Communication in Distributed Systems

13 5G Mobile Networks in a nutshell

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History of mobile communiation standards

A short history of mobile communication standards

1G

Released: 1979

Standards: NMT, AMPS, ...

Capabilities:

Analog voice

2G

Released: 1991

Standards: GSM, CDMA

Capabilities:

Digital Voice
Encryption (broken)
Limited Roaming
SMS, MMS

Extensions:

GPRS
CDMA2000
EDGE

3G

Released: 2002

Standards: UMTS

Capabilities:

Mobile Broadband
Locating services
Multimedia Streaming
Seamless global Roaming

Extensions:

HSPA+

4G

Released: 2009

Standards: LTE

Capabilities:

High Speed mobile Internet
IP-based packet switching
HD-Multimedia Streaming
Seamless global Roaming

Extensions:

New Features with new 3GPP Releases (Rel8 - Rel14), i.e. LTE Advanced

Based on: [9]

5G Vision (wishes)

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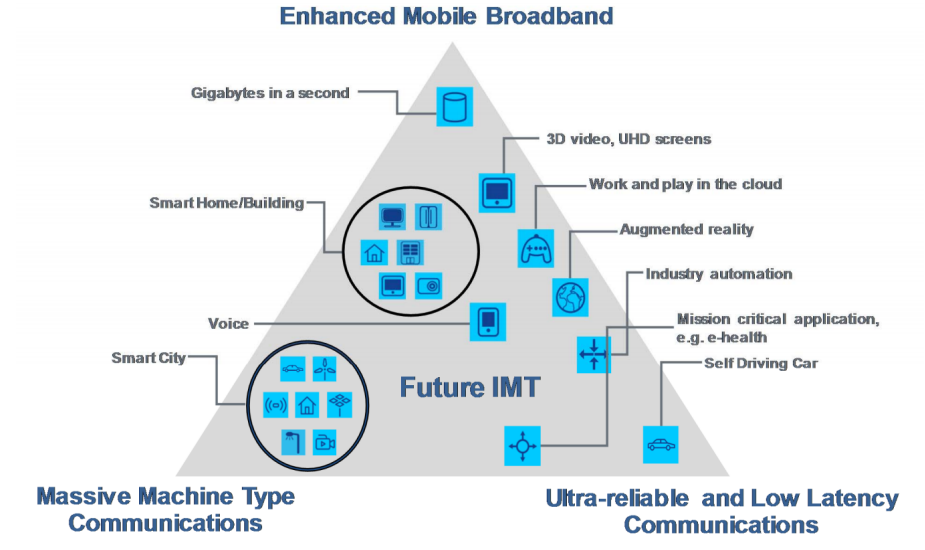


ITU-R Vision for future mobile communciations (2015) [7]

Three types of **service scenarios:**

- Enhanced Mobile Broadband (eMBB)
- Massive Machine Type Communications (mMTC)
- Ultra-reliable low-latency communication (URLLC)

Service Specific 5G networks

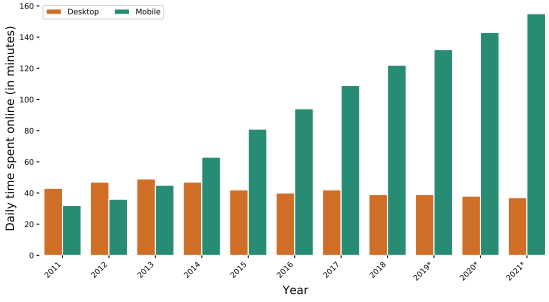
4G

Comparable rooftop base-stations and smartphones

5G

5G networks will be different in **hardware, size and shape** to realize eMBB, mMTC and URLLC,

Enhanced Mobile Broadband (eMBB)



Zenith's Media Consumption Forecasts [6]

- People spend more and more time online with their smartphones
- New applications require more throughput
  * 4K or 8K Video-Streaming
  * Video Calls
- Virtual and Augmented Reality applications
  * Maintenance or remote surgery

  Downlink: 20 Gbit/s, Uplink: 10 Gbit/s [10]

Massive Machine Type Communications (mMTC)

Communication of people using smartphones is not the only application for mobile communications anymore (Internet of things, Industry 4.0, Smart Homes).

