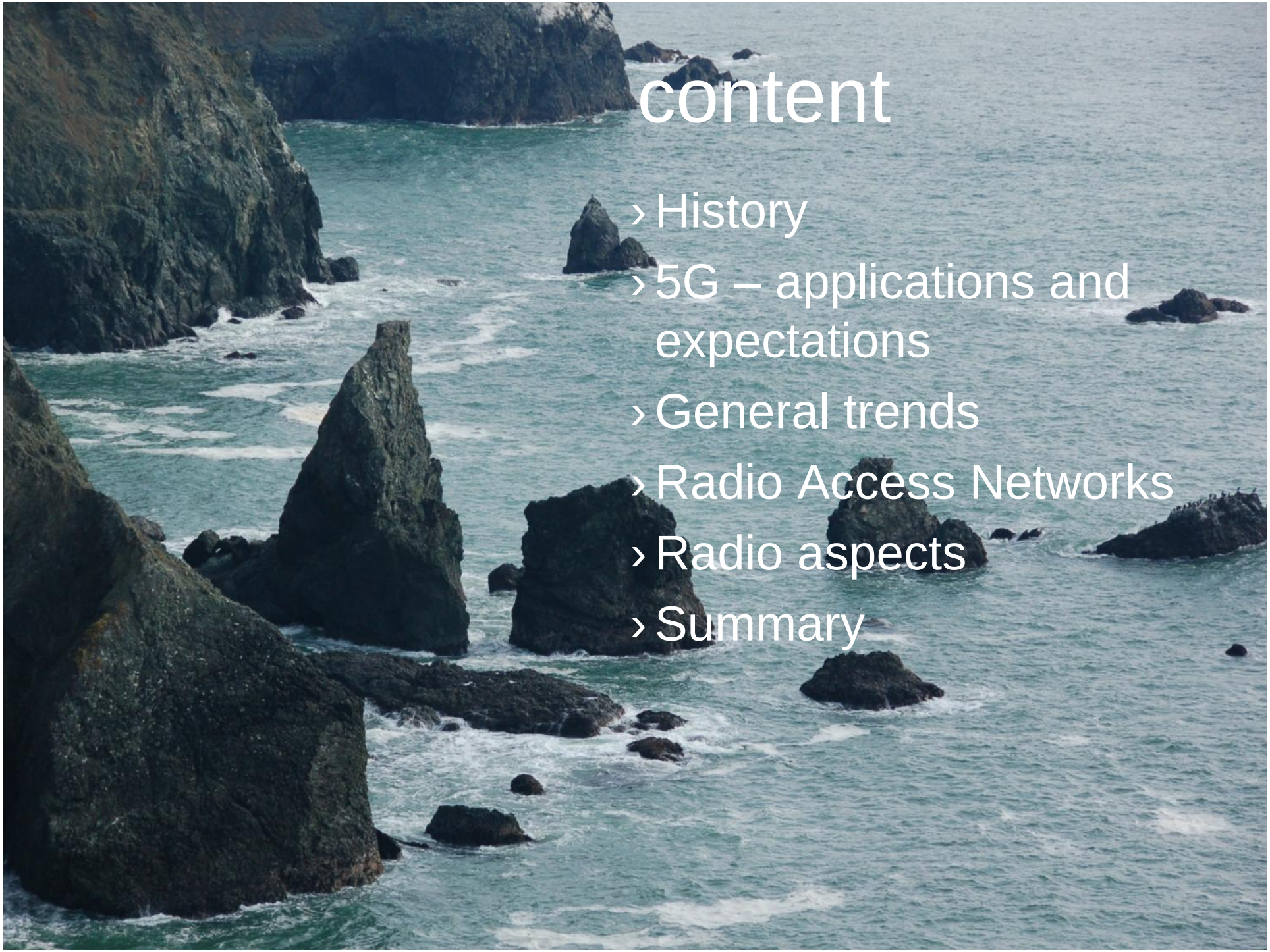
Network Evolution Towards 5G

Dr Peter Olanders,
Ericsson

Last week in Barcelona

“Huawei and Qualcomm differ on 5G”

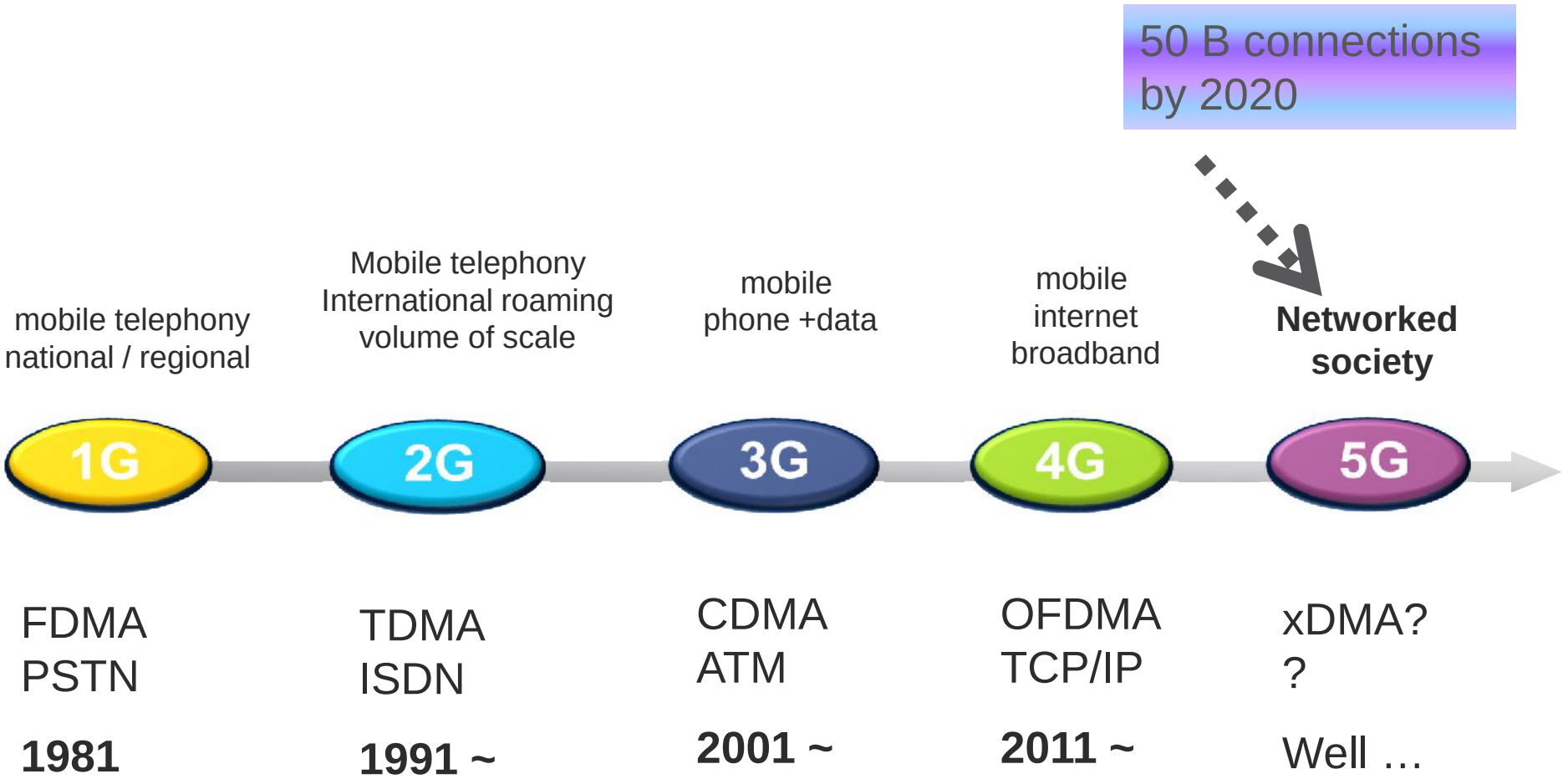


content

- History
- 5G – applications and expectations
- General trends
- Radio Access Networks
- Radio aspects
- Summary

History

Wireless systems



5G: evolution of existing standards + complementary new technologies

in-between generations

- 2G GSM
  - GPRS, merging the capacity of two (++) separate time slots
  - EDGE, increasing modulation resulting in higher data rates
  - These two moved GSM into 3G, but – alas – too late!
  - GSM MC
- 3G WCDMA
  - HSDPA (DL 14 ++ Mb/s)
  - HSUPA (UL 5.8 ++ Mb/s)

  } HSPA

  - Evolved HSPA / HSPA+: 337 Mb/s DL, 34 Mb/s UL
  - WCDMA MC
- 4G LTE
  - LTE-A, x10 data rate

Data rate has been a driver

2. GSM ~10 kbps → 64 kbps
3. WCDMA 64kbps, 384 kbps, 2 Mbps
   - HSPA: up to ~ 15 Mbps
4. LTE 100 Mbps
   - LTE-A up to 1 Gbps (nomadic)
5. 5G ?
   - 10 Gbps “hot spots”
   - 100 Mbps “everywhere”

1000x in 10 years
total cost slightly ↓

1000x in 10 years
total cost slightly ↓

=> price/bit decreased
10^6 x over 20 years.

