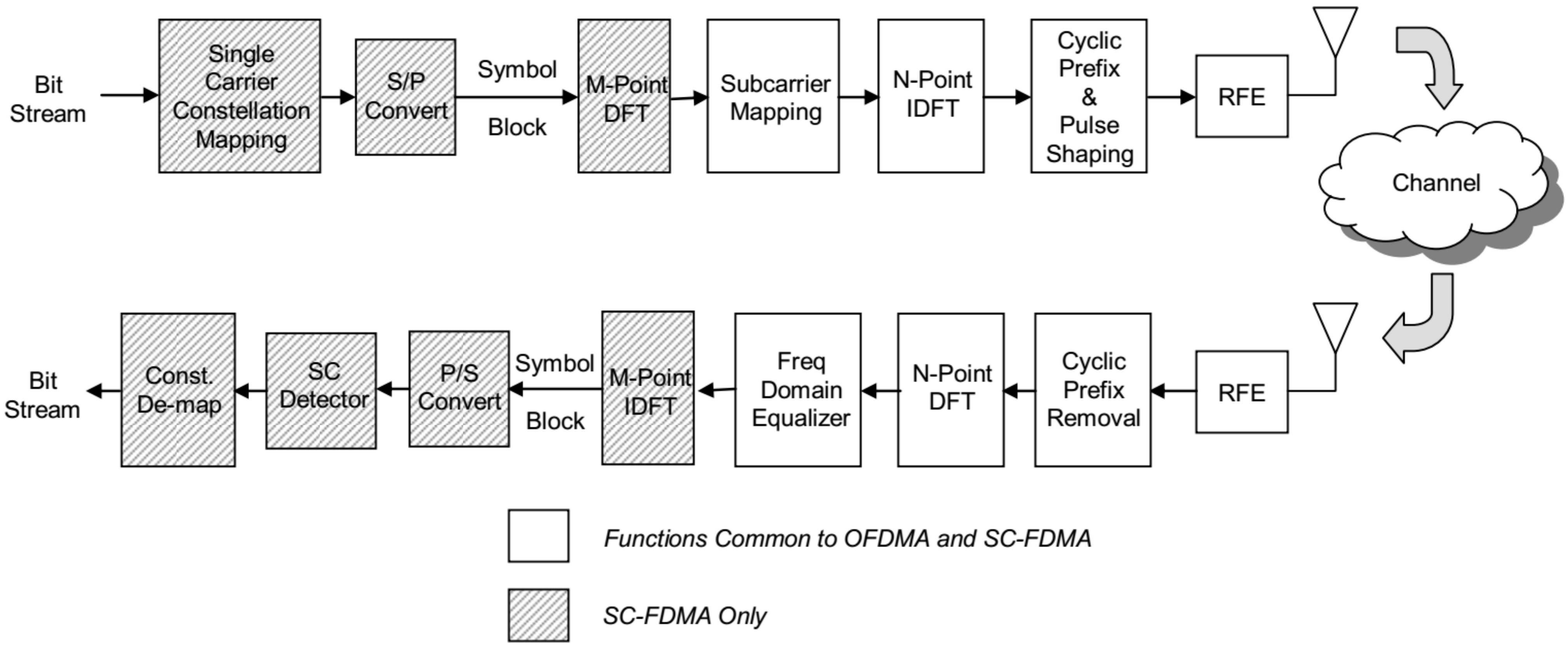


SC-FDMA

- LTE uplink requirements differ from downlink requirements in several ways.
- Not surprisingly, power consumption is a key consideration for UE terminals.
- The high **PAPR** and related loss of efficiency associated with OFDM signalling are major concerns. As a result, an alternative to OFDM was sought for use in the LTE uplink.
- Single Carrier – Frequency Domain Multiple Access (SC-FDMA) is well suited to the LTE uplink requirements.
- The basic transmitter and receiver architecture is very similar (nearly identical) to OFDMA, and it offers the same degree of multipath protection.
- Importantly, because the underlying waveform is essentially single-carrier, the **PAPR is lower**.