- Numerous Devices
- Large Area
- Low Data-Rate
- cf. LoRaWAN

1 Mio. devices p. m^2

10 years Battery life

Ultra-reliable low-latency communication (URLLC)

- Factory Automation
  * i.e. Robots, Emergency Stop switch, maintenance
- Smart City Automation
  * i.e. Autonomous Vehicles

Latency: $<$ **1ms** [8]

Reliability: 99,9999% [8]

(Only One Packet in a Million)

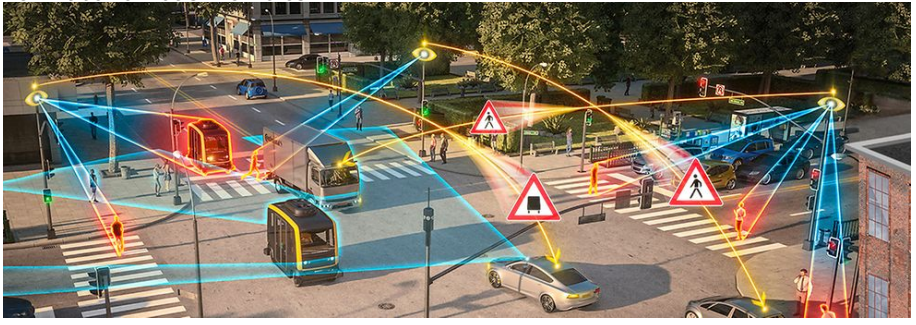


Image Credit: [4]

How?

(Spoiler: we already learned all the basics in this lecture)

5G Key Technologies

Carrier Aggregation and mmWave

Throughput needs Bandwidth, remember? $C = B\log_2(1 + \frac{S_P}{N_0 * B})$

- Mobile Network frequencies are divided in blocks (carrier)
- Aggregate multiple blocks for more bandwidth
- User higher frequencies (mmWave) due to availability of bandwidth