Mobile phone more than a phone without wire

- 1G freed us of the wire – always reachable
- 2G ➔ mass market – for everyone (nearly)
- 3G start of mobile internet, and
- Smartphones!
- 4G high data rates

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5G – applications and expectations

Note: there are no decisions or agreements on 5G yet. Just speculations …

5G Use case examples

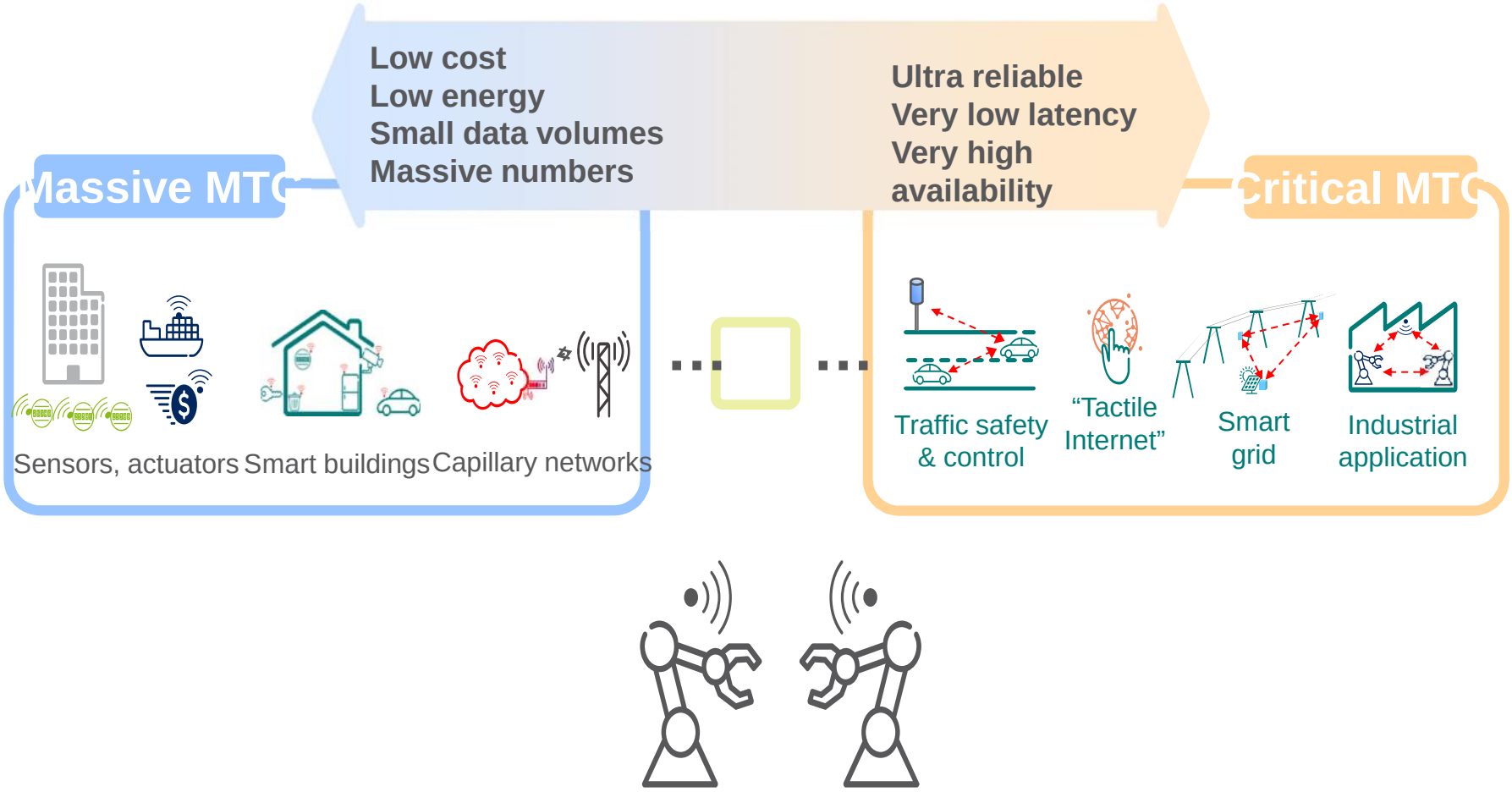
Broadband experience everywhere anytime

Massive Machine Type Communication

Mass market personalized TV

Critical Machine Type Communication

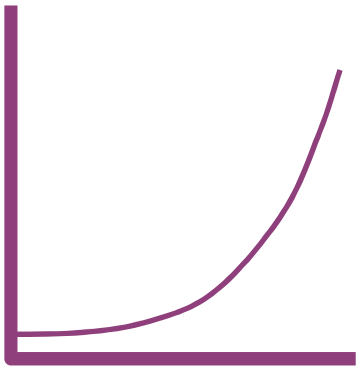
Machine Type Communication



5G Key challenges

Massive growth in

Traffic Volume



Massive growth in

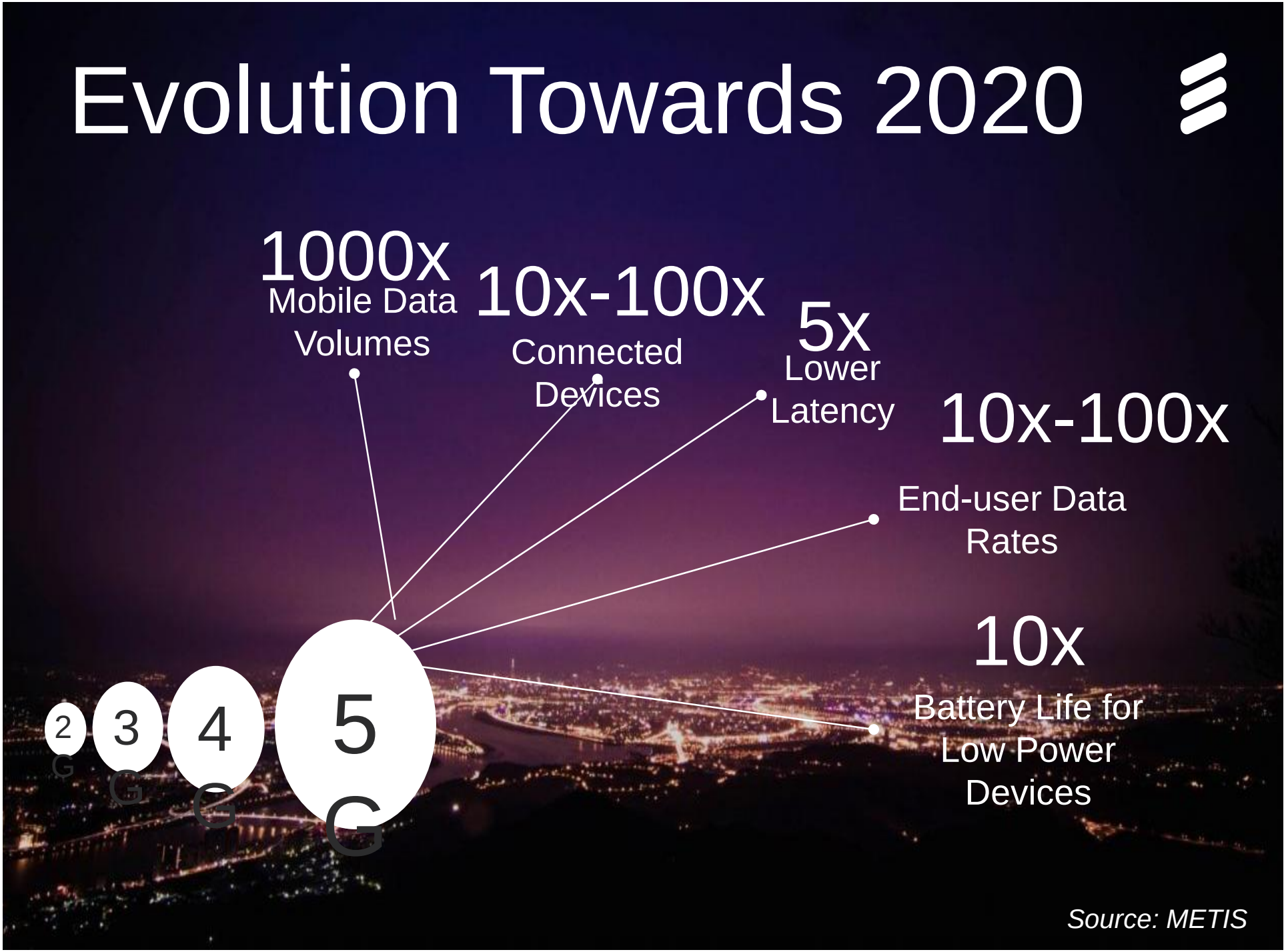
Connected Devices

Wide range of **Requirements & Characteristics**

- **Data rates**
- **Latency**
- **Reliability / availability**
- **Device cost and energy consumption**
- **Security..**

