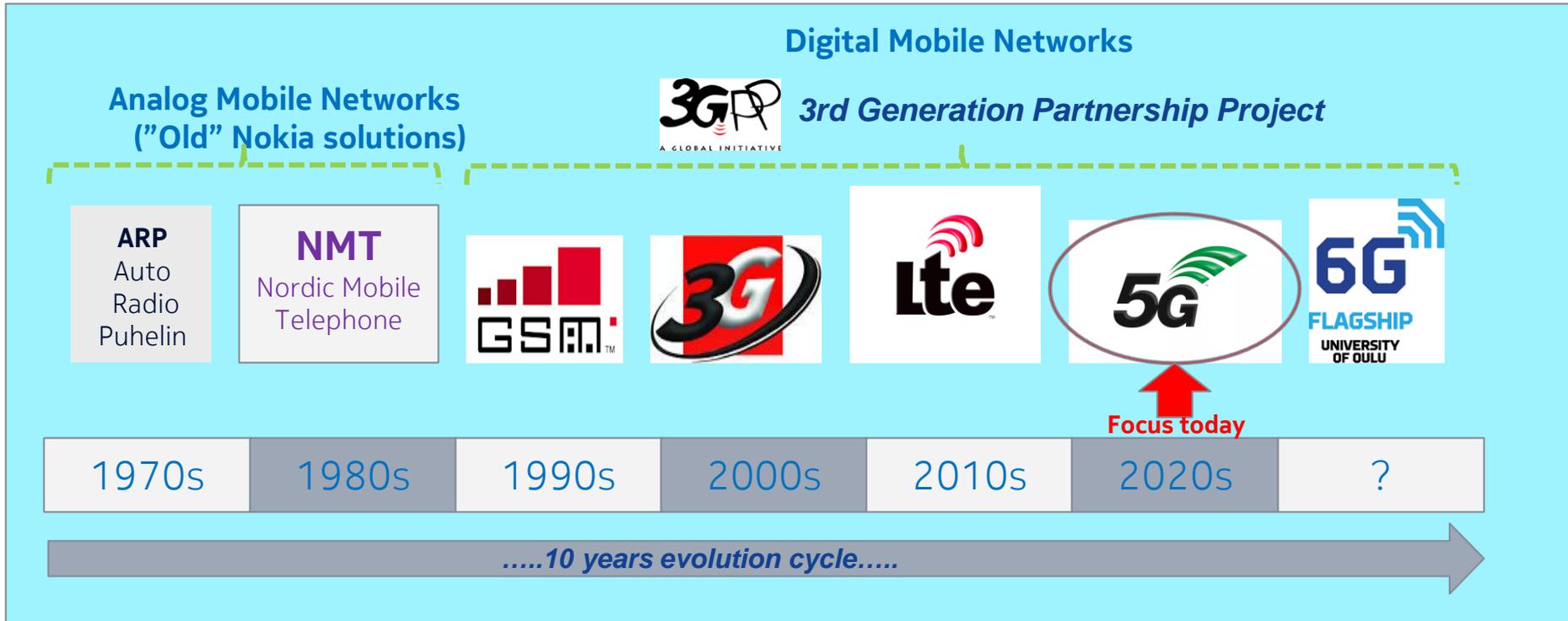# 5G in nutshell

Savonia Kuopio
27th November 2019

Matti Keskinen
Internal Consultant
Nokia, Mobile Networks
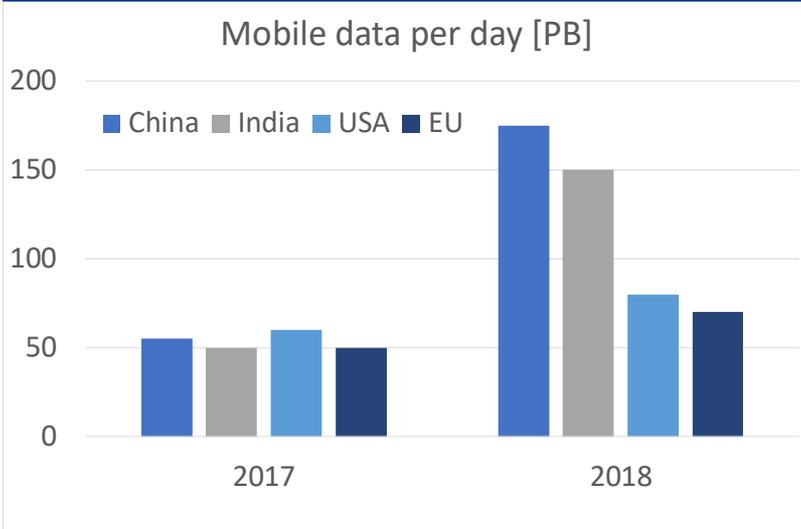
NOKIA

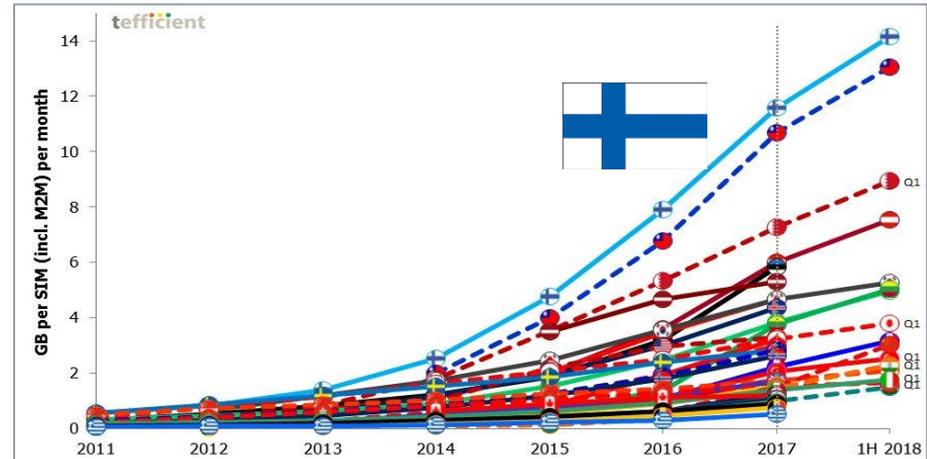# Mobile Networks Evolution in nutshell (Starting with old" Nokia solutions)

Digital Mobile Networks

**Analog Mobile Networks
("Old" Nokia solutions)**

3rd Generation Partnership Project

| ARP
Auto
Radio
Puhelin | NMT
Nordic Mobile
Telephone | GSM | 3G | Lte | 5G | 6G
FLAGSHIP
UNIVERSITY
OF OULU |

Focus today

| 1970s | 1980s | 1990s | 2000s | 2010s | 2020s | ? |

…..10 years evolution cycle…..

