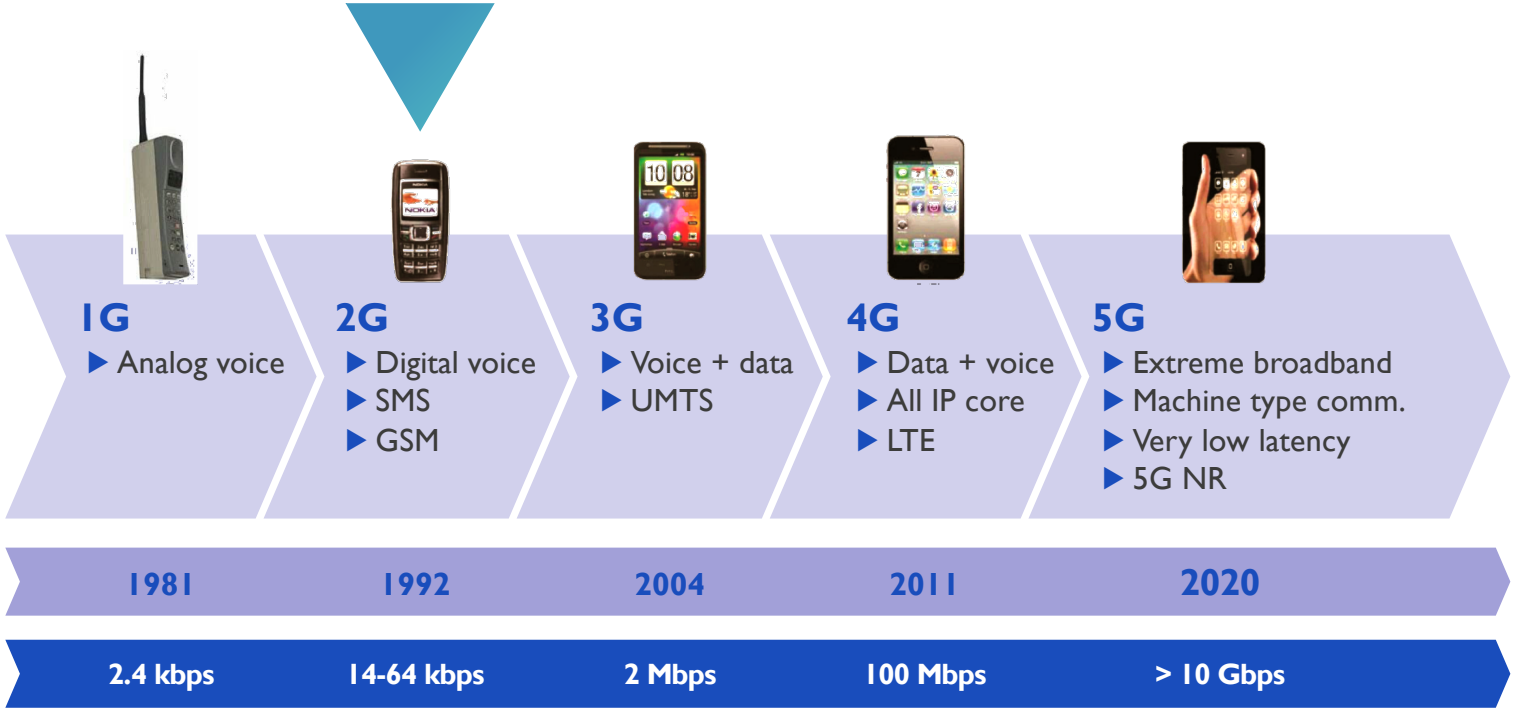
DEMYSTIFYING 5G - A TUTORIAL

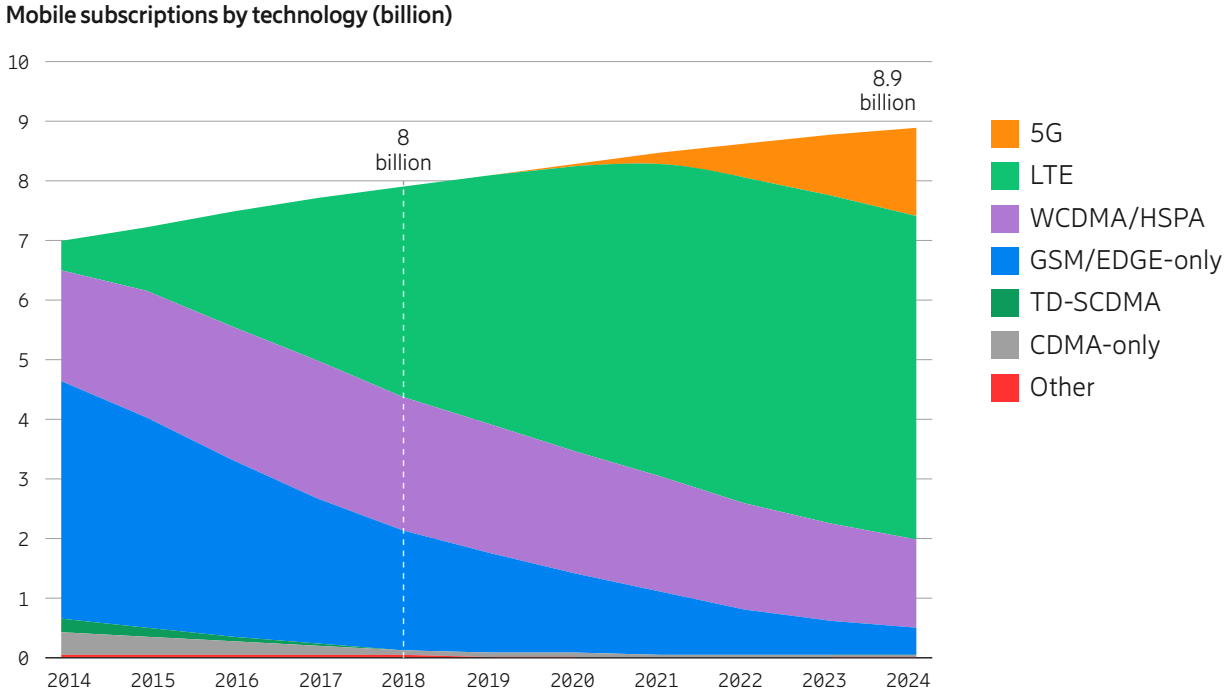
INGRID MOERMAN

EVOLUTION OF CELLULAR NETWORKS



EVOLUTION OF CELLULAR NETWORKS

- Global GSM subscriptions versus other cellular technologies
  - Less then 2 billion GSM only subscriptions in 2018
  - 3.6 billion LTE subscriptions mid 2018



Source: Ericsson Mobility Report – 2018

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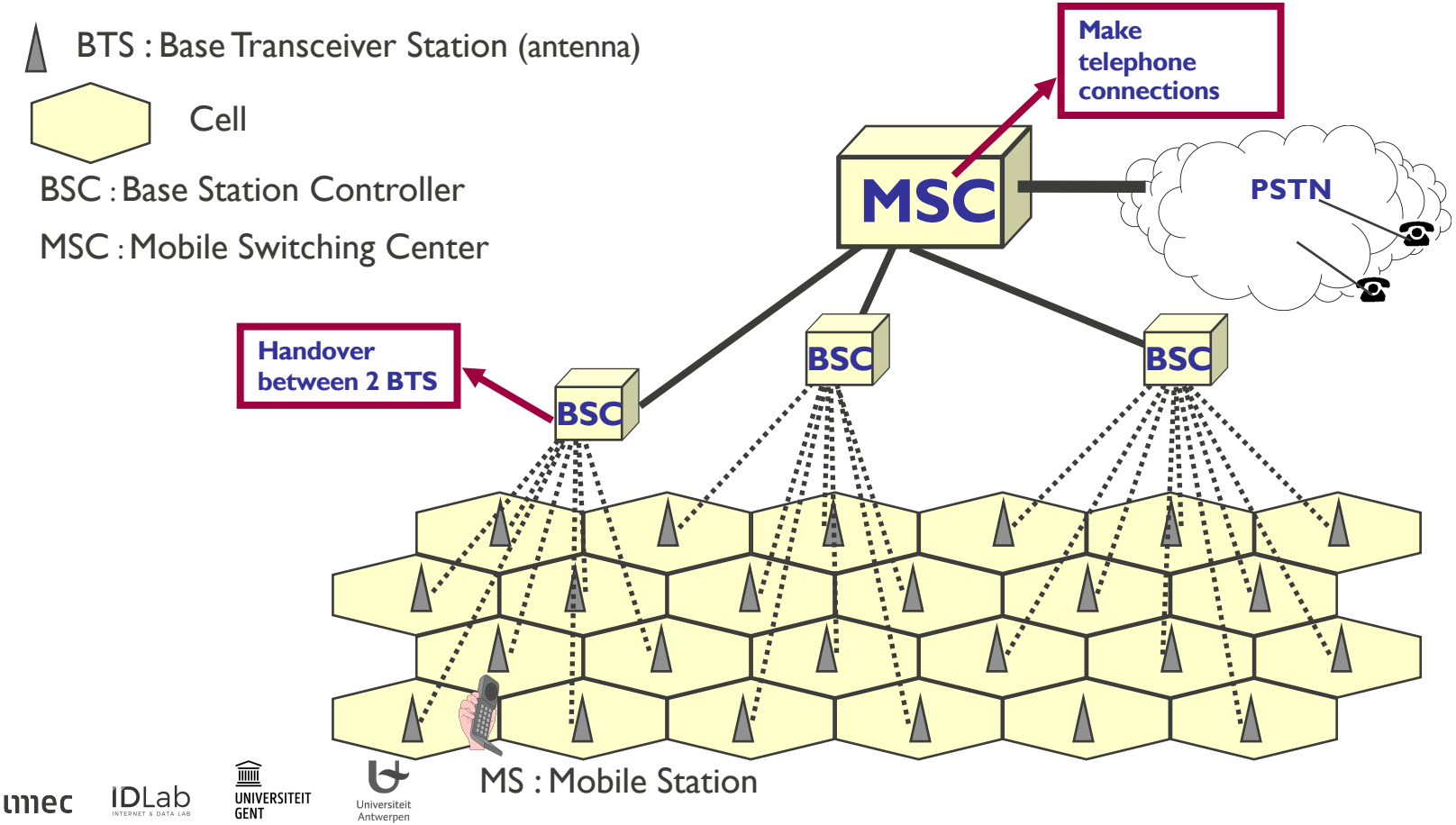
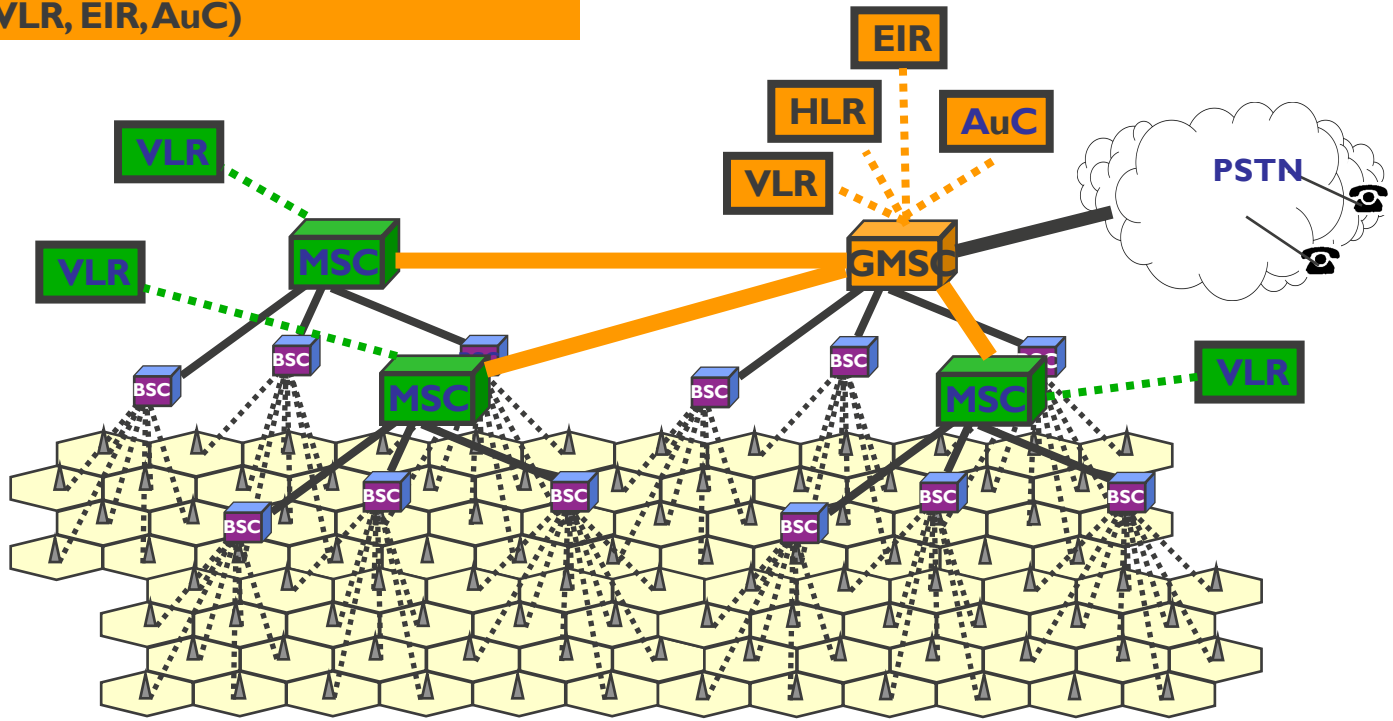
GSM ARCHITECTURE



