The next Mobile Communication System Generation – 5G or 4G-evolution?

Prof. Dr.-Ing. Ulrich Jetzek
Kiel University of Applied Sciences, Germany
Institute of Communications Technology and Embedded Systems

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Overview

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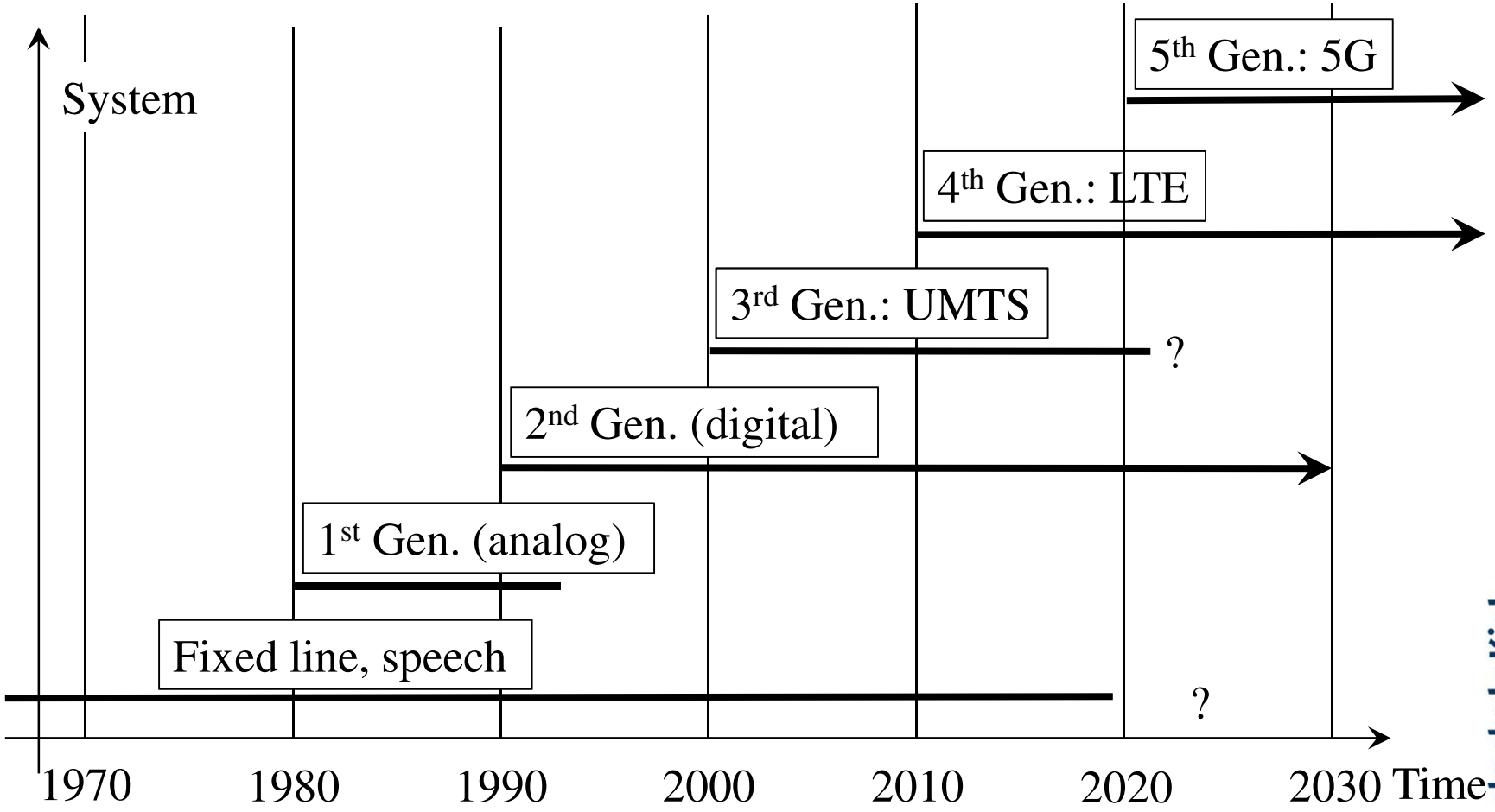
3. Summary

1 5G Overview

- Main NR benefits as compared to LTE:
  - Exploitation of **higher frequency bands** to support very wide transmission bandwidths
  - **Ultra-lean design** to enhance network energy performance and reduce interference
  - **Forward compatibility** to prepare for future use cases
  - **Low latency** to improve performance and enable new use cases
  - **Beam-centric design** enabling extensive usage of beamforming and multiple antenna elements for data transmission as well as for control-plane procedures such as initial access

Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 5

1 Mobile Communication Systems History



Rule of thumb: A new mobile communication technology roughly every 10 years

2.1 5G Technical Requirements

Parameter	Min. techn. Performance requirement	Corresponding LTE requirement (for comparison only)
Peak data rate	DL: 20 Gbit/s UL: 10 Gbit/s	DL: 100 Mbit/s UL: 50 Mbit/s
Peak spectral efficiency	DL: 30 bit/s/Hz UL: 10 bit/s/Hz	DL: 5 bit/s/Hz UL: 2,5 bit/s/Hz
User-experienced data rate	DL: 100 Mbit/s UL: 50 Mbit/s	DL: ~ 10 Mbit/s UL: ~ 5 Mbit/s
Fifth percentile user spectral efficiency	3x IMT-Advanced	IMT-Advanced
Average spectral efficiency	3x IMT-Advanced	IMT-Advanced
Area traffic capacity	10 Mbit/s/m^2 (Indoor hotspot for eMBB)	
User plane latency	4 ms for eMBB 1 ms for URLLC	User Plane: $< 5ms$

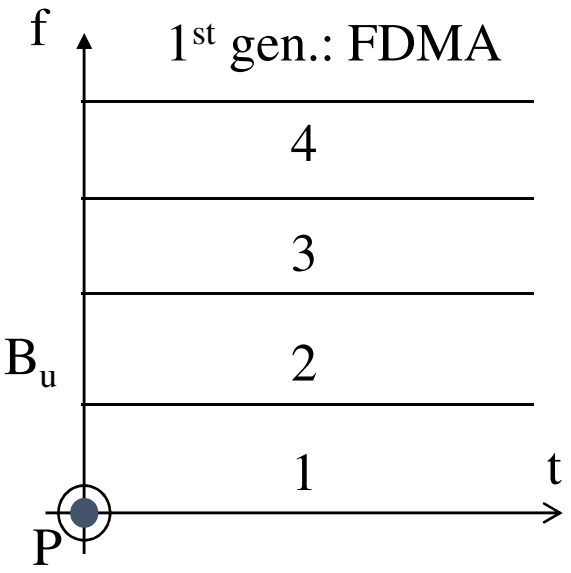
Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 2

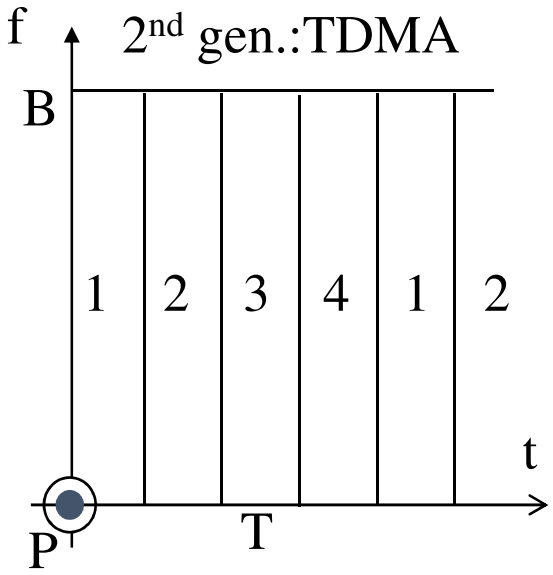
2.1 5G Technical Requirements

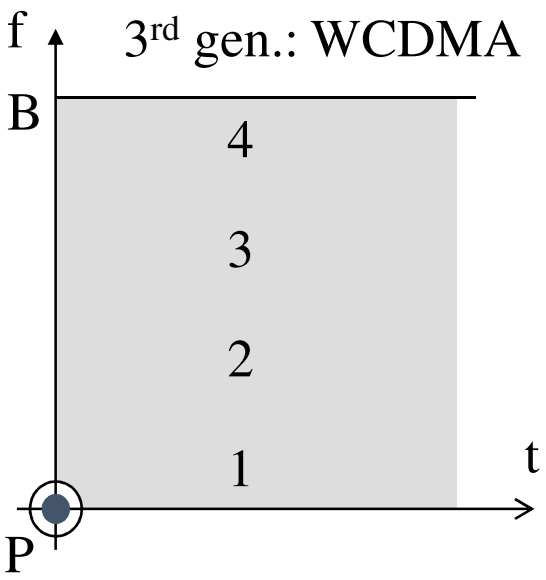
Parameter	Min. techn. Performance requirment
Control plane latency	20 ms (LTE: $< 100\ ms$)
Connection density	1.000.000 devices per km^2
Energy efficiency	For eMBB: a) Efficient data transmission in loaded case b) Low energy consumption when no data
Reliability	$1 - 10^{-5}$ success probability of transmitting a layer 2 PDU of 32 bytes within 1 ms
Mobility	Normalized traffic channel data rates defined at 10, 30 and 120 km/h at ~1,5 x IMT-adv. Users
Mobility interruption time	0 ms
Bandwidth	At least 100 MHz and up to 1 GHz in higher freq.-bands. Scalable bandwidth

