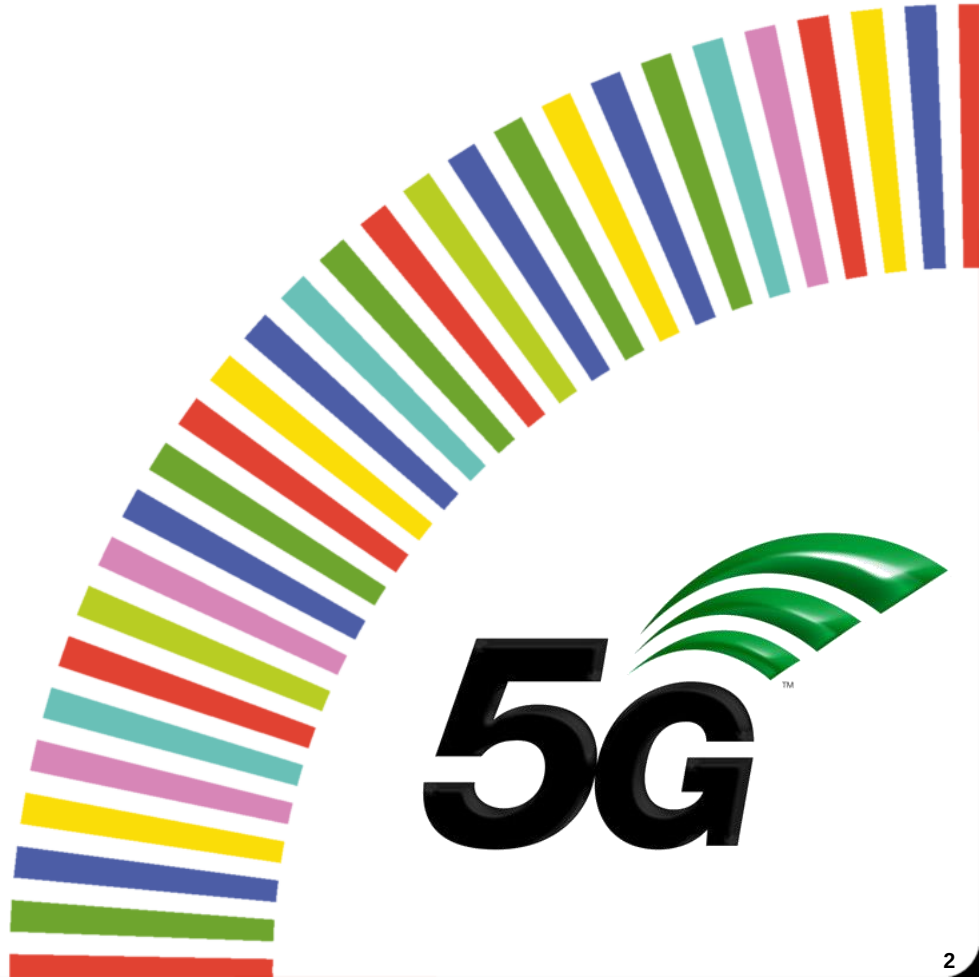
From 4G to 5G

Technology Evolution for a Service Revolution

Instituto Superior Técnico

Outline

- NOS in numbers
- Drivers & Objectives
- Use Cases
- Network Transformation
- 5G @ NOS
- Wrap-up



NOS in numbers

Telecom & Entertainment

TV leader: **1.6M**
Mobile subs: **4.5M subs**
1.3M banda larga fixa
9M cinema tickets

Networks

Fixed: **3.8M** Households
90% Pop 4G
1M Hotspots WiFi

Great Place to Work

Growth

TV subs: **+ 4.5%**
Mobile: **+13.2%**
RGUs Enterprise: **+18.7%**
Cinema: **+21.6%**

2016 Results (highlights)

Revenue: **1 515 M€**
EBITDA: **557 M€**
Net Profit: **90 M€**
CAPEX: **393 M€**

Brand trust

Mobile Generation's Evolution

ODG R7 AR/R8 and R9

?

1980 – 1G

- Analog systems
- Large terminals
- **Several systems**
- Voice only

1990 – 2G

- Digital systems begin
- Smaller Phones
- **Several systems**
- Lower power consumption
- Low data rate services (SMS, email)

2000 – 3G

- Emergence of smart phones
- **Dominated by two standards: UMTS and CDMA2000**
- Data rates up to 42 Mbps
- Wide range of services

2010 – 4G

- Widespread adoption of smartphones
- **Dominated by LTE/LTE-A standard developed by 3GPP**
- Data rates 150+ Mbps
- Rich services

2020 – 5G

- **Global 5G standard developed by 3GPP**
- Massive connectivity
- Data rates 1Gbps+ (fibre like speeds)
- Very fast service introduction

5G Drivers & Use Cases

Improved QoE

More bandwidth as streaming video, augmented reality, AI, peer-to-peer gaming prevail

Extreme Mobile Broadband

New Revenue streams

Smartphones penetration reaching saturation. IoT wanted!

