Cellular networks: modern design and future look

Guest lecture in LiU "TDTS06 Computer Networks"

Imagine a world
where limitless connectivity
means limitless possibility

Cellular networks: modern design and future look

Abstract:

Cellular networks evolution from 1G to 5G was at high degree driven by growing traffic demands which is in turn driven by several trends such as externalization of data storage, remote compute, video traffic etc. However, there are other network capabilities getting momentum, such as enegry efficiency, low-latency, high reliability, positioning, joint communication and sensing and many more.

In this lecture, we will have a look at state-of-the art 5G cellular network building blocks, touch upon technology components and protocols, explain how system has been evolved to 5G and what opportunities are awaiting us in future beyond 5G.

Alexey Shapin

- 2023 – now: CU-CP System architecture developer in Ericsson, Linköping
- 2017 – 2022: Ericsson Research, Luleå
- Worked as associate professor, certification specialist, external consultant for Nokia (Germany) and visiting researcher in LTU (Sweden).
- Author and co-author of 80+ patent applications.
- Graduated Siberian State University of Telecommunication and Information Science (Novosibirsk, Russia)
- Ph.D. in telecommunication (Hybrid ARQ and channel coding)

This is Ericsson

Ericsson by the numbers

We enable communications service providers and enterprises to capture the full value of connectivity

105,500
employees worldwide

47
R&D budget
(SEK b)

60,000
granted patents

272
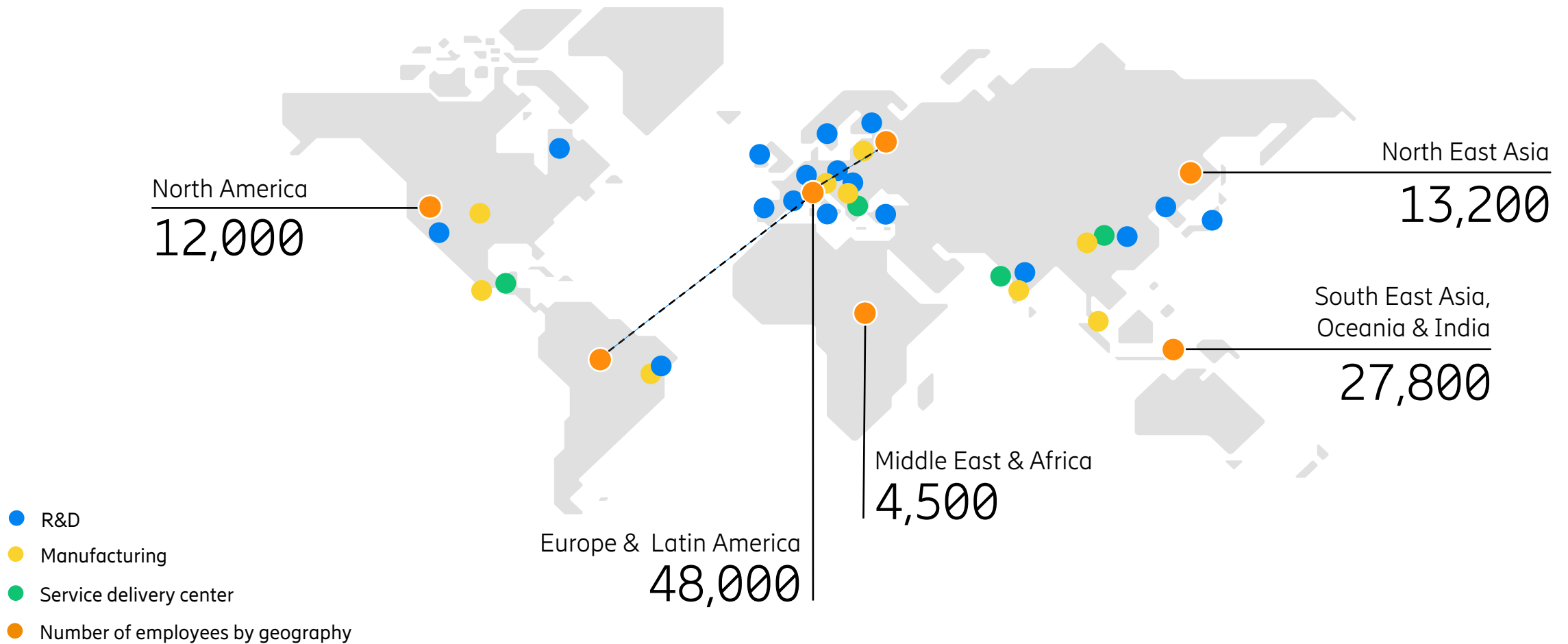sales (SEK b)

180
countries

147 live 5G networks

Note 1. Data as of December 31, 2022

Note2. Average rate during FY 2022 – SEK/USD: 10.04

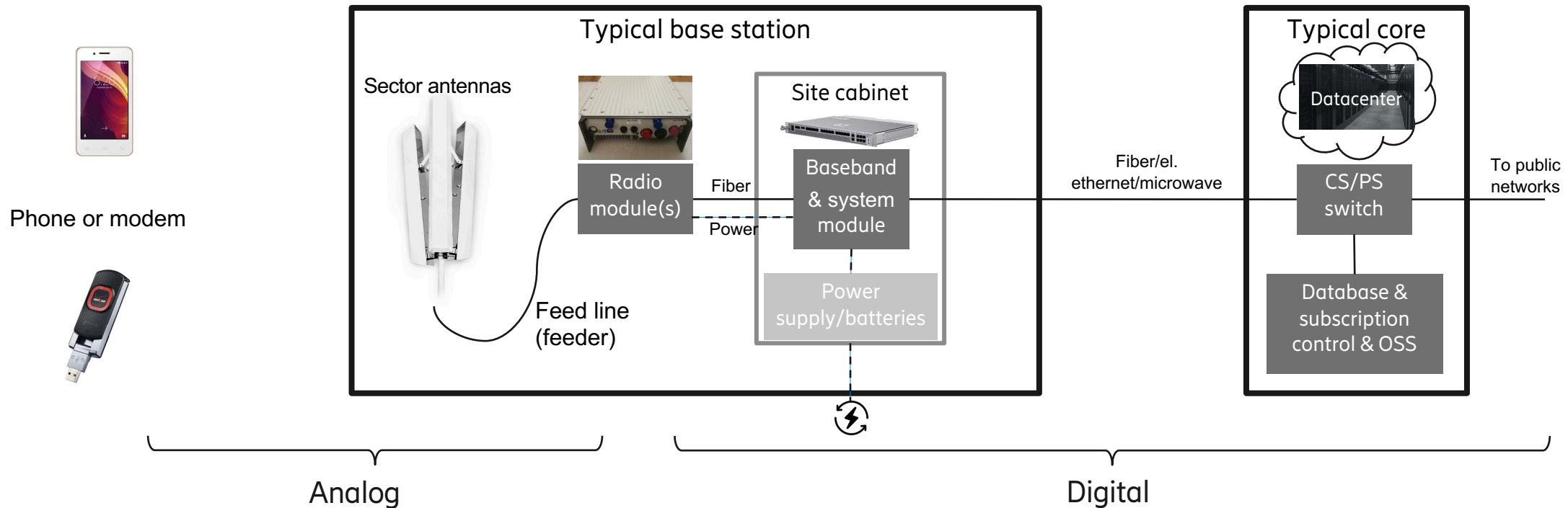# A global team serving customers worldwide

North East Asia
13,200

North America
12,000

South East Asia,
Oceania & India
27,800

Middle East & Africa
4,500

Europe & Latin America
48,000

- ● R&D
- ● Manufacturing
- ● Service delivery center
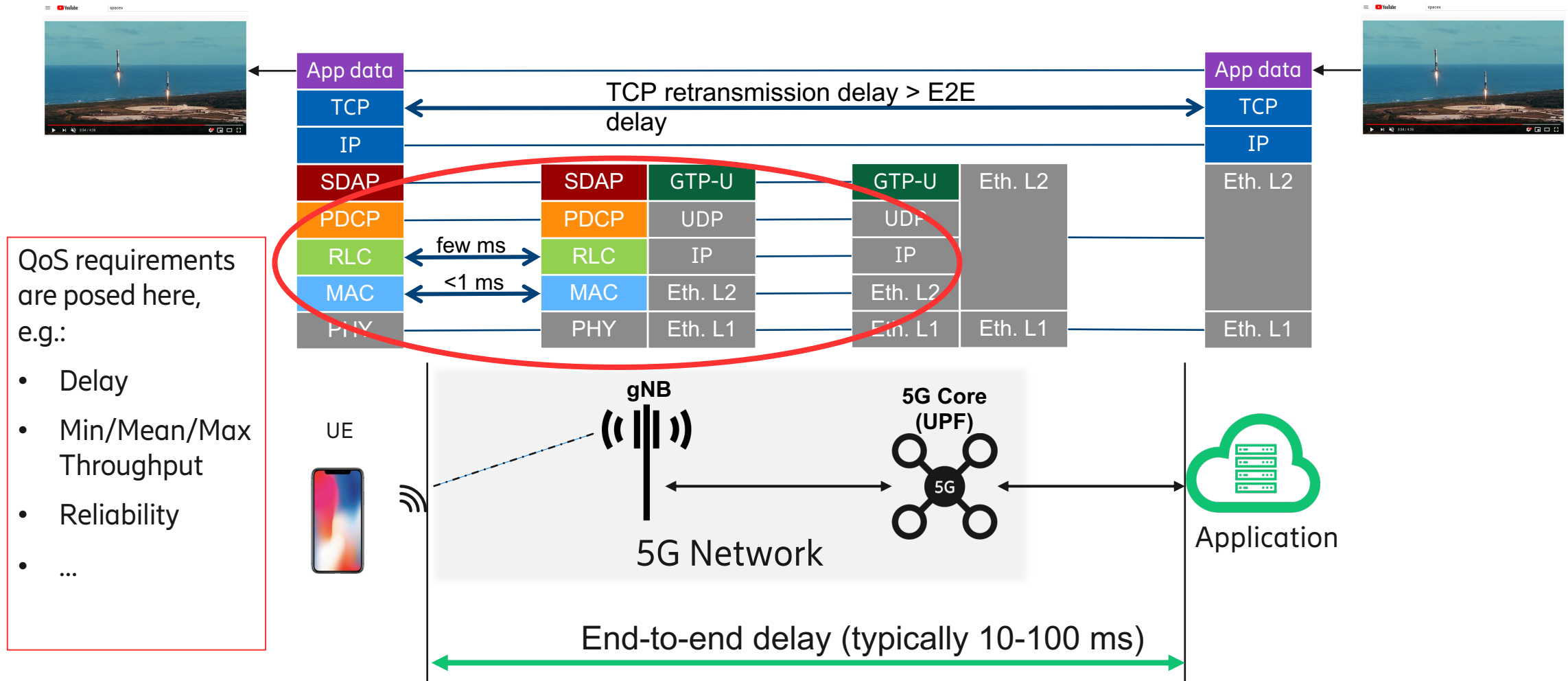- ● Number of employees by geography