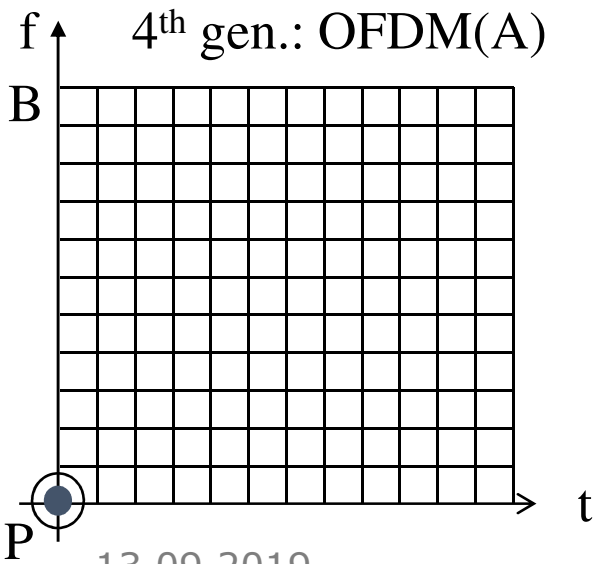
Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 2

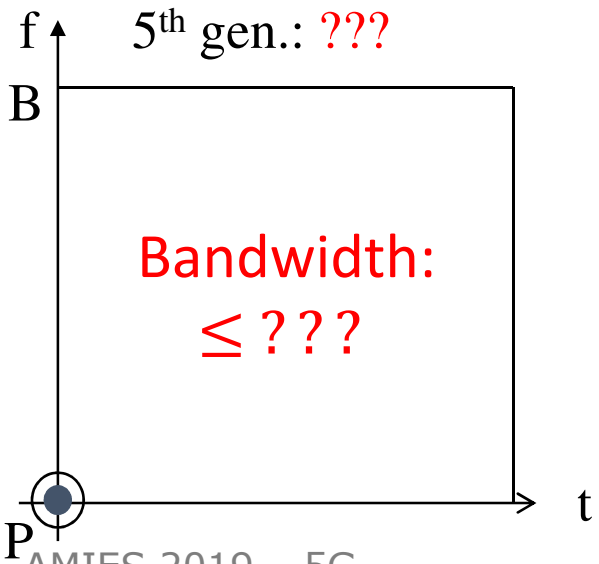
2.2 Multiple Access Schemes











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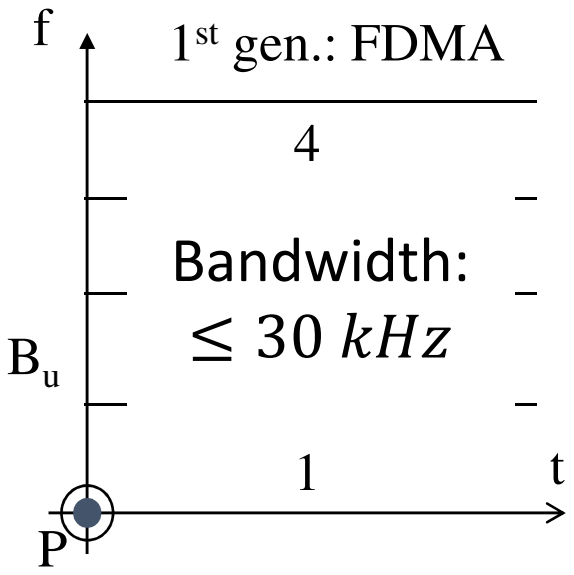
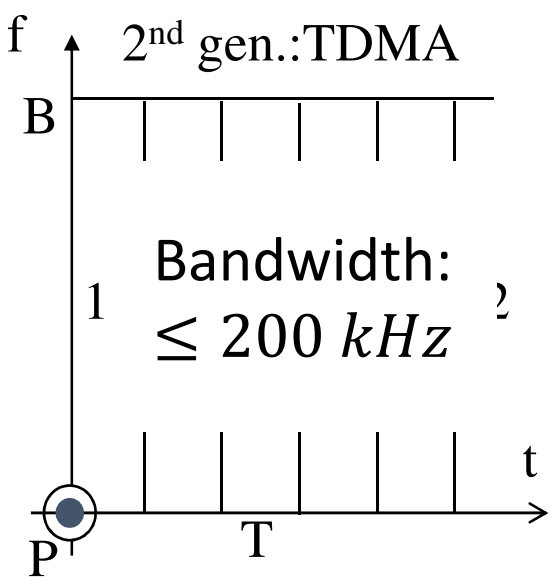
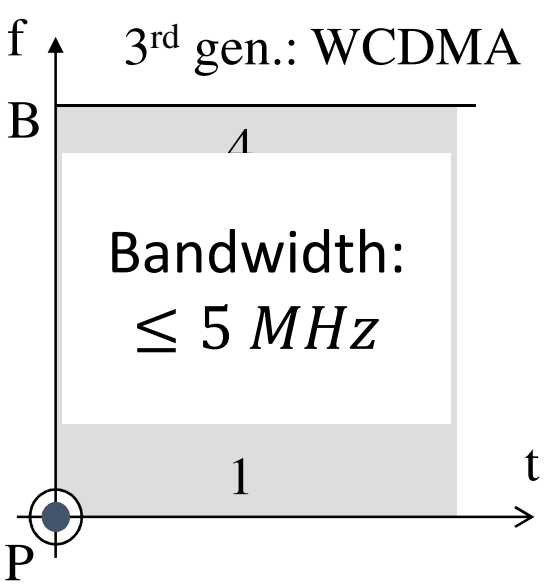
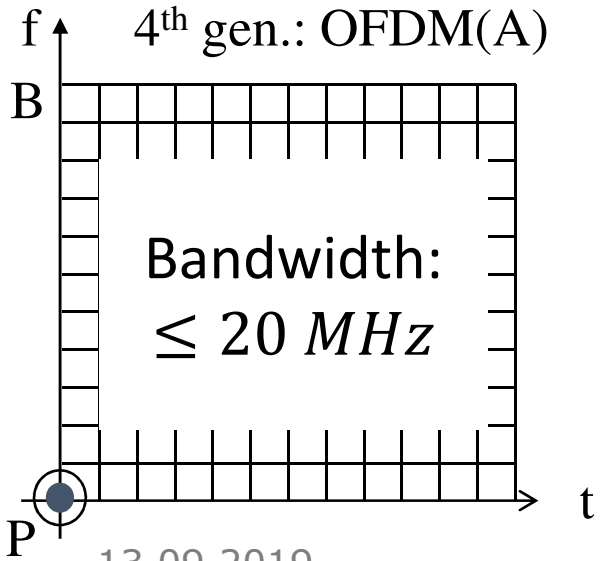
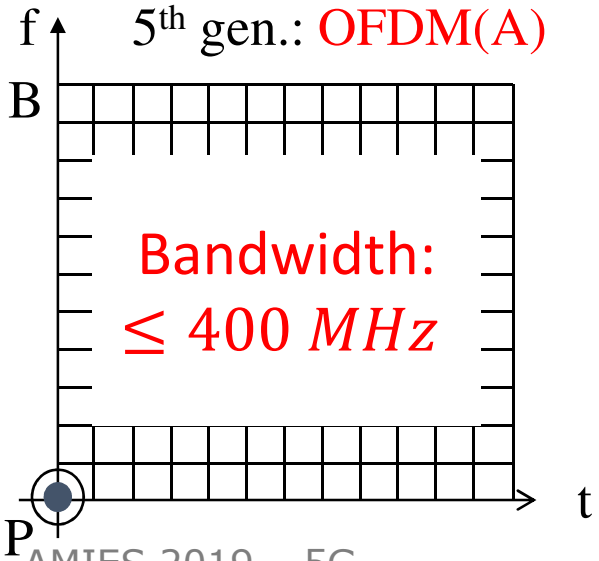