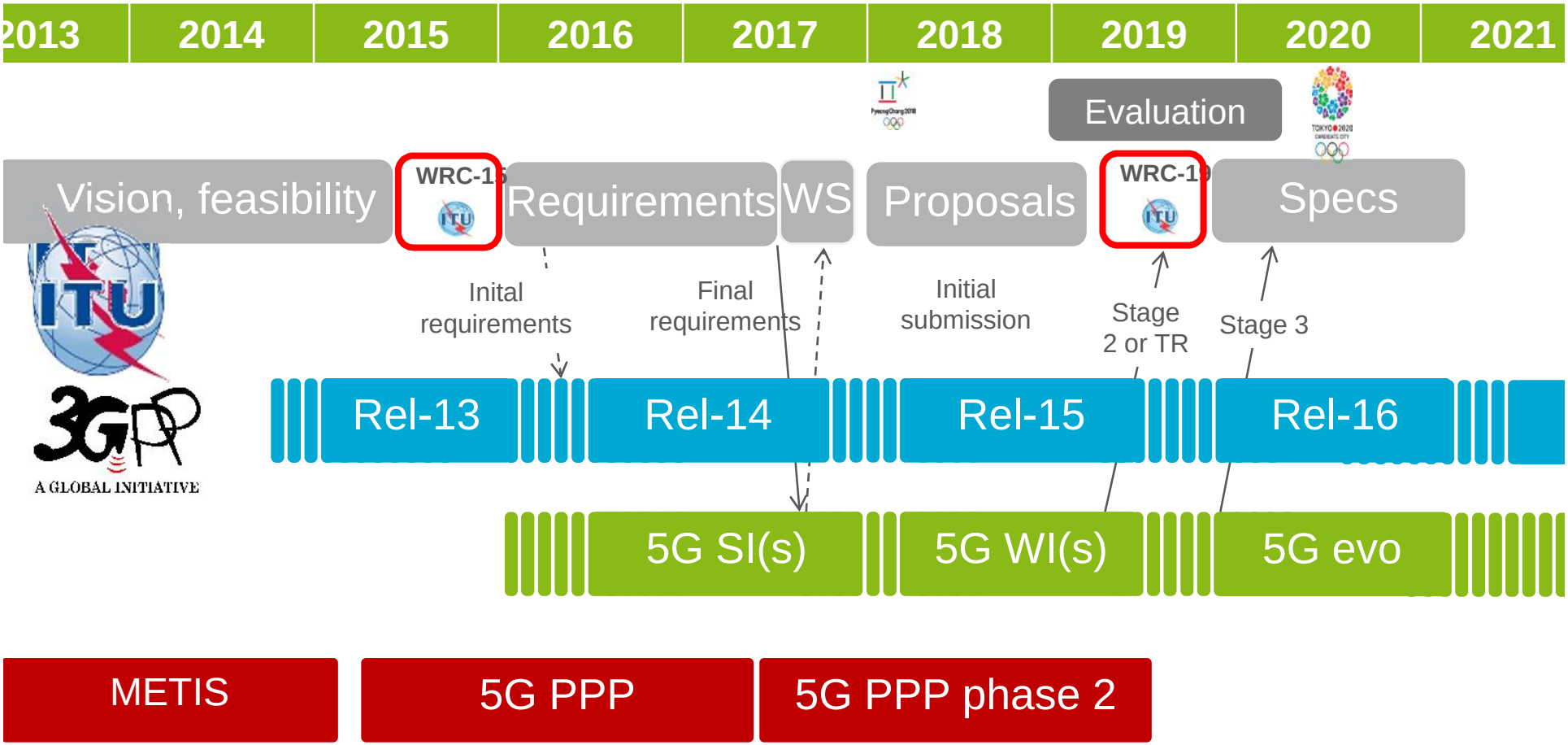
Affordable and sustainable

Evolution Towards 2020



Source: METIS

5G timeplan


2013
2014
2015
2016
2017
2018
2019
2020
2021
Evaluation
Vision, feasibility
WRC-15
Requirements
WS
Proposals
WRC-19
Specs
Inital requirements
Final requirements
Initial submission
Stage 2 or TR
Stage 3
Rel-13
Rel-14
Rel-15
Rel-16
5G SI(s)
5G WI(s)
5G evo
METIS
5G PPP
5G PPP phase 2

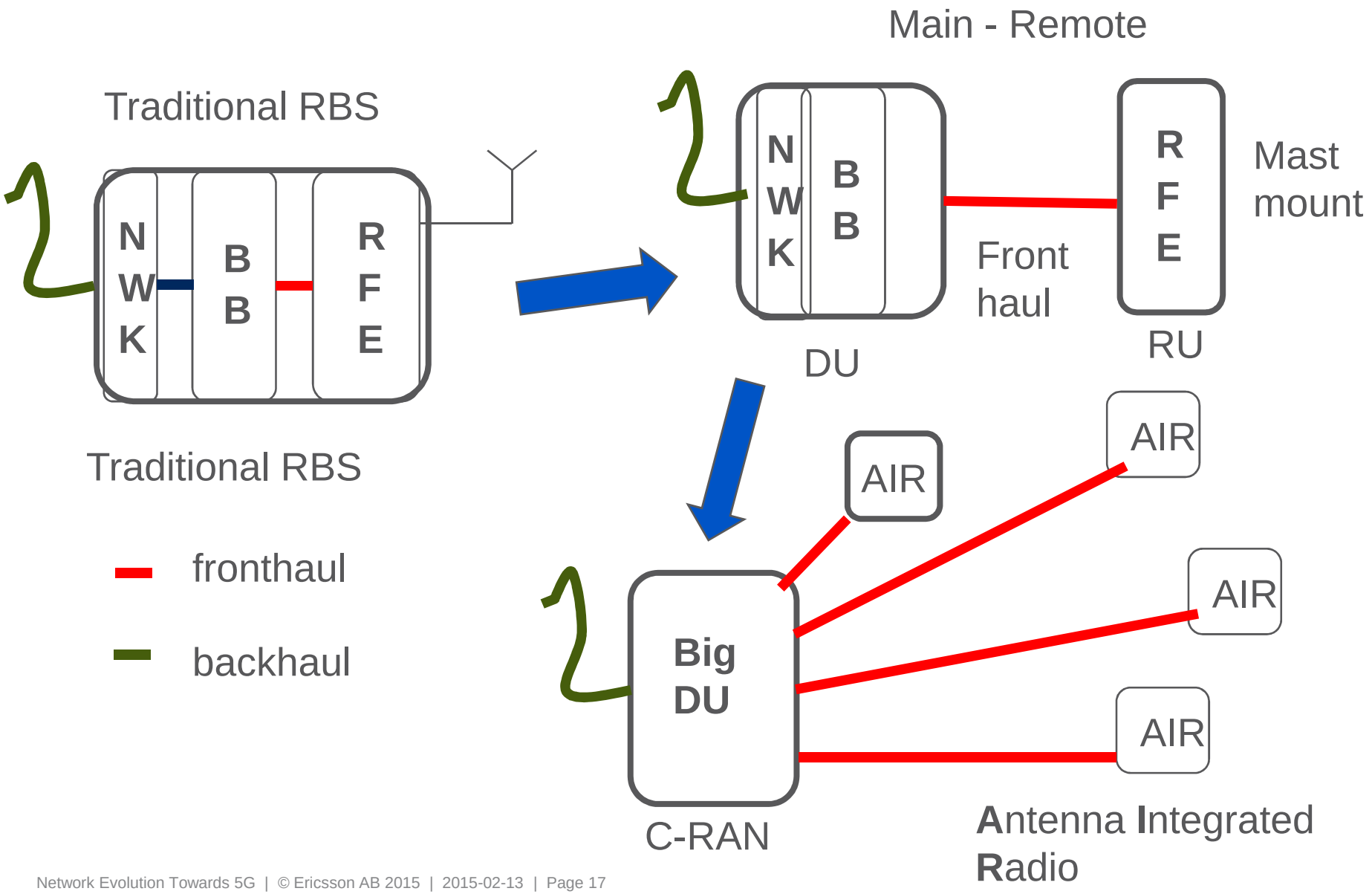
Some general trends

- Generalize & virtualize hardware
- Cloud, and specifically C-RAN
- Main-remote
- Advanced antennas, active antennas, beamforming, CoMP

Generalize & virtualize hardware

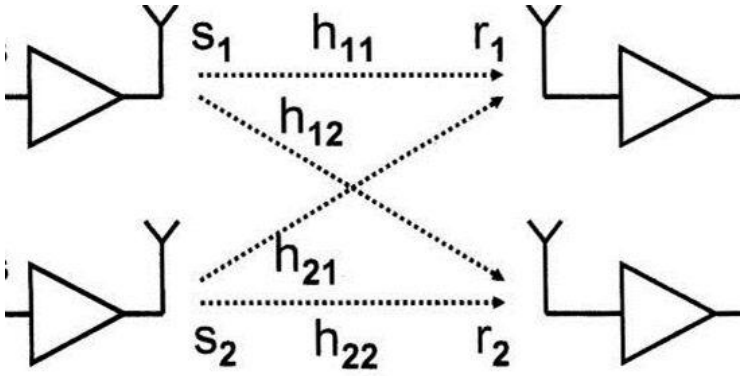
- **Software Defined Radio**, SDR: a radio that has some flexibility built in, controlled by sw.
- **Cognitive Radio**, CR: The radio becomes self-aware, responding on its (radio) environment. Great hopes for White Space – not met unfortunately.
- **Software Defined Networking**, SDN: de-coupling of data and control planes … (this is a new thing ☺)
- **Network Functions Virtualization**, NFV: network arch with virtualization of networks nodes.