Cellular network building blocks

- Core network (packet/circuit switches or routers, database of users with subscription info etc.)
- Base station (antenna, radio module, baseband module, system module)
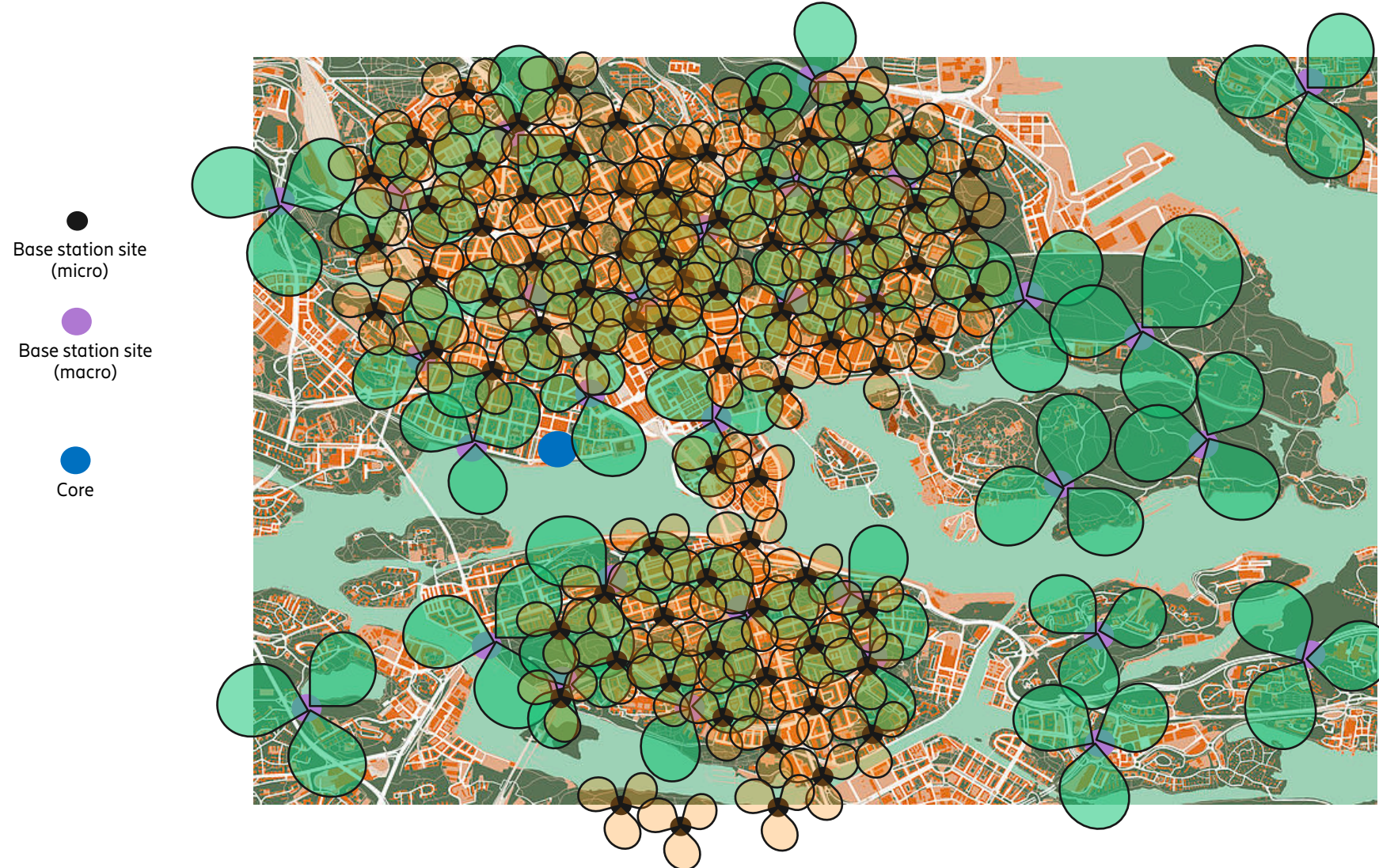- Phone or modem

Phone or modem

Typical base station

Sector antennas

Radio module(s)

Feed line (feeder)

Site cabinet

Baseband & system module

Fiber

Power

Power supply/batteries

Fiber/el. ethernet/microwave

Typical core

Datacenter

CS/PS switch

To public networks

Database & subscription control & OSS

Analog

Digital

User data flow through 5G NR

Radio planning

Base station site (micro)

Base station site (macro)

Core

One need to get frequnecy licenses.

Multiple layers are planned in modern networks:

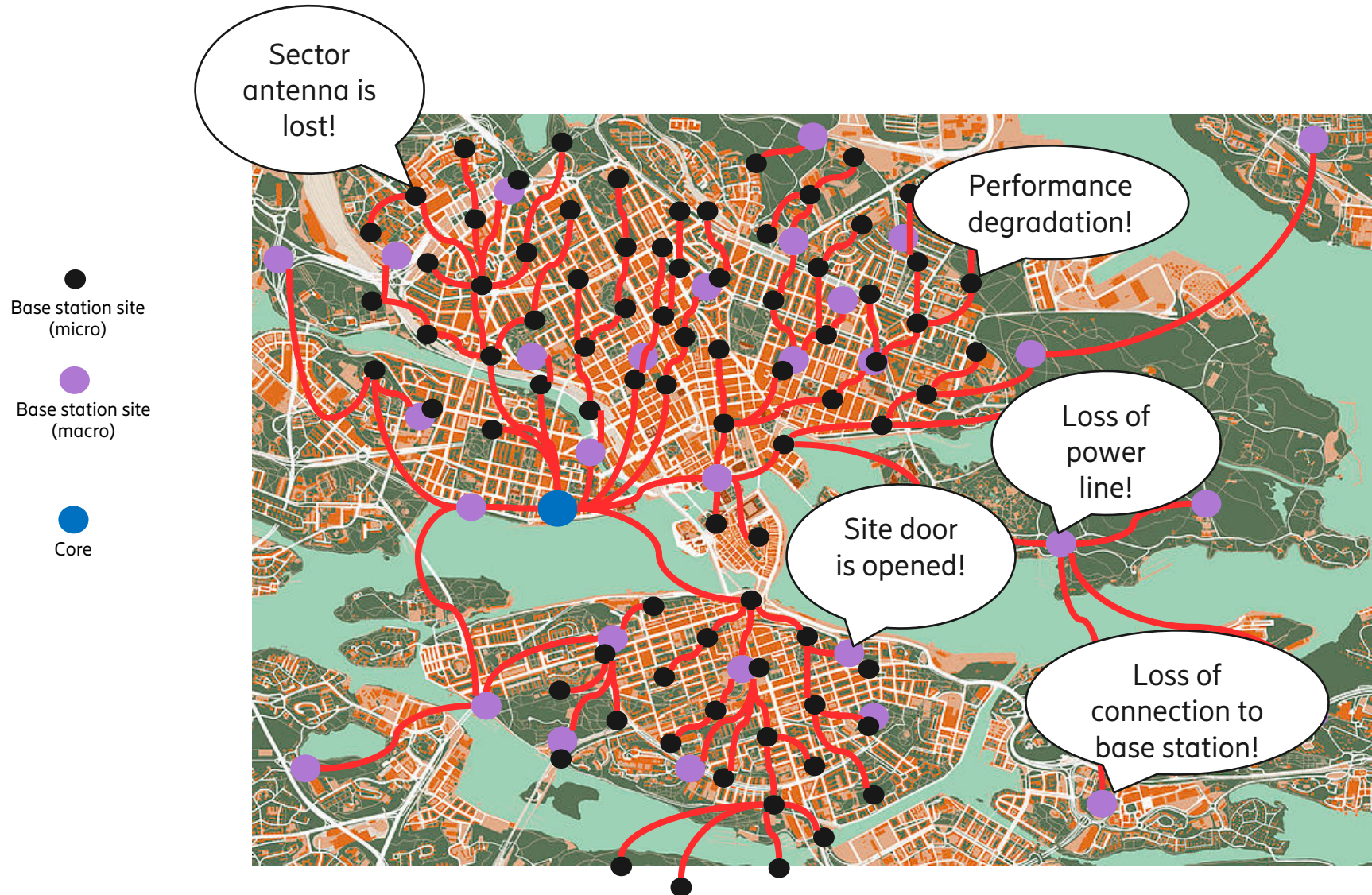- Macro
- Micro
- Indoor, tunnels, subway
- Nano, Pico cells

Transport network

Base station site (micro)