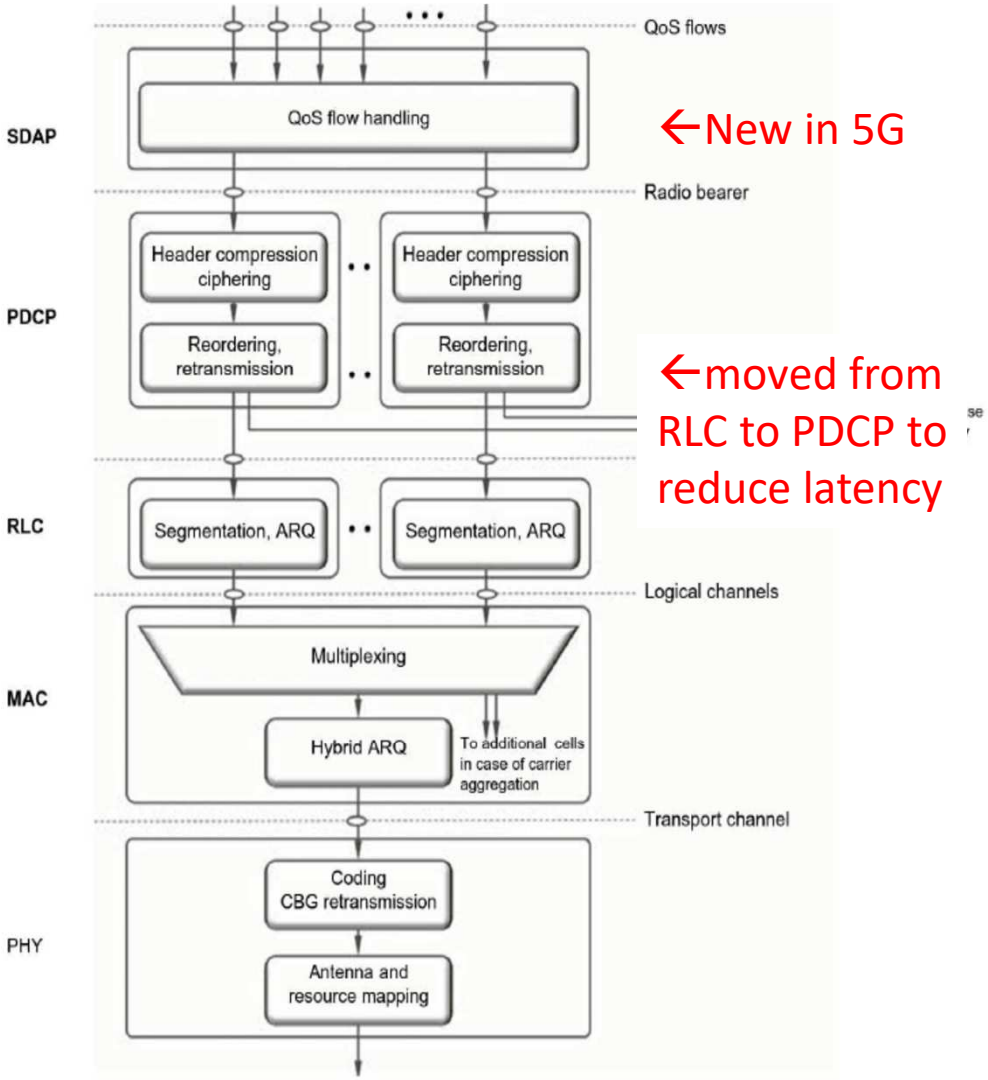






2.3 User Plane Protocols

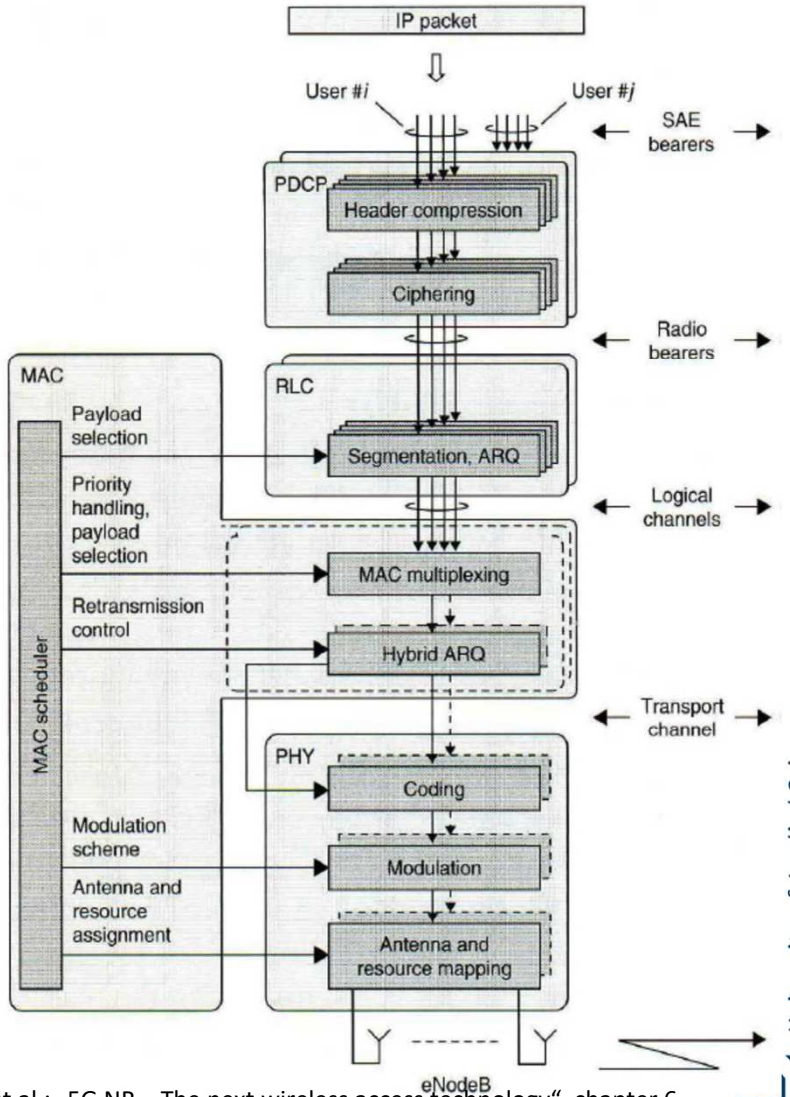
5G Protocol Architecture



←New in 5G

←moved from RLC to PDCP to reduce latency

LTE Protocol Architecture



Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 6