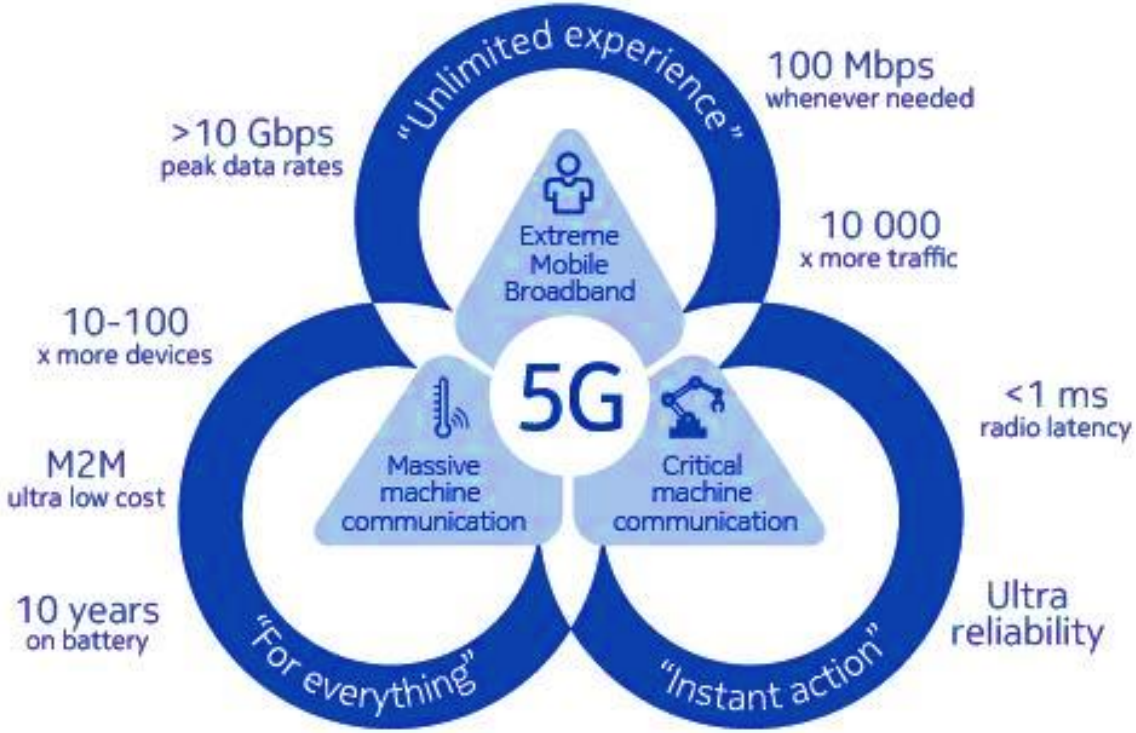
Machine to Machine Communications

Next Generation Apps

Self-driving cars to virtual reality

Critical Machine Communications

5G Technical Objectives



Source: Nokia 5G use cases

Massive Machine Communication (4.5G/5G)

Smart metering

Digital meters, smartgrids

WIRELESS

Nos tests smart meter over new NB-IoT network

Wednesday 16 November 2016 | 11:21 CET | News

Huawei, Janz build first NB-IoT smart meter in partnership with NOS

16 NOVEMBER 2016

Smart cities

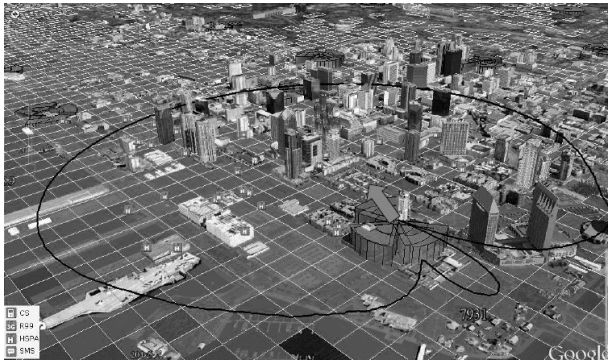
Municipalities & E-government

NOS, Oeiras e Nova assinam protocolo para Smart Cities

Depois de Oeiras, é a vez da Câmara de Lagoa passar a usar uma plataforma de gestão de equipamentos e sensores urbanos fornecida pela Nos.

Mobility & Assets Mgmt

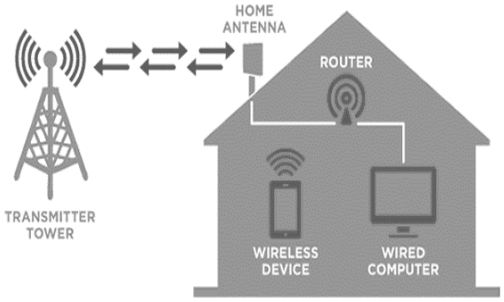
Location based information

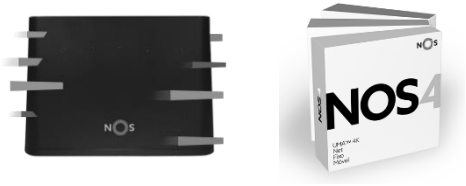


Extreme Mobile Broadband

Fixed Wireless

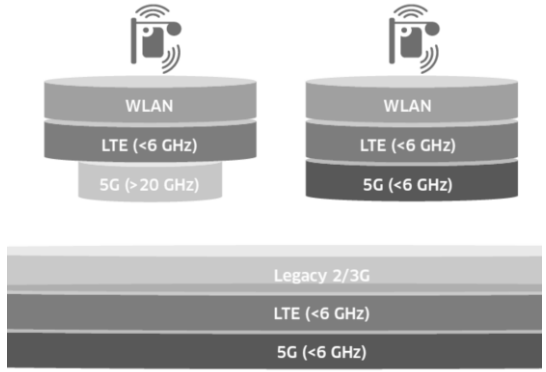
Extending fixed services with wireless last mile





Hotspots

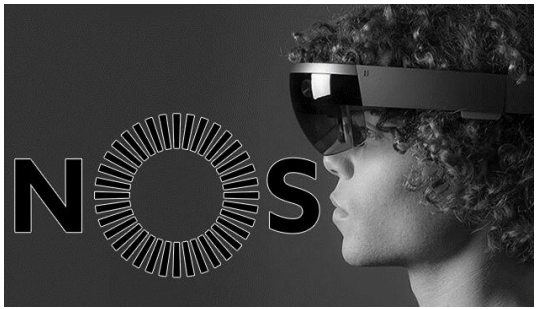
Solving capacity & QoE at events, public hotspots, etc.