NOKIA Bell Labs

Matkapuhelindata kasvu motivoi siirtymistä 5G tekniikkaan

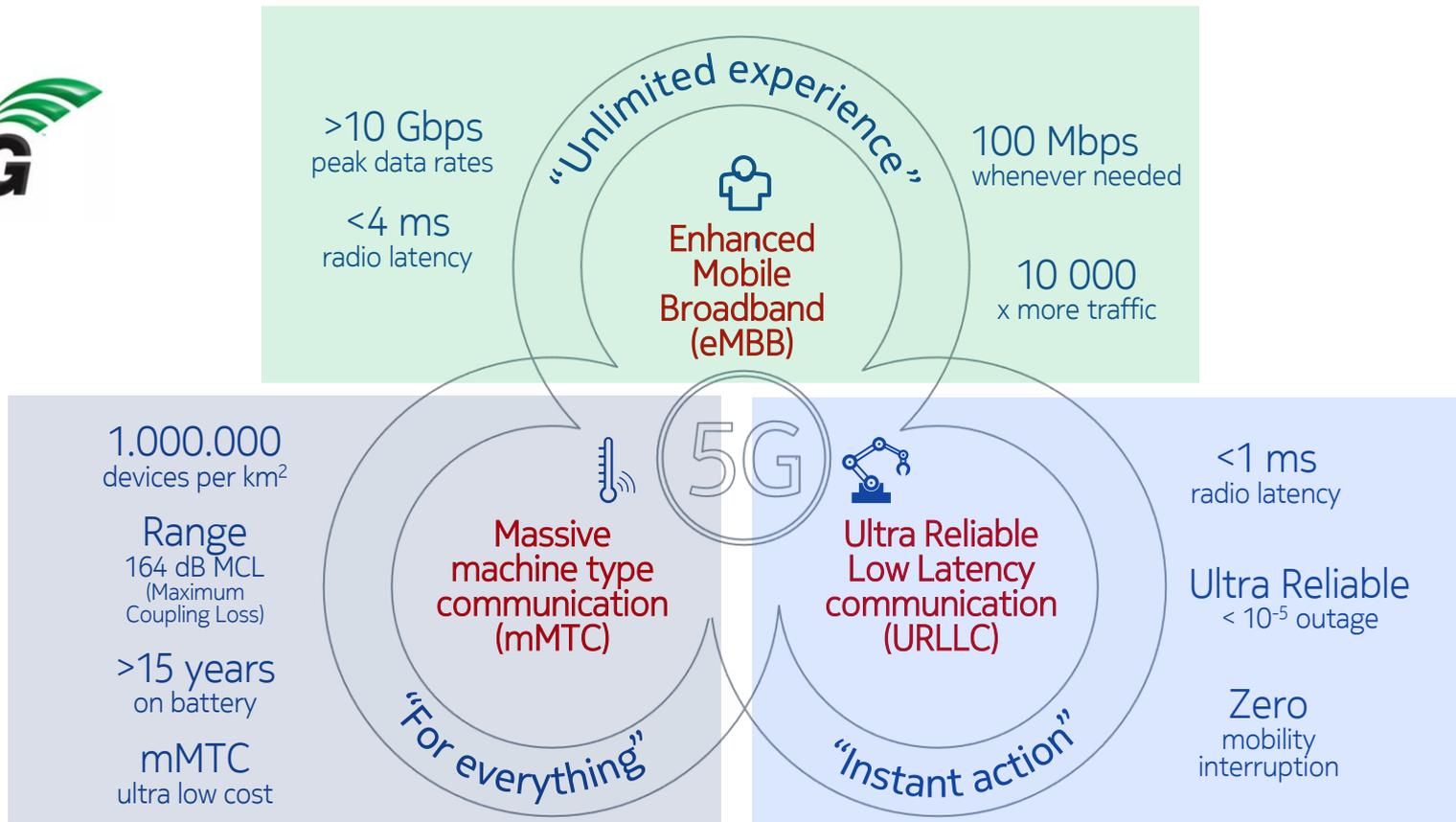## China and India leading in total mobile data traffic >150.000.000 GB/day

Mobile data per day [PB]

Legend: China, India, USA, EU

Years: 2017, 2018

Finland #1 globally in terms of mobile data per person >1 GB/person/day

tefficient

GB per SIM (incl. M2M) per month

Years: 2011, 2012, 2013, 2014, 2015, 2016, 2017, 1H 2018

Note!
Data usage / SIM. In Finland the penetration is 200% e.g. Two SIM cards per user. So the real data usage / user is even two time higer!
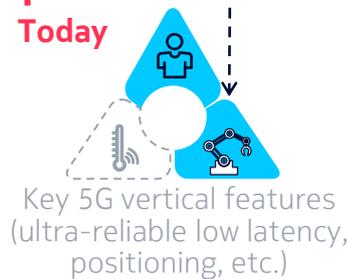
NOKIA

5G – Three Main Segments

"Unlimited experience"

>10 Gbps
peak data rates

<4 ms
radio latency

100 Mbps
whenever needed

10 000
x more traffic

Enhanced
Mobile
Broadband
(eMBB)

5G

1.000.000
devices per km^2

Range
164 dB MCL
(Maximum
Coupling Loss)

>15 years
on battery

mMTC
ultra low cost

Massive
machine type
communication
(mMTC)

"For everything"

Ultra Reliable
Low Latency
communication
(URLLC)

<1 ms
radio latency

Ultra Reliable
< 10^{-5} outage

Zero
mobility
interruption

"Instant action"

NOKIA Bell Labs

Realizing the full promise of 5G through 3GPP evolution

5G standards roadmap

R15	5G NSA Mobile broadband	5G SA

R16	Critical machine communication

R17	Massive machine communication

Optimized 5G standard completing full 5G vision

2017	2018	2019	2020	2021	2022

Today

5G industry roadmap

First standard based
5G deployments possible

Key 5G vertical features
(ultra-reliable low latency,
positioning, etc.)