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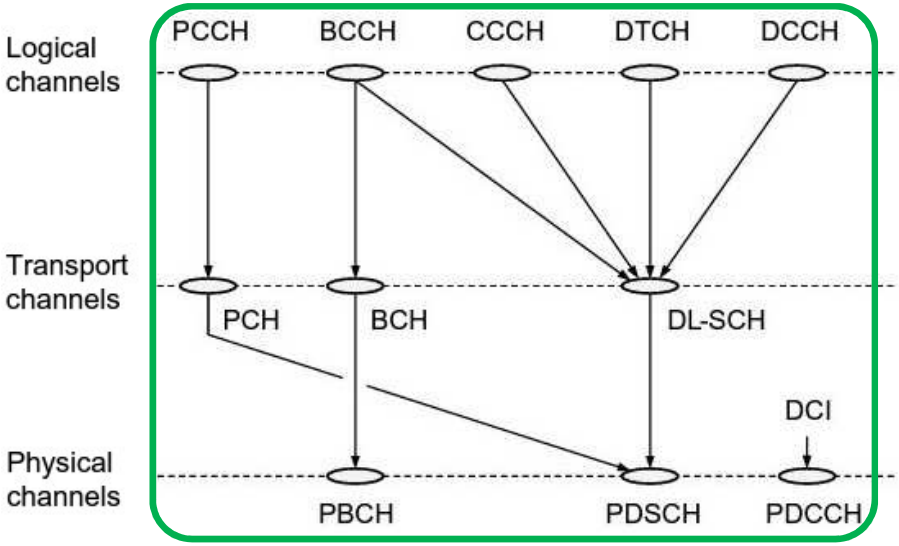
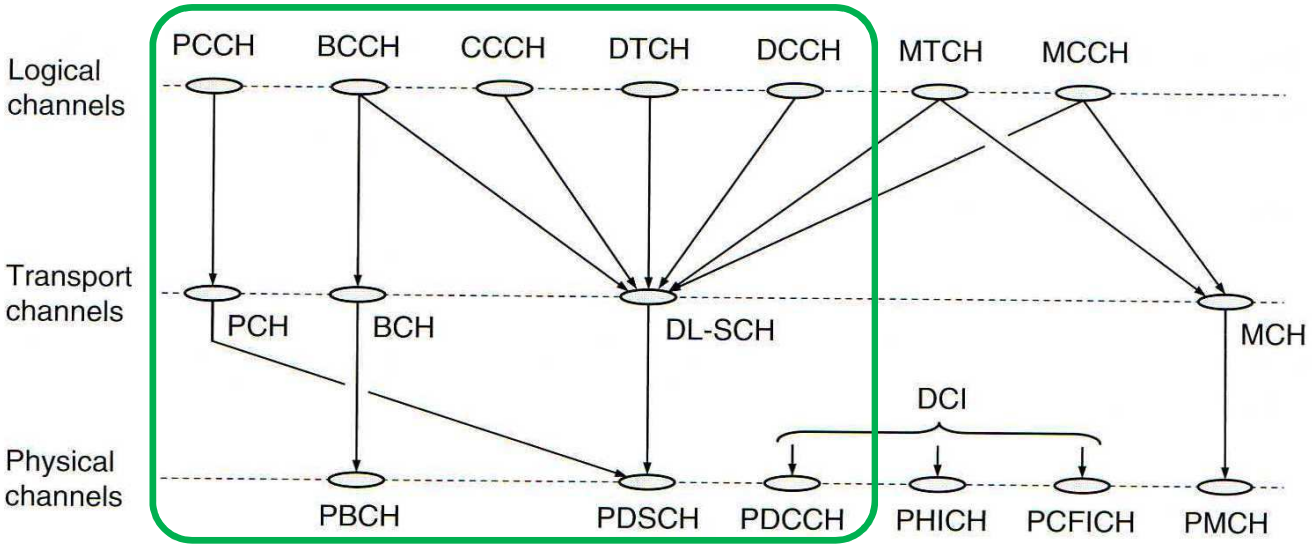
2.4 DL channel architecture

5G DL channels



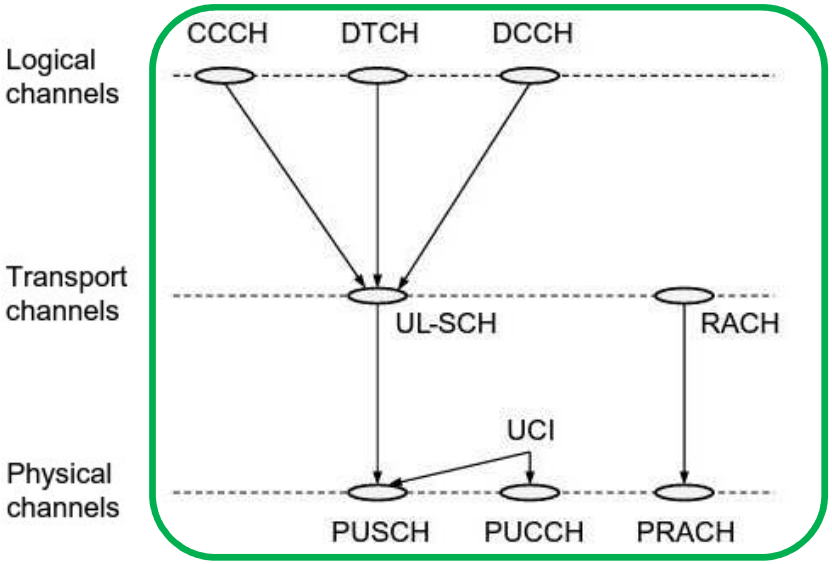
LTE DL channels



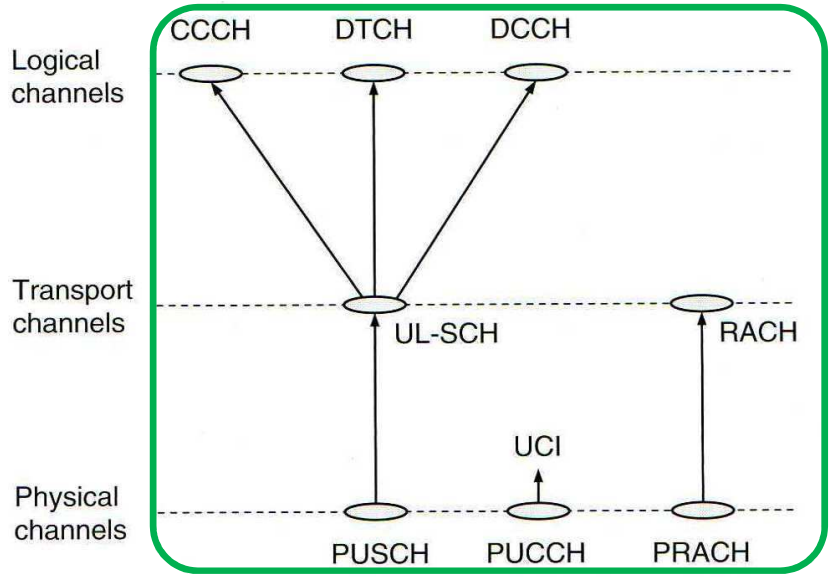
Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 6