Smallcells 5G:
3.5 GHz – macro layer
24-29 GHz – smallcells / indoor

VR/AR - Entertainment

VR – contend extension, education
AR – advertising, gaming, etc.

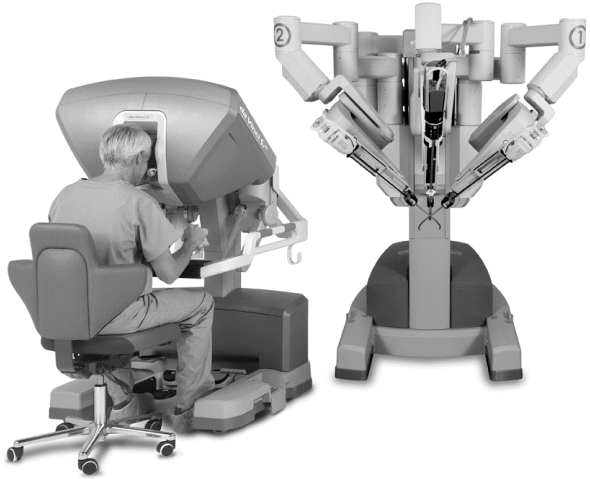


Portugal's NOS operator release HoloLens NOS TV app
IDC2016, Oct 2016

Critical Machine Communication

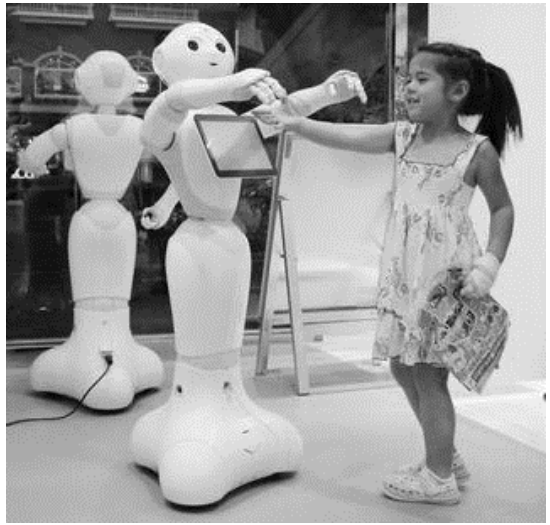
Remote Control

Machinery control, healthcare



Traffic control / saphety

Vehicles & robots



Industry 4.0

Cyber-physical systems

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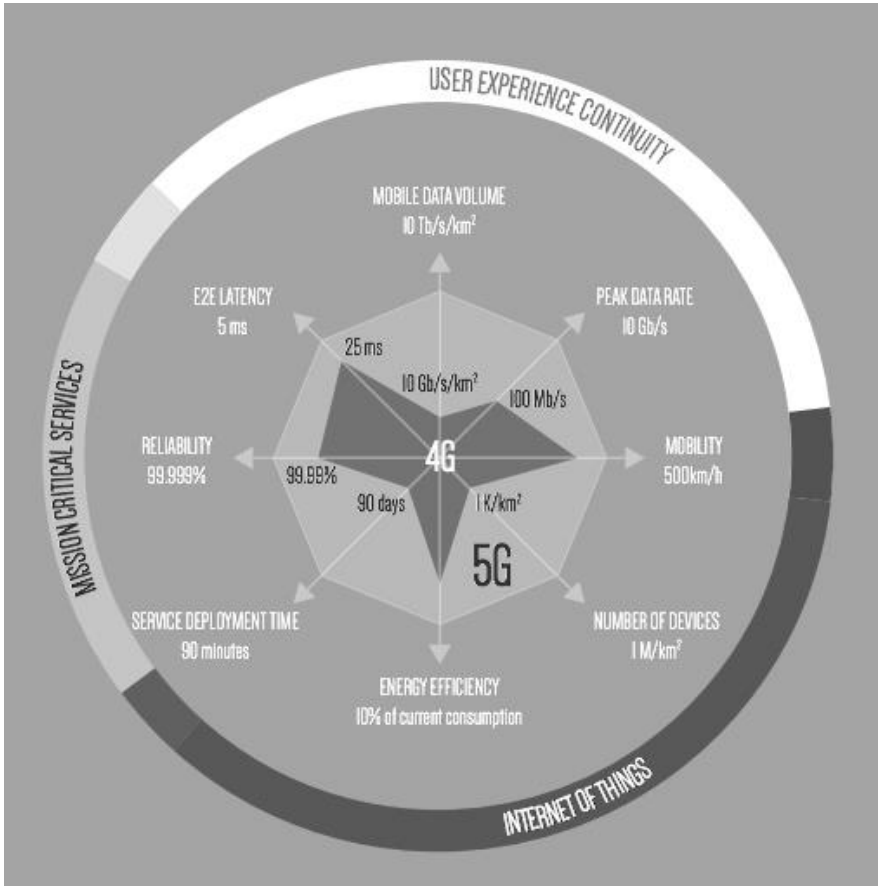
4G to 5G Gap – How to get there?