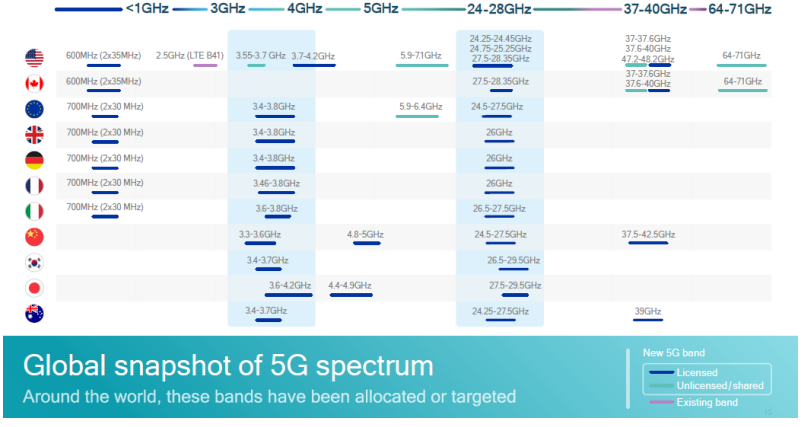
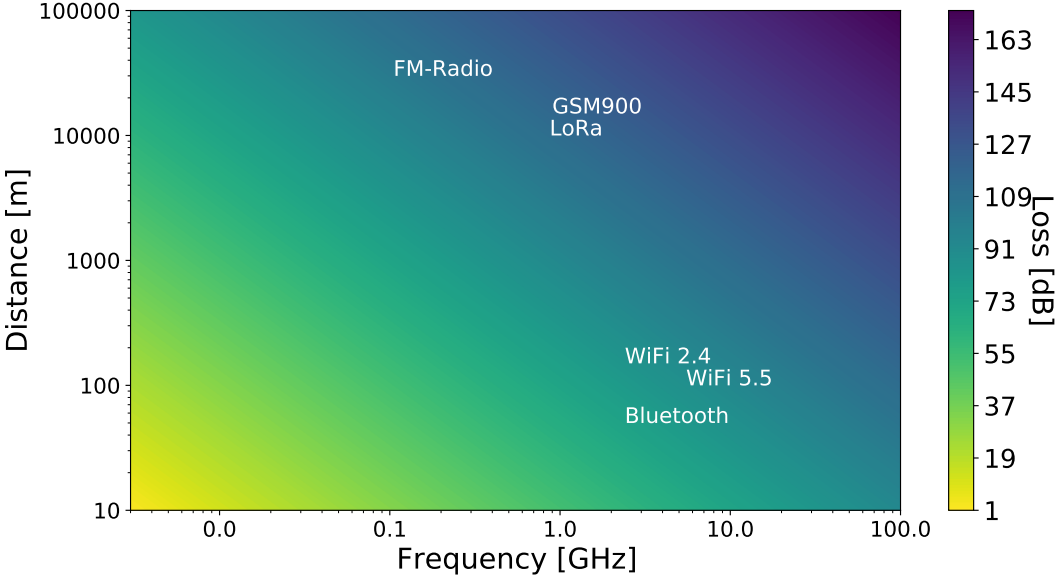
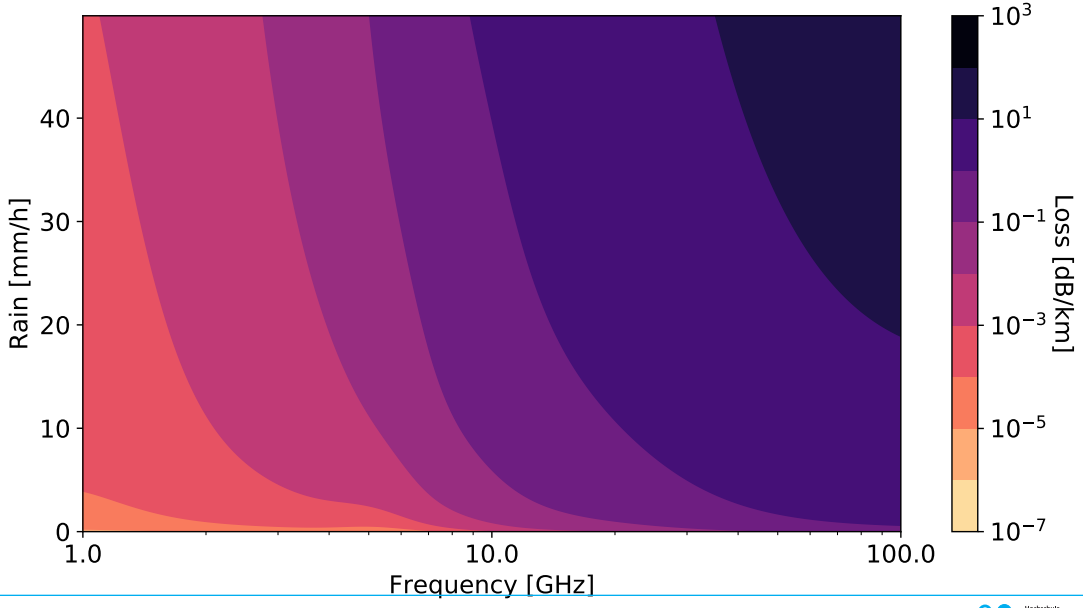


Image Credit: [1]

Free-Space Path Loss (FSPL) and mmWave



Rain and mmWave



Despite the Problems with Physics, we need to make mmWave usable.

Small Cells

Throughput needs Signal power, remember? $C = B \log_2(1 + \frac{S_P}{N_0 * B})$

We want to reuse frequencies as often as possible.