GSM: ARCHITECTURE : OVERALL VIEW

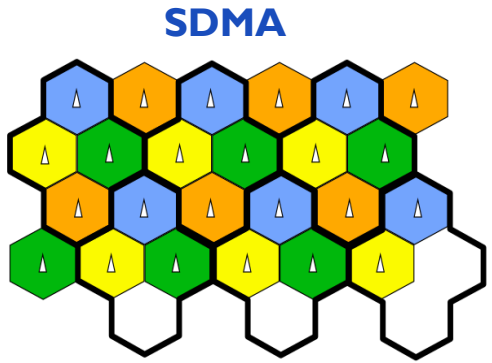
PLMN: Public Land Mobile Network

GMSC: Gateway MSC (connected to PSTN)
(+HLR, VLR, EIR, AuC)



GSM – GENERAL RADIO PROPERTIES

- Multiple access to shared medium
  - Space Division Multiple Access (SDMA)
  - Frequency Division Multiple Access (FDMA)
    - channel spacing: 200 kHz
    - number of frequencies: 124
  - Time Division Multiple Access (TDMA)
    - number of time slots: 8
- Duplex: Frequency Division Duplex (FDD)
    - uplink: 890 - 915 MHz
    - downlink: 935 - 960 MHz
    - duplex distance: 45 MHz
- Bitrates
    - speech bitrate: 13 kbit/s



EVOLUTION OF CELLULAR NETWORKS

1G
- Analog voice

2G
- Digital voice
- SMS
- GSM

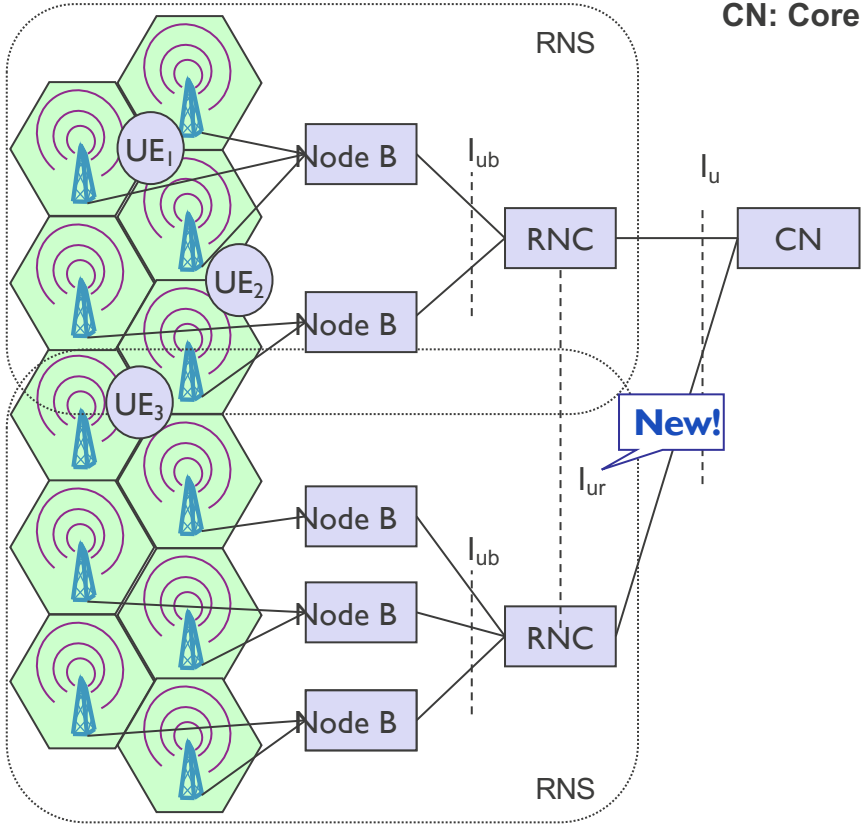
3G
- Voice + data
- UMTS

4G
- Data + voice
- All IP core
- LTE

5G
- Extreme broadband
- Machine type comm.
- Very low latency
- 5G NR

1981	1992	2004	2011	2020
2.4 kbps	14-64 kbps	2 Mbps	100 Mbps	> 10 Gbps

UMTS ARCHITECTURE

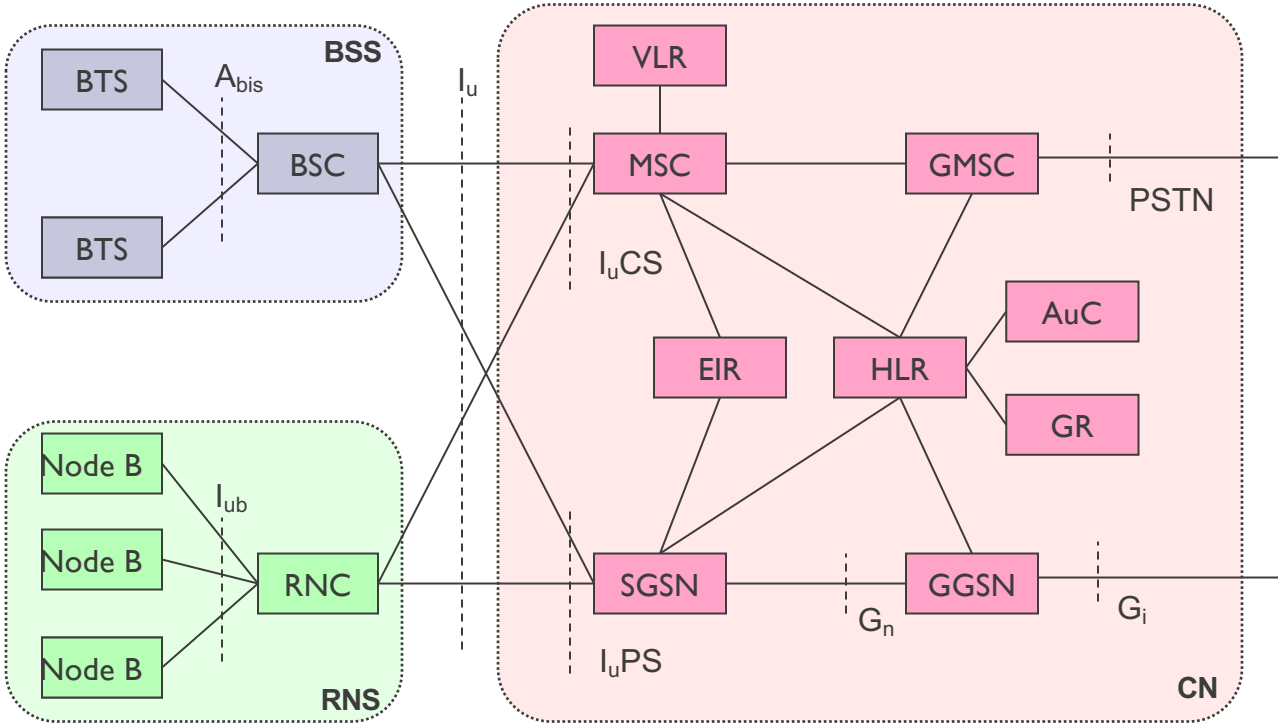


UTRAN components

- [User Equipment (UE)]
- Radio cell
- Node B
  - similar to BTS in GSM
- RNC (Radio Network controller)
  - responsible for handover decisions requiring signaling to the UE
  - similar to BSC in GSM
- RNS (Radio Network Subsystem)
  - controlled by RNC