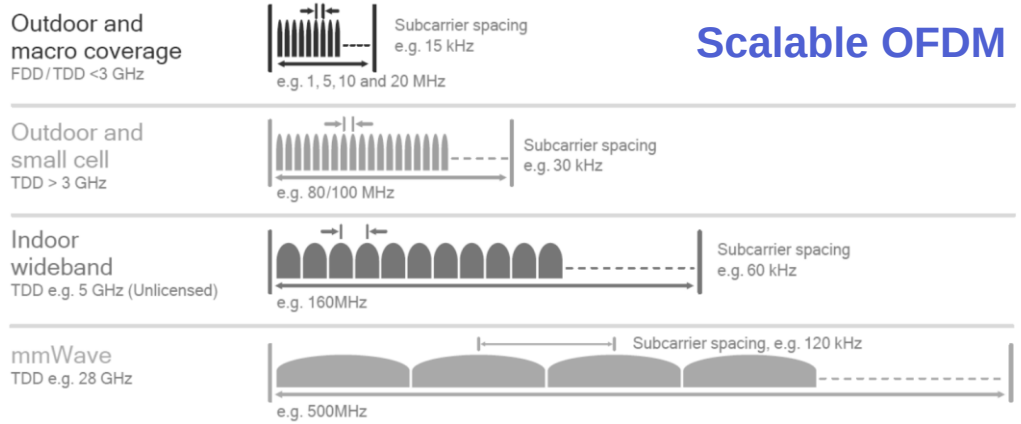
	4G-LTE	5G
Downlink real-world	42 Mb/s	100 Mb/s
Uplink real-world	25 Mb/s	50 Mb/s
Downlink Theoretical	1 GB/s	20 GB/s
Uplink Theoretical	500 MB/s	10 GB/s
Spectral Efficiency (Downlink)	15 bps / Hz	30 bps / Hz
Spectral Efficiency (Uplink)	6.75 bps / Hz	15 bps / Hz
Latency (Control plane)	100 ms	50 ms
Latency (User plane)	10 ms	1 ms

1) New radio Interface
2) New architecture
3) New spectrum & regulation strategies
4) NFV & SDN
5) Network slicing; One network, all use cases supported

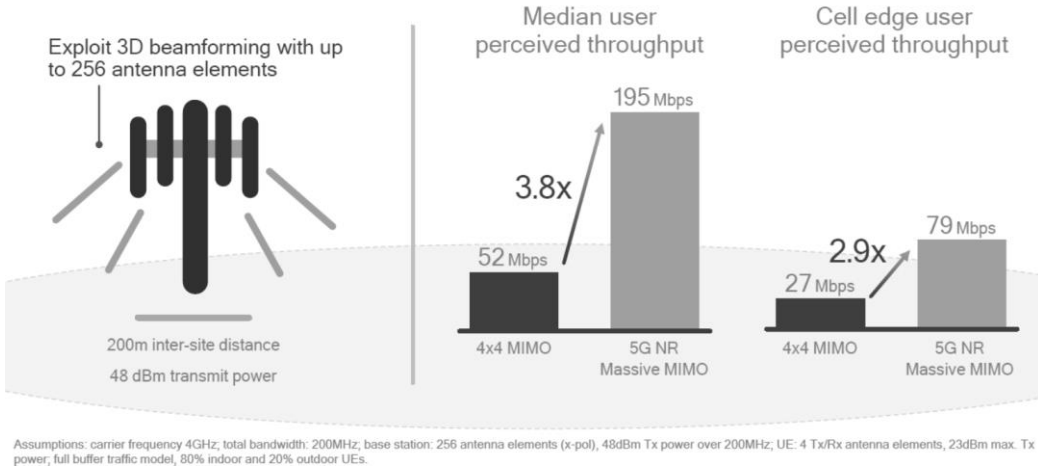
New Radio Interface

- Scalable OFDM numerology
- Multi-user Massive MIMO
- Advanced LDPC channel coding
- Self-contained TDD sub-frame
- Low-latency slot structure design
- Adaptive beamforming/tracking (mmW)

Scalable OFDM



Multi-User Massive MIMO



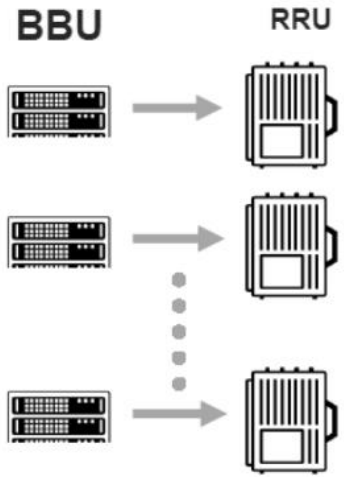
Assumptions: carrier frequency 4GHz; total bandwidth: 200MHz; base station: 256 antenna elements (x-pol), 48dBm Tx power over 200MHz; UE: 4 Tx/Rx antenna elements, 23dBm max. Tx power; full buffer traffic model, 80% indoor and 20% outdoor UEs.