Massive IoT features
& remaining vertical
feature set

NOKIA

5G Radio to Core Connectivity Options in 3GPP

The quest for **new value**

We are reaching the limit of consumer value creation
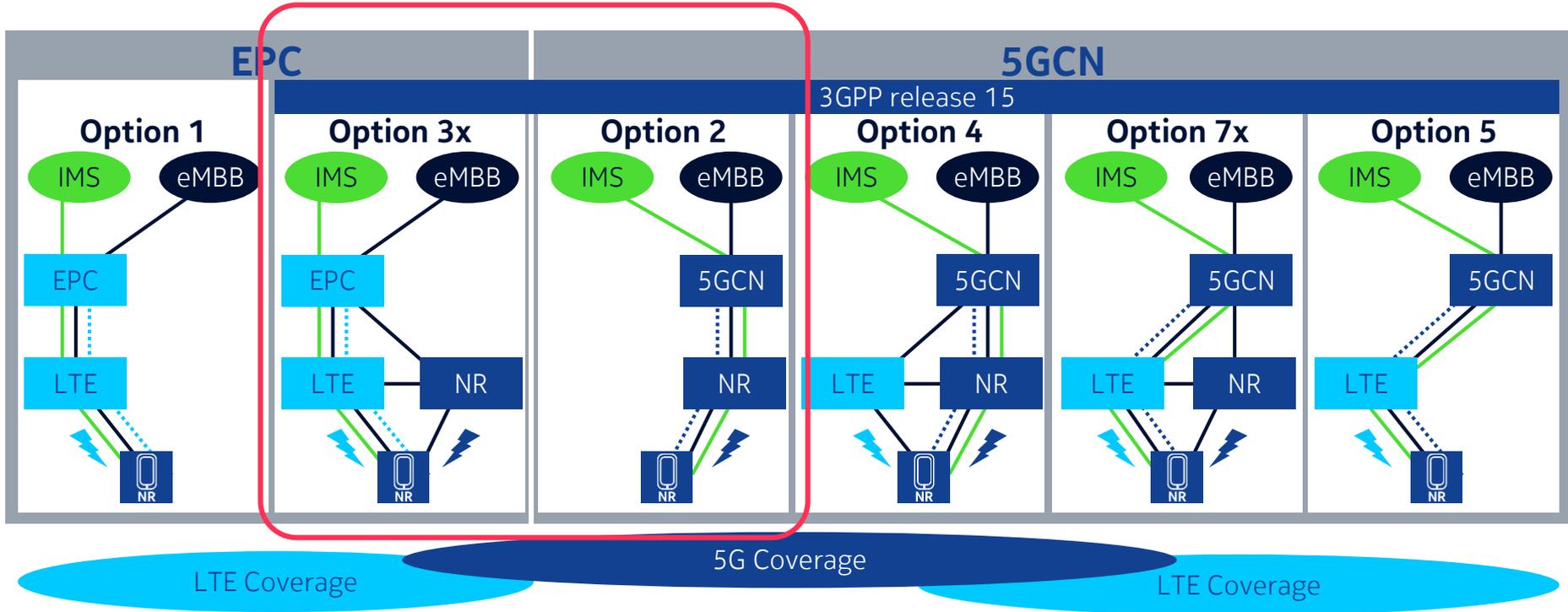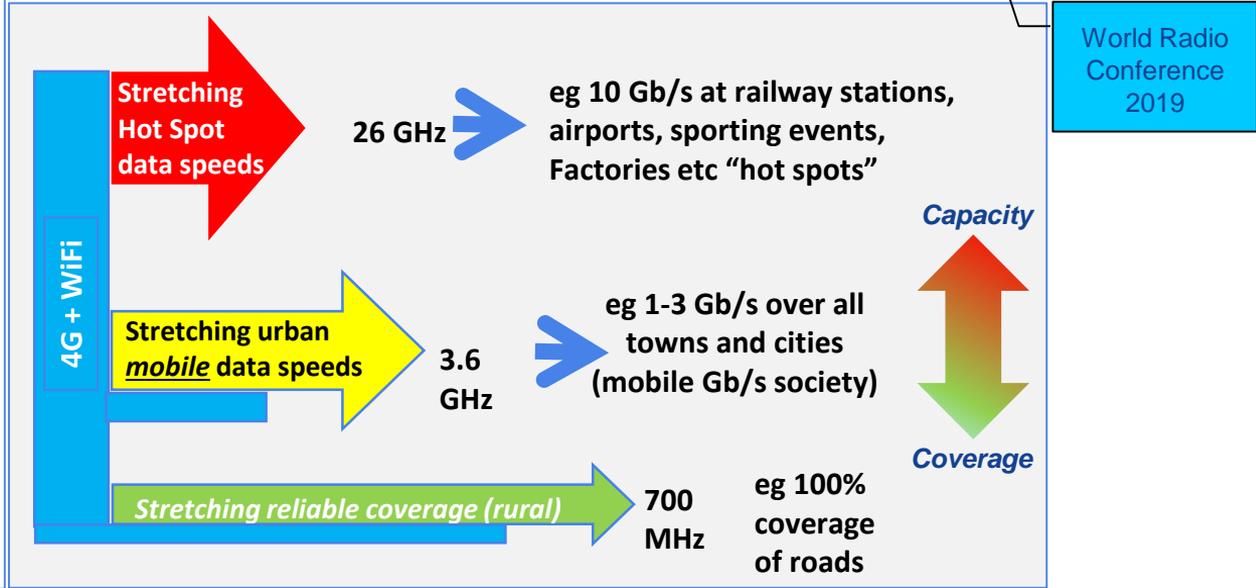
New industrial, infra & enterprise value

The legacy problem!