UMTS NETWORK ARCHITECTURE

UMTS Release 1999: GSM/GPRS core network + GSM BSS + UTRAN RNS

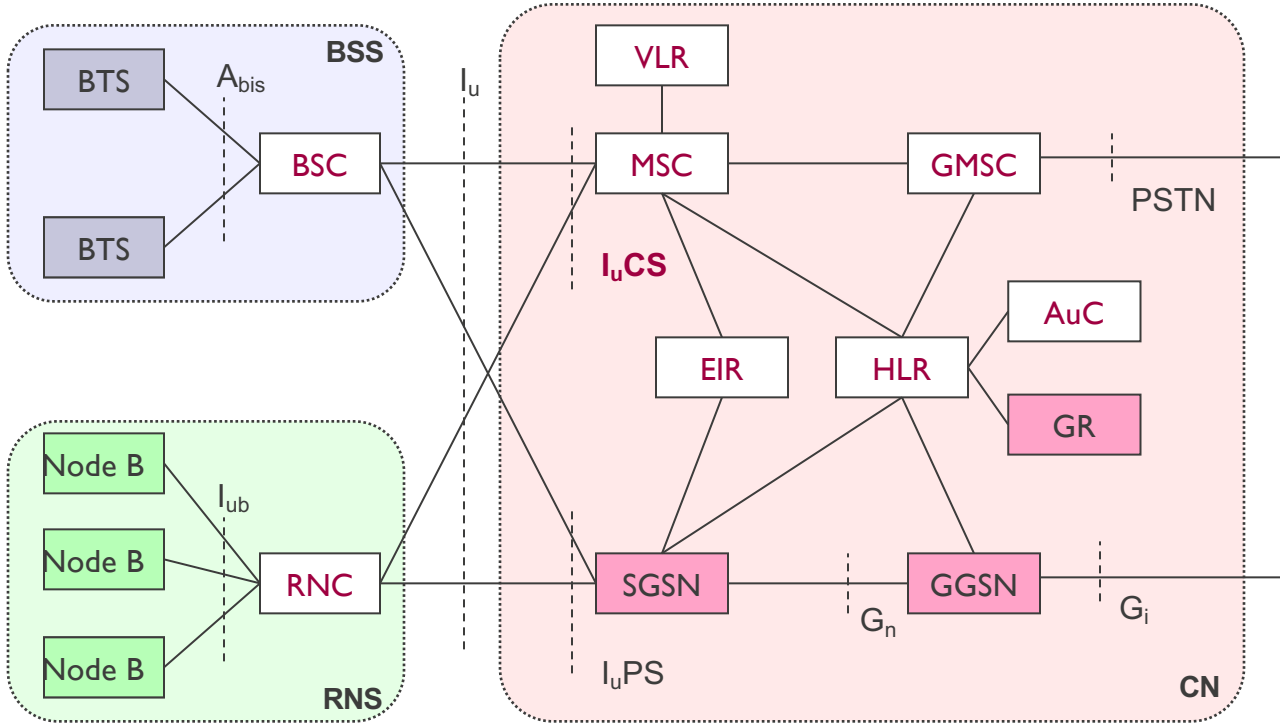


➔ **Reuse of existing infrastructure saves a lot of money!**

➔ **New (all-IP) core network comes later releases of UMTS**

UMTS NETWORK ARCHITECTURE

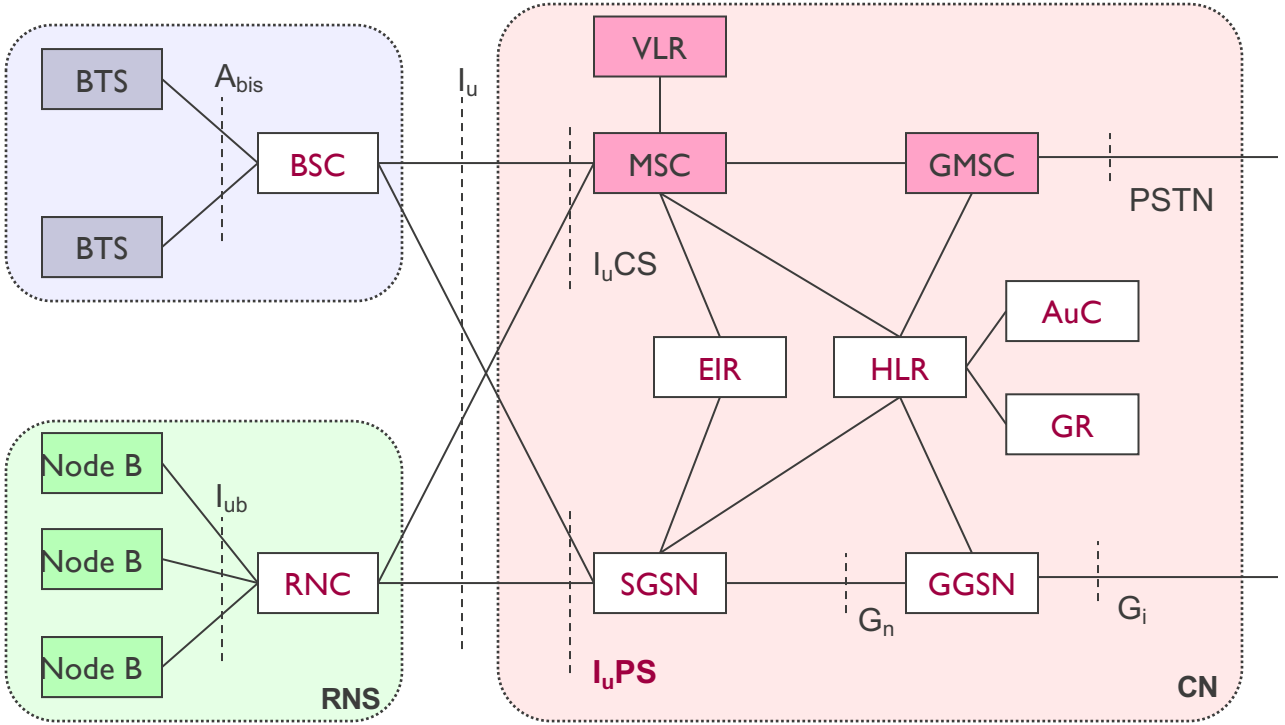
UMTS Release 1999: GSM/GPRS core network + GSM BSS + UTRAN RNS



Circuit Switched Domain (CSD)

UMTS NETWORK ARCHITECTURE

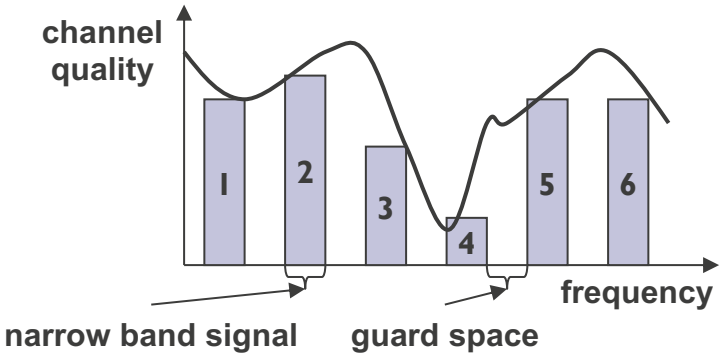
UMTS Release 1999: GSM/GPRS core network + GSM BSS + UTRAN RNS



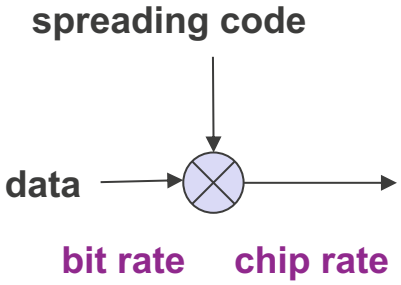
Packet Switched Domain (PSD)