Base station site (macro)
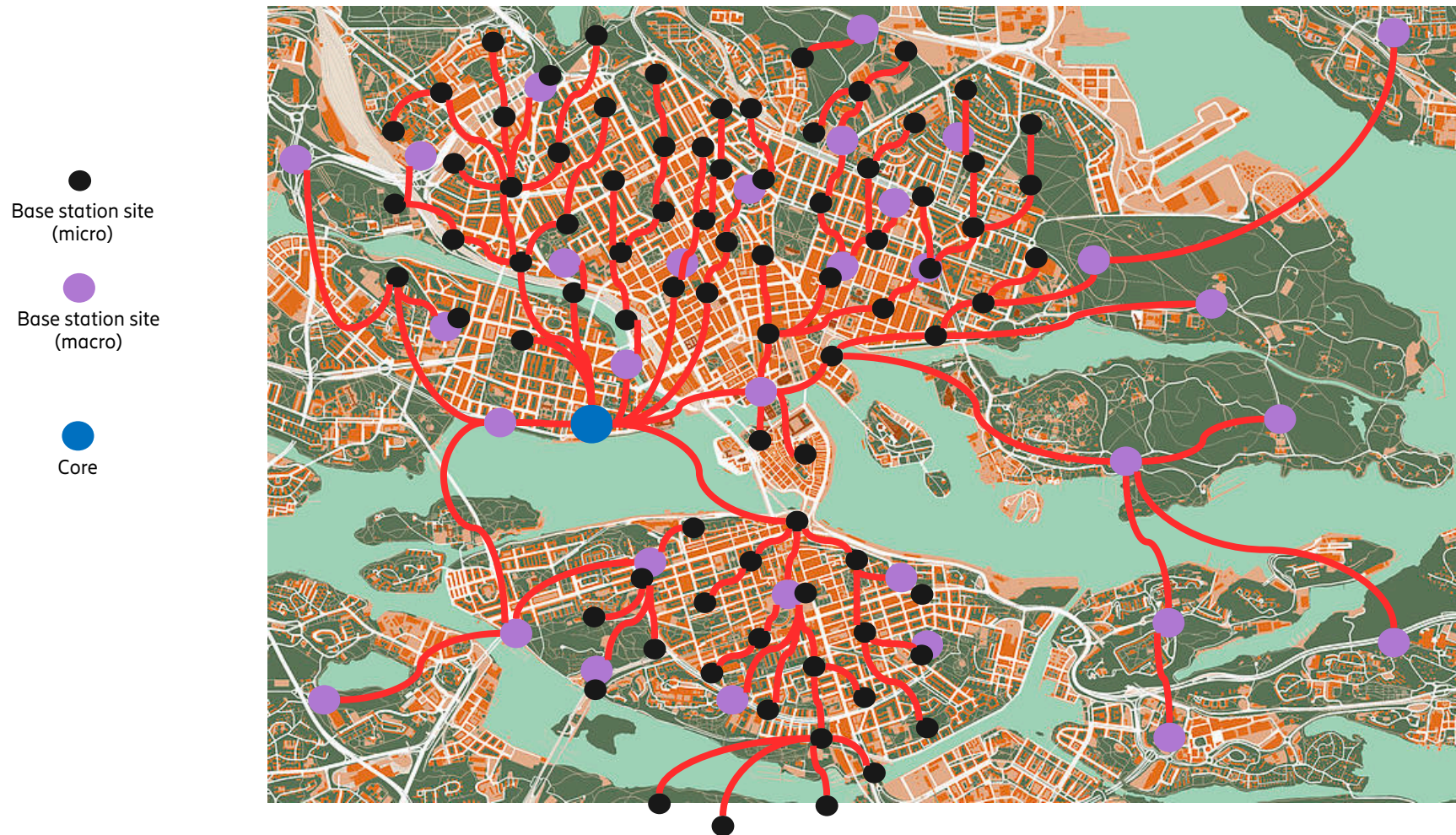
Core

All base stations must be connected in one transport network to be able to reach the Core and communicate with each other handovering users.

Operation & Network Management

ONM is needed to make network functioning well:

- Alarms
- Performance
- (Re)Configuration
- Monitoring
- Logging
- ...

It's visible only for operators.
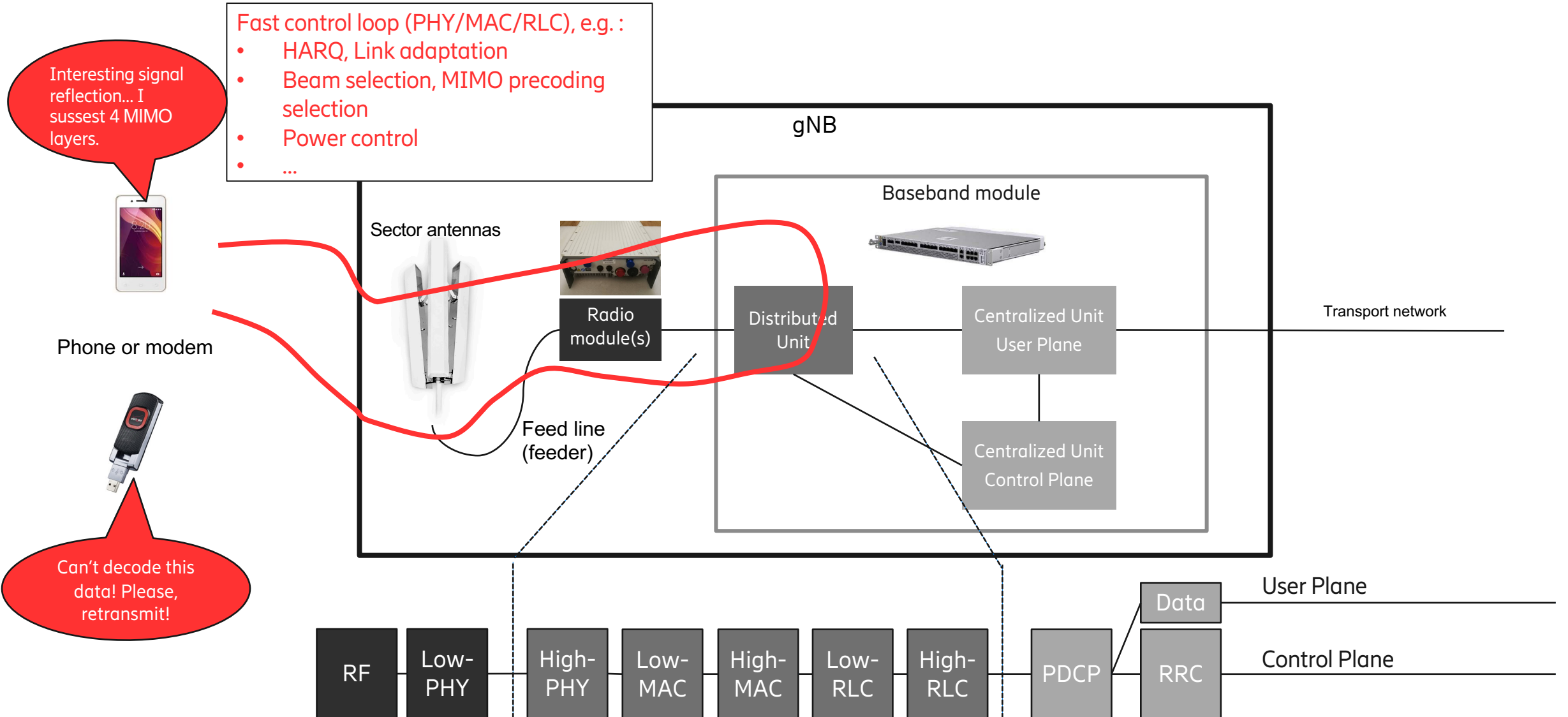
Architecrure - Compiling to one picture
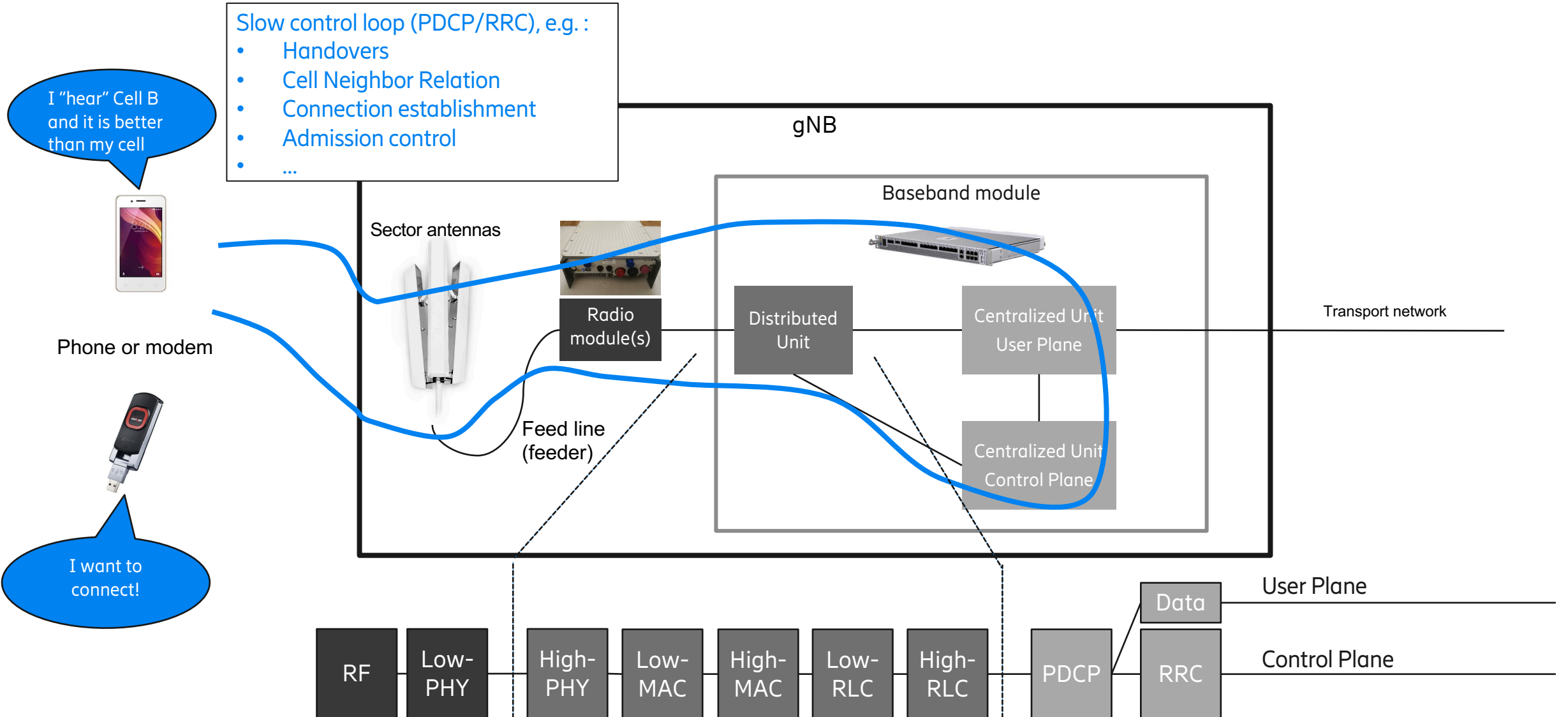
Operation and Management Interface