Some growth, but not all for Telcos

New DSP markets offer growth

($B)

	2015	2019
	1,000	997
TV	200	207
Voice	322	234
Data	479	556

($B)

2015	2019	
	359	
	134	Cloud Advertising
194	56	BPaaS
79	61	SaaS
39	68	Cloud Infra-aaS
31	41	VOD/streaming
25		
19		

($B)

	Low Estimate	High Estimate
Factories	1210	3700
Worksites	160	930
Cities	930	1660
Logistics & Transport	560	850
Health	170	1590
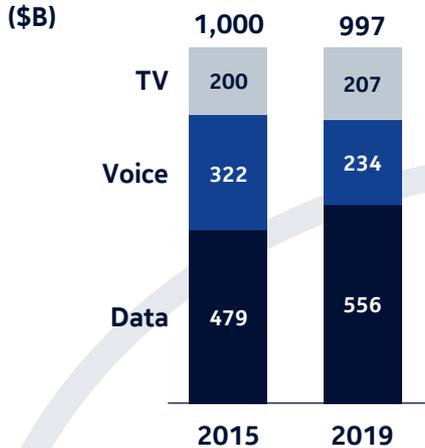
* Western Europe, Canada, USA, Japan, South Korea, Singapore, Australia, and NZ. Source: Gartner

Source: Gartner
BPaaS = Business Processes as a Service
SaaS = Software as a Service

Estimated 2025 value creation potential of the IoT
- *McKinsey Global Institute*
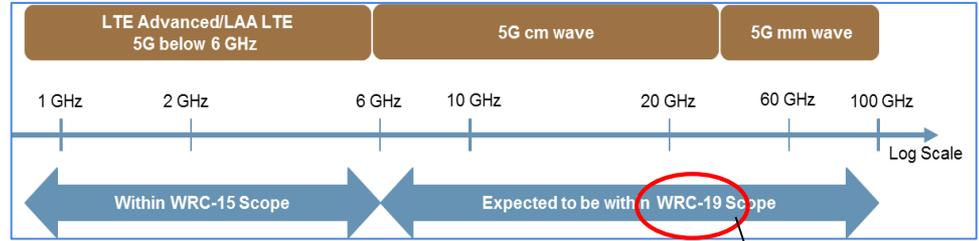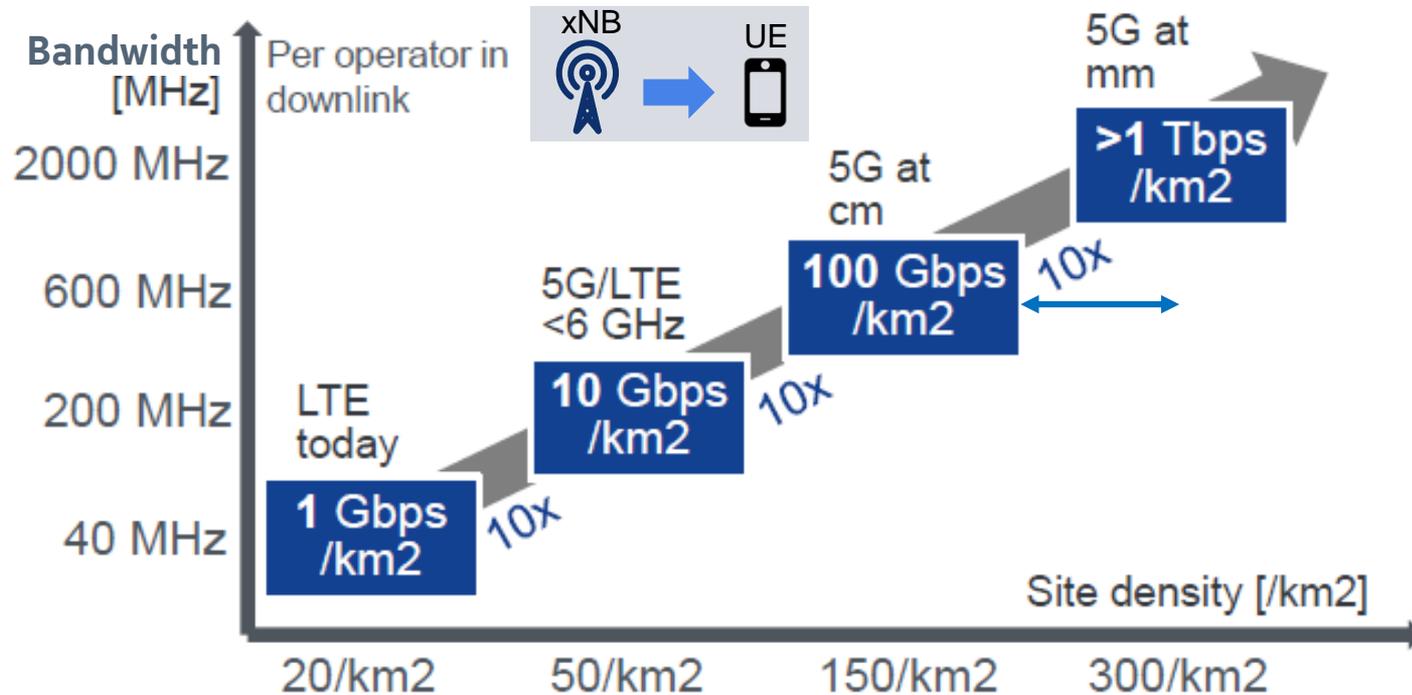
Most consumer focused operators facing long term stagnation – enterprise becomes a key focus
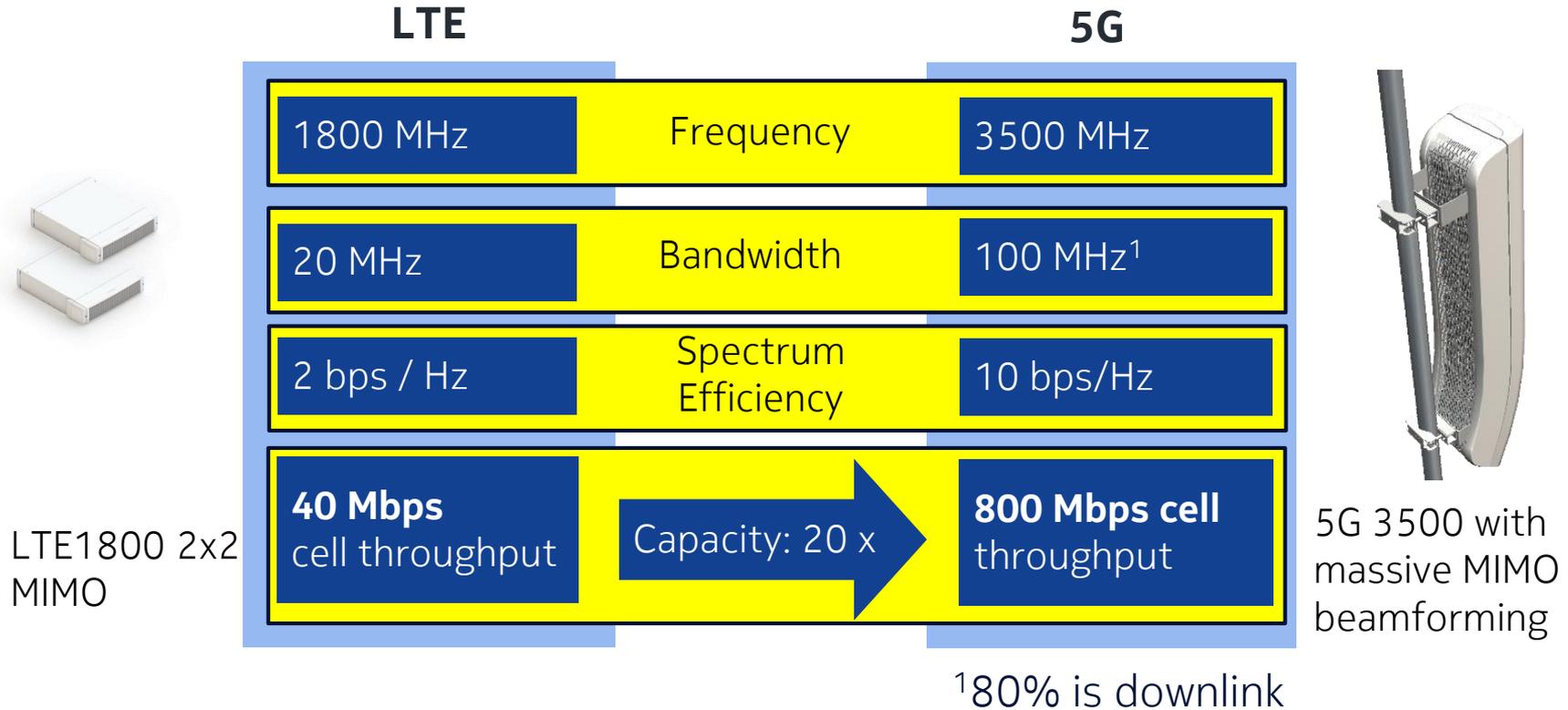
NOKIA