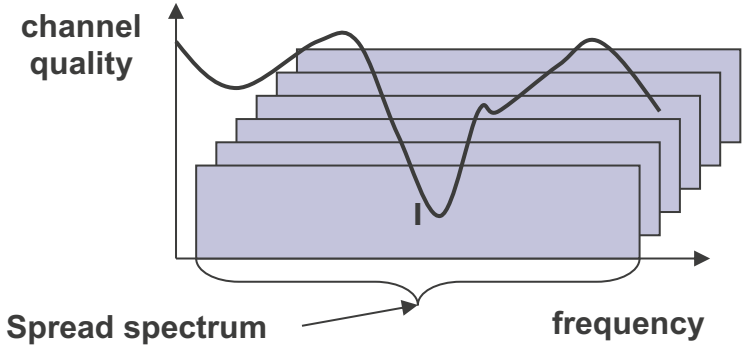
UMTS RADIO - SPREADING SPECTRUM

Narrowband channels

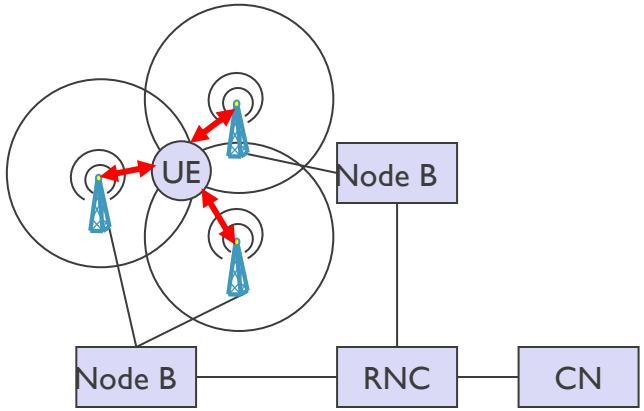


Spread spectrum channels



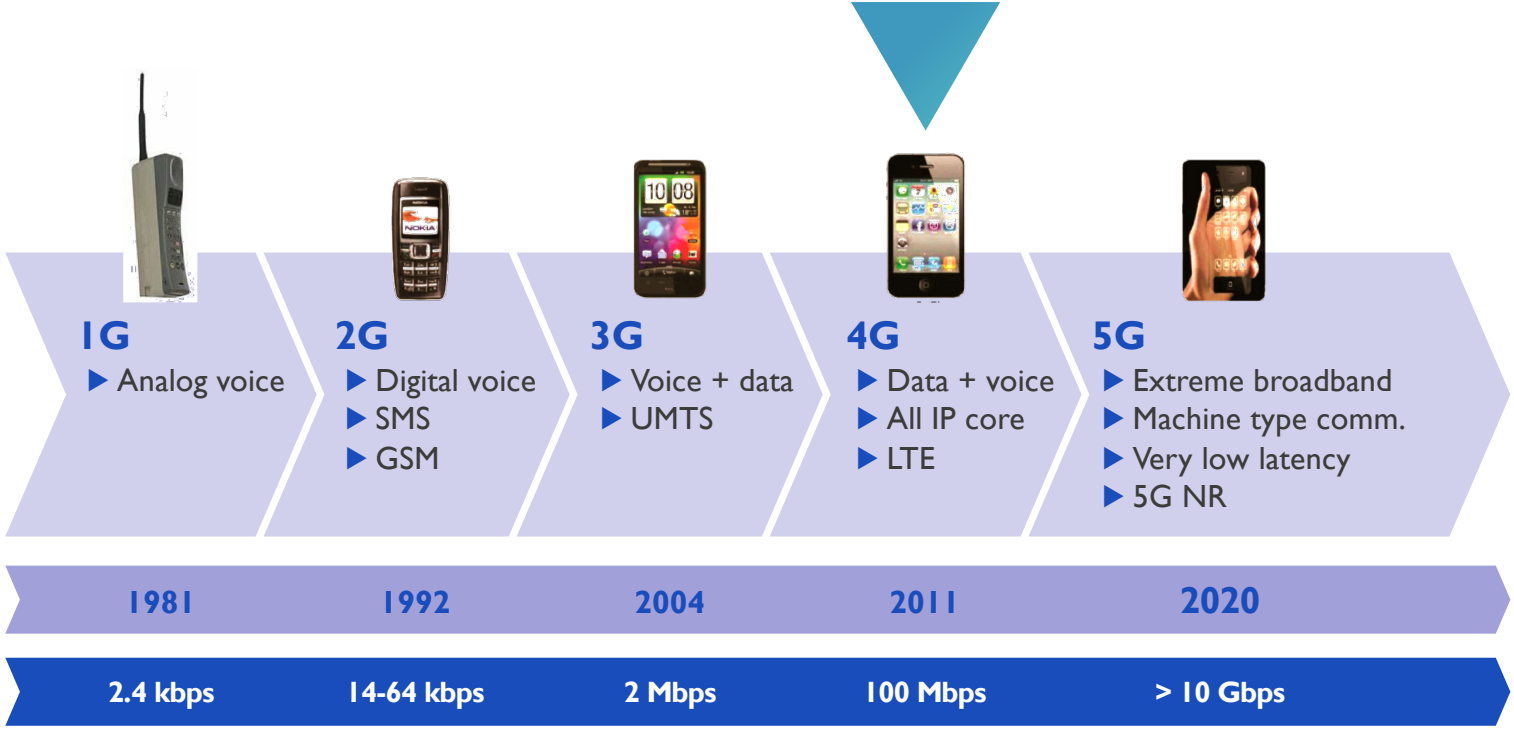


UMTS SOFT HANDOVER



- Macro diversity
  - multicasting of data via several physical channels
  - Uplink
    - simultaneous reception of UE data at several Node Bs or antennas
    - reconstruction of data at Node B, RNC
  - downlink
    - simultaneous transmission of data via different antennas or cells
    - reconstruction of data at UE
  - characteristics
    - more robust transmission
    - power control from all involved node Bs

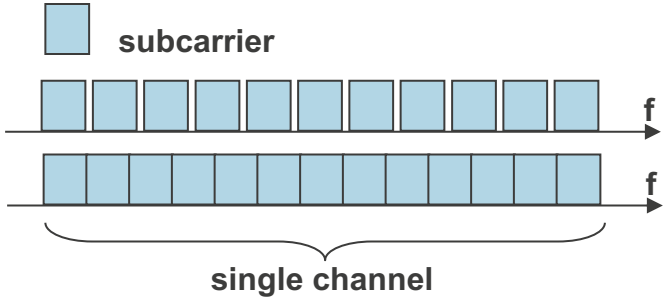
EVOLUTION OF CELLULAR NETWORKS



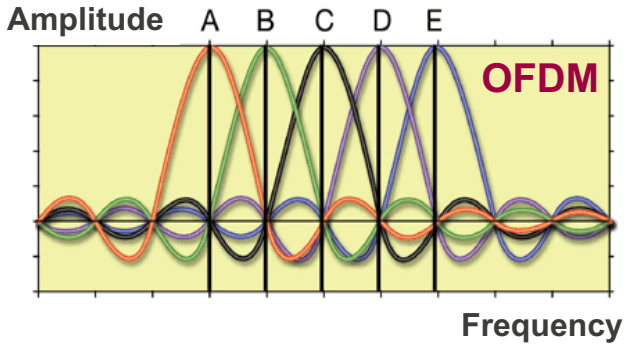
MULTI CARRIER MODULATION (MCM)

- Concept
  - Only one channel
  - Multiple subcarriers
  - Split high bit rate stream in many lower bit rate streams
  - If n symbols/s and c subcarriers

    → c flows with n/c symbols/s

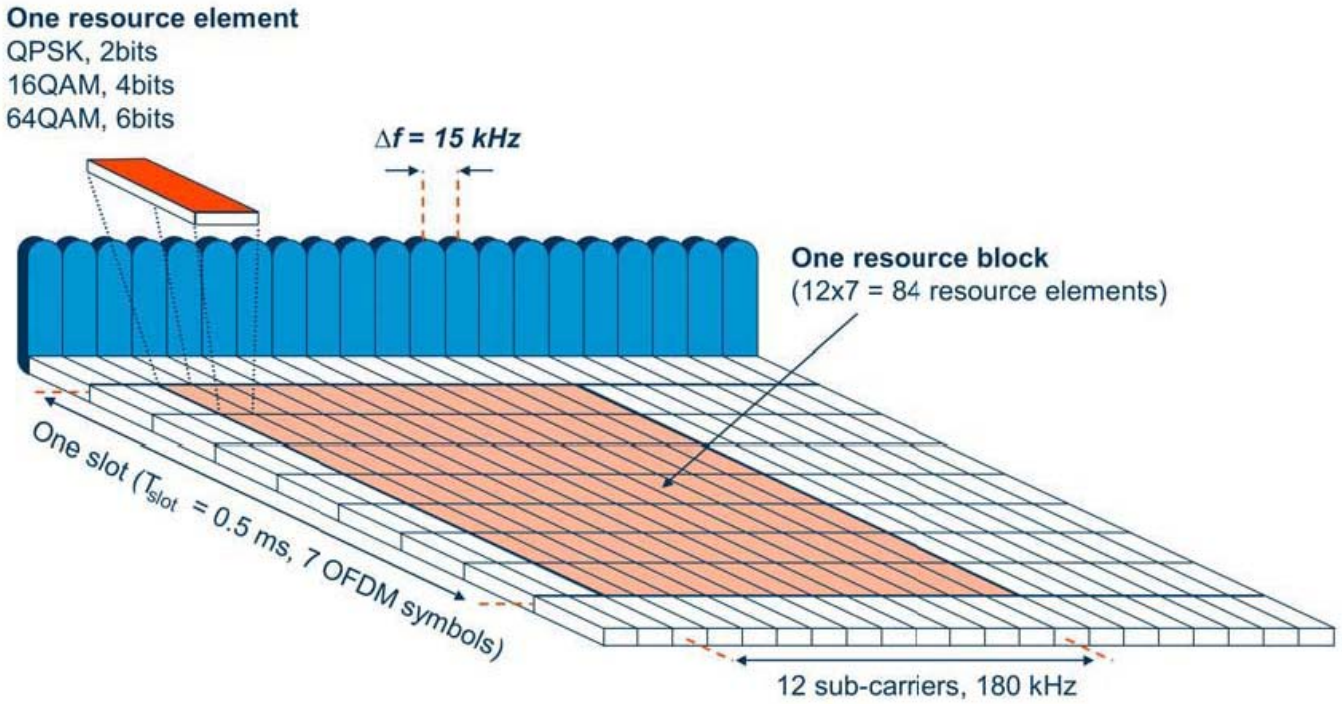


- Advantages
  - Less vulnerable to ISI
  - More robust against frequency selective fading
  - No guard spaces (OFDM)