Management

Core network of
other operator

Interconnect
network

Public networks

User equipment

Access network

Core network

Transport network

Control signalling
User payload
Management traffic
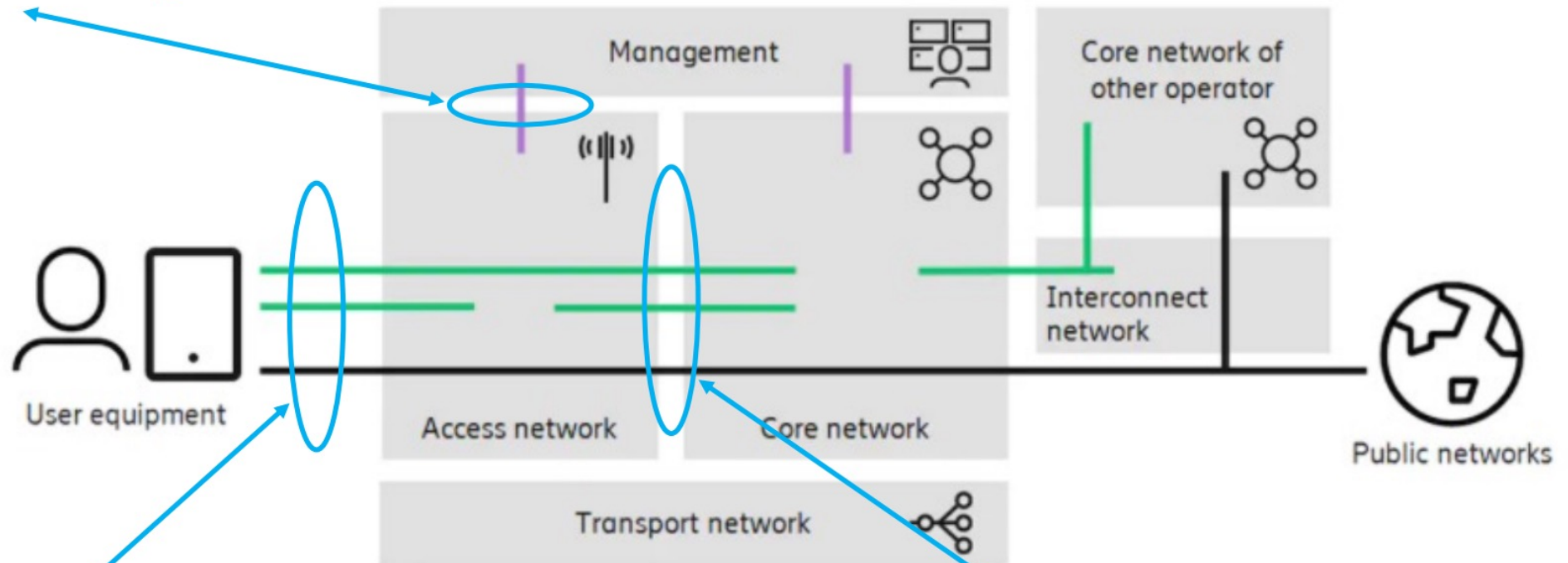
5G Air Interface

NG Interface

5G RAN Split architecture

5G RAN Split architecture

Evolution of cellular networks:
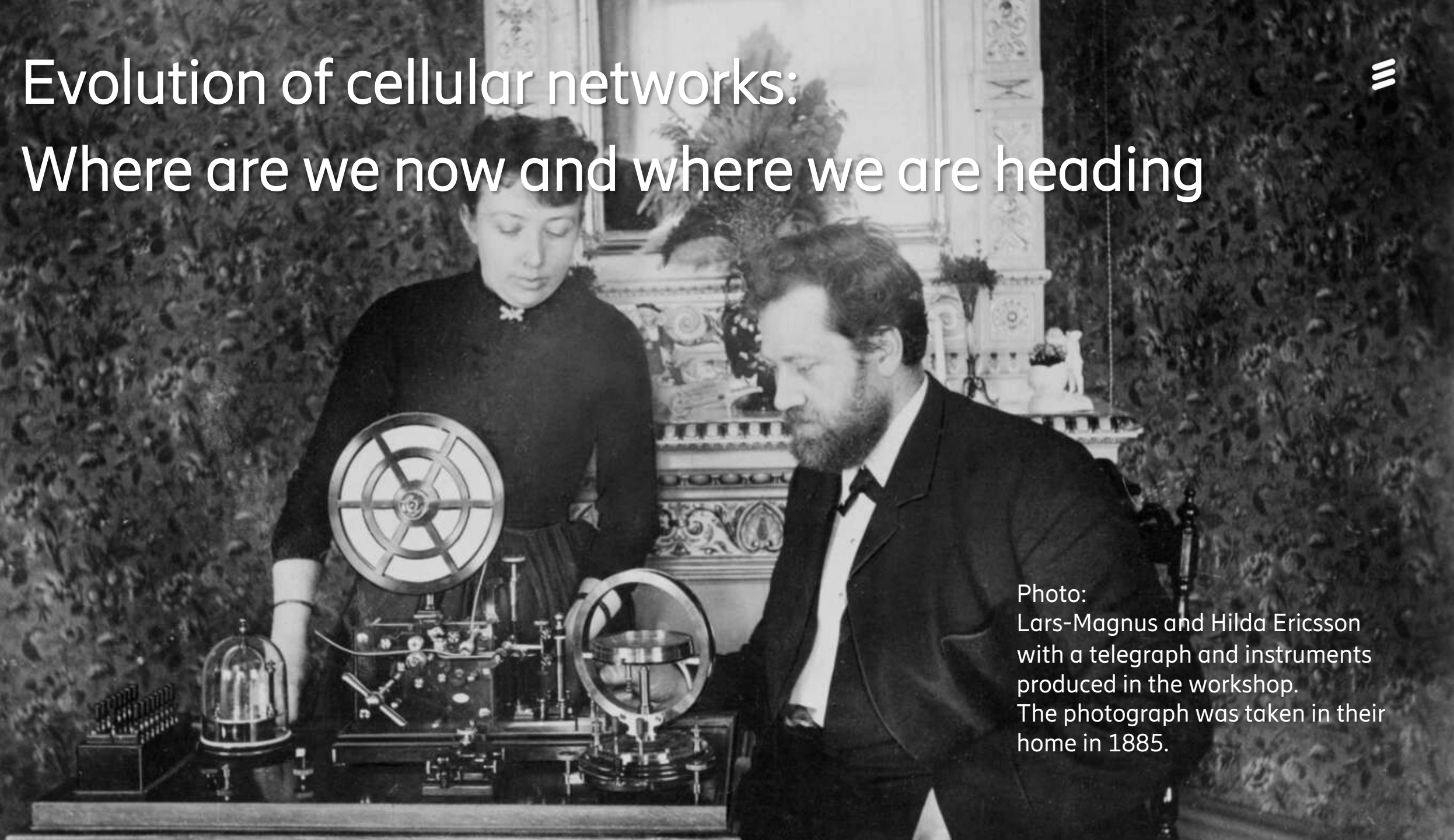# Where are we now and where we are heading

Photo:
Lars-Magnus and Hilda Ericsson with a telegraph and instruments produced in the workshop.
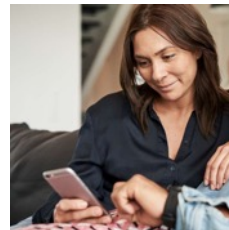The photograph was taken in their home in 1885.