5G Spectrum

High data rates up to 20 Gbps require bandwidth up to 1 GHz which is available at higher frequency bands.
5G is the first radio technology that is designed to operate on any frequency bands between 450 MHz and 90 GHz.

LTE Advanced/LAA LTE 5G below 6 GHz | 5G cm wave | 5G mm wave

1 GHz | 2 GHz | 6 GHz | 10 GHz | 20 GHz | 60 GHz | 100 GHz

Log Scale

Within WRC-15 Scope | Expected to be within WRC-19 Scope

World Radio Conference 2019

CAPACITY

>10 Gb/s

24.25-27.5 GHz

3,5GHz auction results in Finland (130 MHz/MNO):

Telia: 3,410-3,540 GHz
Elisa: 3,540-3,670 GHz
DNA: 3,670-3,800 GHz

capacity

Consumer Benefit

coverage

3.4 – 3.8 GHz

700 MHz

COVERAGE

>99.9%

RSPG "PIONEER" BANDS
RSPG = Radio Spectrum Policy Group

4G + WiFi

Stretching Hot Spot data speeds — 26 GHz — eg 10 Gb/s at railway stations, airports, sporting events, Factories etc "hot spots"

Stretching urban *mobile* data speeds — 3.6 GHz — eg 1-3 Gb/s over all towns and cities (mobile Gb/s society)

Stretching reliable coverage (rural) — 700 MHz — eg 100% coverage of roads

Capacity

Coverage

9

NOKIA

Throughput relation to used frequency / bandwidth and Base Stations site density

NOKIA

5G Boosts Cell Capacity by 20x with 3.5 GHz Band
4x More Spectrum and 5x More Efficiency

	LTE		5G
Frequency	1800 MHz		3500 MHz
Bandwidth	20 MHz		100 MHz[1]
Spectrum Efficiency	2 bps / Hz		10 bps/Hz
	40 Mbps cell throughput	Capacity: 20 x	**800 Mbps cell** throughput

LTE1800 2x2 MIMO

5G 3500 with massive MIMO beamforming

[1]80% is downlink

NOKIA

Five new capabilities in <u>5G radio</u> resource management

New 5G capability

| | Impact to RRM design |

Massive MIMO → 5G is first ever radio system that is designed for massive MIMO

Slicing and critical communication → 5G can support variety of different services including critical low latency communication

New spectrum options → 5G uses sub 6 GHz + mmWave + unlicensed bands together

In-band backhauling and dynamic TDD → 5G radio can be utilized for backhauling (IAB). 5G supports dynamic TDD.

Dynamic spectrum sharing with LTE → Fast coordination between 5G and LTE when sharing the carrier with millisecond resolution
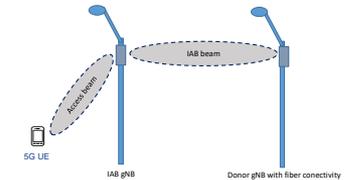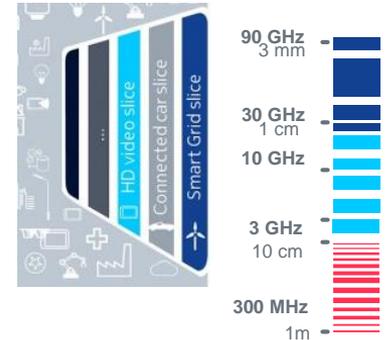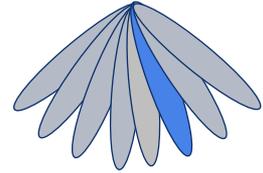
Innovations for Low Latency Radio Transmission – 1 millisecond in 5G