2.4 UL channel architecture

5G UL channels

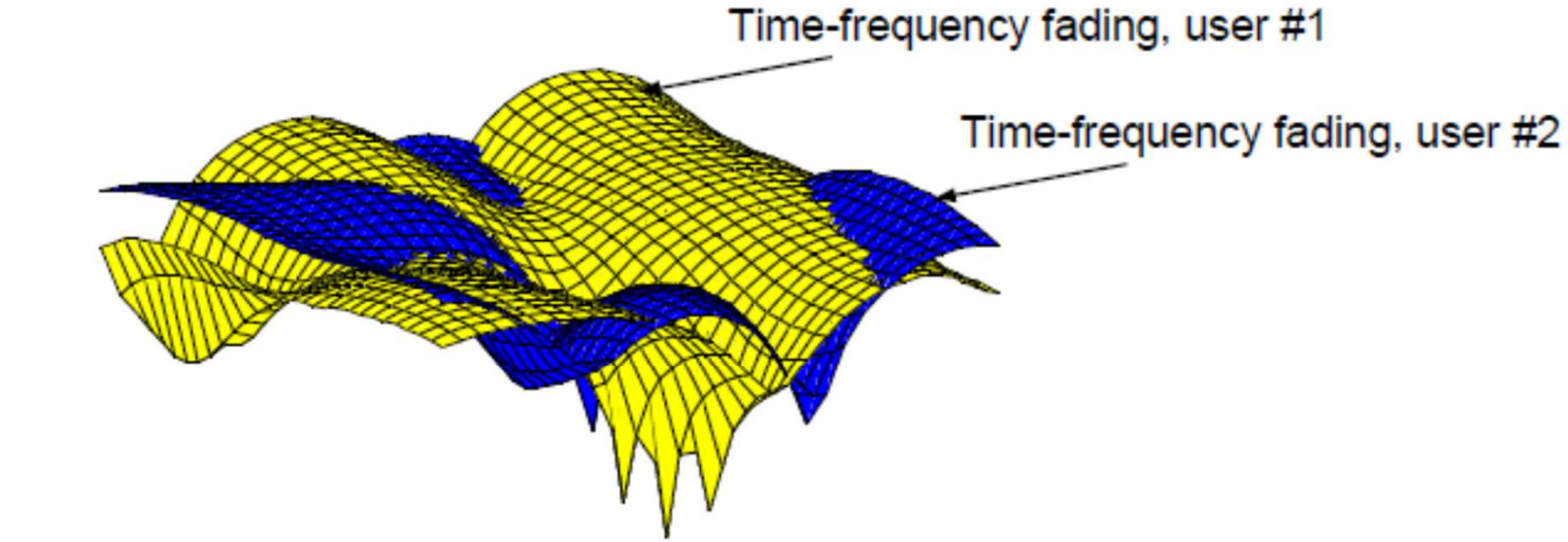


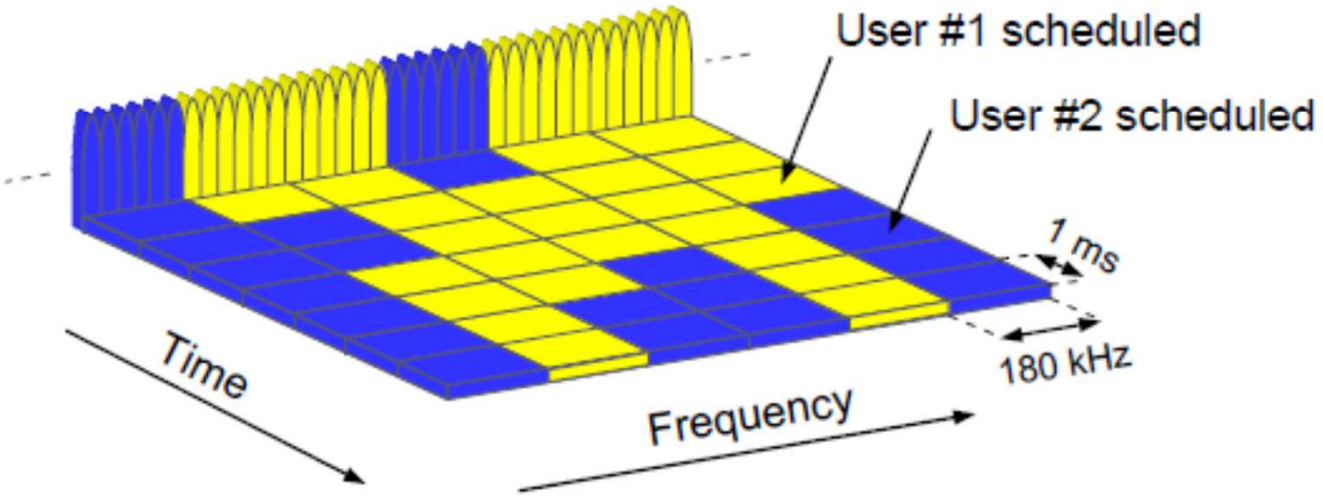
LTE UL channels



Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 2

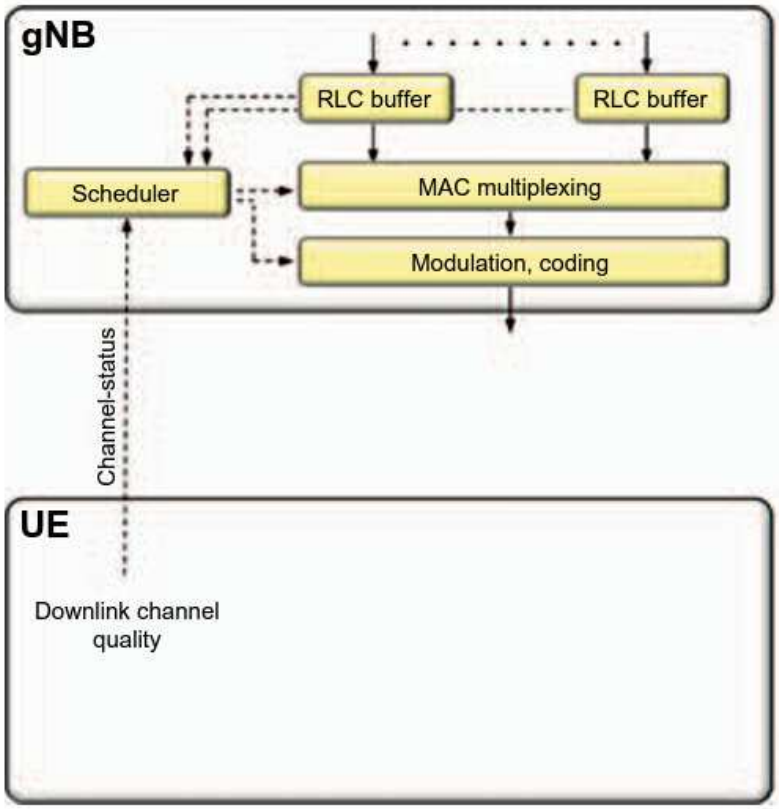
2.5 5G Scheduling



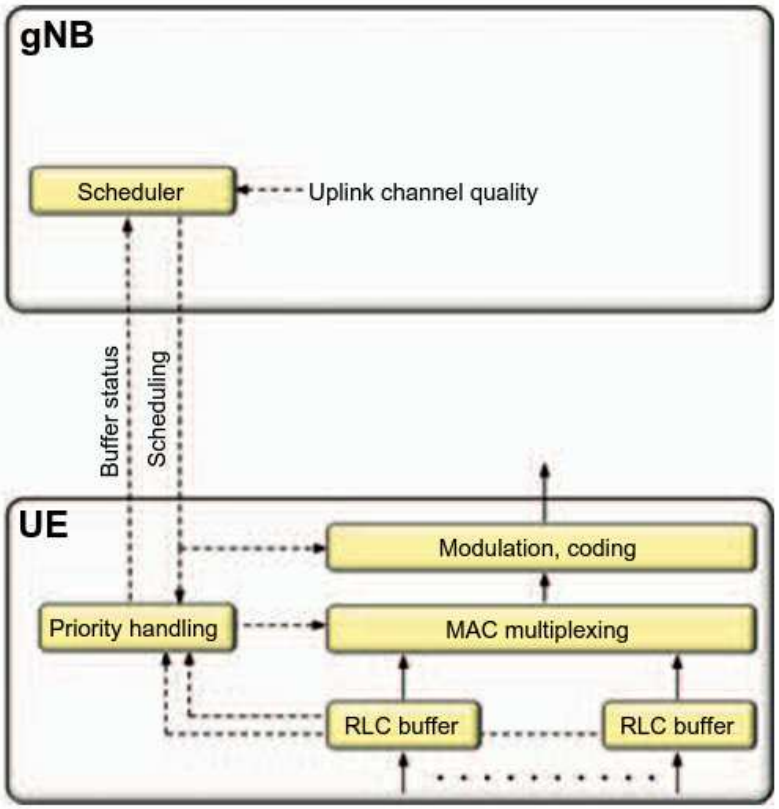


Source: E. Dahlman: Presentation: Mobile Broadband – Part II,