Use cases

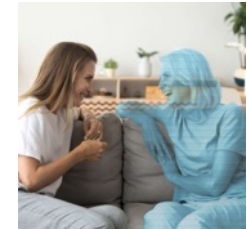

Voice

SMS

Mobile
broadband

App economy

Mobile social
networking
with video

IoT

Fixed Wireless
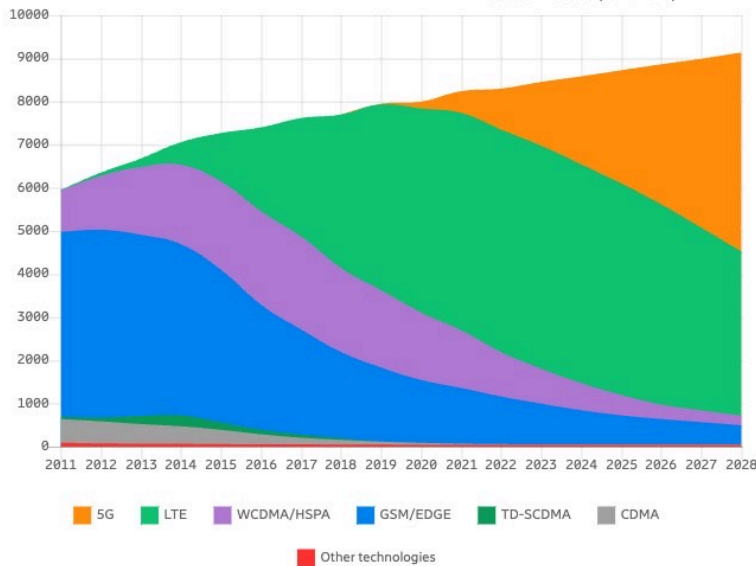Access

Industries goes
wireless

Mobile gaming

XR

●	2G	3G	4G	5G	6G
1980s	1990s	2000s	2010s	2020s	2030s

Cellular standard generations

Subscriptions and traffic (incl. forecast)
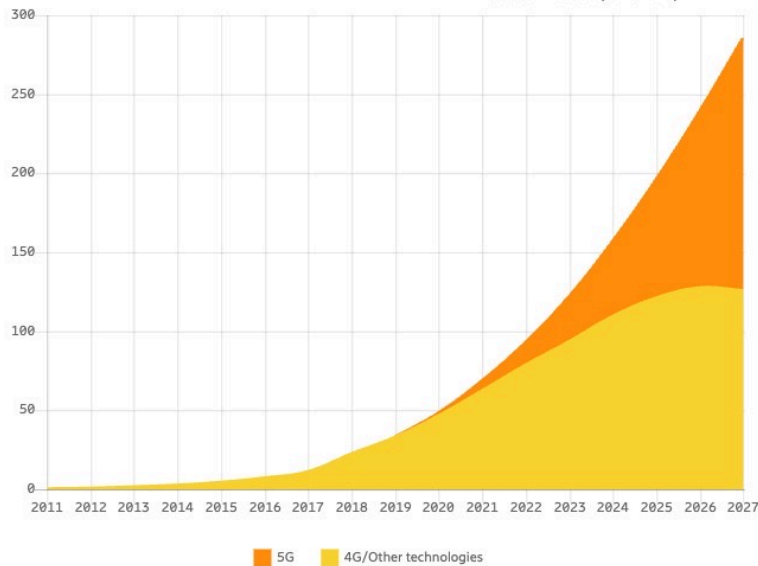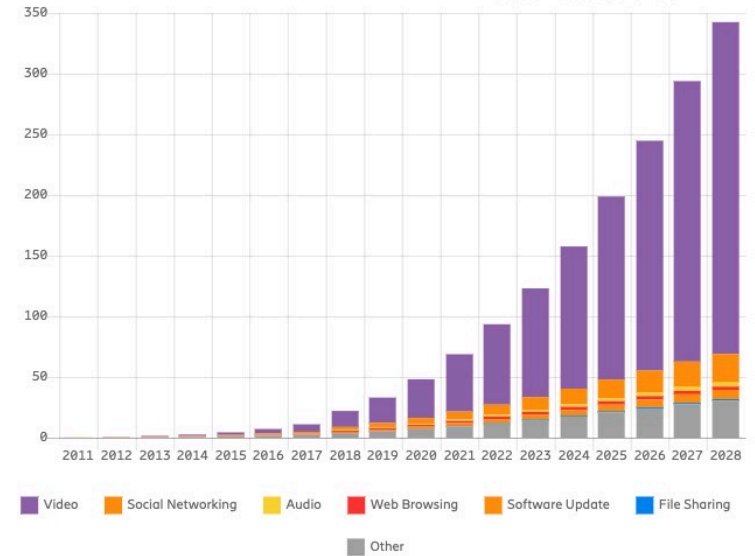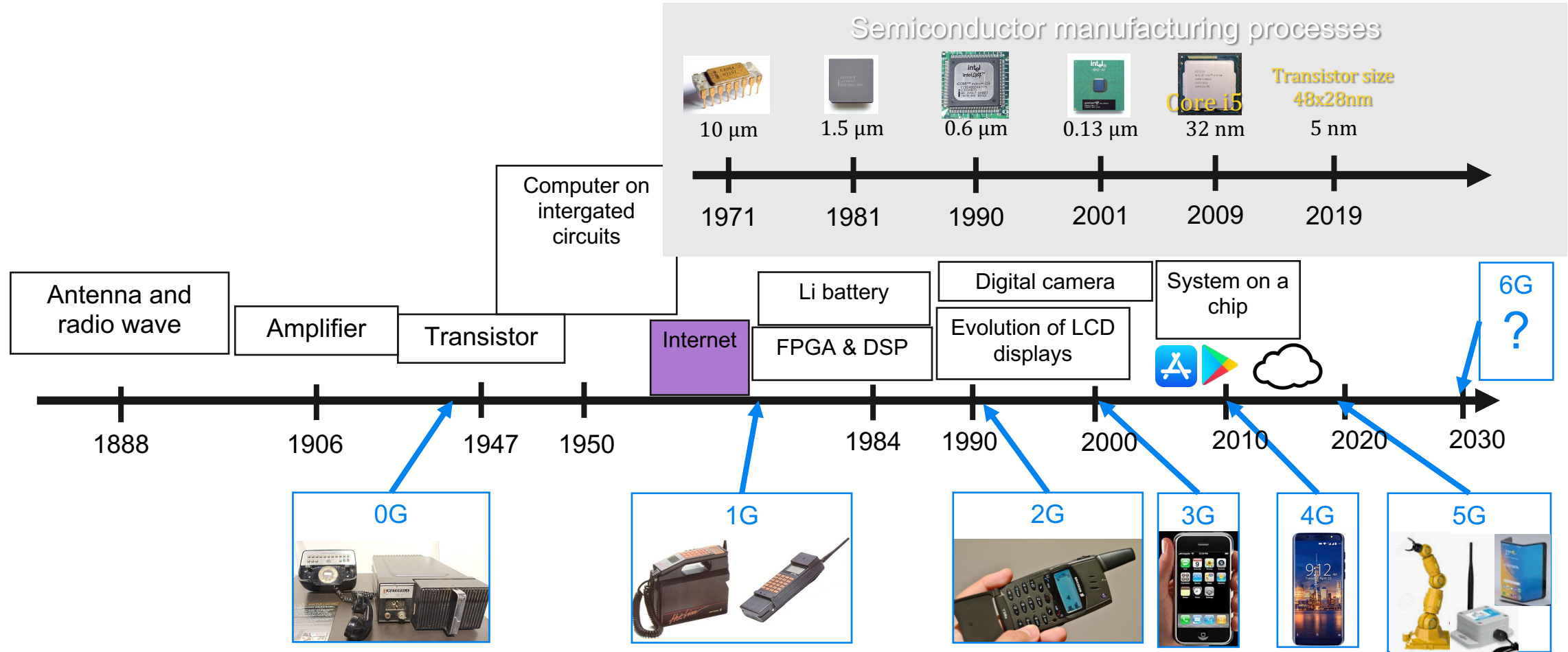

Ericsson Mobility Visualizer – Mobility Report - Ericsson

* EB = Exabytes = 10^{18} bytes

Push to/from outside

Evolution of communication is tightly connected to electronics and technology evolution in general.

Semiconductor manufacturing processes

10 μm	1.5 μm	0.6 μm	0.13 μm	32 nm	Transistor size 48x28nm 5 nm
1971	1981	1990	2001	2009	2019

Core i5

Computer on intergated circuits

Antenna and radio wave

Amplifier

Transistor

Internet

Li battery

FPGA & DSP

Digital camera

Evolution of LCD displays

System on a chip

6G ?

1888 1906 1947 1950 1984 1990 2000 2010 2020 2030

0G

1G

2G

3G

4G

5G

FPGA - field-programmable gate array
DSP – digital signalling processor

Radio Spectrum

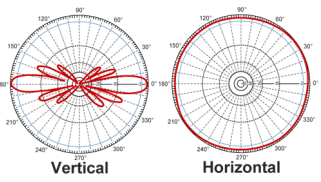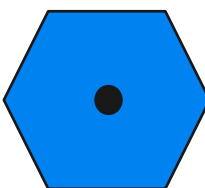| Stan-dardized bands	2G - FDD only	3G	4G	5G	6G
	P-GSM-900 DL+UL: 25+25 MHz	FDD (21 bands) DL: 816 (or 545 unique) MHz UL: 772 (or 505 unique) MHz	57 FDD and TDD bands FDD DL: 1518 MHz FDD UL: 1005 MHz TDD: 1920 MHz	Frequency Range 1: 68 FDD and TDD bands $\sum \approx 8919$ MHz Frequency Range 2: 26-60 GHz 7 TDD only bands $\sum \approx 30$ GHz Non-terrestrial (2 bands): $\sum \approx 64$ MHz	Guess what is next ?
	DCS-1800 (Asia+EU) DL+UL: ~75 + 75 MHz	TDD (8 bands) 365 (or 180 unique) MHz			
	PCS-1900 (America) DL+UL: ~60+60 MHz				
	Other bands (in some countries) ~100 MHz for UL&DL				
Total BW: For all operators	$\sum \approx 0.52$ GHz Of unique spectrum	$\sum \approx 1.95$ GHz Or ≈ 1.23 GHz of unique spectrum	$\sum \approx 4.4$ GHz	$\sum \approx 49$ GHz	
Carrier BW: For one user	200 KHz	5 MHz	Up to 20 MHz	FR1: Up to 100 MHz FR2: Up to 400 MHz	
Carrier Aggregation: For one user:	up to 2	DL: up to 8 UL: up to 2	up to 5	up to 16	

Antenna techniques

6G ?	
5G	
4G	
2G & 3G	

?

Omni (360°) 1 port

Vertical Horizontal

Sector X-pol (120°) 2 ports

Vertical Horizontal
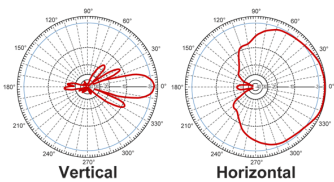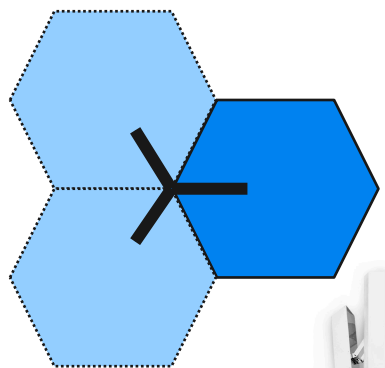
Multiple X-pol sector antennas for MIMO (e.g. 8 ports)
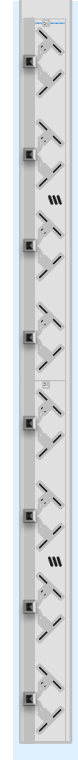

Look inside
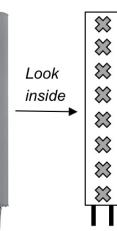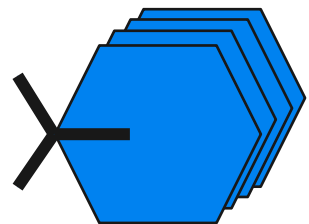
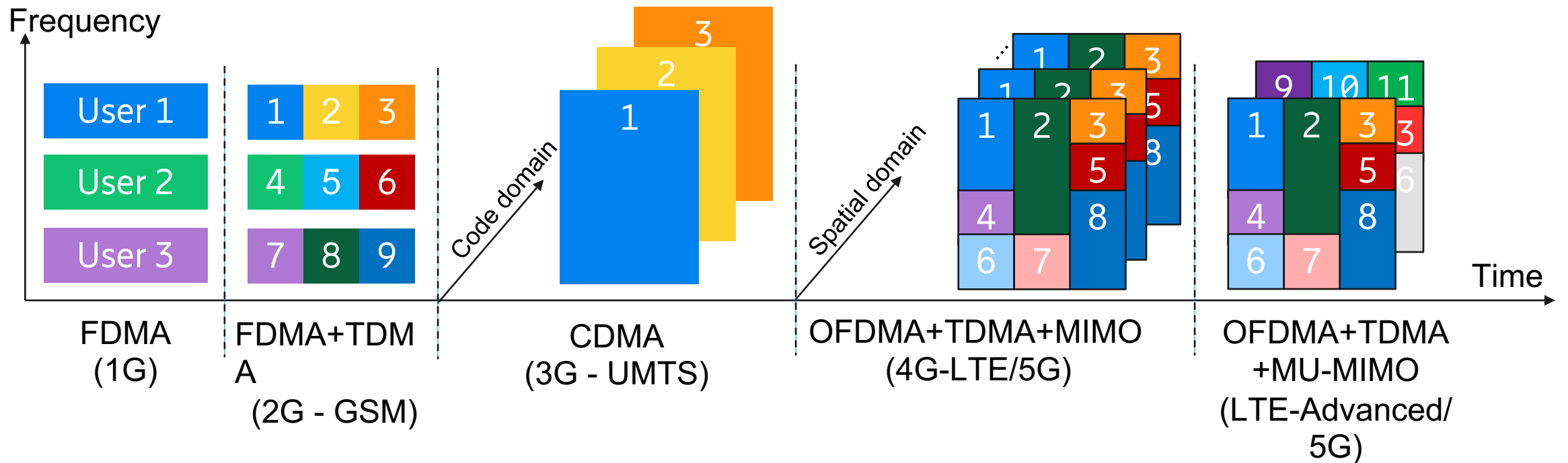## Beamforming antenna array (e.g. 64 ports)