Minimum transmission time

Round trip time

HSPA — 2 ms — 20-30 ms

LTE — 1 ms — 10-15 ms

5G — 0.125 ms — 1 ms

NOKIA
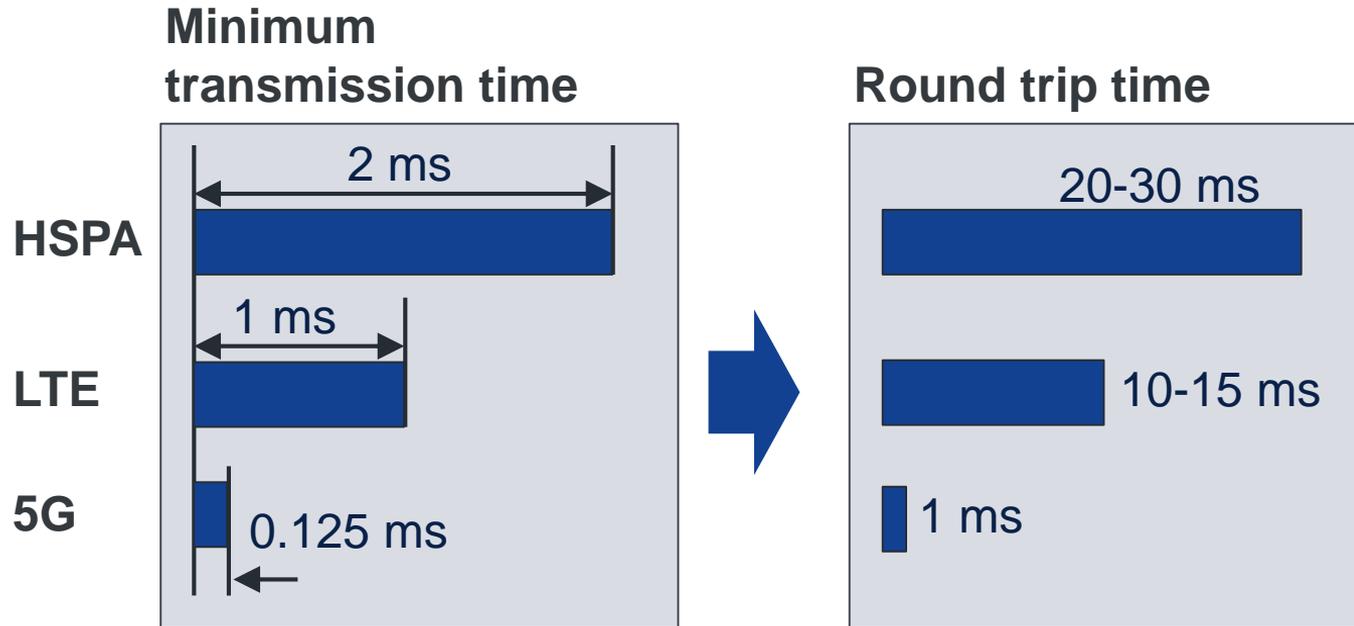
Distributed Core Network Needed for Low Latency Services

Helsinki
- UE
- Gateway
- Server

Ping 11ms

(4,5+4,5)ms = 9ms

Oulu
- UE

Helsinki
- Gateway
- Server

+9 ms = Ping 20ms

2 x (4,5+4,5)ms = 18ms

Oulu
- UE
- Server

Helsinki
- Gateway

+9 ms = Ping 29ms

NOKIA
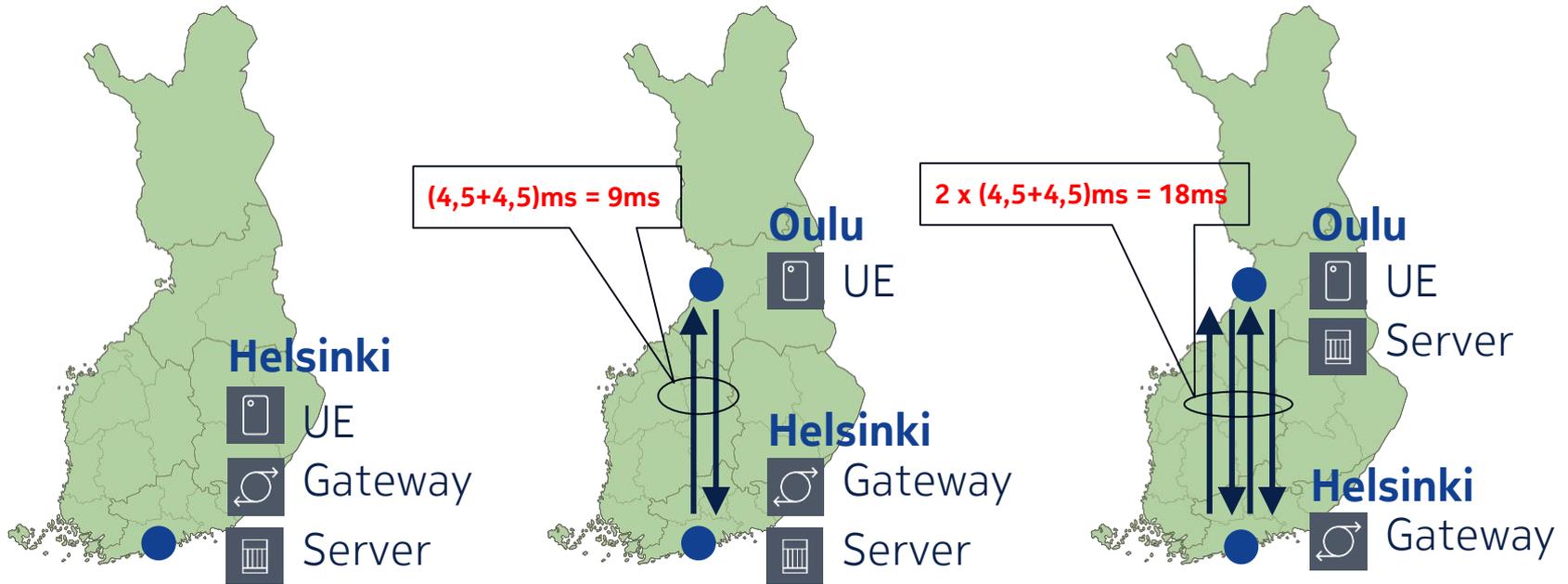
Speed of Light is the Limit – Content Must be Close to the Radio