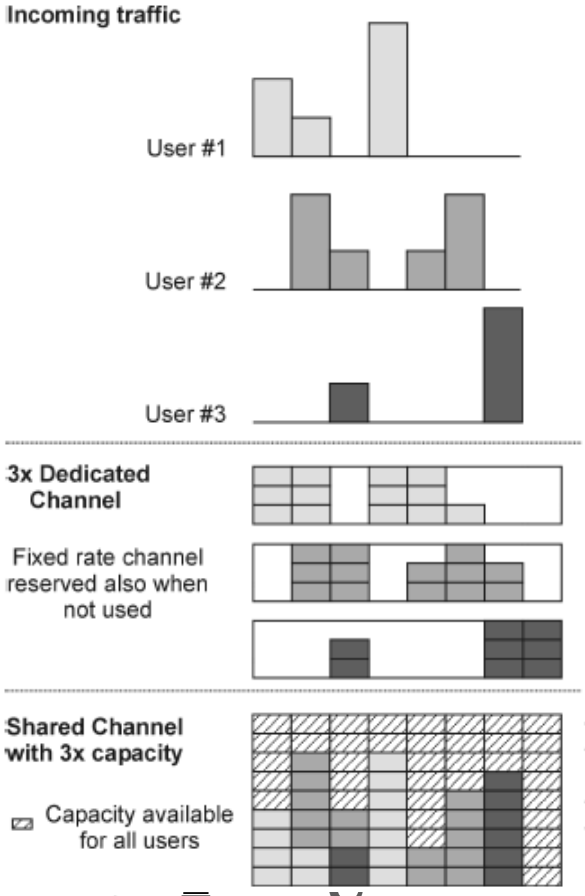


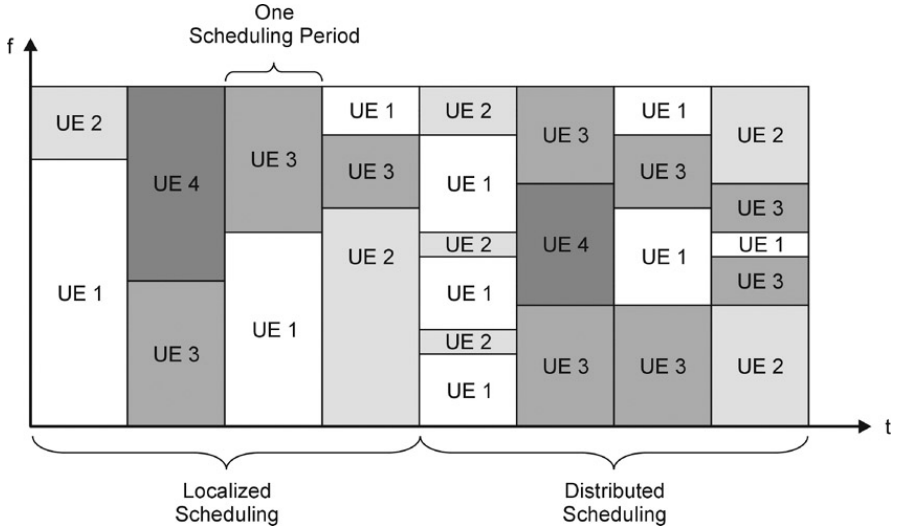
- Examples
  - LTE
  - Wi-Fi

LTE RADIO - RESOURCE ELEMENTS & BLOCKS



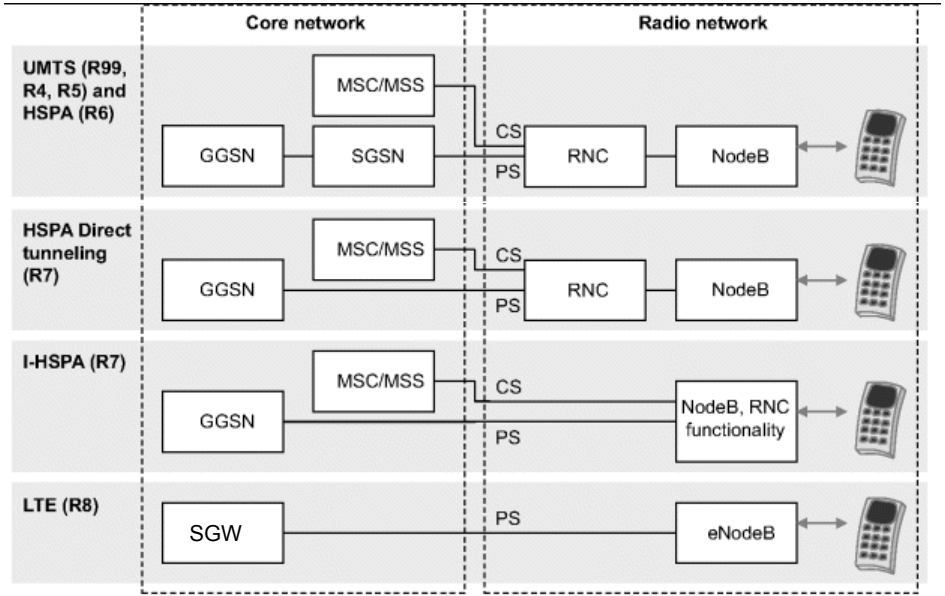
MULTIPLE ACCESS WITH OFDM - OFDMA





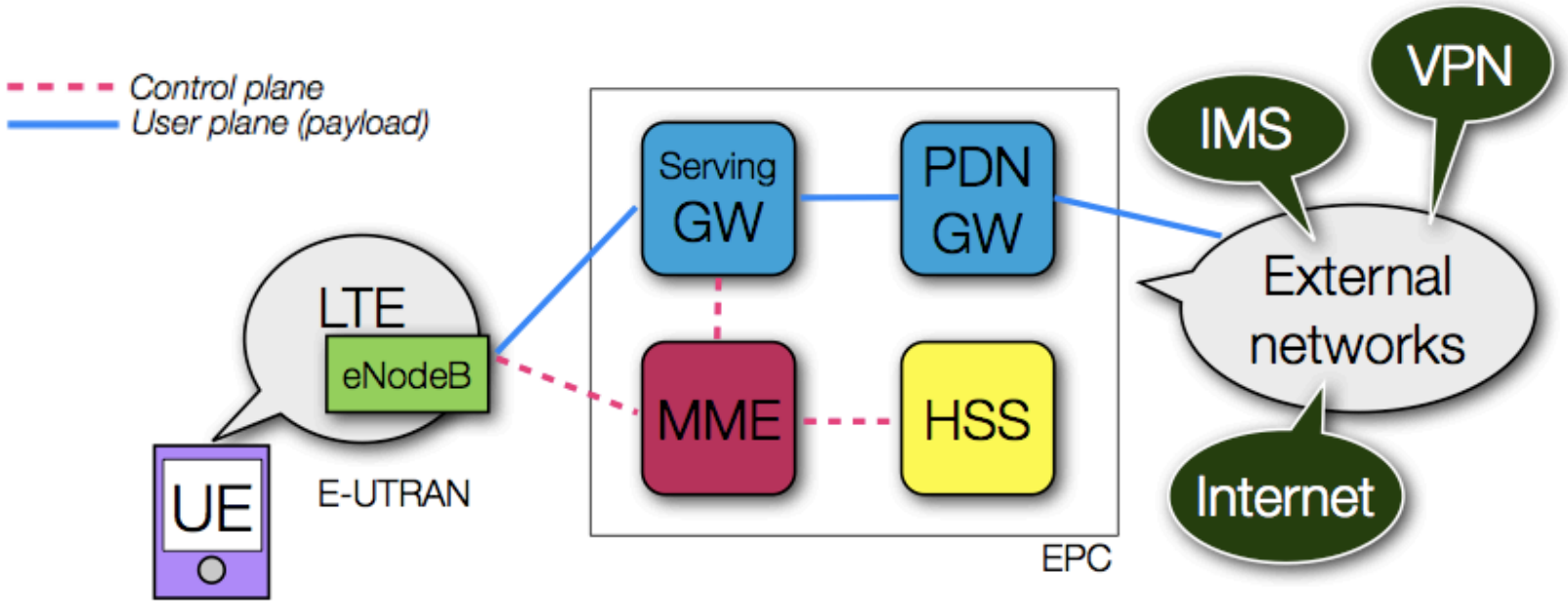
- Resources shared between users
- Data transmitted almost instantaneously
- Perfectly suited for bursty IP traffic
- The more users, the bigger the effect

FROM UMTS TO LTE

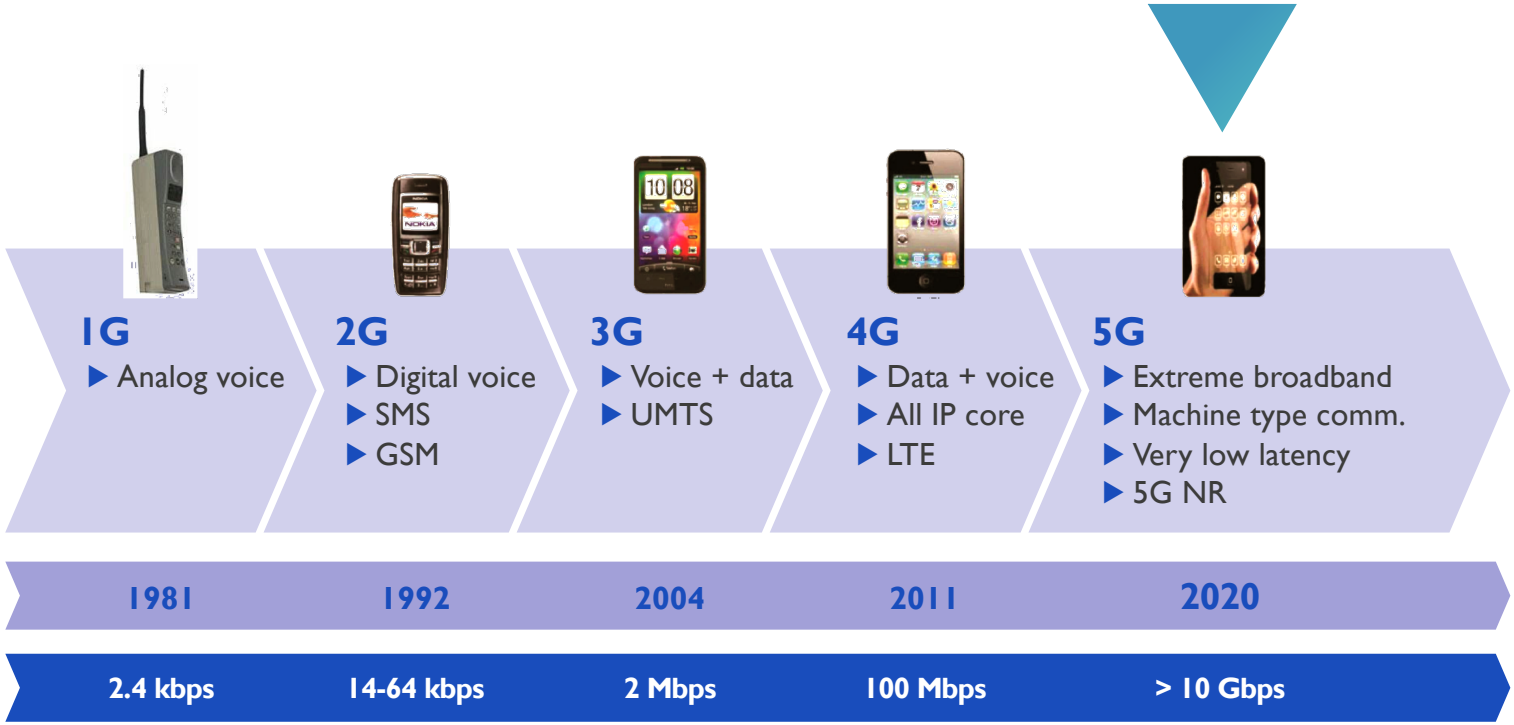


- "Flat" architecture
  - only one element type for the radio network: eNodeB
  - only one element type for the core network: SGW (or SAE-GW)
  - Benefit: shorter round trip delays for signaling

LTE CORE NETWORK: EPC



EVOLUTION OF CELLULAR NETWORKS



WHAT IS 5G?