Main – Remote ++

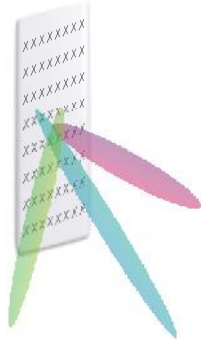

Main - Remote
Traditional RBS
N
W
K
B
B
R
F
E
Traditional RBS
N
W
K
B
B
Front
haul
R
F
E
Mast
mount
DU
RU
AIR
AIR
AIR
AIR
Big
DU
C-RAN
fronthaul
backhaul
Antenna Integrated
Radio

Antennas are getting advanced

Traditional 3-sector antennas, multiband

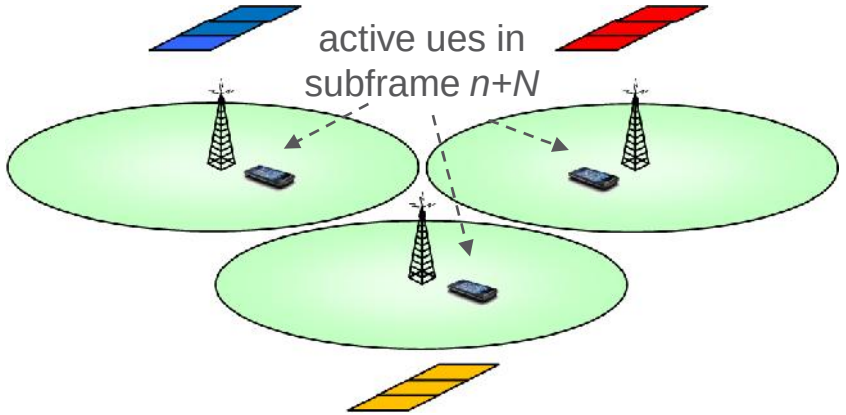


Multiple **I**nput, **M**ultiple **O**utput
Element dist > λ



Beamforming
Element dist < λ

Cooperative Multi-Point, CoMP.
Requirements on cell sync & scheduling



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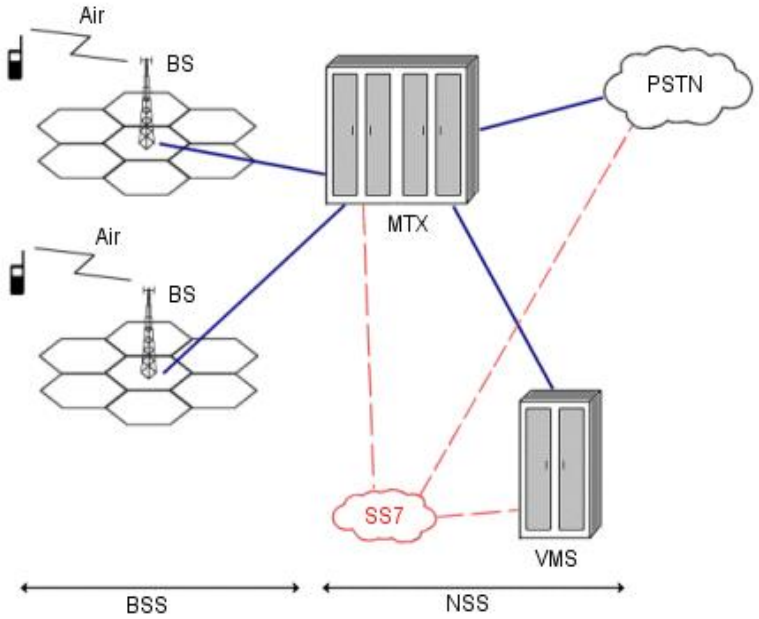
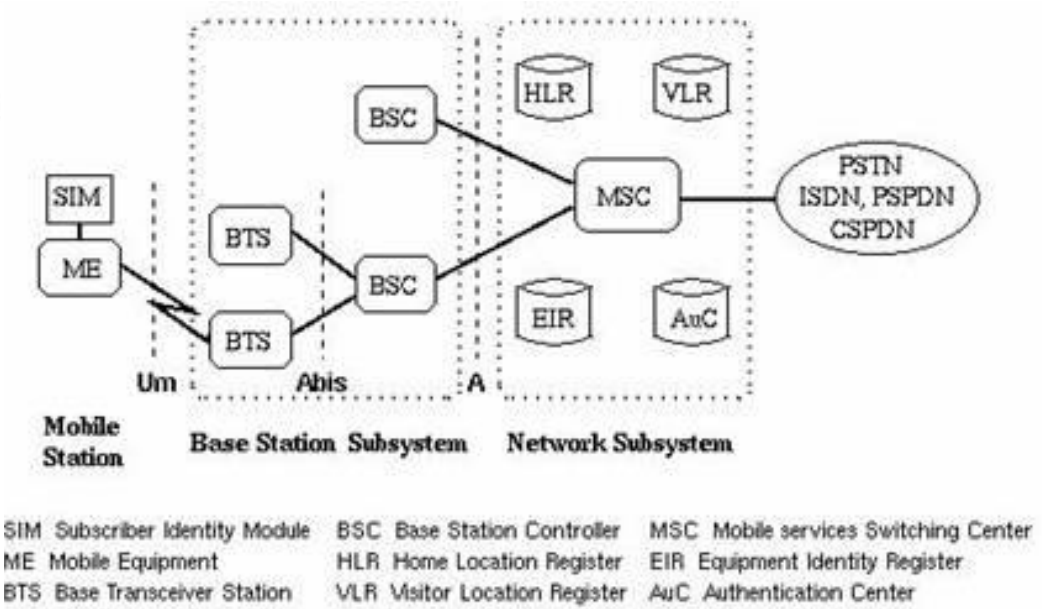
Radio Access Networks

Some history?