Round trip time in fiber
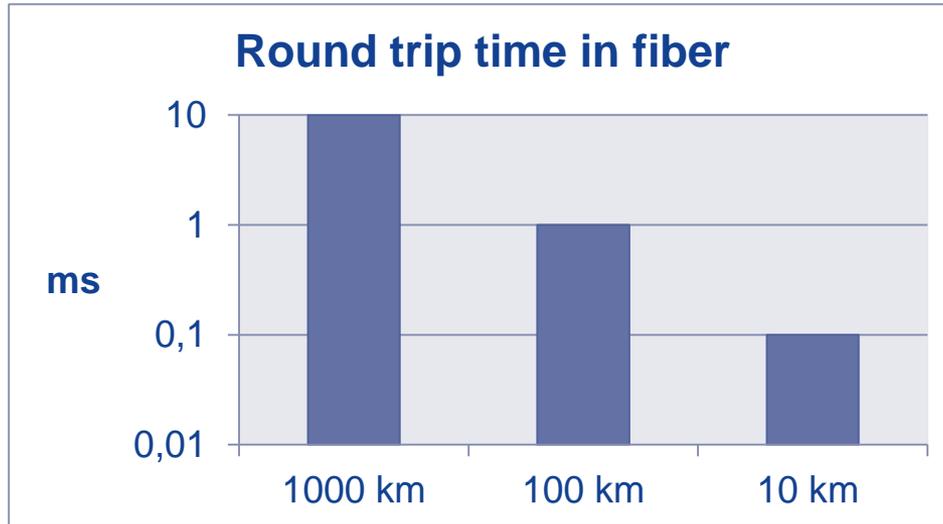
- 5G target is 1 ms round trip time
- 100 km two-way propagation delay in optical fiber is to 1 ms
- 10 km propagation delay to 0.1 ms
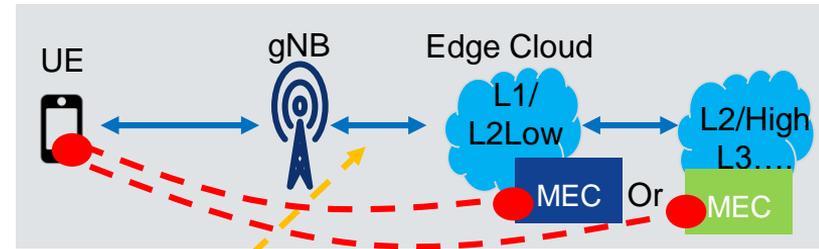
Content must be close to the radio (within a few 10 km) to get full benefit from the 1-ms round trip time in the radio ⇒ **Multi access Edge Computing (MEC/vMEC)** and **Local break out** will be needed for low latency services

NOKIA

LuxTurrim5G - Solution

LuxTurrim5G develops and pilots concrete technology enablers and service concepts for open Smart City Digital Ecosystem

Operators
Business models for:
- Existing ones
- **New ones?**

Indoor/Outdoor connections
Signal propagation through construction materials
- RF permeable windows:
Lammin Windows

Smart city services on top of a common platform
Examples:
- Video surveillance, public safety, infotainment screens: **Teleste**
- Air quality, weather: **Vaisala**
- Location, navigation: **Indagon**
- Lighting/charging: **Ensto**
- Drones: **Rumble Tools**

Transportation

Citizens

5G network
High capacity, low latency
Small cells -> many sites
5G network: **Nokia Bell Labs**
Light pole: **Exel Composites**

City Infrastructure
Light pole infra, power, data transport
Infra planning: **Sitowise**

Public partners contributing in each research area:
VTT, Aalto, TUT
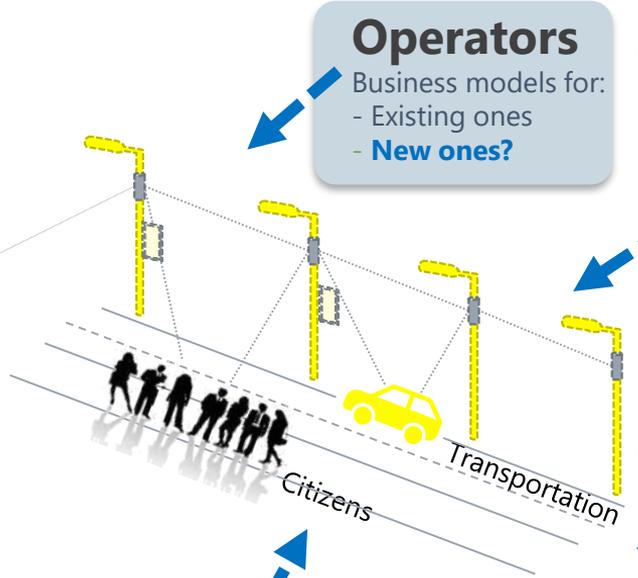
# 5G FXR Lab. Essential e2e environment to support 5G specification work

5G TNF — **Contributions** → **3GPP** A GLOBAL INITIATIVE

5G FXR (Future X Research) Lab will contribute to:
1. Significant amount of research projects funded by Business Finland and EU
2. Impact in the initial phase on 3GPP release 16 and 17 standardization (research period 2019-2020)
**3. Creation of test environment to support Finnish ecosystem and universities**

Utilize →
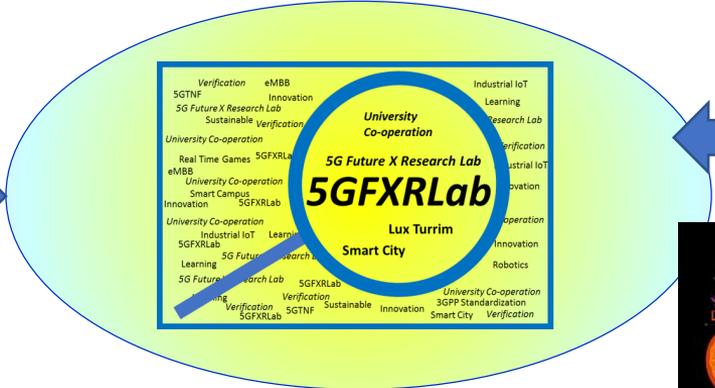
5GFXRLab supports also Nokia projects like:
- **Smart Campus Espoo**
- **Smart City (Lux Turrim, Neutral Host)**
- **6G Flag Ship initiatives**
- **X-IoT**
- **Edge Computing use cases**