IEEE Talks 5G: Ivan Seskar

***Ivan Seskar** serves as co-chair of the IEEE 5G Initiative Testbed Working Group and is an IEEE Senior Member. He also serves as Associate Director and Chief Technologist of WINLAB at Rutgers University, where he is Principal Investigator for the National Science Foundation-supported GENI Wireless project. In this interview, Seskar defines 5G, discusses the ORBIT 5G Testbed and IEEE's support for innovation and competition in 5G-related technology and standards development.*

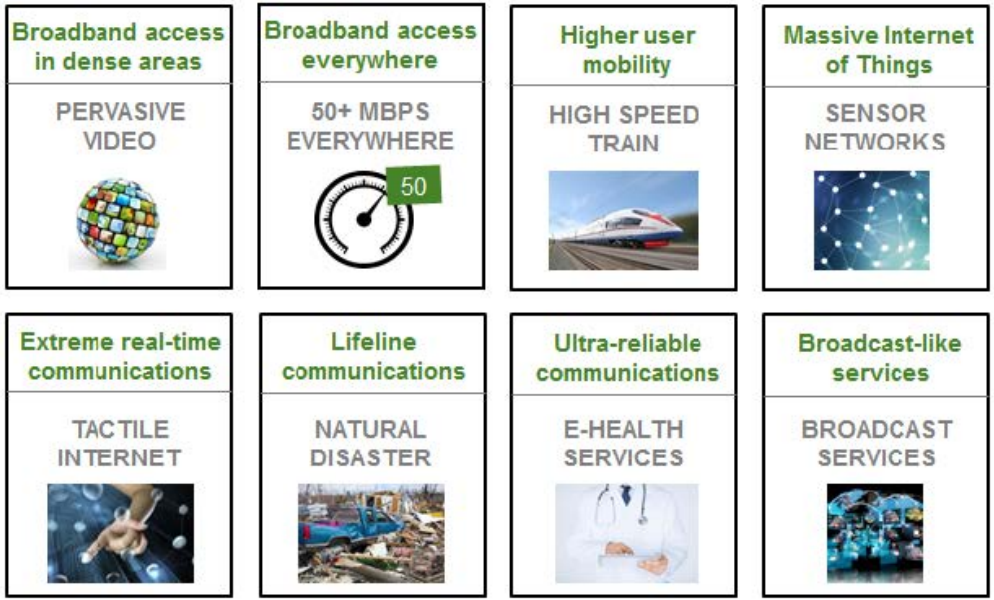
Question: At the IEEE 5G and Beyond Testbed Workshop in Toronto last fall, you joked that you didn't know what "5G" is. Would you explain why?

Seskar: A little humor can be a good thing in public speaking, if only to make an audience sit up. When people talk about "5G" they're actually talking about a collection of technologies, most of which remain in development. It's still not clear whether 5G will turn out to be a compound collection of various technologies or whether there will be a deeper integration that ties them all together. So when people discuss 5G in the media, they often emphasize very different technologies to explain it. So it's a simple, umbrella term for multiple technology advancements still under development. That's why we're exploring use cases with the help of the ORBIT 5G Testbed.

- **mmWave**
  - Proximus (+Huawei): https://www.youtube.com/watch?v=fLtu11ITF68 [Dutch]
  - Samsung: https://www.youtube.com/watch?v=iXr7W_KDIOA
- **Massive MIMO**
  - Telenet [+ZTE]: https://www.youtube.com/watch?v=WS8lziUaT4I&feature=youtu.be
- **Drone & network slicing**
  - Ericsson [+China Mobile]: https://www.youtube.com/watch?v=0KTdMypaopo

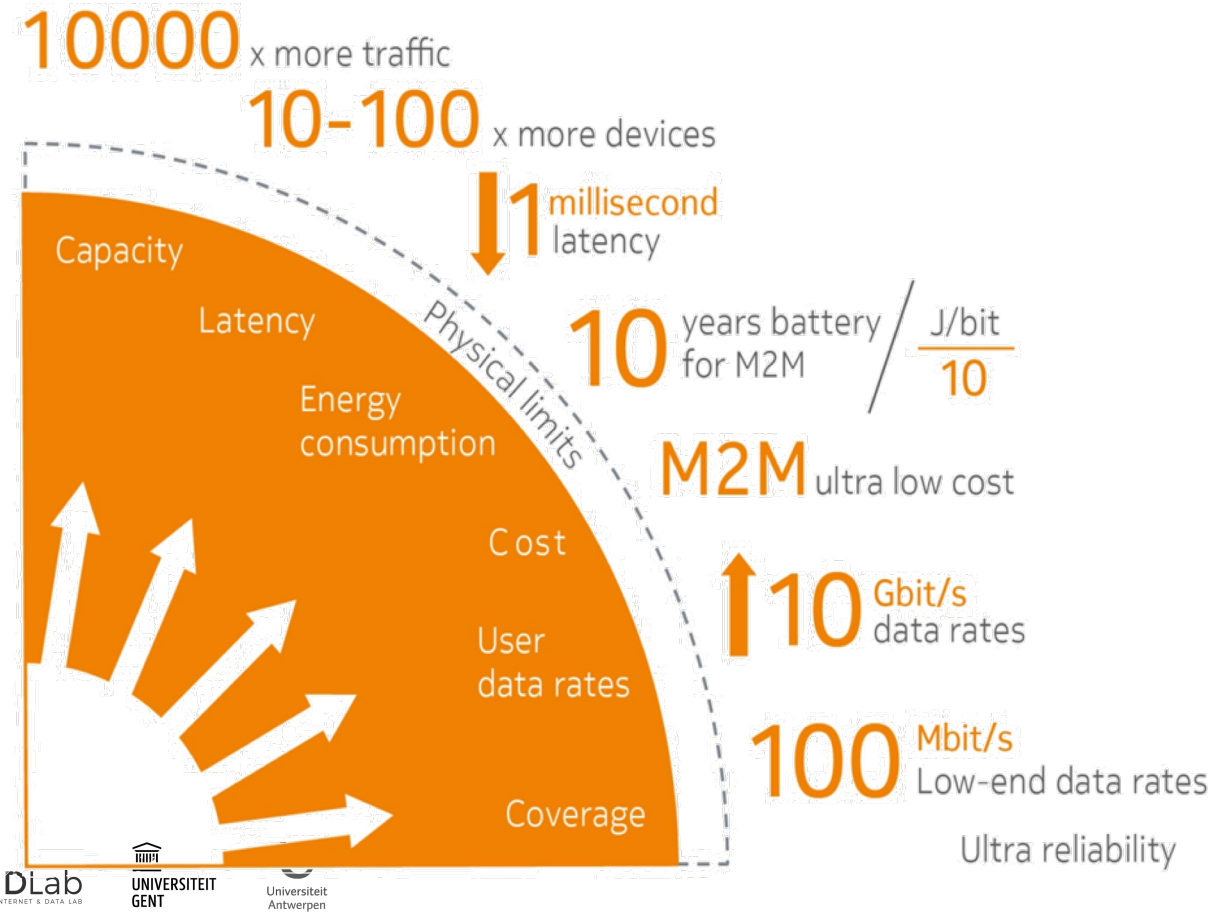
WHAT IS 5G?

- **The 5G vision according to NGMN Alliance:**
  - "5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models."
- 8 use case families have been defined



https://www.ngmn.org/fileadmin/ngmn/content/downloads/Technical/2015/NGMN_5G_White_Paper_V1_0.pdf

5G CHALLENGES



5G PPP
PUBLIC-PRIVATE PARTNERSHIP

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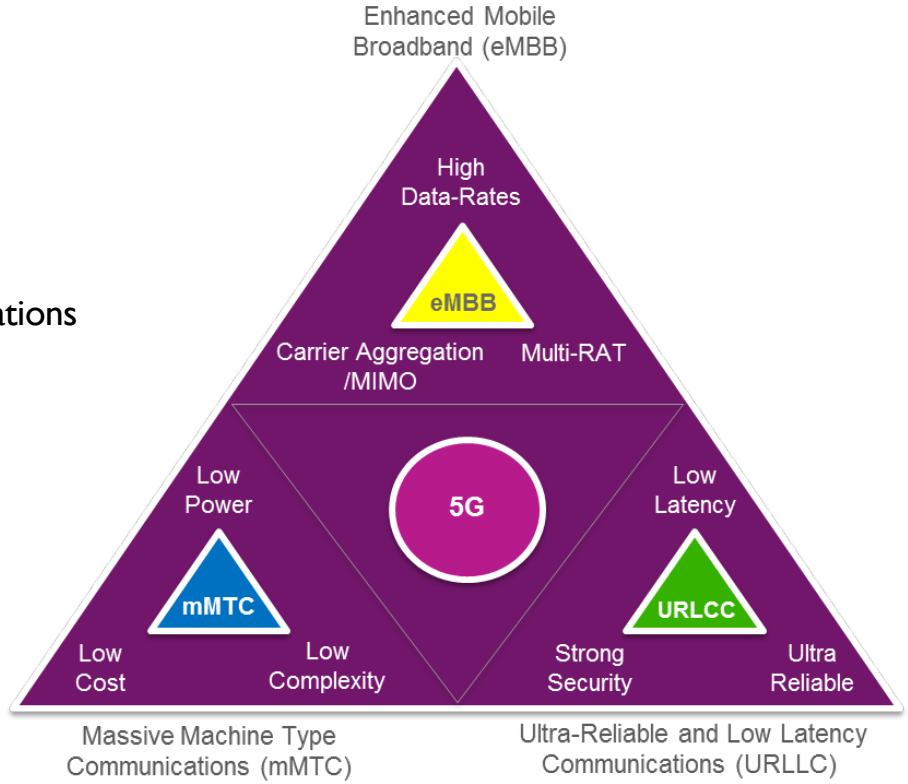
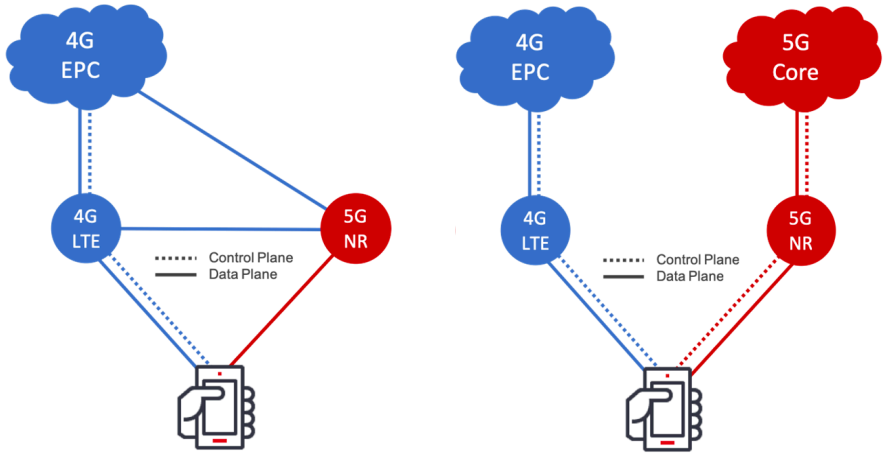
5G NEW RADIO (NR)

- 5G NR is a new air radio technology that enables the 3 following types of communication, each one having different objectives:
  - **eMBB** – enhanced Mobile Broadband
    - Low latency
    - High spectral efficiency
    - High throughput
    - Extreme coverage – beyond 4G
  - **URLLC** – Ultra Reliable Low Latency Communications
    - Monitor and control in real time
    - High reliability
    - Low latency
    - High security
  - **mMTC** – massive Machine Type Communications
    - Low device complexity
    - Long device battery life
    - High density device deployment