2.5 5G Scheduling



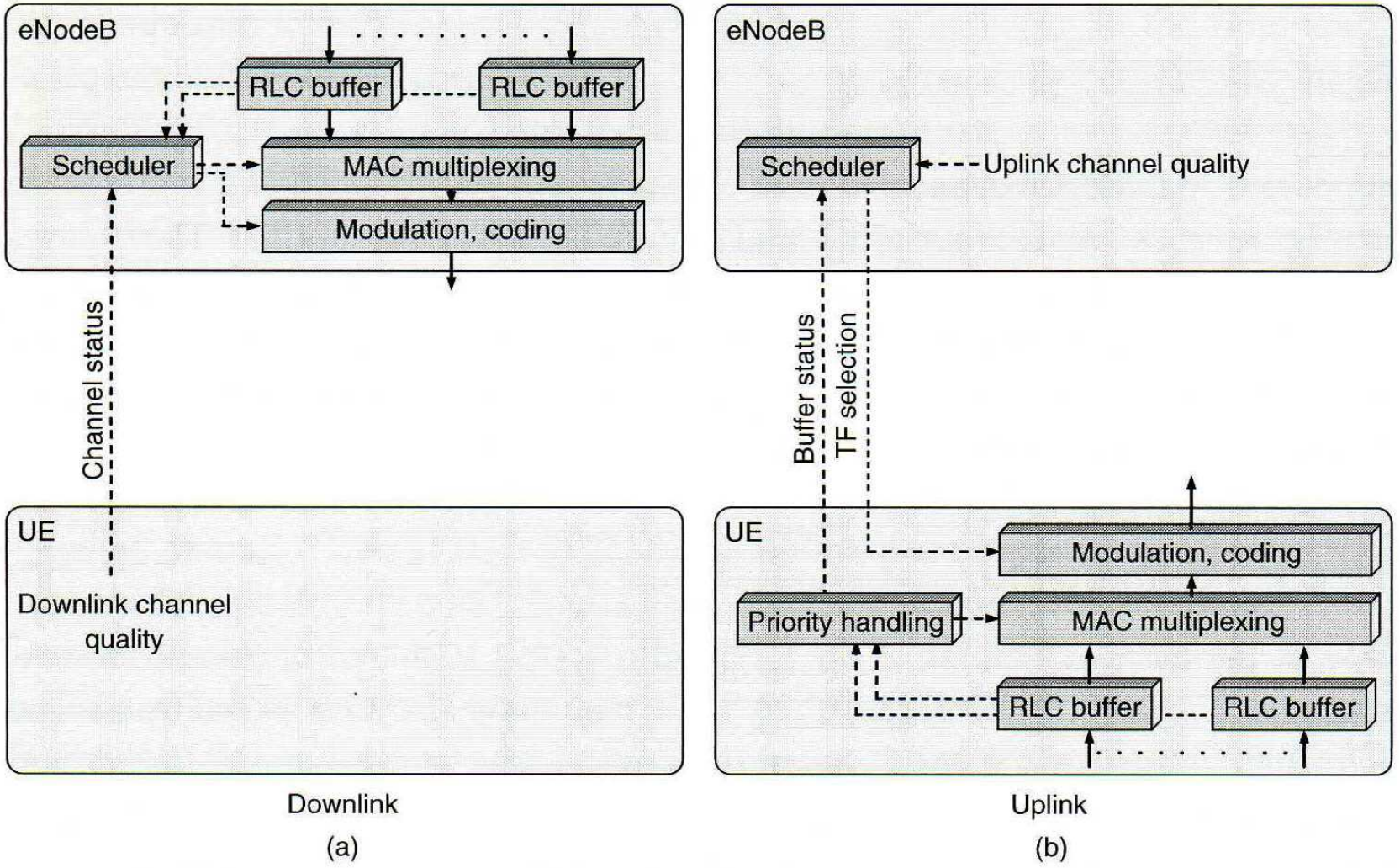
Downlink



Uplink

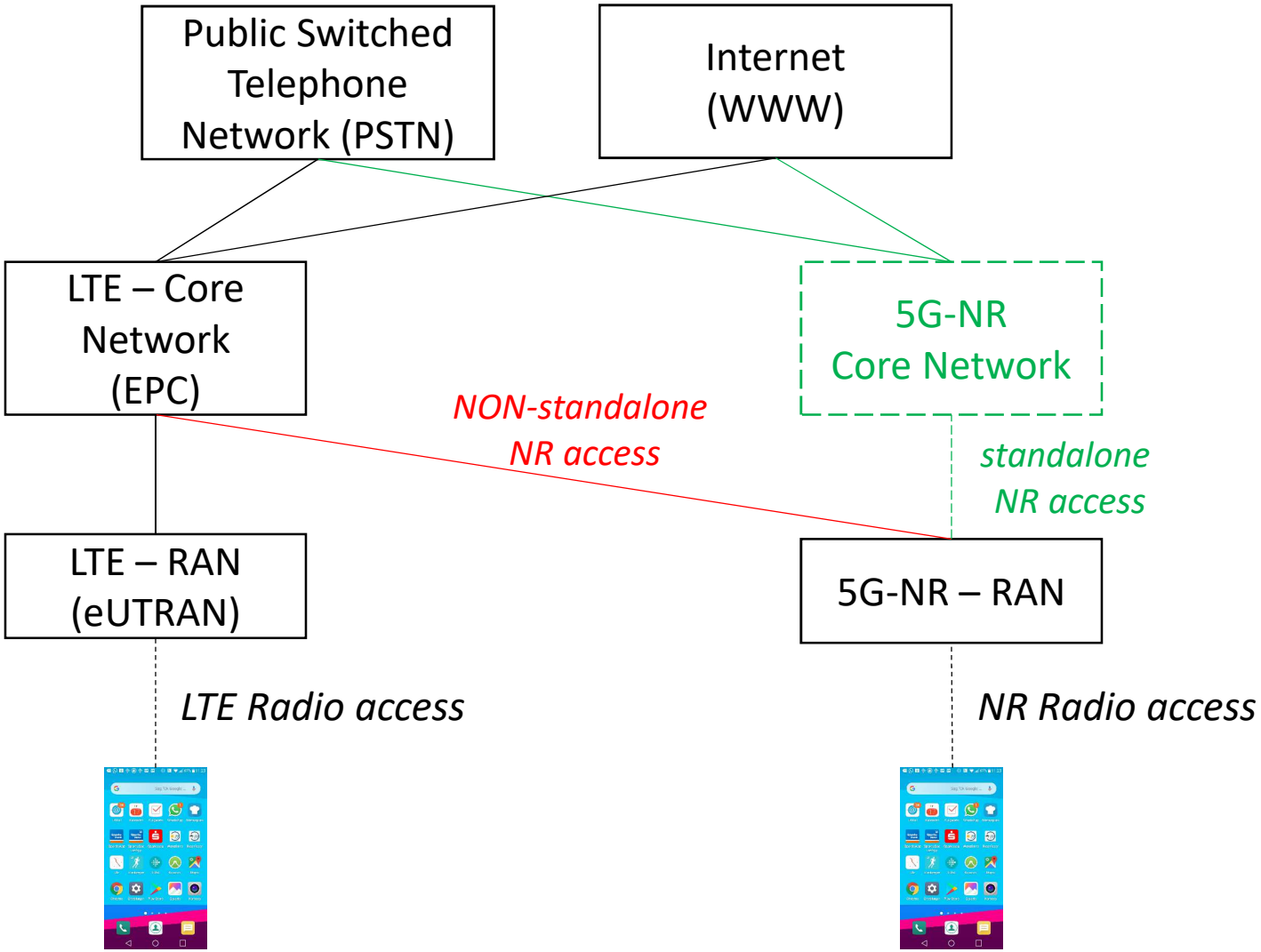
Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 6

2.5 in comparison: LTE Scheduling



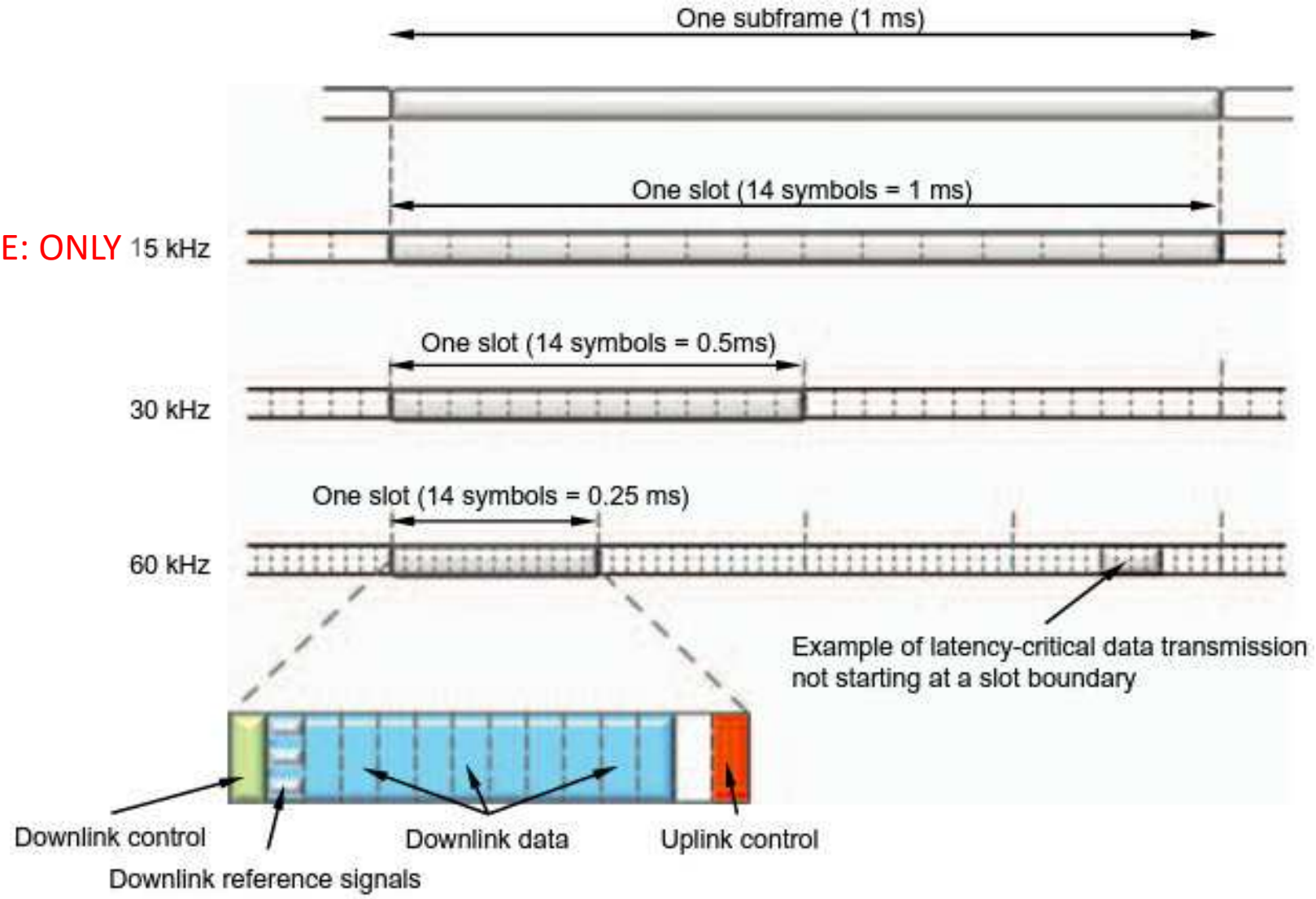
Source: E. Dahlman, S. Parkvall und J. Sköld, 3G Evolution: HSPA and LTE for Mobile Broadband