SC-FDMA Transceiver

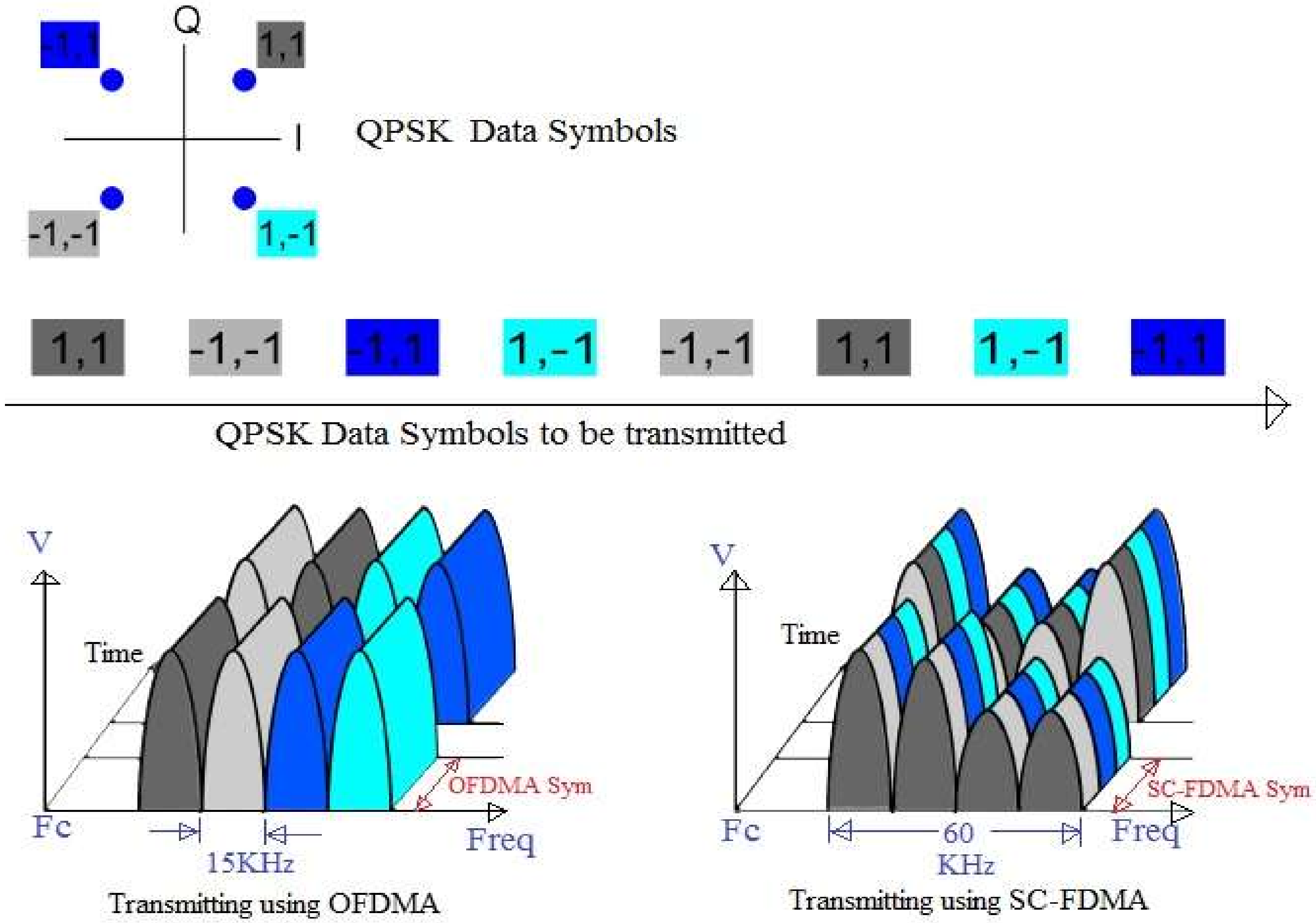
Fig. 2.5-1 SC-FDMA and OFDMA Signal Chains Have a High Degree of Functional Commonality