Source: accelerating-5g-new-radio-nr-for-enhanced-mobile-broadband-and-beyond, Qualcomm

New architecture: Distributed to Virtual RAN (vRAN)

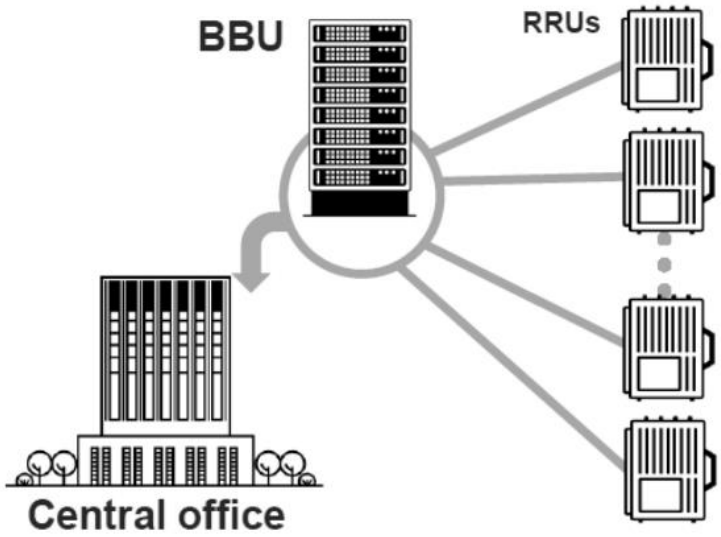
Distributed RAC

BBU – RRU separation on site



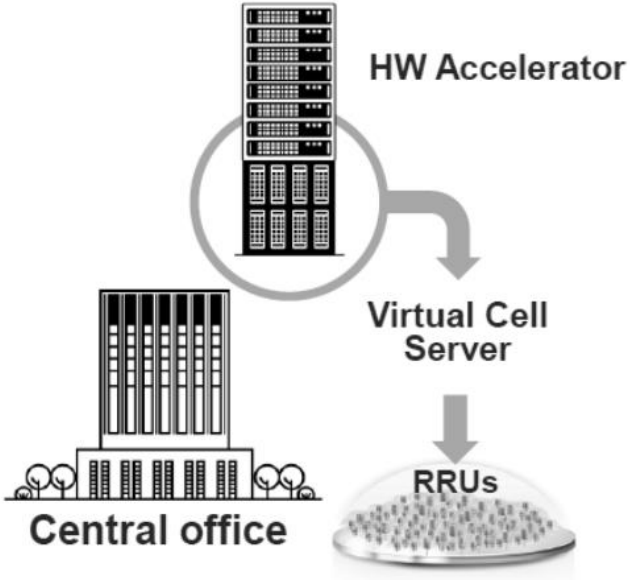
Centralised RAN

BBU Hotel or light BBU centralisation with coordination features



Virtual RAN

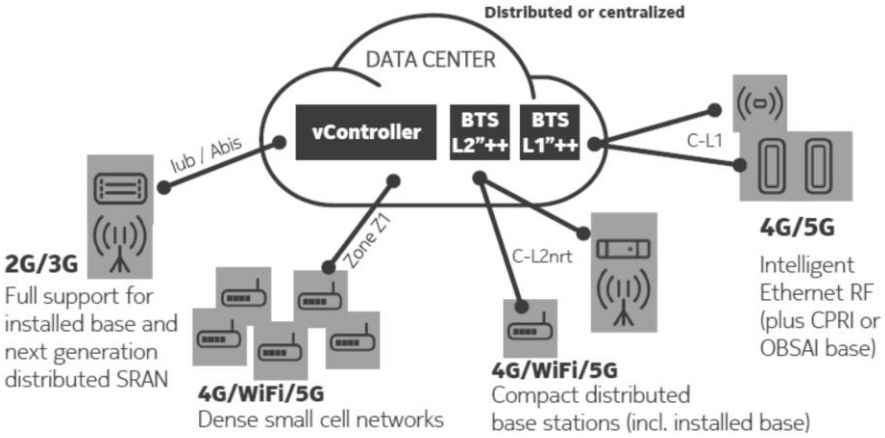
Virtualisation of L3-up layers in COTS. HW acceleration for L2/L3 interconnection



New architecture: 4G and 5G to converge in vRAN

vRAN for 4G & 5G

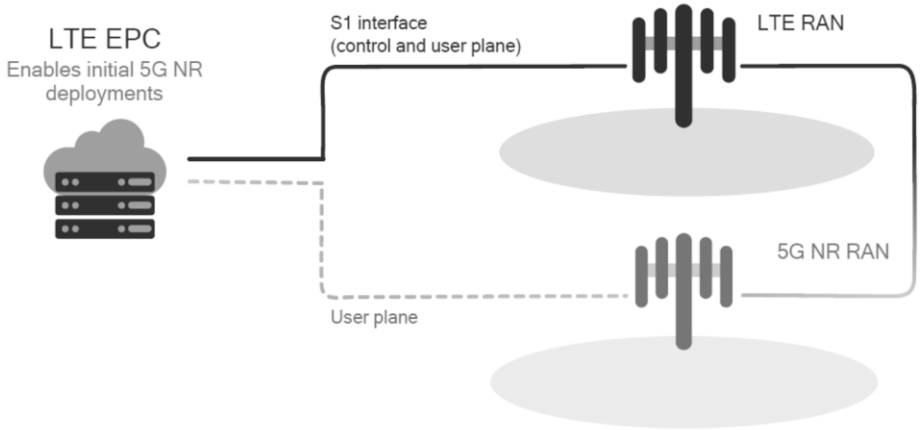
L2nrt (non-real-time) is the L2/L3 split architecture