2.6 NR NON-standalone and standalone



2.7 Frame structure

In LTE: ONLY



Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 5

2.8 Low-Latency support

- Important characteristic of 5G NR
- Reference signals and DL control signaling ‚located' at the beginning of a slot → device can start processing the data immediately, minimizing decoding delay.
- Requirements on device processing times significantly tightened as compared to LTE. Device has to respond with hybrid-ARQ-acknowledgement of roughly one slot (or less).
- Time from grant reception to UL data transfer in the same range (one slot).

- Comparison with LTE:
  - Control plane latency requirement:
    - Transition time from idle to active mode < 100 ms
  - User plane latency requirement:
    - Transmission time from terminal to RAN edge node (eNode B) < 5 ms in an unloaded network (no other terminals)

Source: E. Dahlman et al.: „5G NR – The next wireless access technology", chapter 5

2.9 5G Key parameters

LTE (based on table 20.3 in 3G Evolution)			5G NR		
# of subcarriers	Subcarrier spacing (kHz)	Bandwidth (MHz)	MAX. # of subcarriers	Subcarrier spacing (kHz)	Bandwidth (MHz)
72	15	1,4	<smaller>	15	<smaller>
180	15	3,0			
300	15	5,0	3300	15	50,0
600	15	10,0	3300	30	100,0
900	15	15,0	3300	60	200,0
1200	15	20,0	3300	120	400,0

- Message:
  - 5G NR Max. bandwidth increased by a factor of 20, as compared to LTE
  - Subcarrier spacing in 5G flexible (in LTE: fixed) and increased by a factor of 8 as compared to LTE (15 kHz → 120 kHz)
  - Max. subcarrier number increased by factor of 2,75 (1200 →3300)

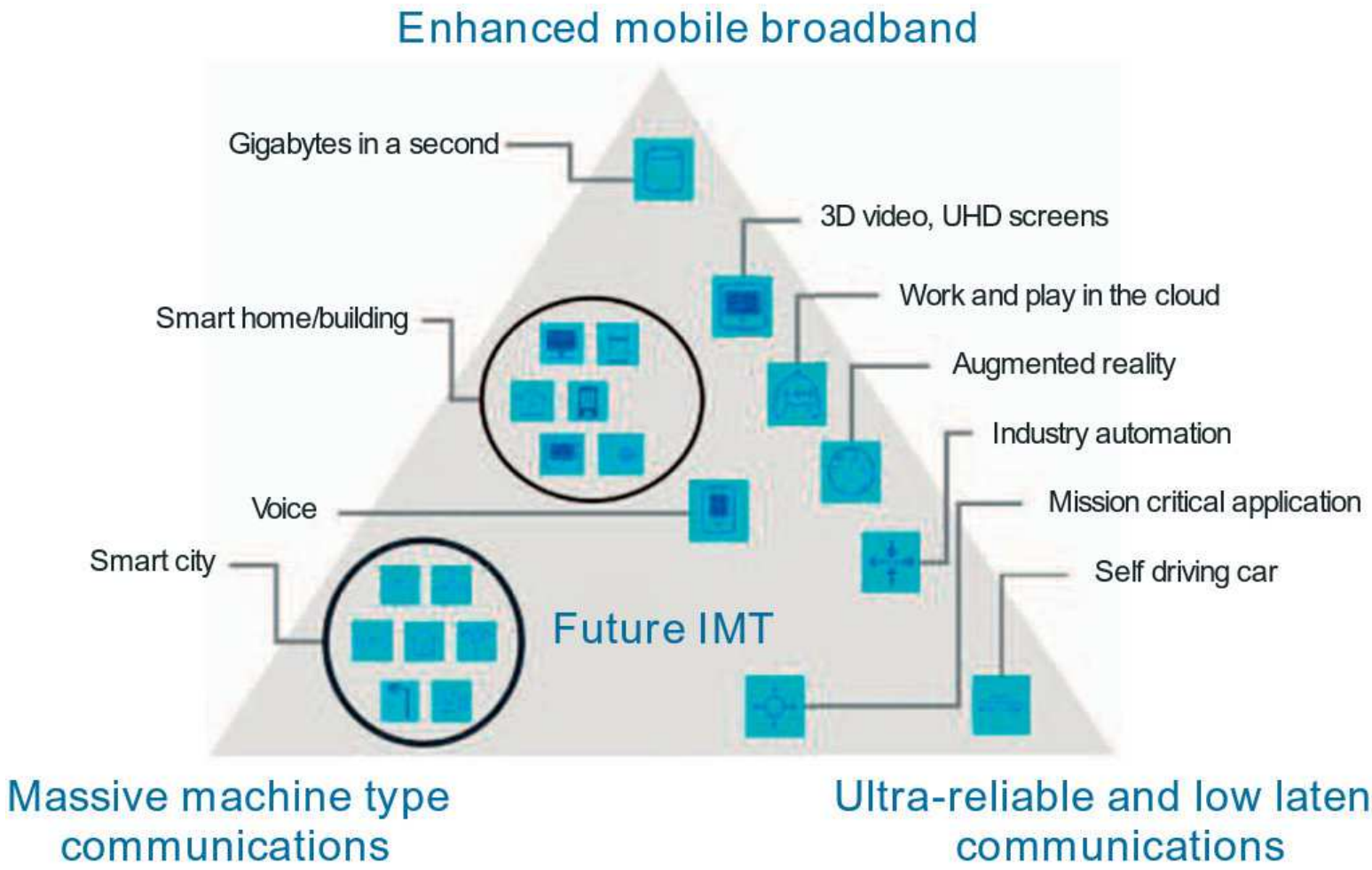
Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 5

2.10 5G use cases

- Enhanced Mobile Broadband (eMBB)
  - Straightforward evolution of today‘s mobile broadband services
  - **Larger data rates**
  - **Enhanced user experience**, e.g. supporting higher end-user data rates
- Massive Machine-type communication (V2X-communication) (mMTC)
  - **Massive number of devices**, such as sensors, actuators,…
  - Requirements are:
    - Very low device cost
    - Very low device energy consumption
  - Each devices consumes and generates only small amount of data
- Ultra-reliable and low-latency communication (URLLC)
  - **Very low latency**
  - **Extremely high reliability**
  - Possible applications:
    - Traffic safety
    - Automatic control
    - Factory automation