SC-FDMA Transceiver

- Note that many of the functional blocks are common to both SC-FDMA and OFDMA. The functional blocks in the transmit chain are:
  1. **Constellation mapper**: Converts incoming bit stream to single carrier symbols (BPSK, QPSK, or 16QAM depending on channel conditions)
  2. **Serial/parallel converter**: Formats time domain SC symbols into blocks for input to FFT engine
  3. **M-point DFT**: Converts time domain SC symbol block into M discrete tones
  4. **Subcarrier mapping**: Maps DFT output tones to specified subcarriers for transmission.
- 5. **N-point IDFT**: Converts mapped subcarriers back into time domain for transmission
  6. **Cyclic prefix and pulse shaping**: Cyclic prefix is pre-pended to the composite SC-FDMA symbol to provide multipath immunity in the same manner as described for OFDM. As in the case of OFDM, pulse shaping is employed to prevent spectral regrowth.
  7. **RFE:** Converts digital signal to analogue and up convert to RF for transmission
- **Unlike OFDM, the underlying SC-FDMA signal represented by the discrete subcarriers is—not surprisingly—single carrier. This is distinctly different than OFDM because the SC-FDMA subcarriers are not independently modulated. As a result, PAPR is lower than for OFDM transmissions**.

SC-FDMA vs OFDMA

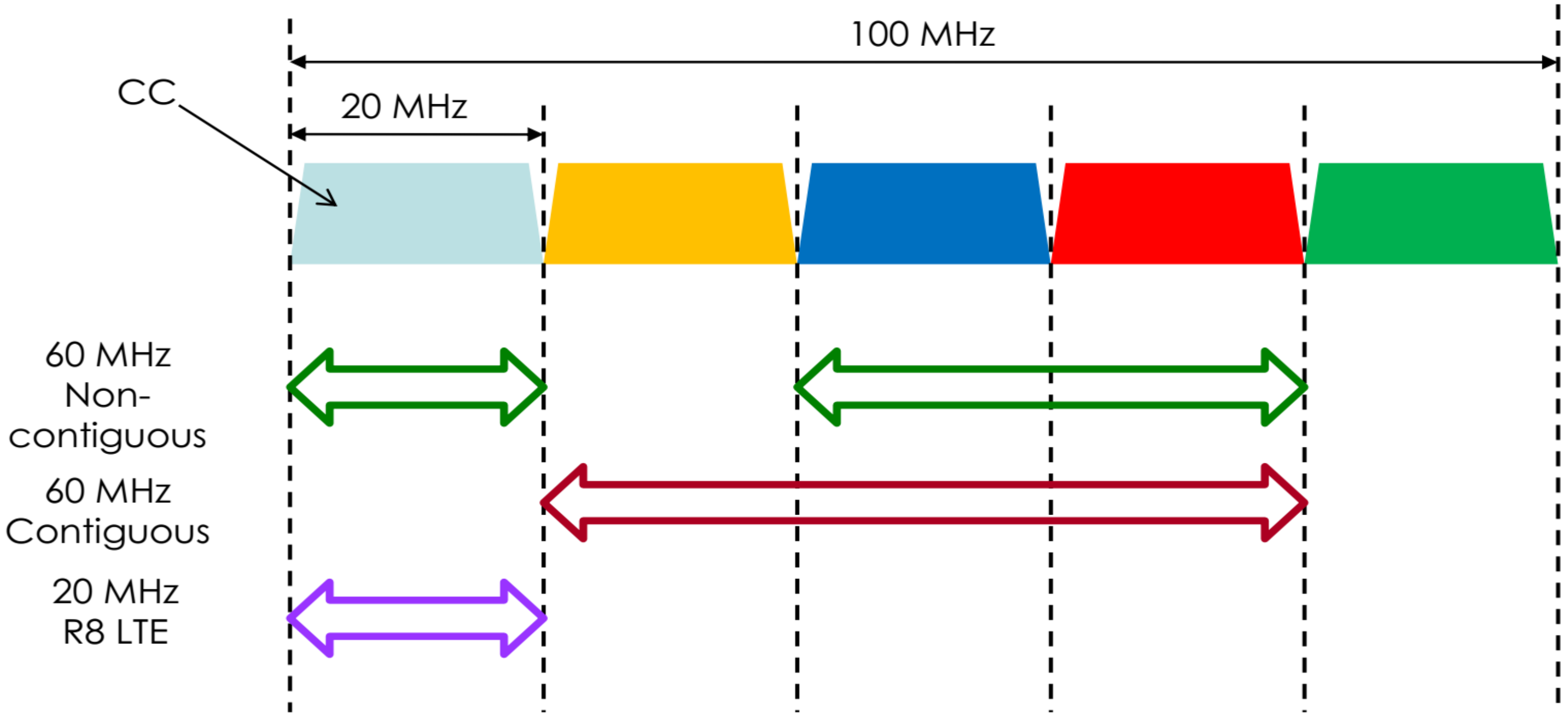


LTE-A: Carrier Aggregation

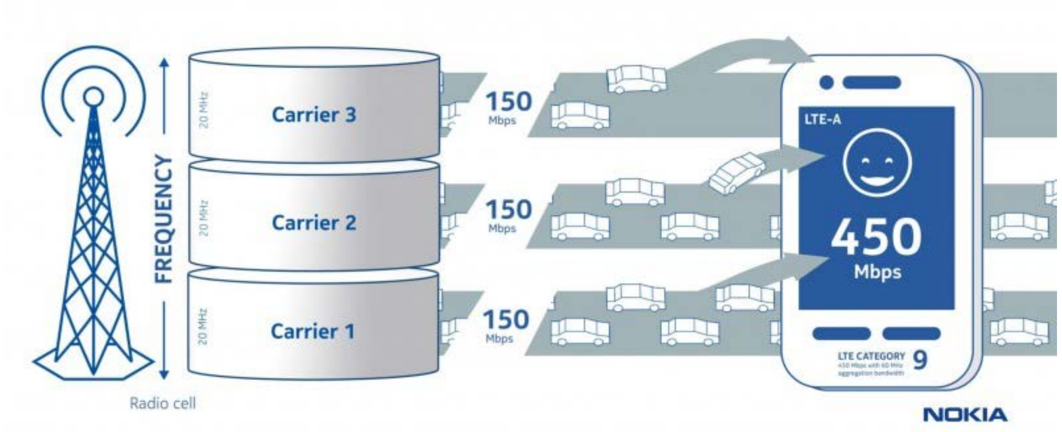
• In order to support up to 100 MHz bandwidth, two or more component carriers aggregated
– Component carrier (CC): Basic frequency block which comply with R8 LTE numerology
– Each CC is limited to 20 MHz bandwidth (110 resource blocks).
– Maintains backward compatibility with R8 LTE.
• Supports both contiguous and non-contiguous spectrum.
• Also supports asymmetric bandwidth for FDD.

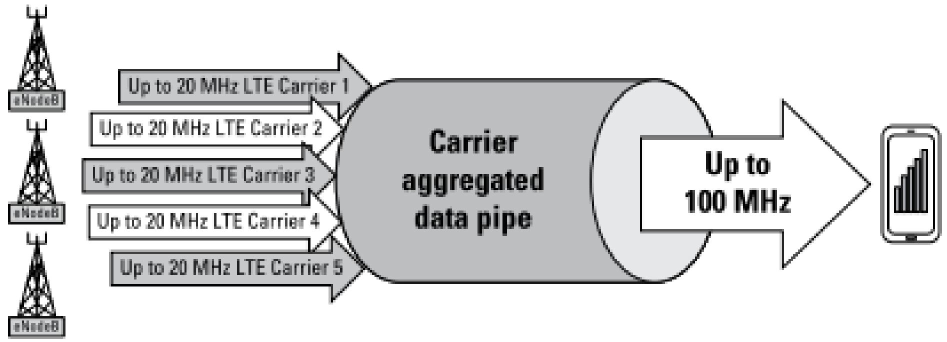
LTE-A: Carrier Aggregation

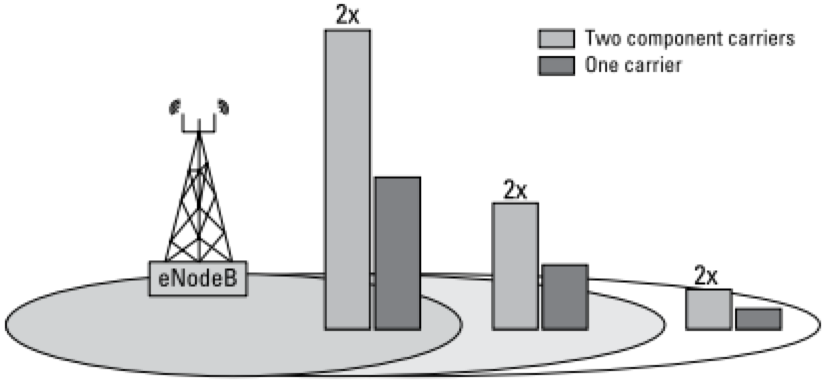
– cont.