Source: Nokia

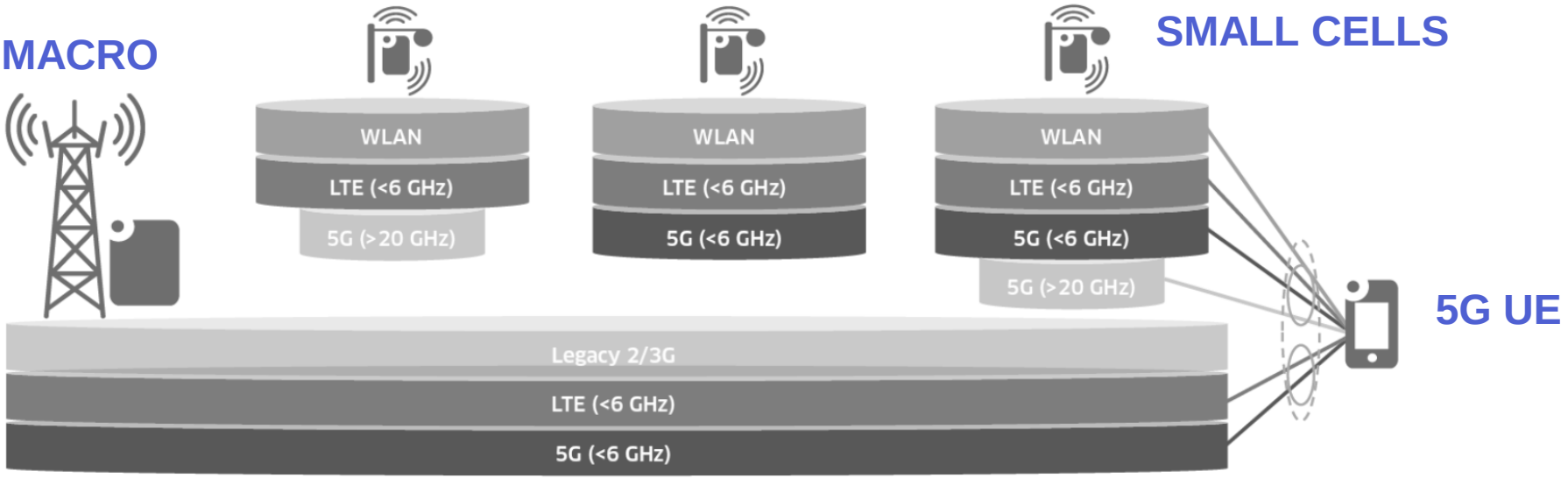
Non-Stand Alone operation key to 5G

Signalling goes over 4G; 5G is user plane aggregation



Source: Qualcomm

New Spectrum & Regulation Strategies



5G Spectrum (WRC-19)

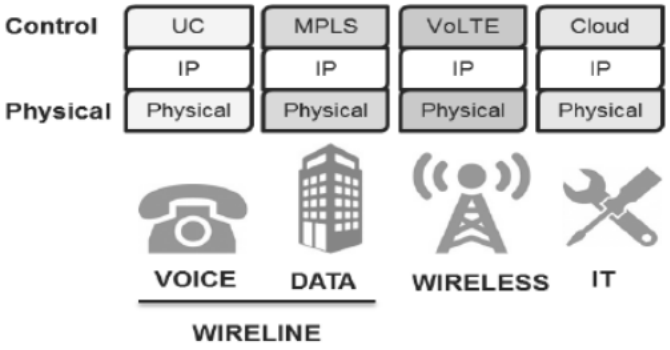
- 24.25 – 27.5 GHz
- 31.8 – 33.4; 37.0 – 43.5 GHz
- 45.5 – 50.2; 50.4 – 52.6 GHz
- 66 – 76 GHz, 81 – 86 GHz

New spectrum regulation strategies (4G & 5G)

- Licensed (sub-6GHz e mmW)
- Anchor licensed + unlicensed (e.g. LAA, LWA)
- Licensed Shared Access
- Unlicensed spectrum only (e.g. MuLTEfire™)

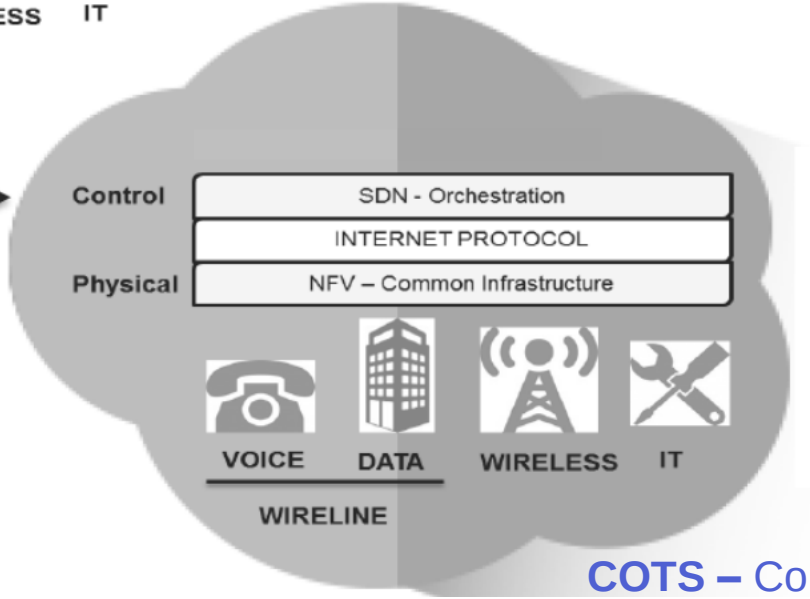
Source: 5G_Whitepaper, ALU, Novembro 2015