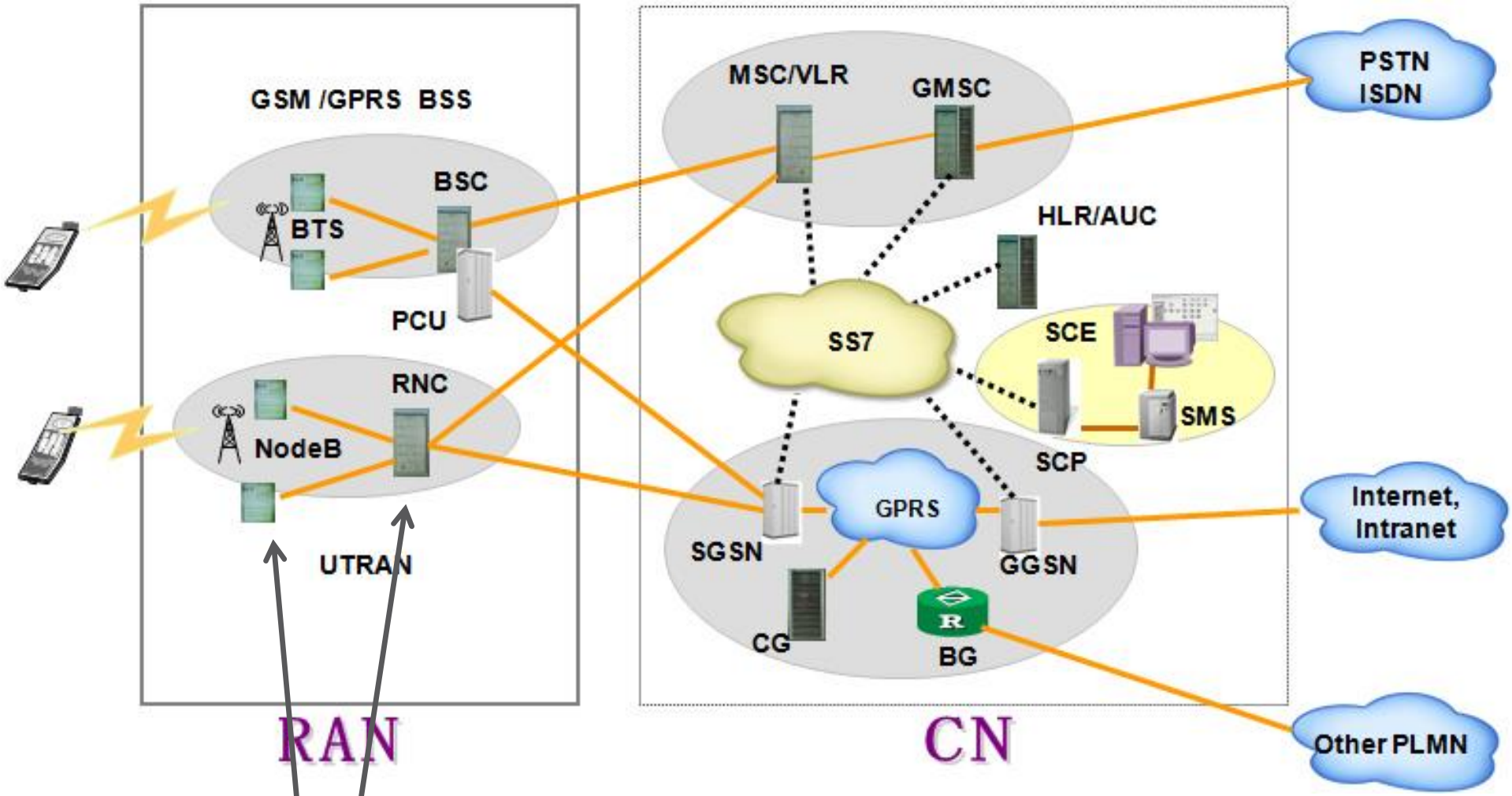
1G – NMT

Small scale system,
integrated functionality

2G – GSM

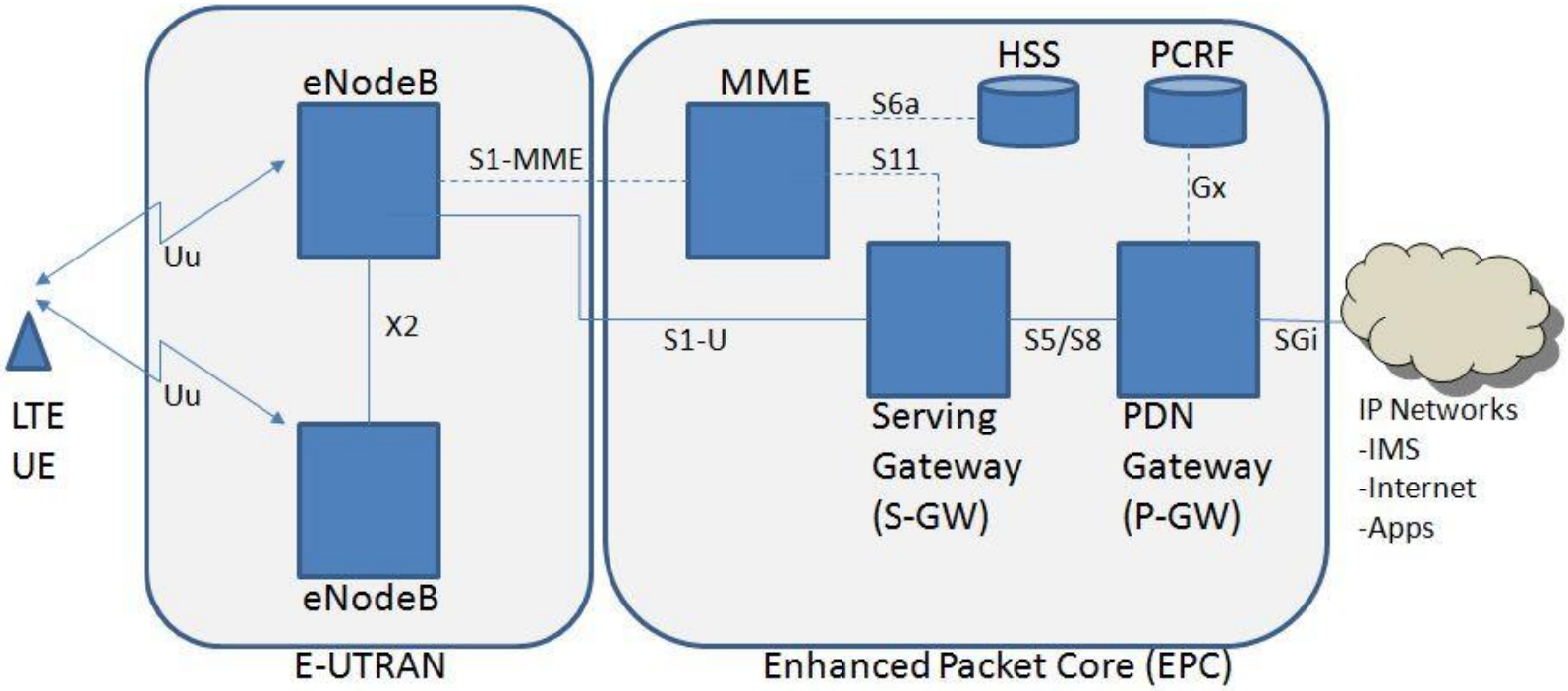
BS and controller levels
Open architecture

3G – WCDMA ….



Still 2 level RAN. Separate voice and data tracks, MSC remains

4G – LTE



Base station Controller level skipped.

No voice channel!

5G Vision architecture

Radio Base Station

Backhaul: ethernet, fibre, µ-wave

Is this a new node level?

Central office /Digital Unit

Signal processing /BB ? / ctrl / coord

midhaul

Fronthaul: fibre, µ-wave

Partitioning DU/RU?

Radio Unit Many RATs

Macro – Micro – Pico – Nano

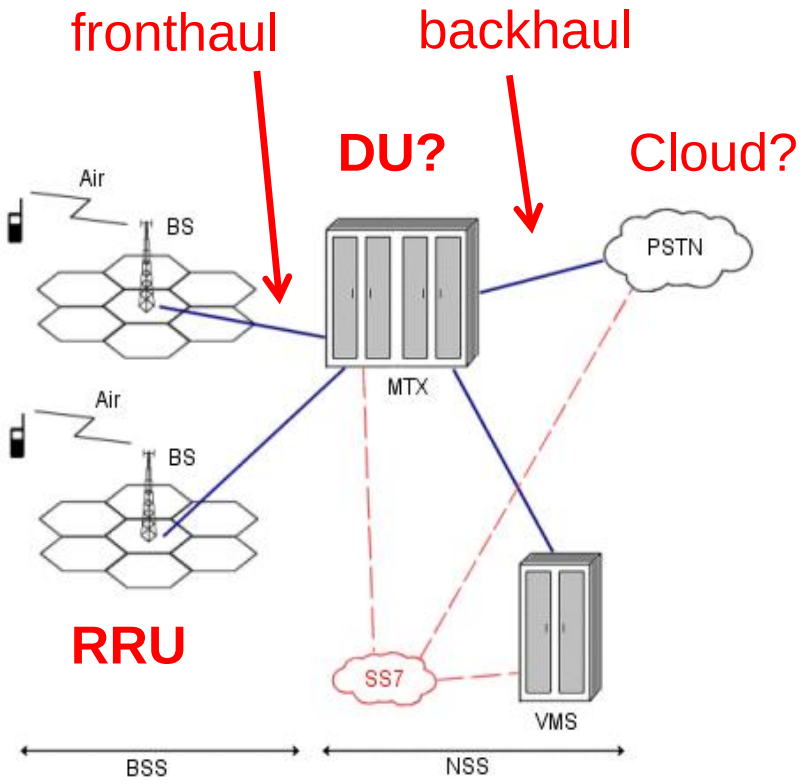
----- out-door ------ rather analog

-- in-door --

Some are integrated

Antennas SiSo, MiMo, BF, MaMiMo, CoMP

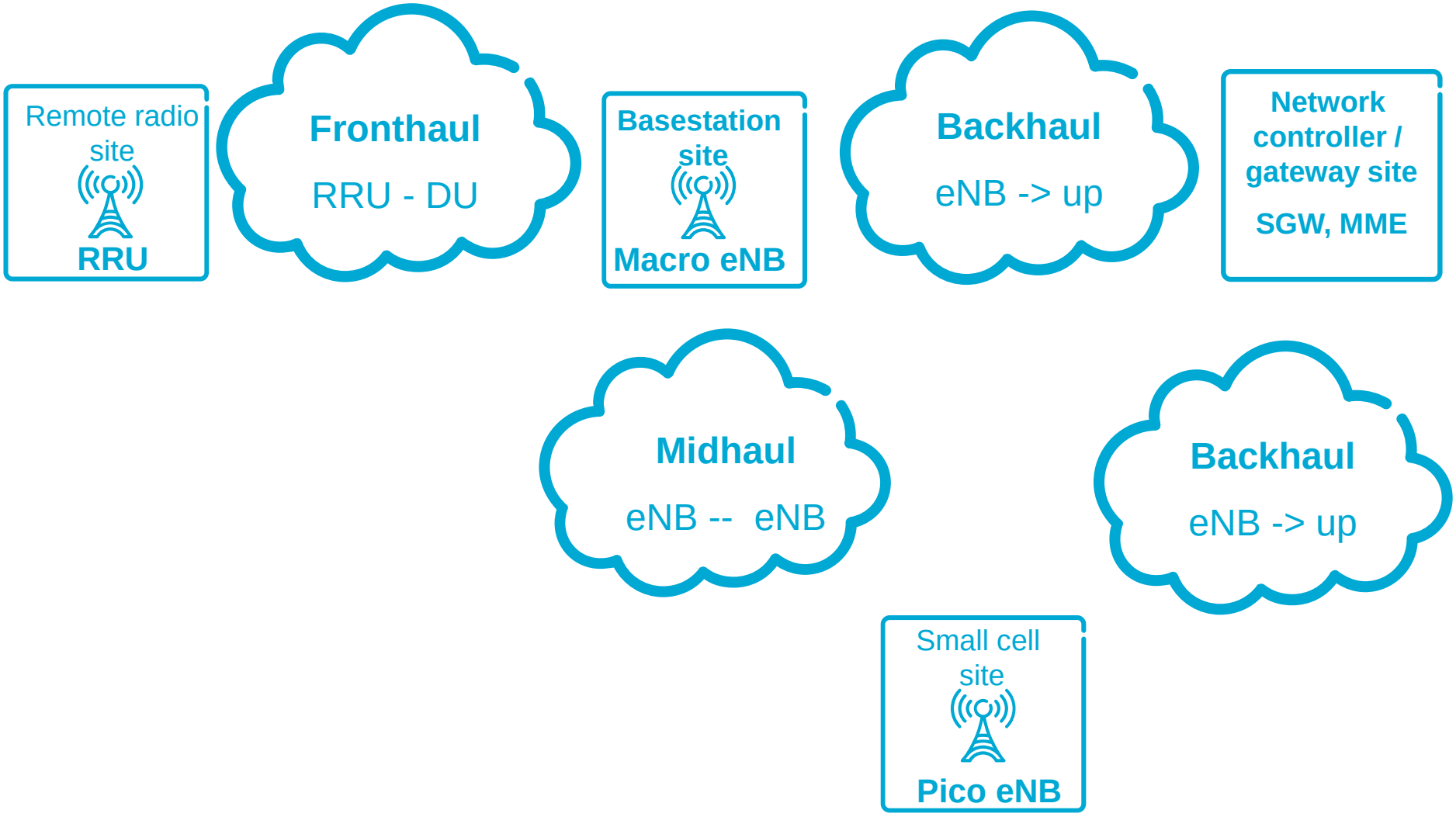
Revival of old arch?