LTE Carrier Aggregation: Data rate improvement

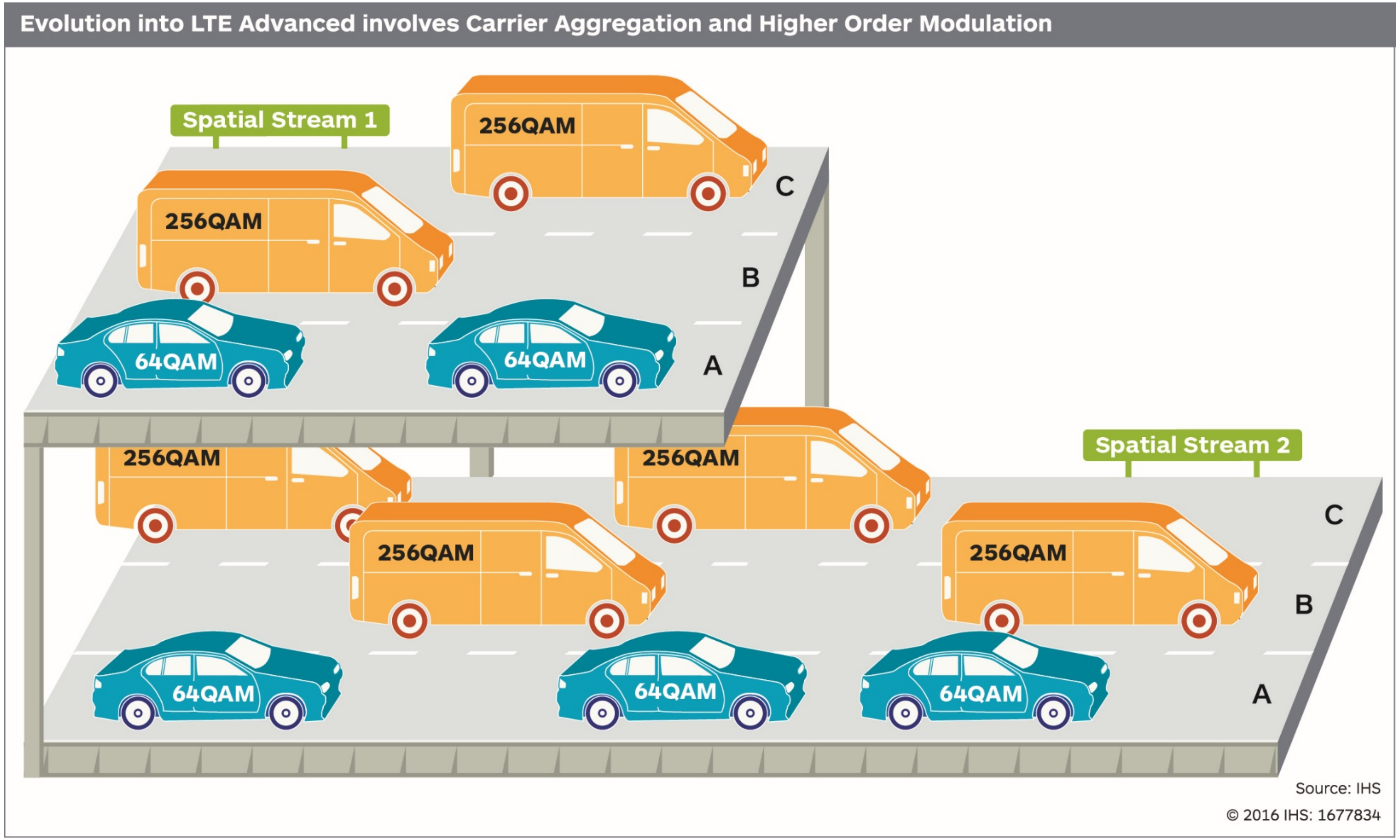






100 percent improvement in physical layer output

LTE Carrier Aggregation: Data rate improvement



LTE-A - MIMO (Multiple input multiple output)