5G WIRELESS ACCESS

- Smooth introduction of 5G through interworking between LTE evolution and new radio (NR) access technologies
  - Support for dual connectivity between LTE and 5G NR
- 5G deployment
  - non-standalone mode: evolution of existing wide area LTE, use of LTE core network (EPC), add 5G NR access
  - standalone mode: 5G NR + 5G Core Network (standardization in progress)



5G-NR SPECTRUM

Low bands below 1 GHz: longer range for e.g. mobile broadband and massive IoT
e.g. 600 MHz, 700 MHz, 850/900 MHz

Mid bands 1 GHz to 6 GHz: wider bandwidths for e.g. eMBB and mission-critical
e.g. 3.4-3.8 GHz, 3.8-4.2 GHz, 4.4-4.9 GHz

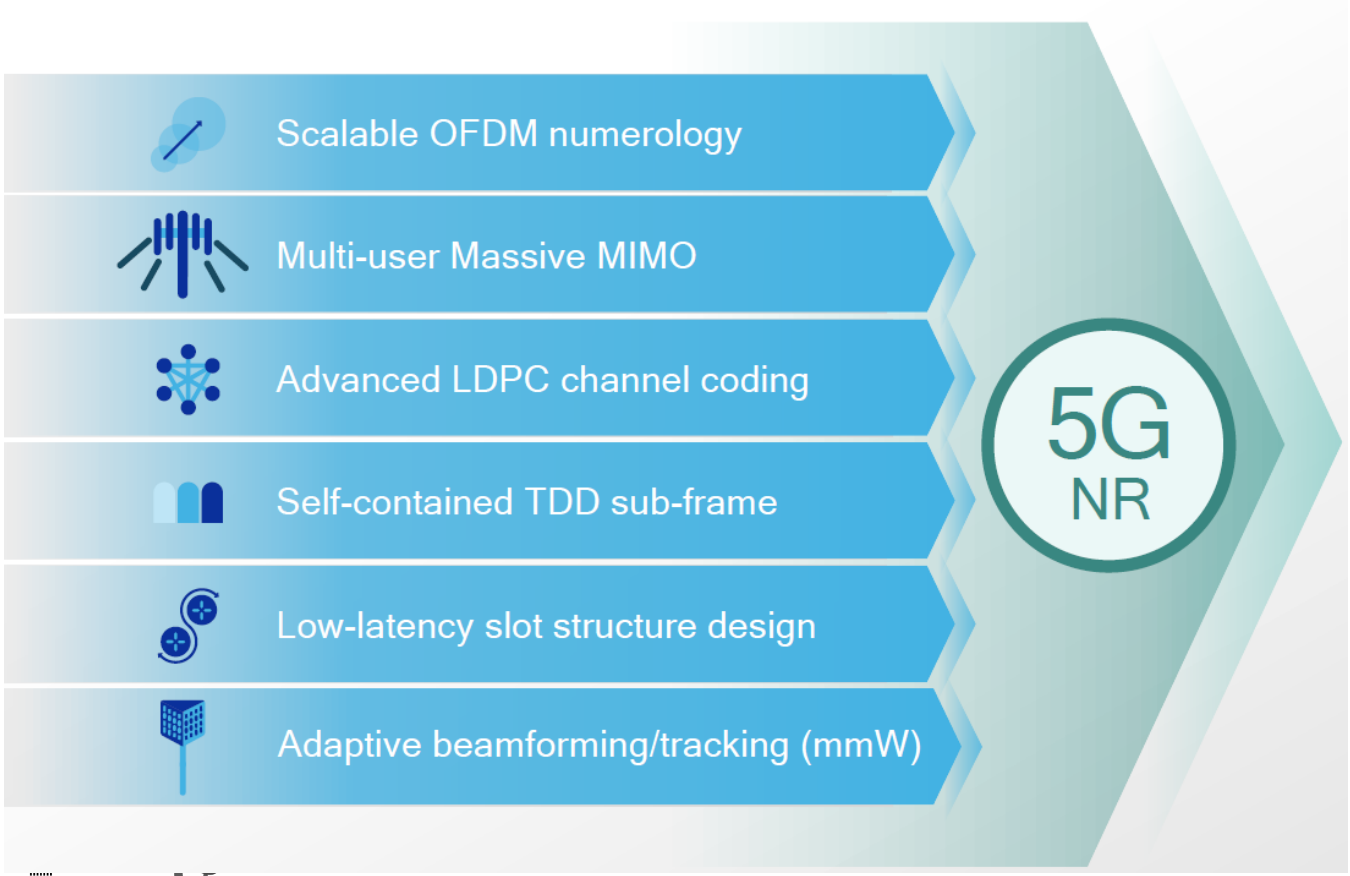
High bands above 24 GHz (mmWave): extreme bandwidths
e.g. 24.25-27.5 GHz, 27.5-29.5, 37-40, 64-71 GHz

Licensed Spectrum
Exclusive use

Shared Spectrum
New shared spectrum paradigms

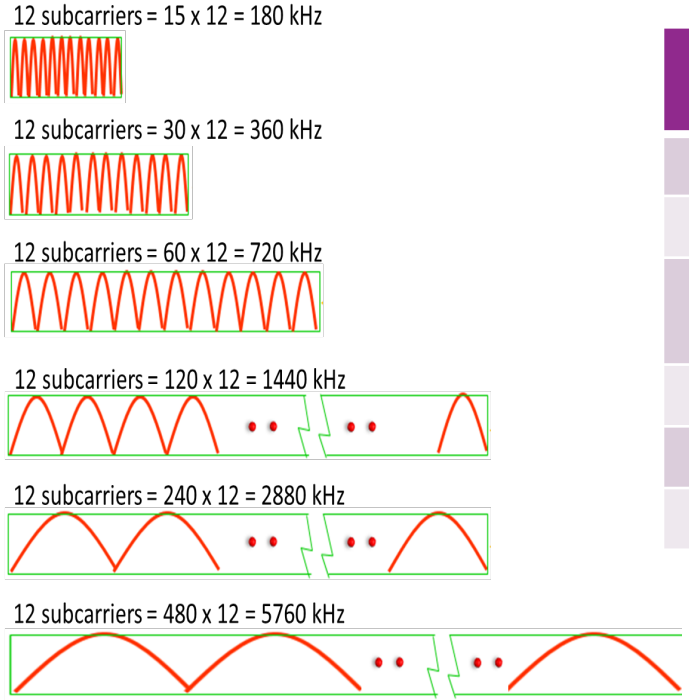
Unlicensed Spectrum
Shared use

5G NR TECHNOLOGY ENABLERS



5G NR SUBCARRIER SPACING

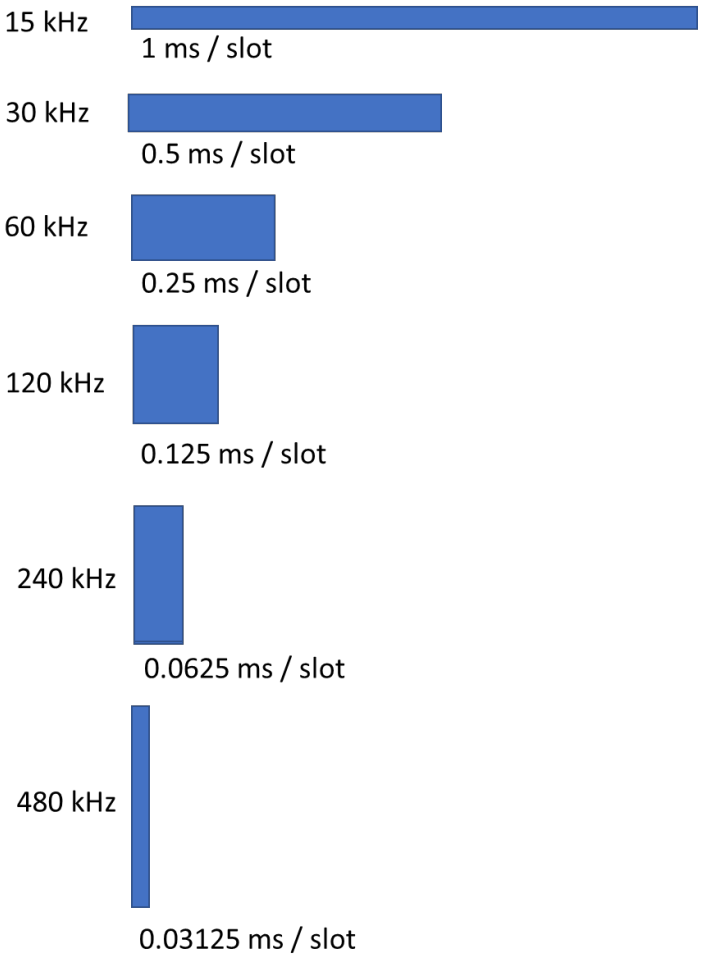
- 5G NR supports multiple different types of subcarrier spacing
  - cf. LTE: only subcarrier spacing of 15 kHz



μ	$\Delta f = 2^{\mu} \times 15$ [kHz]	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal
5	480	Normal

5G NR – SLOT LENGTH

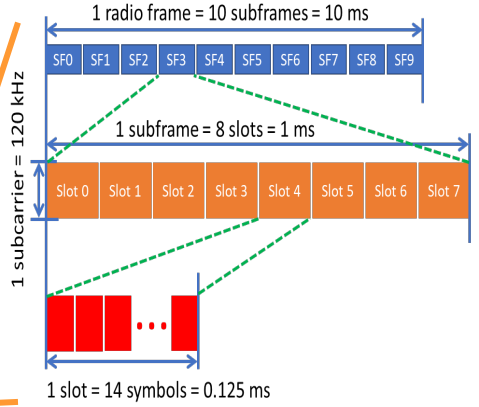
- Slot length versus subcarrier length



5G NR – RADIO FRAME STRUCTURE

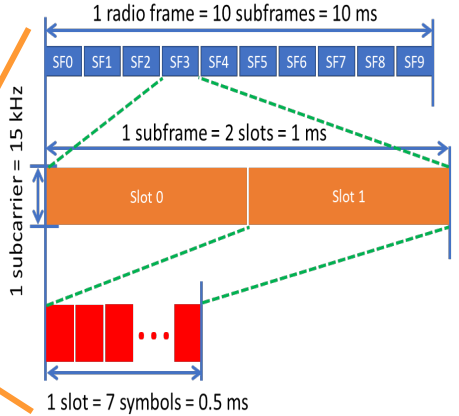
5G NR

μ	Sub-carrier spacing	Sym-bols/slot	Slots/ frame	Slots/ Sub-frame	OFDM symbol duration (μs)	Slot duration (ms)	Cyclic prefix
0	15 kHz	14	10	1	66.7	1	Normal
1	30 kHz	14	20	2	33.3	0.5	Normal
2	60 kHz	14	40	4	16.67	0.25	Normal
2	60 kHz	12	40	4	16.67	0.25	Extended
3	120 kHz	14	80	8	8.33	0.125	Normal
4	240 kHz	14	160	16	4.16	0.0625	Normal
5	480 kHz	14	320	32	2.08	0.03125	Normal