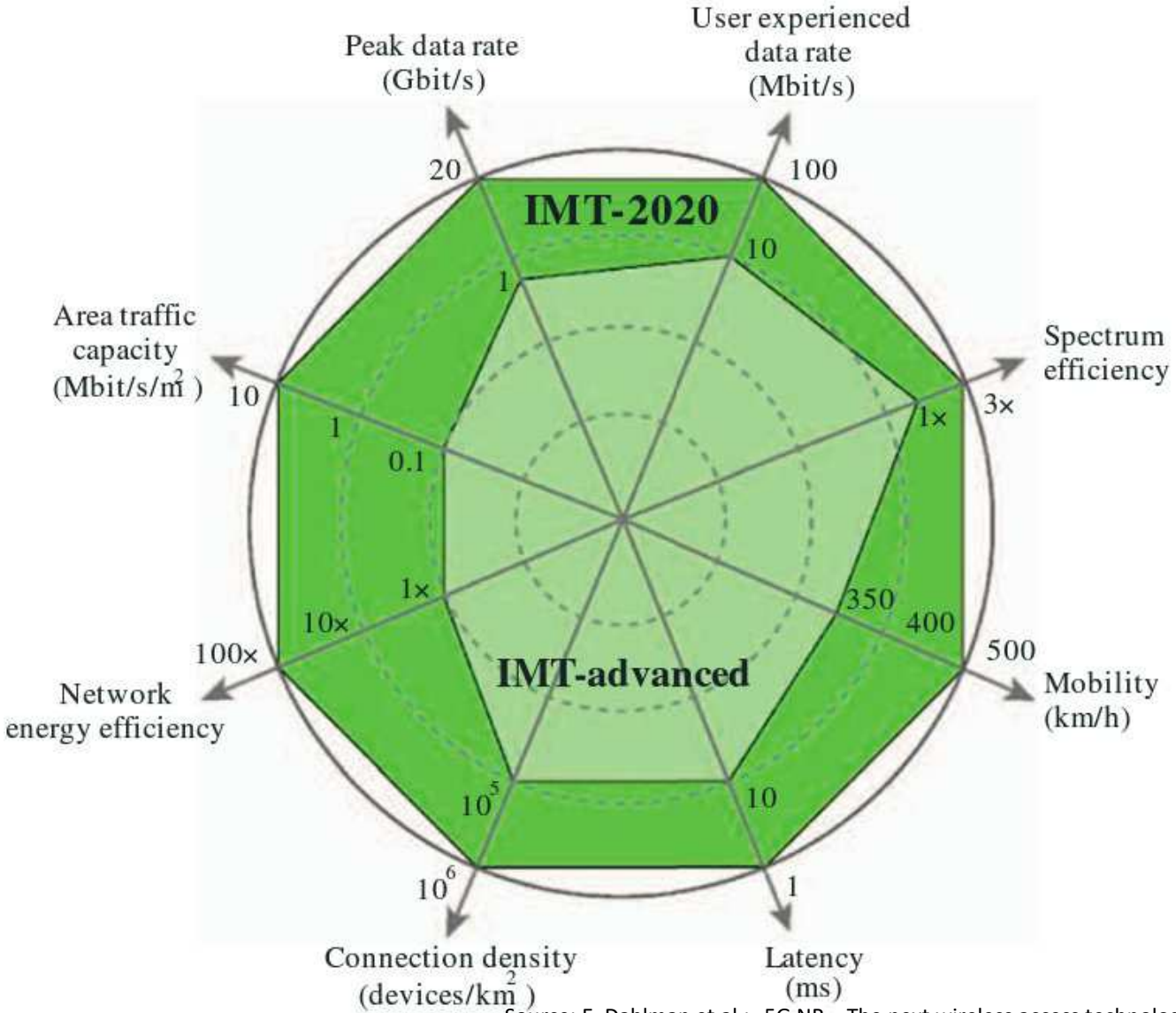
Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 1

2.10 Usage scenarios for IMT-2020



Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 2

2.11 IMT-2020 (5G) capabilities (8 out of 13)



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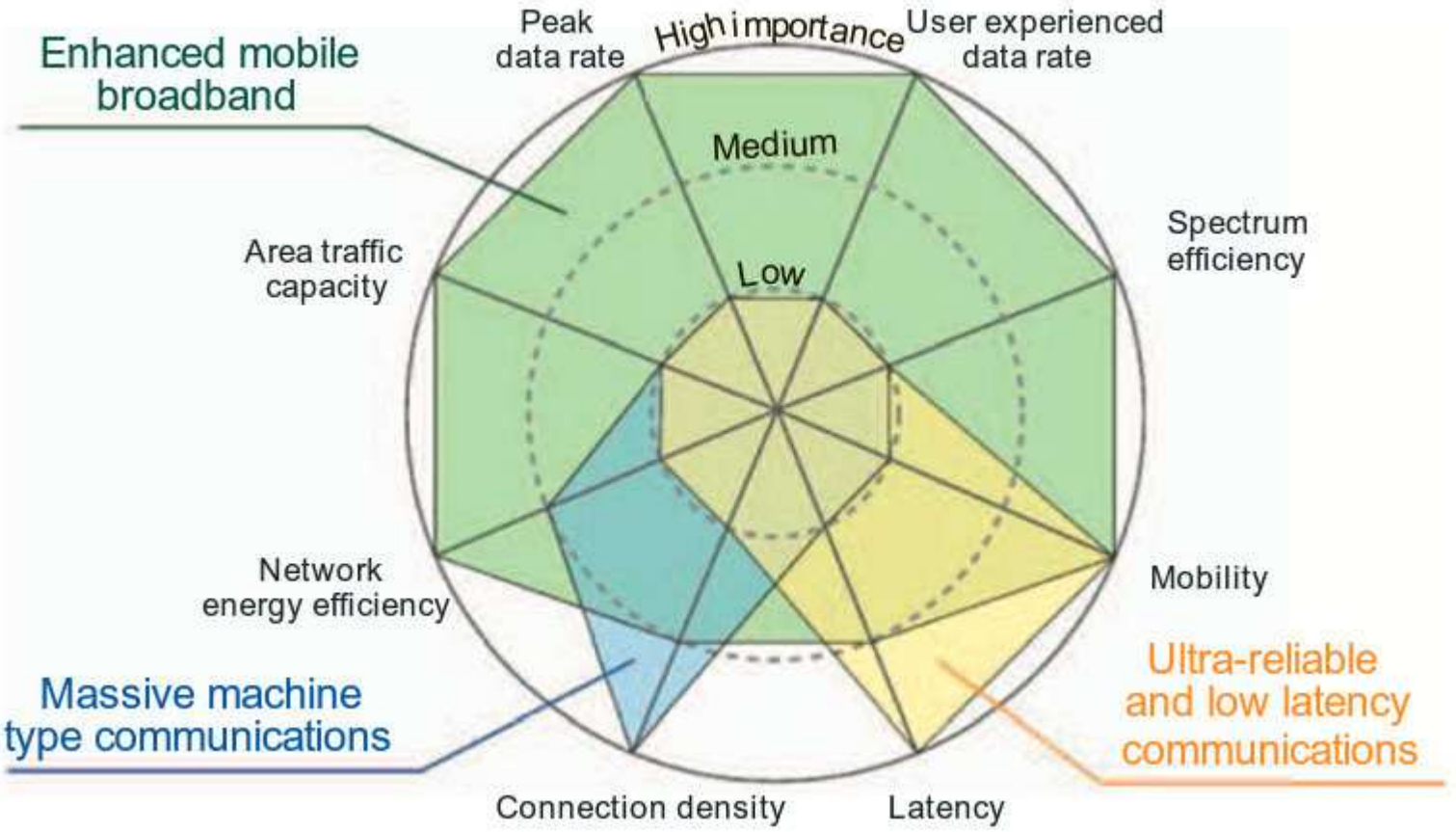
2.11 IMT-2020 (5G) capabilities (8 out of 13)



Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 2

2.11 IMT-2020 (5G) capabilities (remaining 5)

- Spectrum and bandwidth flexibility
  - Possibility to operate in different frequency ranges with different bandwidths
- Reliability
  - Corresponds to the availability level of one or more services (should be as close as possible to 100%)
- Resilience:
  - Ability of the network to continue operation during and after disturbances (e.g. loss of mains power)
- Security and privacy
  - Encryption and integrity protection of user data and signaling
  - End-user privacy
  - Preventing unauthorized user tracking
  - Protection of network against hacking, fraud, denial of services, …
- Operational lifetime
  - Refers to operation time per stored energy capacity.

Source: E. Dahlman et al.: „5G NR – The next wireless access technology“, chapter 2

Summary

- 5G
  - Same technology as LTE (4G): OFDM
  - Very similar protocol architecture as LTE (4G)
  - Almost the same DL and UL channel architecture as LTE (4G)
  - Same scheduling concept as LTE (4G)
- BUT:
  - LTE (4G) frame structure forward compatible towards 5G,
  - 5G frame structure is LTE (4G)-enhanced with subcarrier spacing up to $120\ kHz$
  - 5G bandwidth increased up to $400\ MHz$ (LTE 4G: $\leq 20\ MHz$)
  - Datarates up to:
    - DL: $\leq 20\ Gbit/s$
    - UL: $\leq 10\ Gbit/s$
  - Low latency support
- Conclusion:

  5G should be seen as a 4G-evolution rather than a new technology, but is intended to and will offer a lot of new use cases and applications!

Thank you very much for your attention!

References

1. E. Dahlman, S. Parkvall und J. Sköld, 5G NR - The next generation wireless access technology, London: Academia Press, 2018.
2. E. Dahlman, S. Parkvall und J. Sköld, 4G LTE-Advanced Pro and the road to 5G, London: Accademic Press, 2016
3. E. Dahlman, S. Parkvall und J. Sköld, 3G Evolution: HSPA and LTE for Mobile Broadband, London: Academic Press, 2008