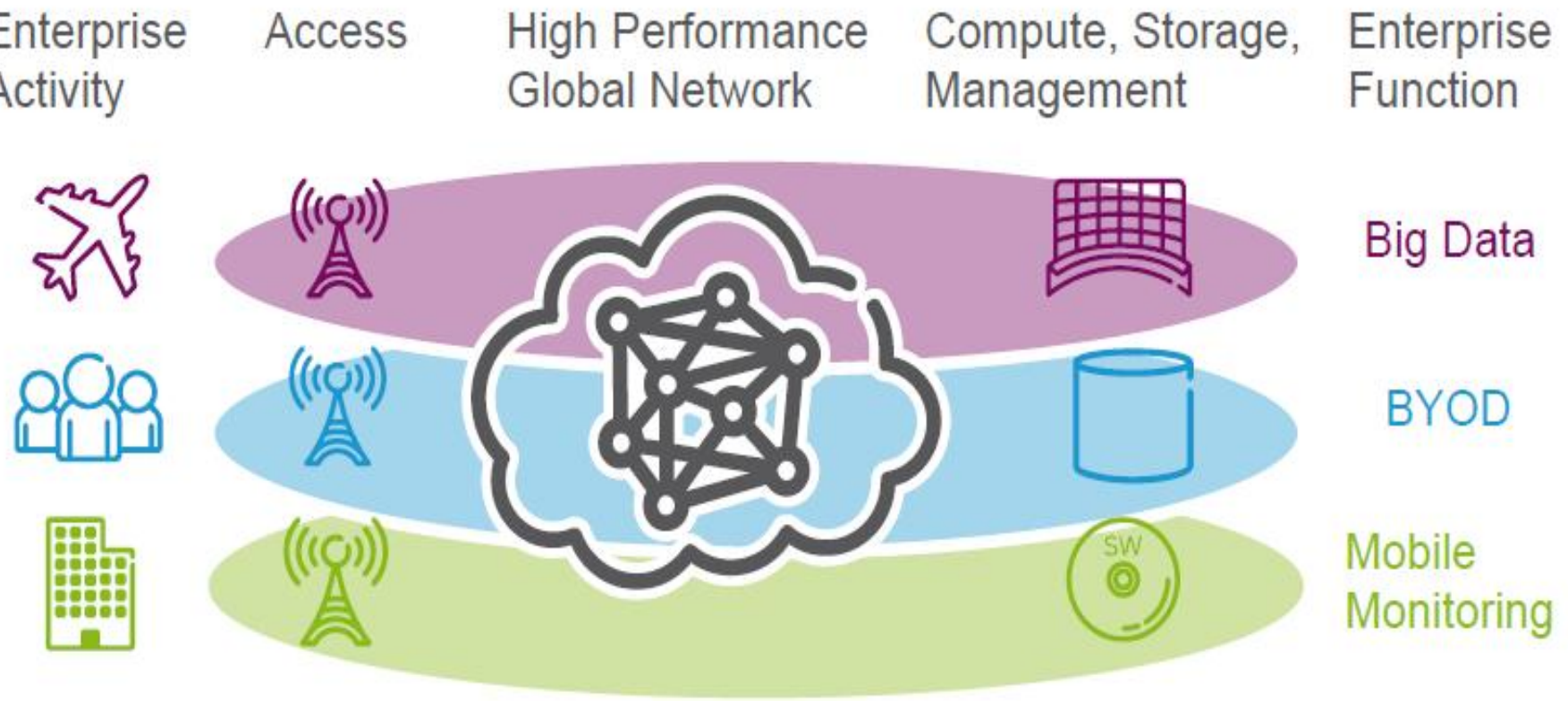
No, not really!

- Fronthaul is very demanding
  - BER 10^{-12}
  - Latency 10-50 µsec
  - Jitter < 10 nsec
  - 10-25-50(?) Gb/s

Fronthaul, midhaul & Backhaul



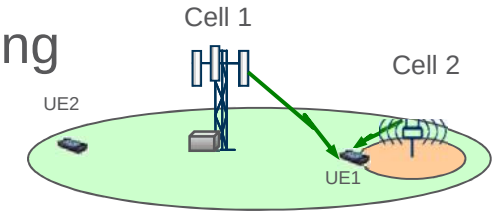
NETWORK SLICES: SDN/NFV



Dynamic, secure & separate, cross-domain, activity-specific

Sync?

- Former mobile systems had sync mainly for frequency sync, maybe for special applications as positioning.
- Sync in 5G also for new features
  - TDD
  - Coordination
  - Advanced radio schemes as CoMP, Beamforming
  - New fronthaul?
- Sync may also be needed for new services as
  - Power grid
  - ITS
  - MTC
- < µsec, maybe 10-100 nsec.



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Radio Aspects

Squeezing 1-10 Gb/s user data rate from radio

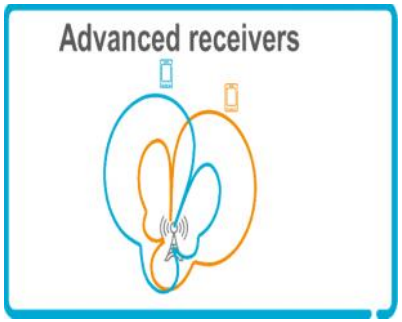
How to increase Traffic Capacity

$$R < C = m\left(\frac{W}{n}\right)\log_2\left(1+\frac{S}{I+N}\right)$$

Traffic capacity = Available spectrum ò No of streams

System efficiency

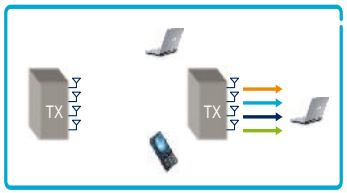
Network density ò Spectrum efficiency



Spectrum efficiency
Interference rejection
Higher order modulation

New Spectrum

Carrier Aggregation



More MIMO streams

Mobile Spectrum

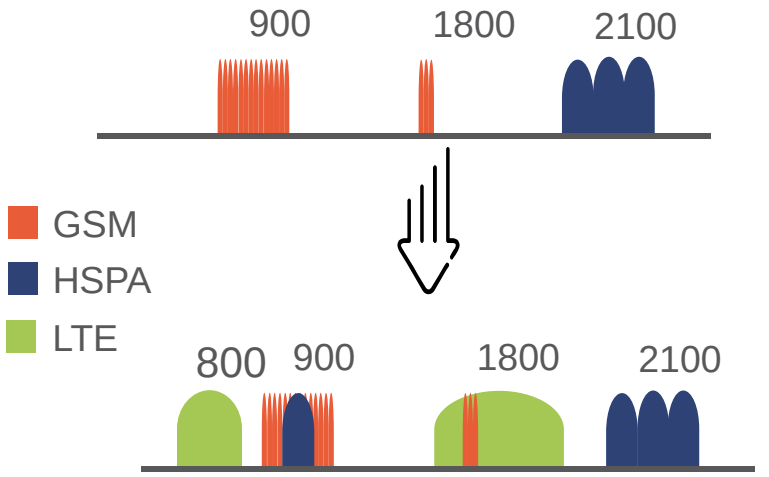
Spectrum : Prime operator asset

AWS-3 auction, with bids passing $43.7B (FierceWireless | December 15, 2014)

Dish could generate $10B per year from wholesaling its spectrum, analysts say

- Fragmented Spectrum Allocations
  - Lack of global harmonization
  - More than 40 3GPP Bands defined
- Spectrum Migration in progress
  - Refarming 2G to 3G to 4G
  - Multi-Standard Radio (MSR) support spectrum migration