5G FXR Lab strengthen University Collaboration

1. contribution to proposed 3GPP standardization
2. creation of new IPRs
3. Increased university co-operation and support
4. Co-operation with the Finnish Ecosystem around 5G technologies
5. Internal testing (PoC)
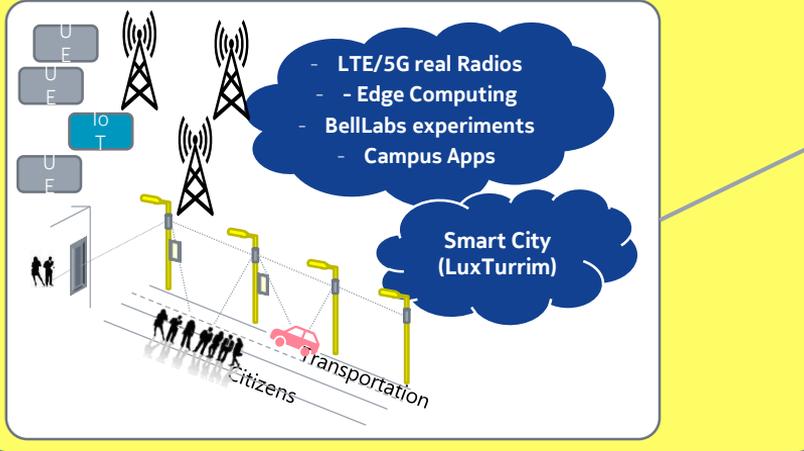6. Learning (shared lectures with universities, hands on training)
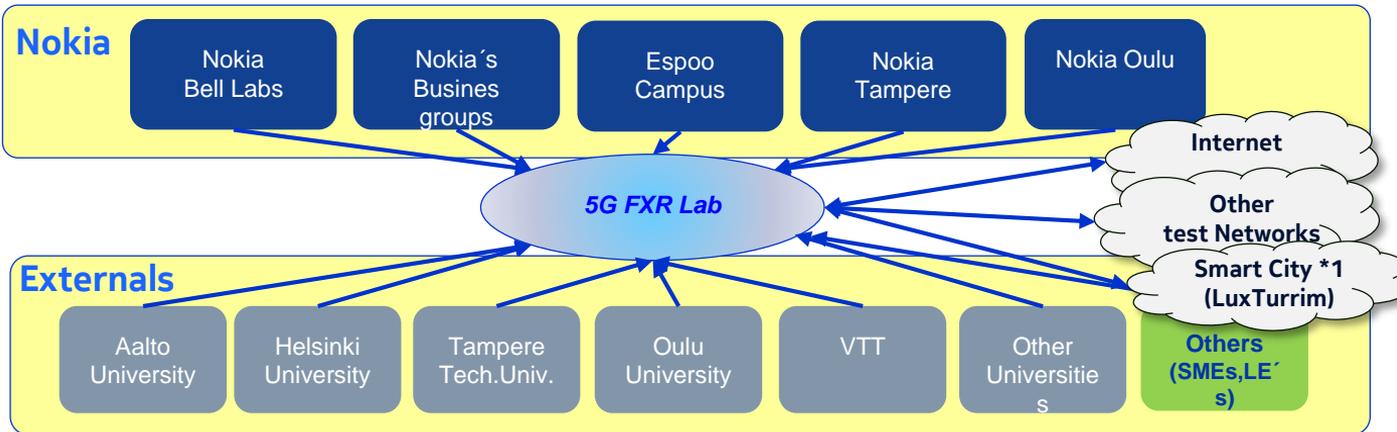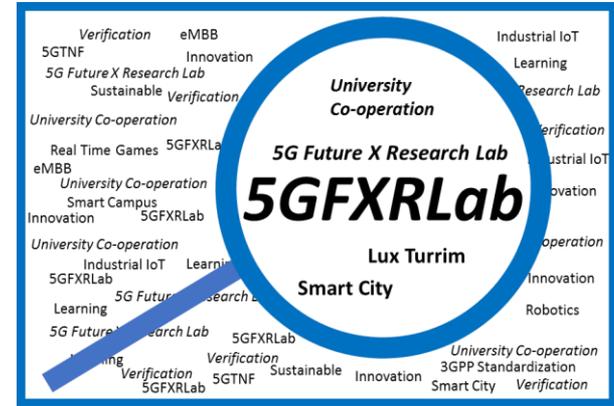
Features (for example):
- **Radio access for: 4G/5G/ mm and cm waves.**
- **WiFi and Fixed access**
- **Cellular and fixed IoT**
- **Cloud RAN, ORAN**
- **Network Slicing**
- **DevOps mechanism with SAFe**
- **Data Collection and Analytic (ML/AI – DCAP & AVA) for Internal and External data**
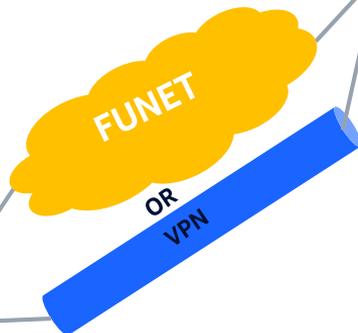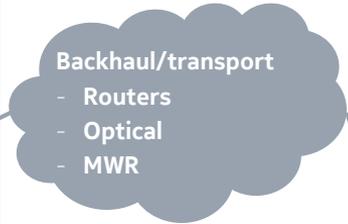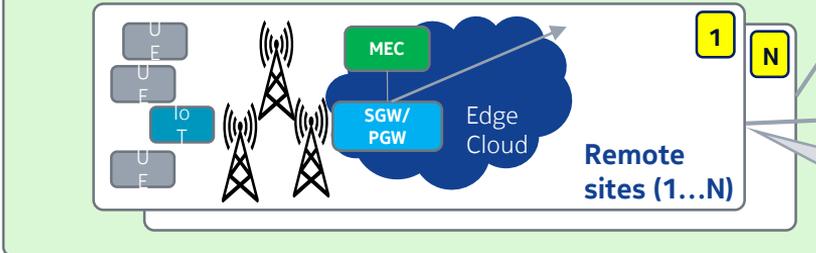- **URLLC/MEC for Games, Health Care, Robotic…etc….**
- **Cloud Core (Voice & Data)**

Nokia

Nokia Bell Labs	Nokia´s Busines groups	Espoo Campus	Nokia Tampere	Nokia Oulu

5G FXR Lab

Internet

Other test Networks

Smart City *1 (LuxTurrim)

Externals

Aalto University	Helsinki University	Tampere Tech.Univ.	Oulu University	VTT	Other Universities	Others (SMEs,LE´s)

NOKIA

5G Future X Research Lab. - technical view

© 2019 Nokia

NOKIA
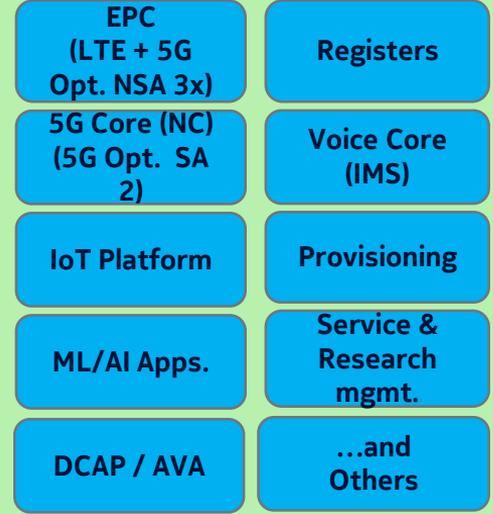
Thank You!

Autumn colours in Häme region 2019