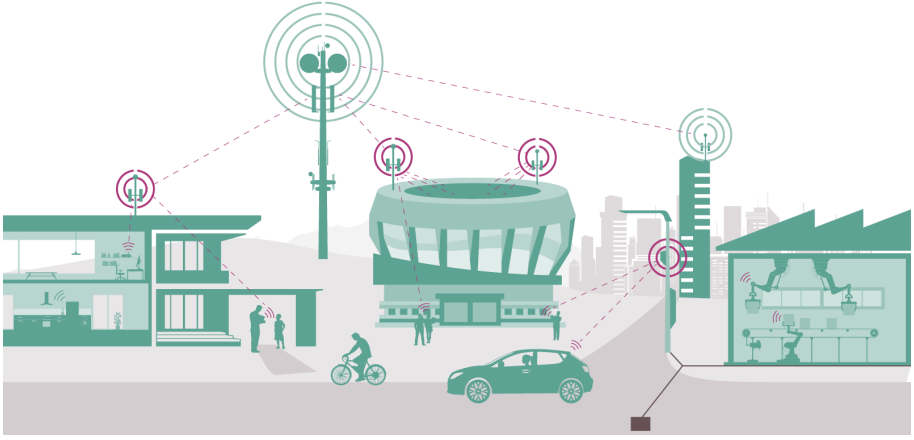


Image Credit: [2]

Beamforming and Massive Multiple Input Multiple Output

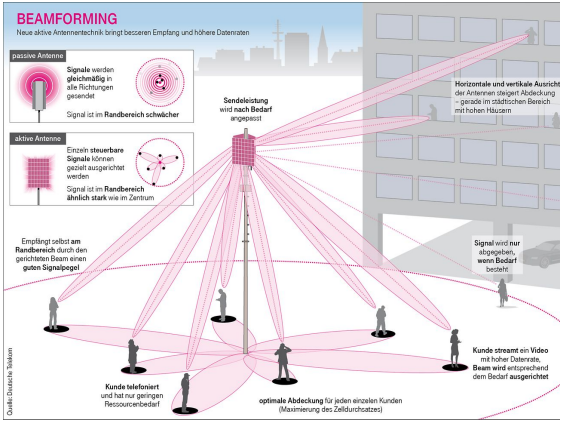


Image Credit: [5]

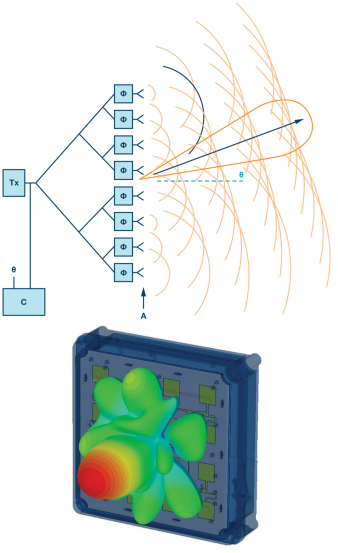
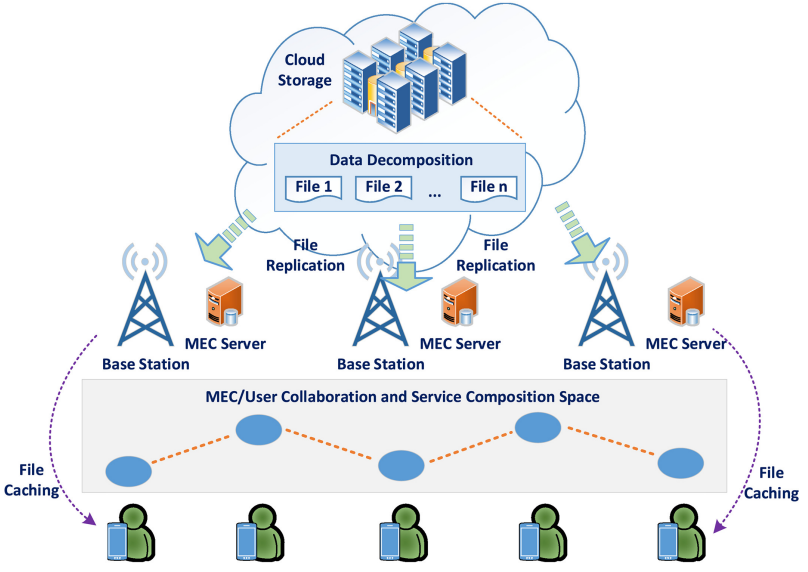


Image Credit: [3]

But how do we reach an end-to-end latency if the next data-center is hundreds of kilometers away?

Mobile Edge Computing (MEC)



There is more...

- SDN Based core network
- Network slicing
- Device-to-device communications
- New Multiple access techniques (i.e. NOMA)
- New Security and Privacy Mechanism

...

Thank you for your attention.
Are there any questions left?

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