V-pol H-pol

Radio Unit
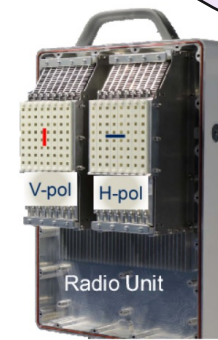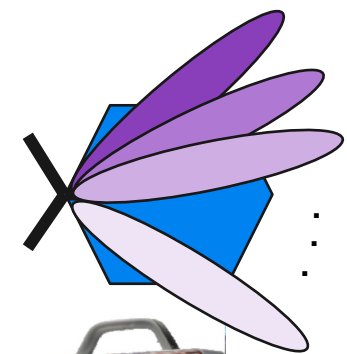
D-MIMO

E/// Radio stripe

User multiplexing methods in radio

From simple long term channel reservation to very fine granularity scheduling
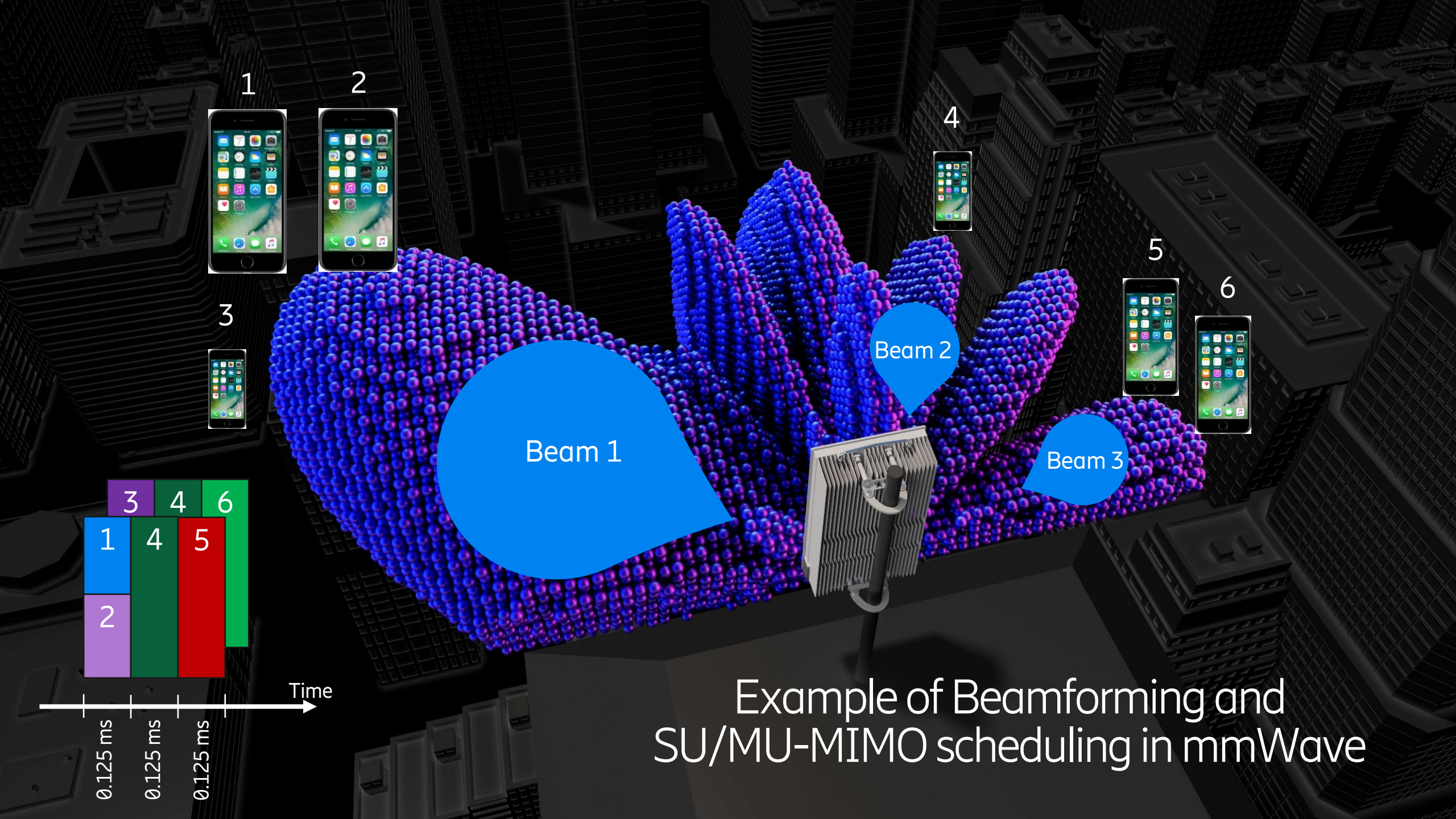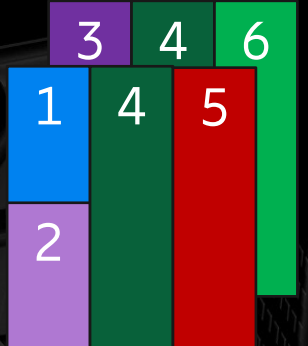
What's next?
Full duplex?
Other signal forms?