NFV & SDN



Today: Different (monolithic) platforms for different services

- Internet traffic flows across different service platforms
- Services operated on specialized Physical and Control infrastructure



5G: Converged Cloud Based

- Services that previously required dedicated hardware are abstracted into software functions
- Services will be provisioned and controlled on common infrastructure
- **SDN/NFV will unify ALL SERVICES**

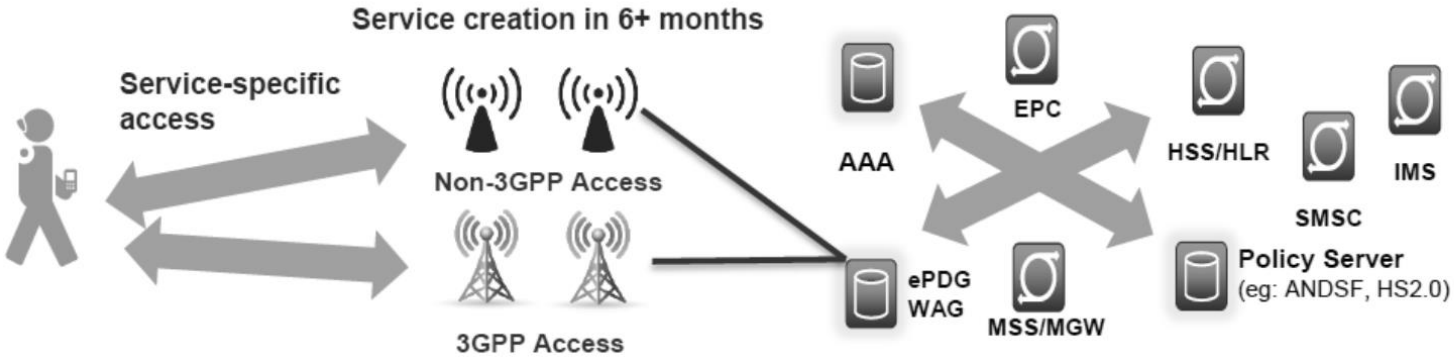
SDN is the application functions that control and **orchestrate** all NFV entities

COTS – Common Off The Shelf hw/servers

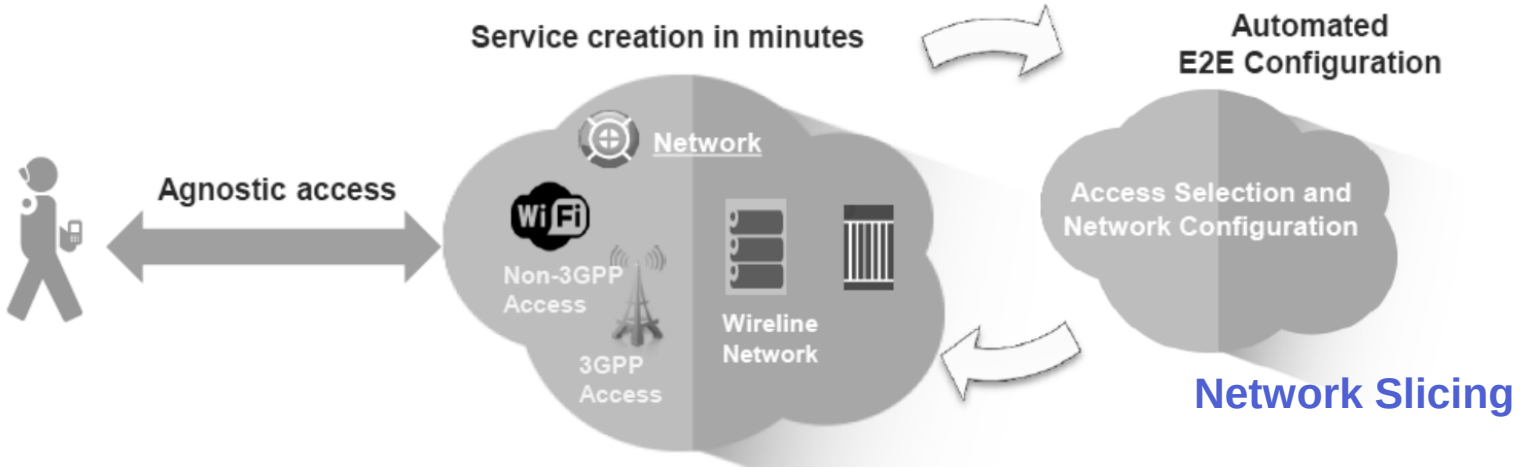
Source: Ivo-Maljevic-5GSummit-Toronto-11142015.pdf

Network Slicing & Service Creation

Today:
E2E access dependent service creation



5G: Network slicing will instantiate (via NFV) a network config. for the service target QoS