Spectrum Migration Example



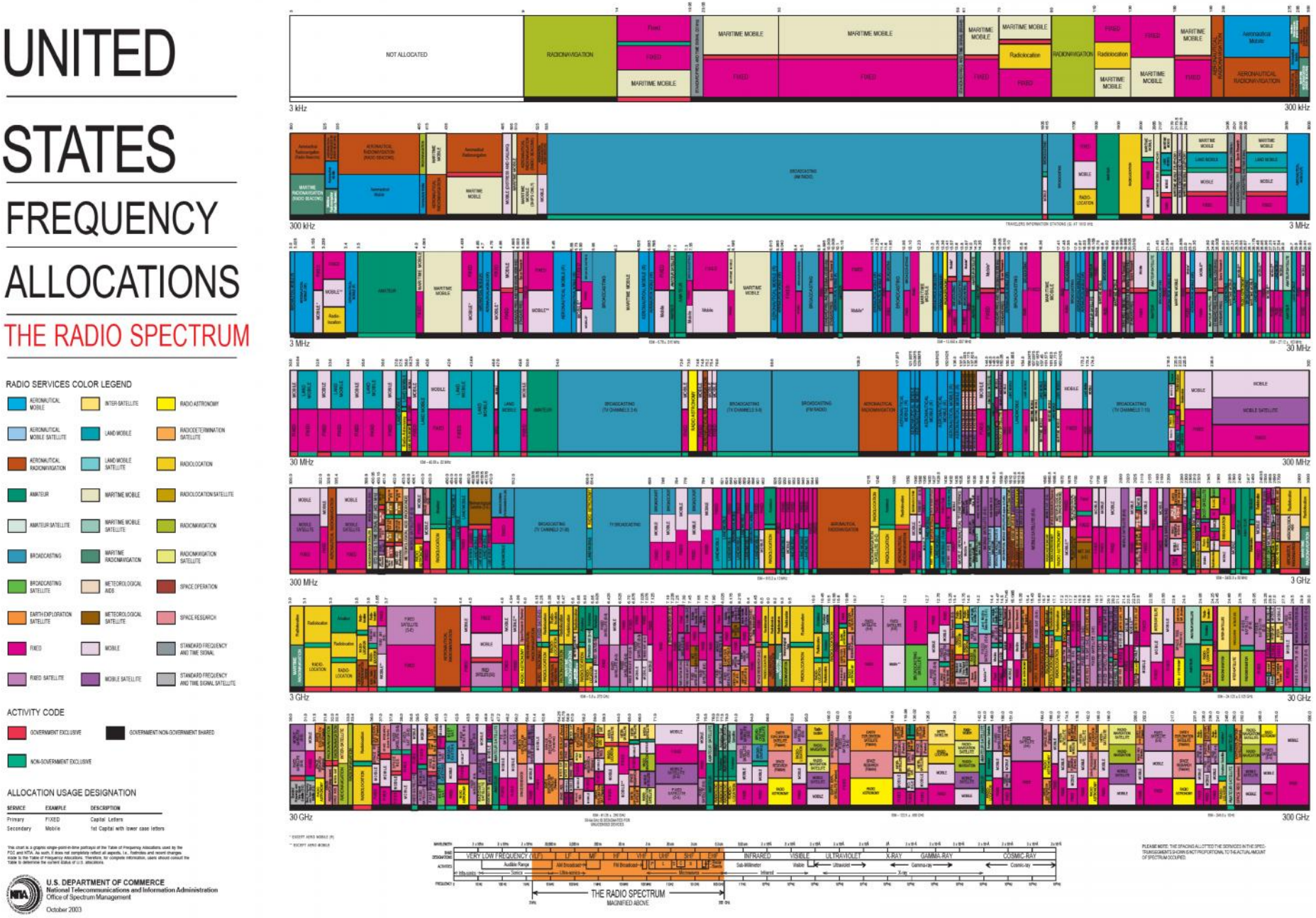
- Minimize site impact
  - Amount of antennas
  - Footprint

Multi-band Antennas L/H

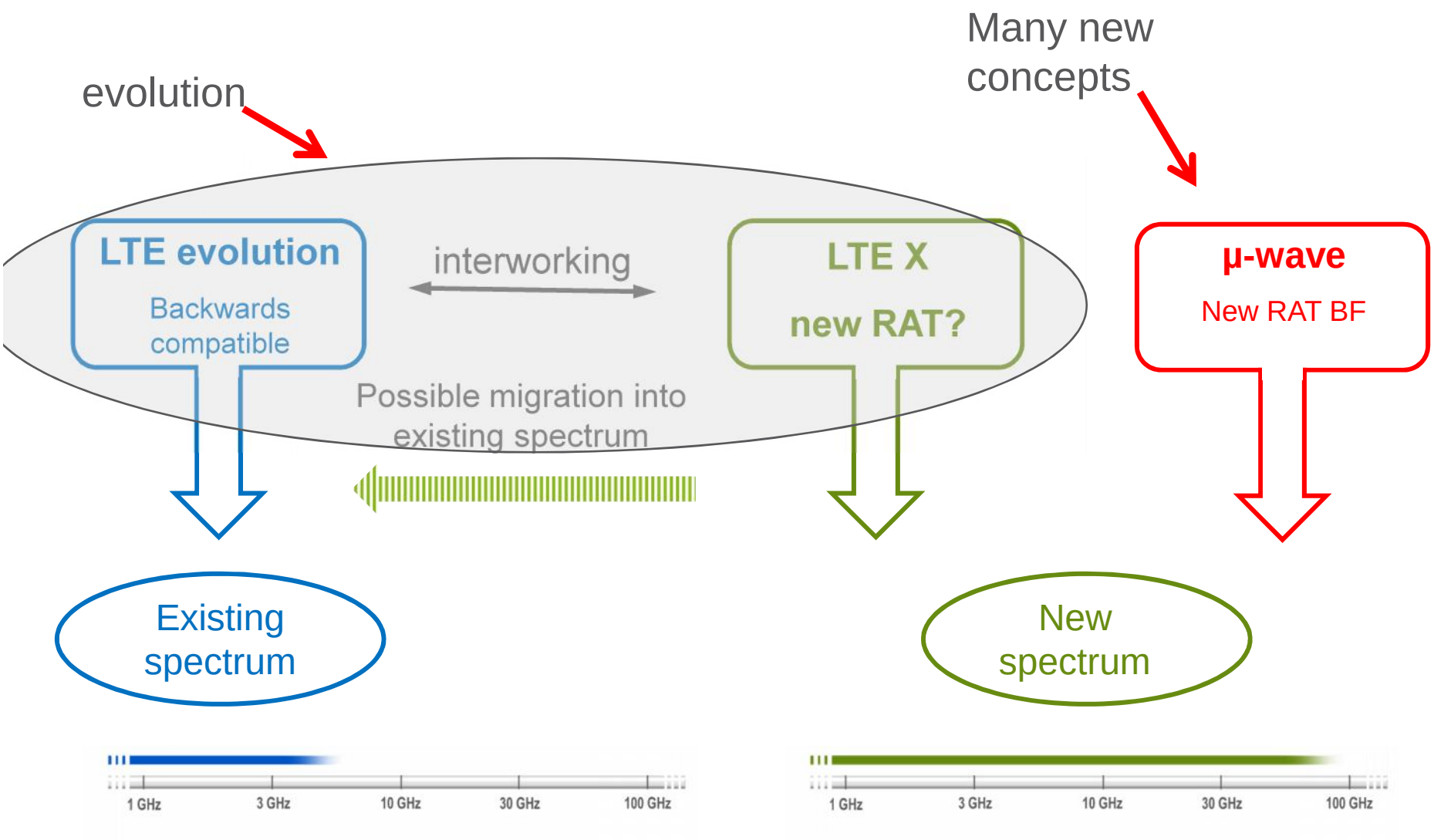
Multi-band MSR L/H

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

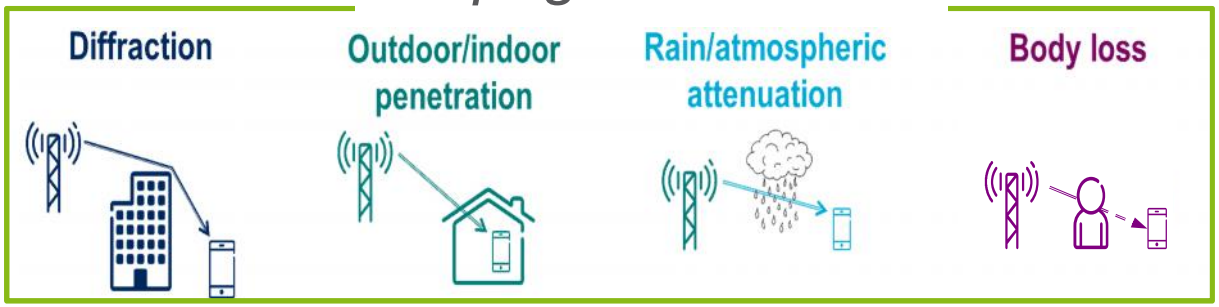


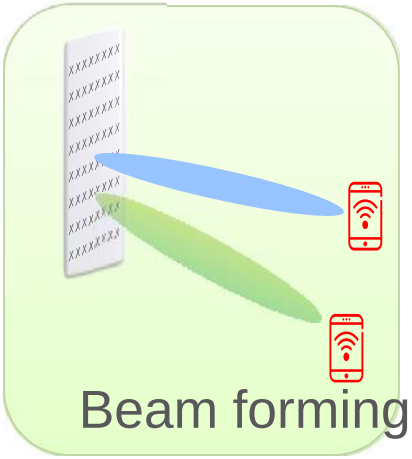
5G Radio Access



Micro - / Millimeter – wave RBS

Propagation Issues





- Higher frequency bands
  - More challenging link budget
  - Short wavelength ➡ many antenna elements
- Beam forming for improving link budget
- MU-MIMO / Massive MIMO for higher capacity