LTE

Sub-carrier spacing	Sym-bols/ Slot	Slots/ frame	Slots/ Sub-frame	OFDM symbol duration (μs)	Slot duration (ms)	Cyclic prefix
15 kHz	7	20	2	66.7	0.5	Normal
15 kHz	6	20	2	66.7	0.5	Extended



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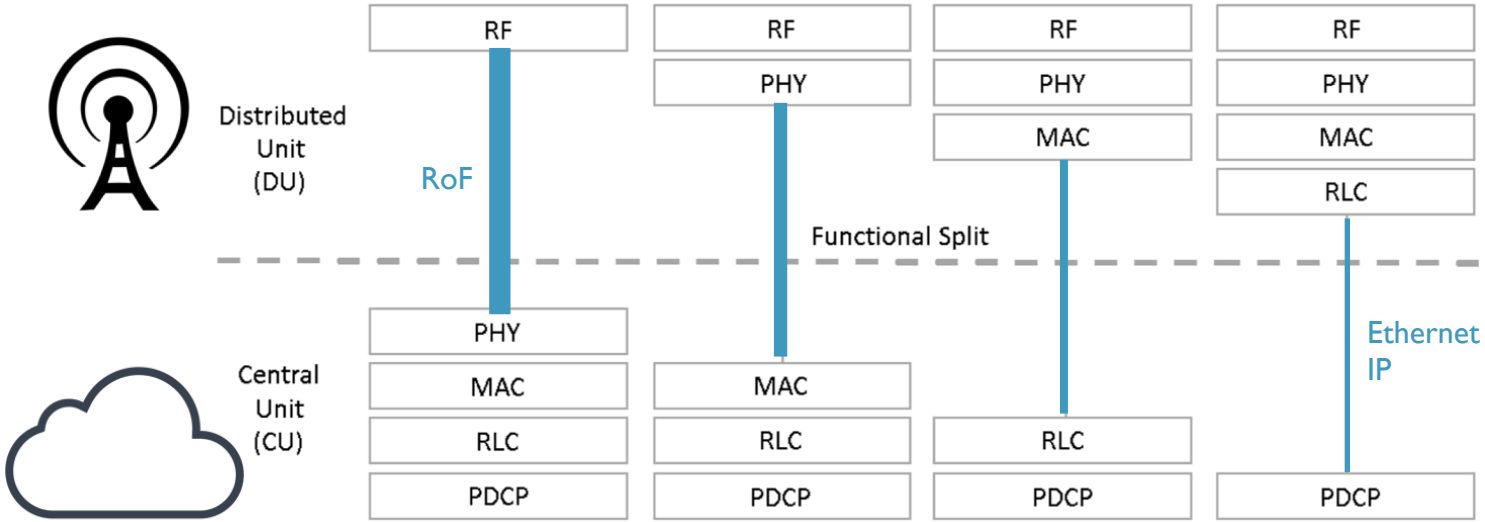
5G - SOFTWARIZATION

- Using software rather than hardware to perform the processing of radio and network functions
- Great for non real-time (NRT) services, but RT services need hardware acceleration close to antenna



High infrastructure sharing
Full central coordination

HIGH COVERAGE

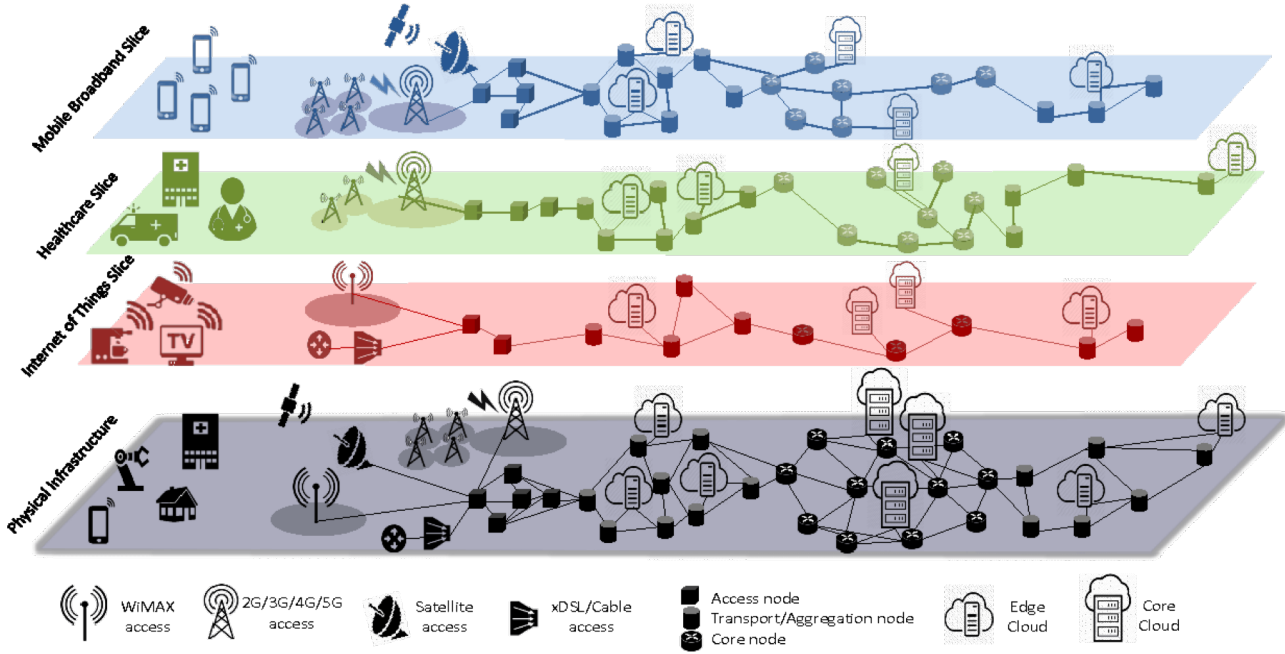
Low infrastructure sharing
Central + local coordination

LOW LATENCY

https://www-file.huawei.com/-/media/CORPORATE/PDF/mbb/cloud-ran-the-next-generation-mobile-network-architecture.pdf?la=en

5G - NETWORK VIRTUALIZATION

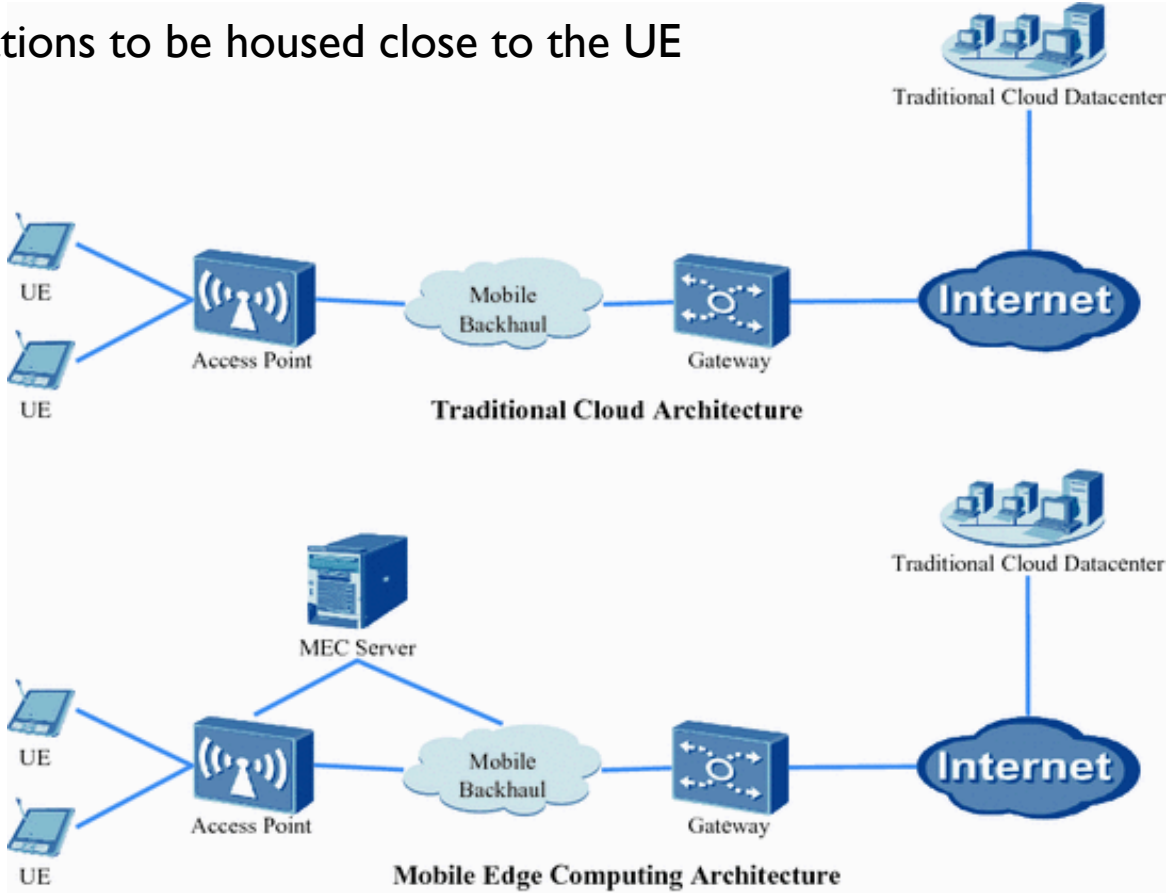
- Sharing of physical network resources by creation of isolated virtual networks (network slices)
- Each network slice can be individually configured to serve a particular purpose (vertical), guaranteeing a particular set of performance characteristics
- SDN centralized control of network slices



https://www.onug.net/blog/5g-network-slicing-and-enterprise-networking/

5G MOBILE EDGE COMPUTING (MEC)

- enable data and applications to be housed close to the UE
- Low round trip time



5G: CURRENT STATUS

- TODAY
  - Main focus on eMBB (enhanced Mobile BroadBand)
  - Main focus on the core
  - start of pre-commercial launches
- Official launches expected in 2020 or later

5G = umbrella of multiple technology advancements

embracing a better life