Source: Ivo-Maljevic-5GSummit-Toronto-1

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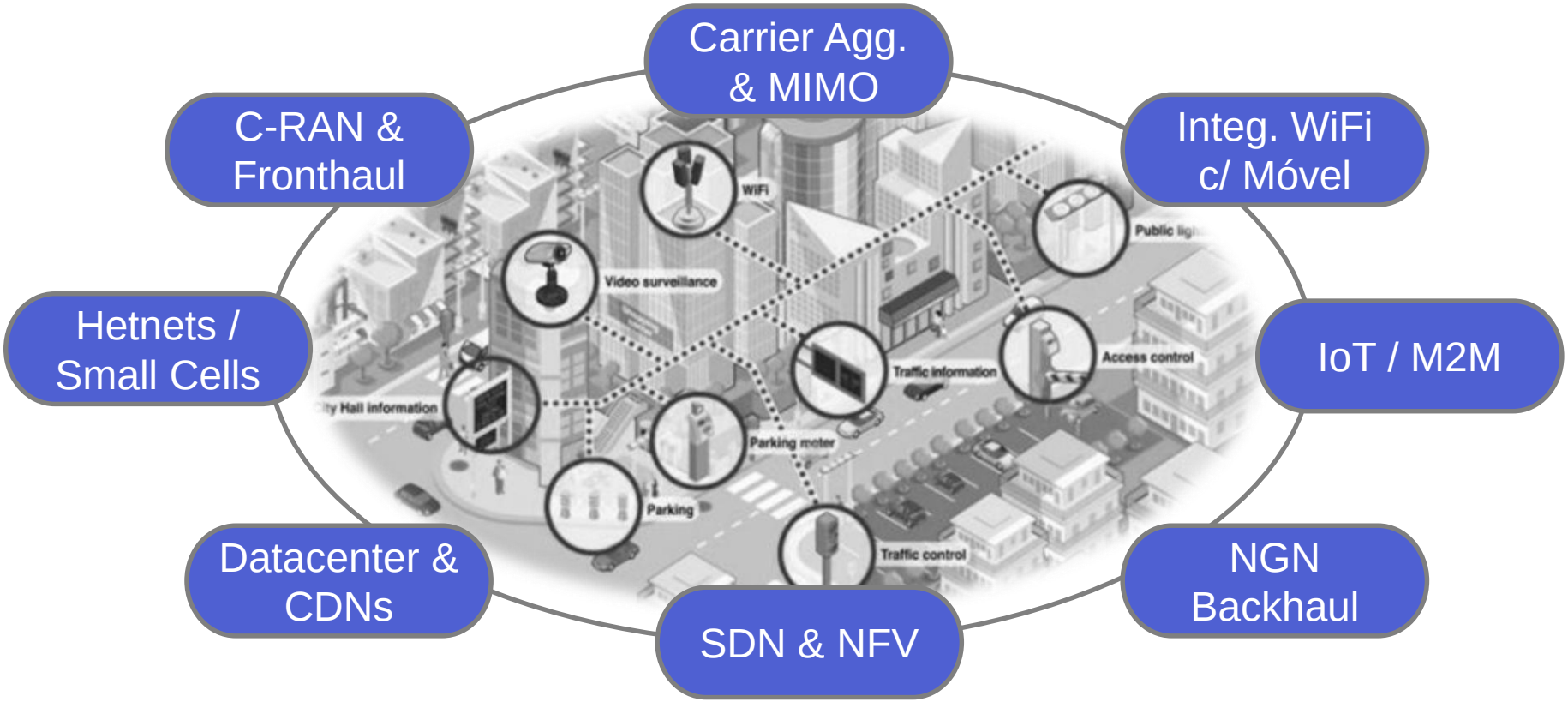
5G @ NOS is already happening…



5G Roadmap

2015

RADIO DEMOS & PPP
- Start 5G PPP
- **WRC15 – Spectrum > 20 GHz**
- Start 3GPP standard 5G

2016

SYSTEM DEMOS & SPEC
- First proposals 5G PPP – system level
- **Standards evolution standards 5G, layer 1, etc.**

2017

FULL SPEC & PREP. TRIALS.
- Standards 3GPP – system level
- **IMT2020 evaluation**
- Olimpic games 5G premier preparation – South Korea

2018

TRIALS PRE-STANDARD
- 3GPP PH1 standards closed
- **USA pré launch 28 GHz (Verizon)**
- WRC19 preparation – new spectrum for 5G

2019

TRIALS PRE-COMERCIAIS
- 3GPP PH2 standards closed
- IMT2020 (ITU-R) defined
- **WRC19 – new spectrum definition for 5G**

2020

5G READY
- First comercial networks: **South Korea & Japan**

Wrap-up

1. Growth over 4G seems challenging beyond 2020; even evolutions as high order MIMO will be limited by cost/implementation. A new radio (5G) is required to allow more capacity
2. 5G drivers are clearly growth and sustainability; new revenue streams are expected from resilient use cases and lower cost per bit will provide long term benefits
3. NOS is starting use case's priorisation and developing its business cases. Spectrum is key to such assessment. Current spectrum cost model strongly affects 5G attractiveness
4. 5G approach is likely to be evolutive; while 4G will pay a role as macro national coverage, 5G is likely to be confined to urban areas/ hotspots with specific use cases
5. 5G has already started; several technologies, key to 5G are being developed and explored. NFV, SDN and RAN virtualisation are baseline for 5G architecture

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