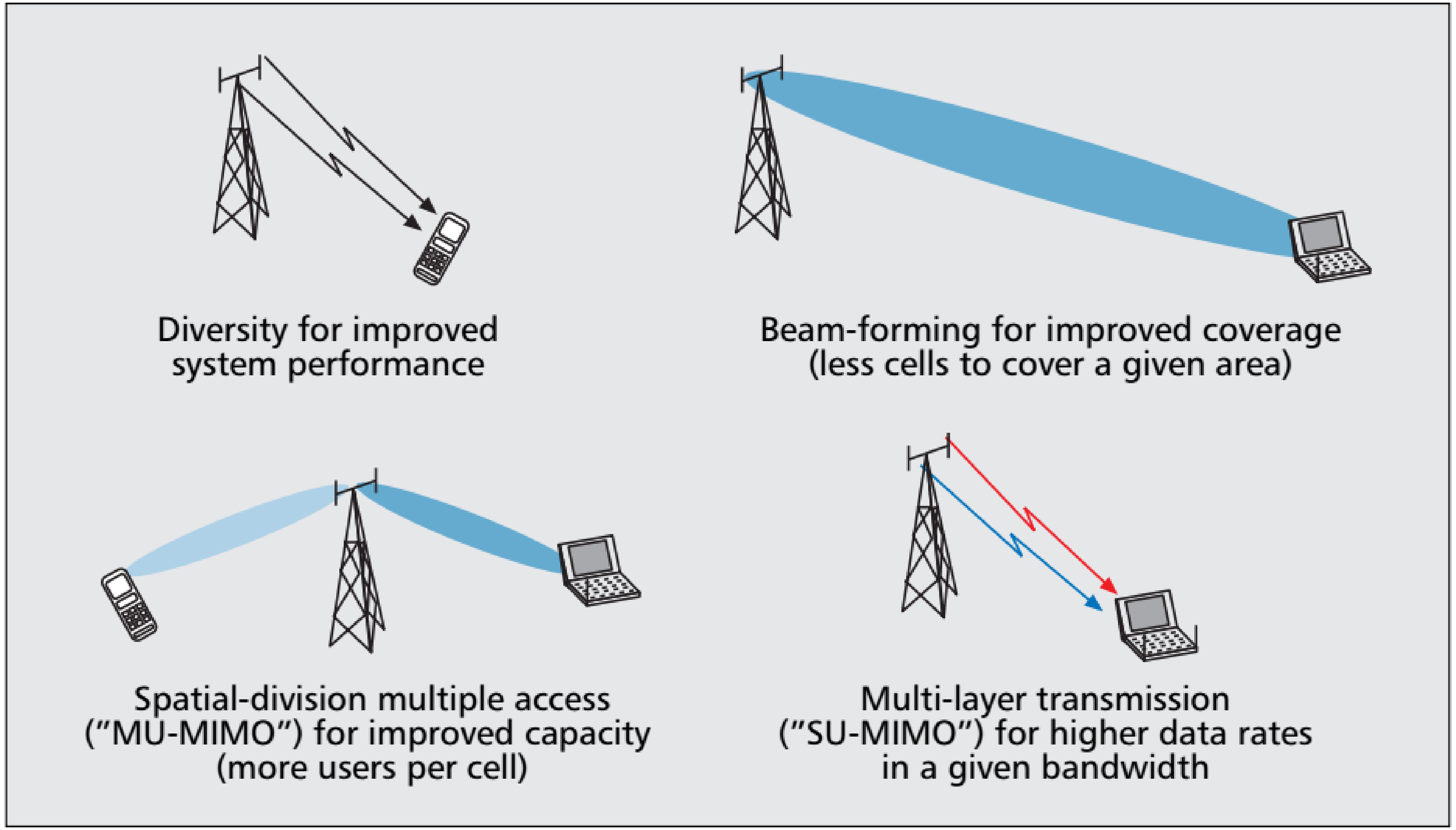


Figure 5. *Multiple-antenna techniques in LTE.*