Example of Beamforming and SU/MU-MIMO scheduling in mmWave

Evolution of base stations

2G, 3G

Ericsson RBS 2206 – max 12TRXs (3x4)
Fully equipped cabinet – 230 kg

ALL G in one

Ericsson RBS 6302
Weight of RRU is 20 kg
Main cabinet – 70 kg

Ericsson Radio Dot

Cloud RAN

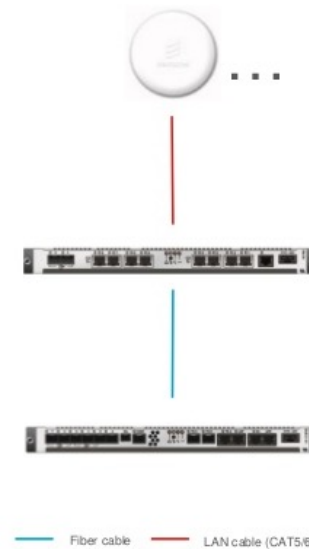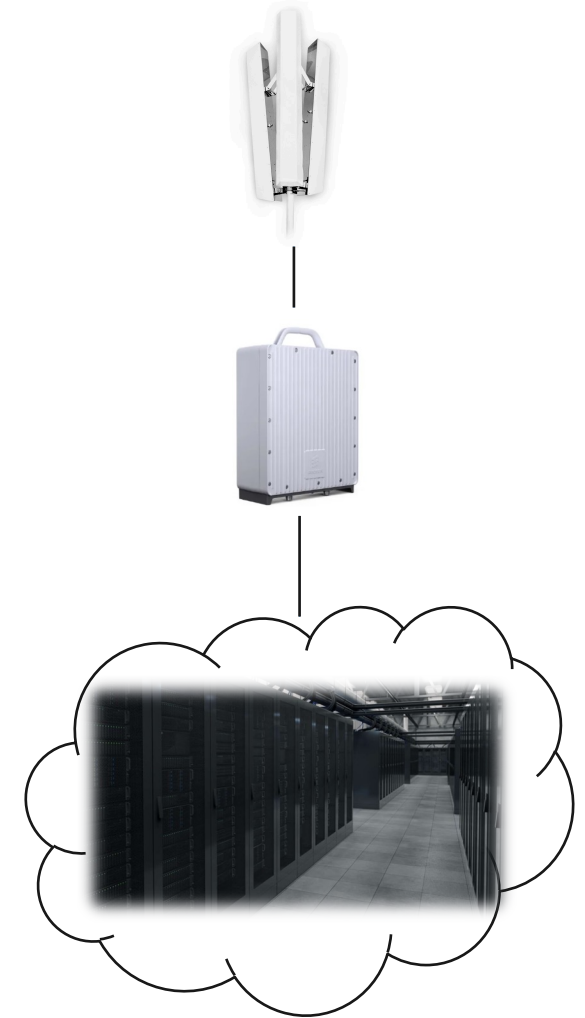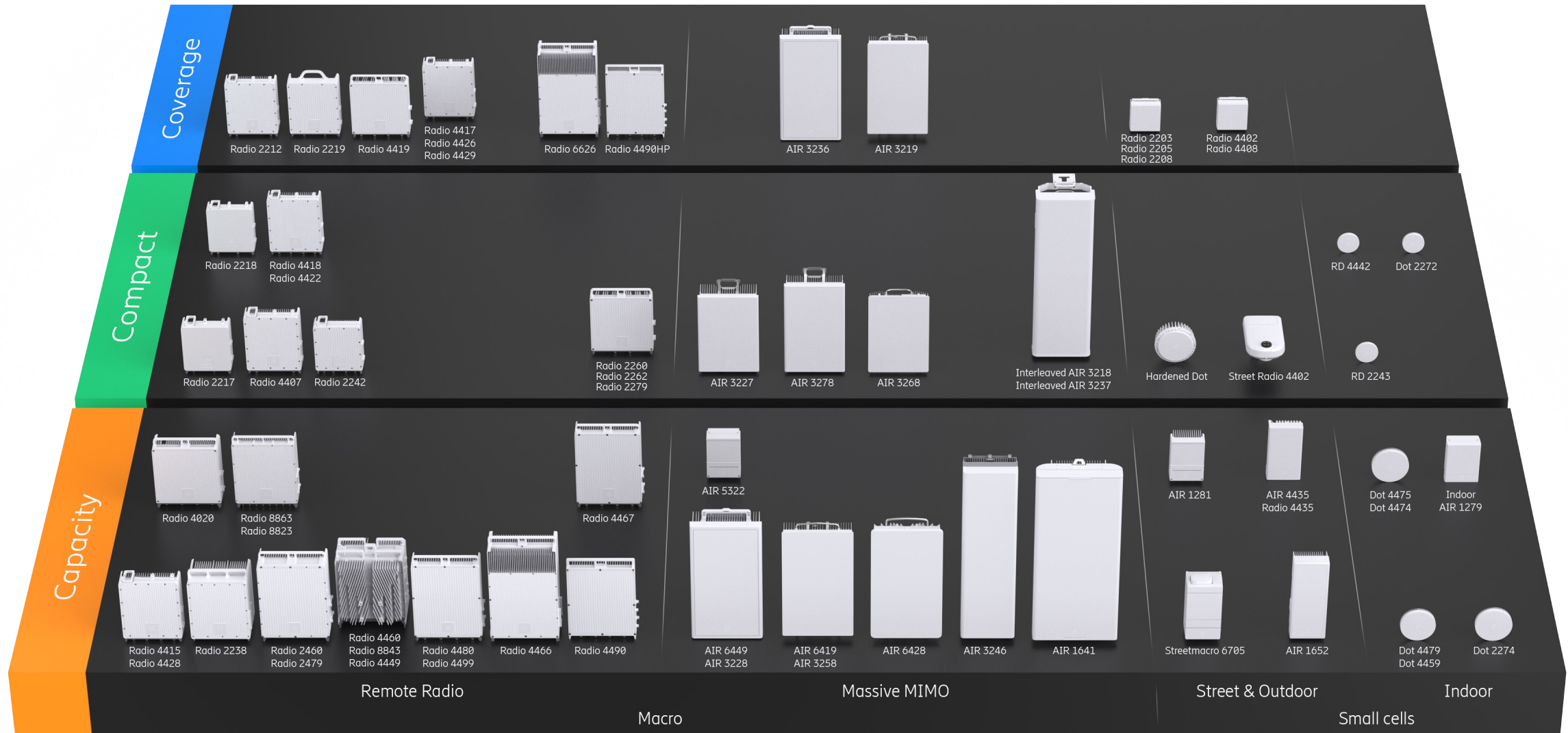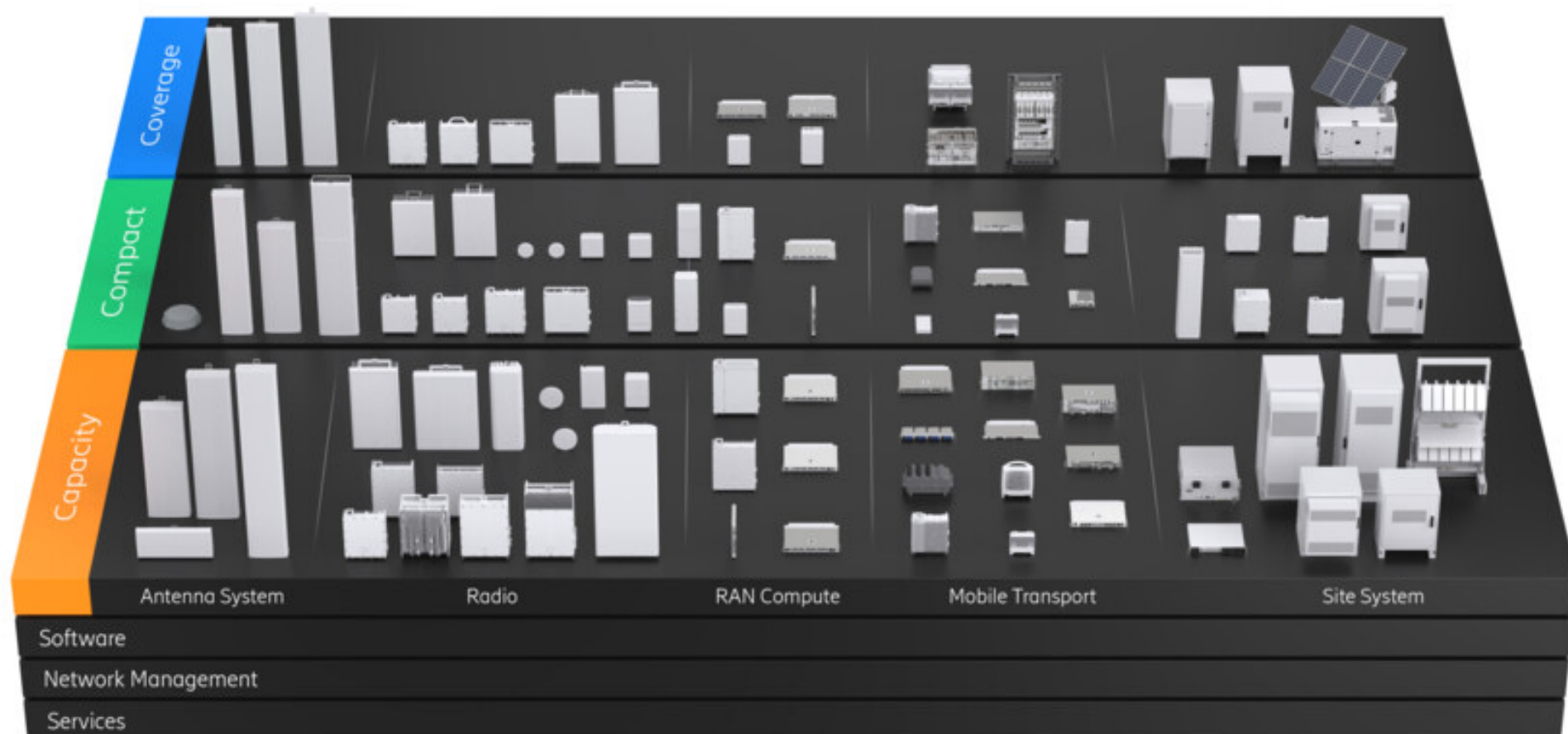# Example of different radios - Ericsson...

Coverage
Radio 2212 | Radio 2219 | Radio 4419 | Radio 4417 Radio 4426 Radio 4429 | Radio 6626 | Radio 4490HP | AIR 3236 | AIR 3219 | Radio 2203 Radio 2205 Radio 2208 | Radio 4402 Radio 4408

Compact
Radio 2218 | Radio 4418 Radio 4422 | Radio 2217 | Radio 4407 | Radio 2242 | Radio 2260 Radio 2262 Radio 2279 | AIR 3227 | AIR 3278 | AIR 3268 | Interleaved AIR 3218 Interleaved AIR 3237 | Hardened Dot | Street Radio 4402 | RD 4442 | Dot 2272 | RD 2243

Capacity
Radio 4020 | Radio 8863 Radio 8823 | Radio 4415 Radio 4428 | Radio 2238 | Radio 2460 Radio 2479 | Radio 4460 Radio 8843 Radio 4449 | Radio 4480 Radio 4499 | Radio 4466 | Radio 4467 | Radio 4490 | AIR 5322 | AIR 6449 AIR 3228 | AIR 6419 AIR 3258 | AIR 6428 | AIR 3246 | AIR 1641 | AIR 1281 | AIR 4435 Radio 4435 | Streetmacro 6705 | AIR 1652 | Dot 4475 Dot 4474 | Indoor AIR 1279 | Dot 4479 Dot 4459 | Dot 2274

Remote Radio | Massive MIMO | Street & Outdoor | Indoor

Macro | Small cells

... and complete Ericsson Radio System

Coverage · Compact · Capacity

Antenna System · Radio · RAN Compute · Mobile Transport · Site System

Software
Network Management
Services

Radio Controllers and Core

Voice and dara core

All services

2G, 3G
MCS

2G
BSC

3G
RNC

2G/3G
SGSN
GGSN

4G
S-GW
P-GW

MME

Compact all in one
4G EPC or 5GC

Cloud 4G EPC & 5GC

Links for backhaul and backbone
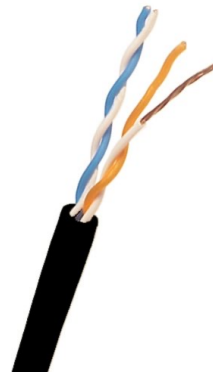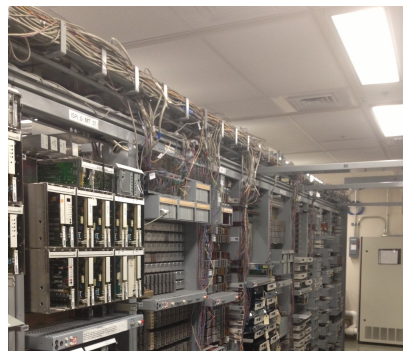
Analog line