BF with many elements

Beamforming

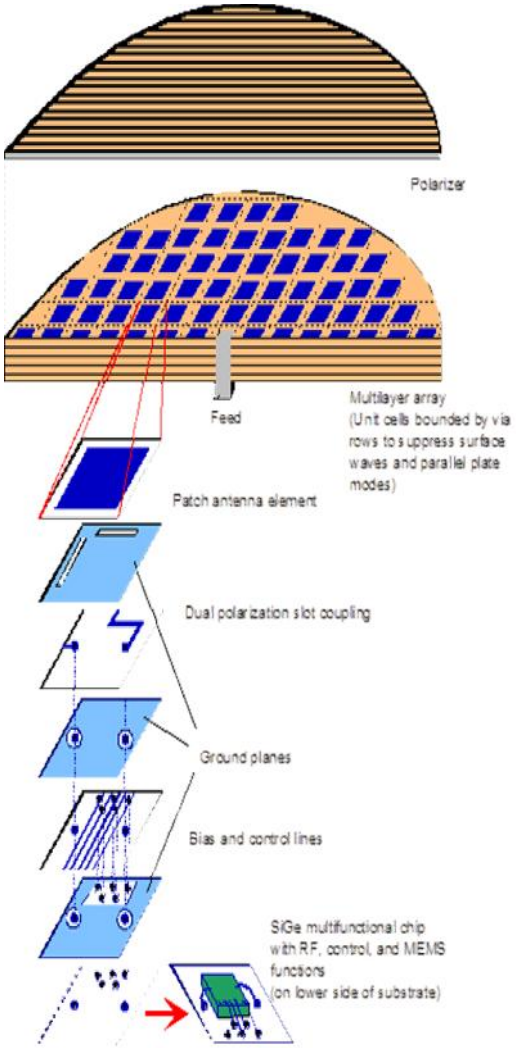
- Form factor not an obstacle at mw
- High antenna gain is necessary to defeat high damping at mw
- Active antenna array, integrated solution

- Low interference
- Increases radio range and capacity
- Frequency re-use

Massive (multi user)MiMo - MuMaMiMo?

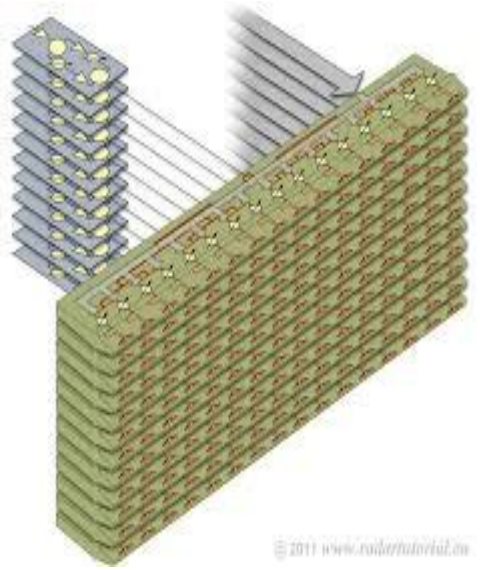
- *increased data rate*, the more antennas, the more independent data streams can be sent out and the more terminals can be served simultaneously;
- *enhanced reliability*, the more antennas the more distinct paths that the radio signal can propagate over;
- *improved energy efficiency*, the base station can focus its emitted energy into the spatial directions where it knows that the terminals are located; and
- *reduced interference* because the base station can purposely avoid transmitting into directions where spreading interference would be harmful.

Baking the antenna cake



Antenna array elements integrated in a multilayer structure.

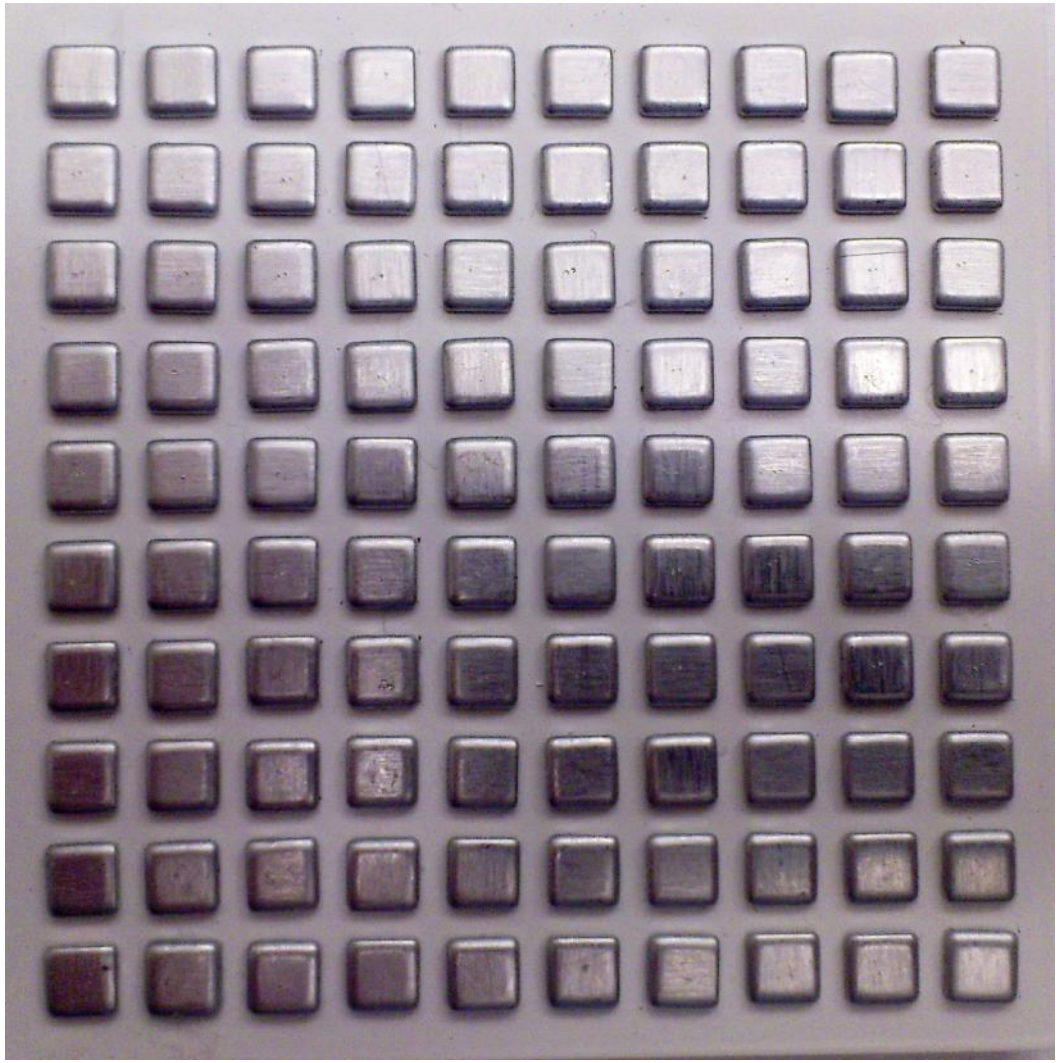
From FP-7 FLEXWIN



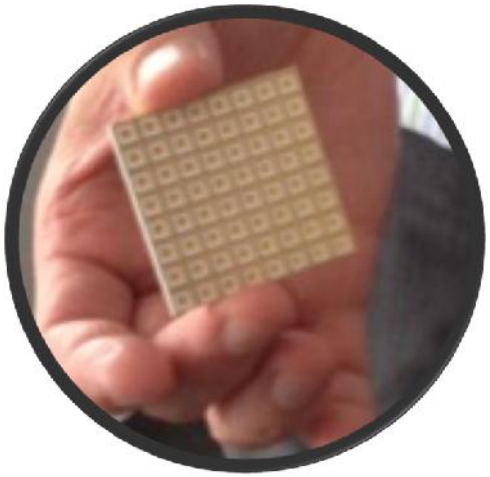
Power dissipation budget!

Antenna array elements fed by rf FE ***modules*** behind the array.

mm-wave beamforming antenna?



10-15 cm



Summary

- 5G – no decisions yet!
- Launch expected **2021, or earlier**
- Application space will be greatly expanded
  – encompassing nearly everything! ➔ **Networked Society!**
- Resulting in high requirements (x10 – x1000)
  → new architectures
- Likely to use many of the **generalized concepts**
  - SDR, CR, SDN, NFV, …
- Centralizing and de-centralizing
- **Advanced antenna** concepts – BF, MiMo, CoMP and more

- Mainly **evolution**,

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