1 pair = 1 line
Up to 100 kbps
Half duplex

E1

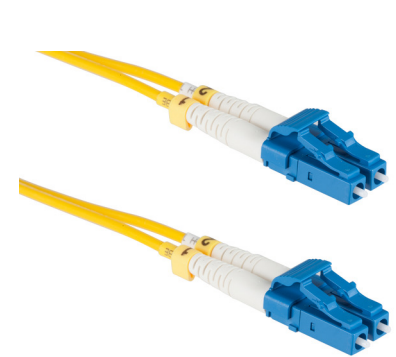2 pairs = 30 lines
2 Mbps
Full duplex

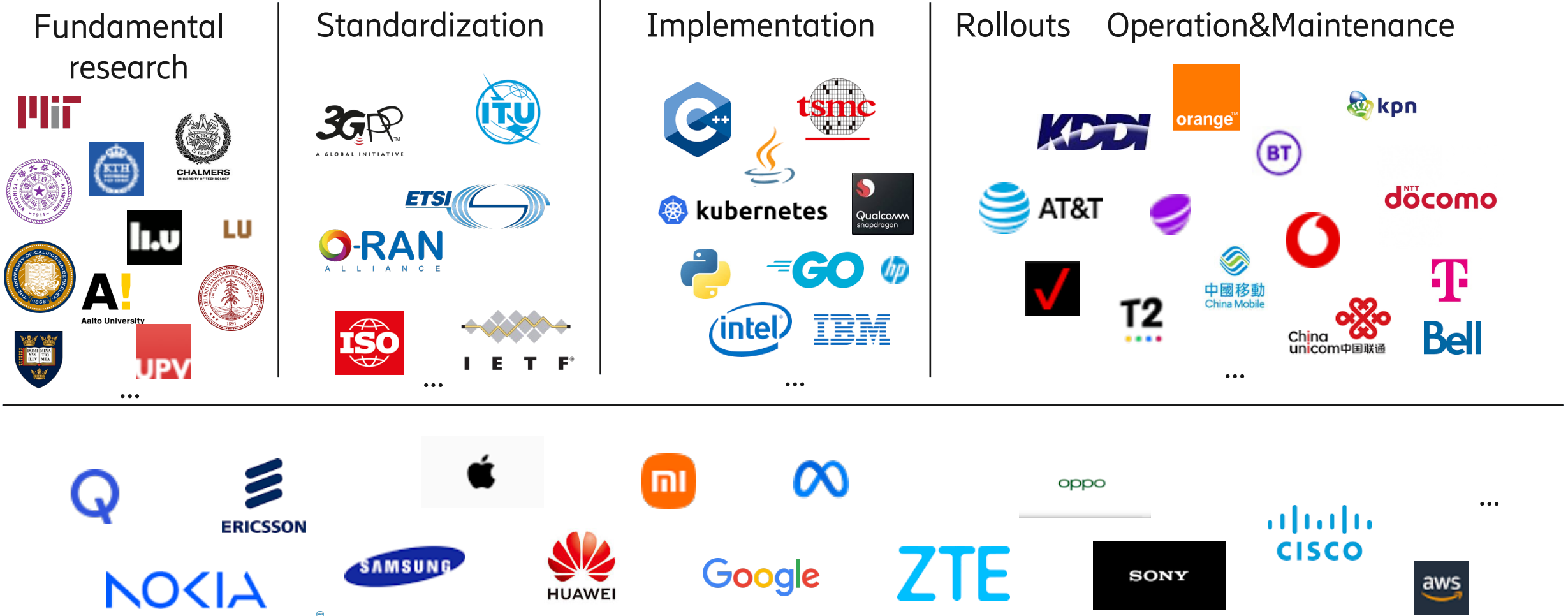**Ethernet**

4 pairs
10/100/1000 Mbps
Full duplex

Fiber

1 pair
1-400 Gbps
Full duplex
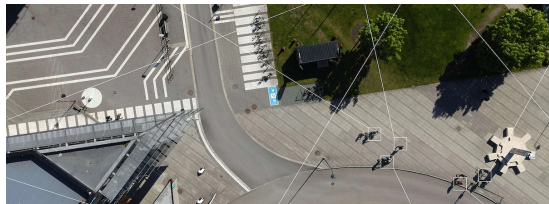
Stages of evolution for every G

Fundamental research	Standardization	Implementation	Rollouts	Operation&Maintenance

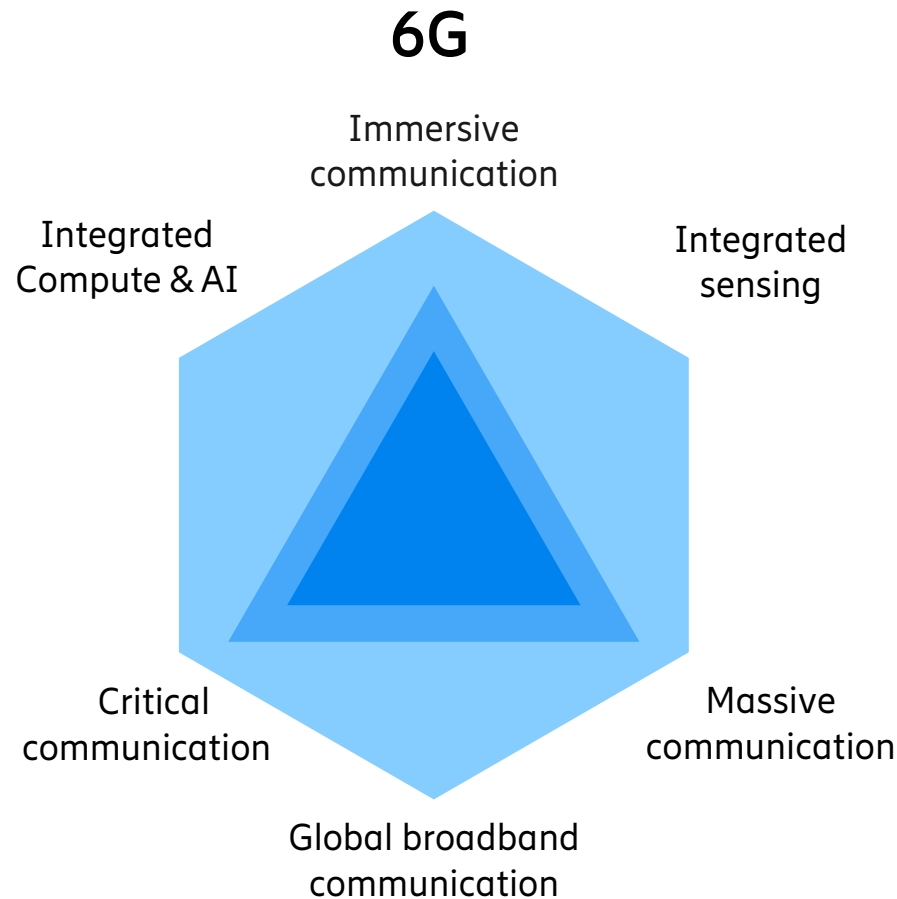# 6G

Communication beyond 5G & Further enhanced MBB

Immersive communication – expanding on eMBB

Critical communication – expanding on URLLC

Massive communication – expanding on mMTC

6G

Immersive communication

Integrated Compute & AI

Integrated sensing

Critical communication

Massive communication

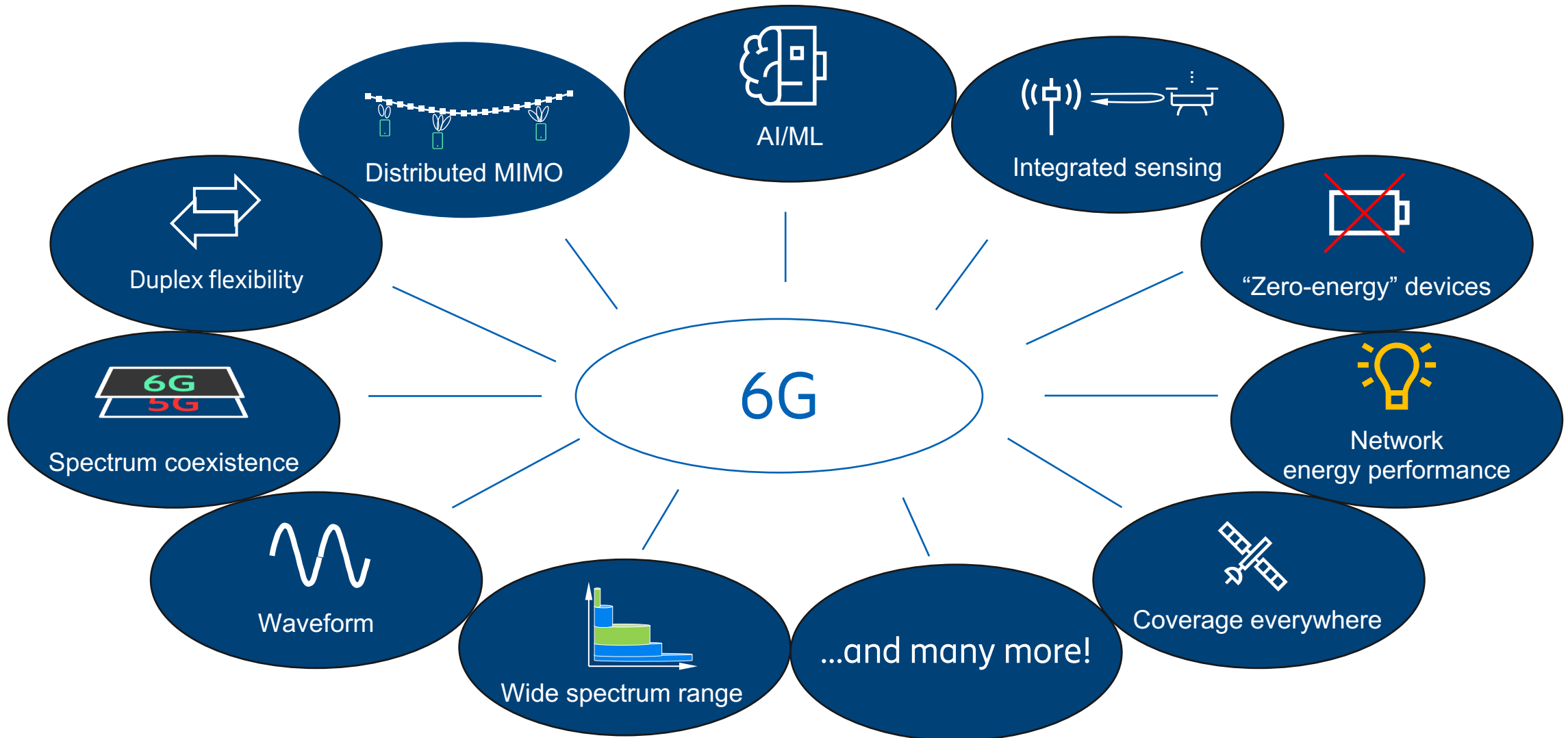Global broadband communication

Beyond-communication networks

New services on 6G platform

Sustainable and trustworthy networks

Sustainability and trust imperatives

6G technology components

Distributed MIMO

AI/ML

Integrated sensing

"Zero-energy" devices

Duplex flexibility

Network energy performance

Spectrum coexistence

6G

Waveform

Wide spectrum range

...and many more!

Coverage everywhere

5G Proof points to learn further

Industrial control	Mobility automation	Remote control	Real-time media
Manufacturing of jet engines (MTU Aero – Fraunhofer – Ericsson)	**Cooperative vehicle maneuvers** (EU project – 5GCAR)	**Remote bus driving** (Telefonica – EasyMile – Ericsson)	**Virtual reality** (Verizon – Ericsson)
Manufacturing of vehicles (Audi – Ericsson)	**Autonomous truck** (Einride – Telia – Ericsson)	**Remote control of mining equipment** (Boliden – Ericsson)	**Augmented reality** (Telia – Ericsson)

Imagine Possible

ericsson.com/careers