5G for the Programmable World

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5G era - The shift to the Programmable World is already underway
Explosion of possibilities: new performance levels of people and things

AUGMENTED
- Augmented shopping
- Augmented dashboard
- Augmented gaming

INTERCONNECTED
- 4k Video
- 8k Video beamer
- Real time work in cloud
- Mobile living

VIRTUAL
- Communication
- Virtual 3D presence

REDEDICATED
- Work & game while traveling
- Logistics
- Maintenance optimization

TACTILE
- Real-time remote control
- Touch & steer

AUTOMONOUS
- Self driving
- Assisted driving
- Factory automation
- Real-time remote control

REVOLUTIONIZED
- Traffic Mgmt.
- Industry 4.0

VIRTUAL
- Real-world mobility
- Advanced monitoring
- Health

INTERCONNECTED
- Travel & commute
- Real-time cloud access
- 8k Video beamer

REAL MOBILITY
- Real-time road traffic
- 4k Video
- 8k Video beamer

4th Industrial Revolution

People & Things

High performance infrastructure

SAFE & SECURE
- Reliable emergency communications

SUPEREFFICIENT
- Waste mgmt.
- Traffic steering & management

TOURING & COMMUTE
- Work & game while traveling
- Logistics
- Maintenance optimization

POWER & EFFICENCY
- Reliable emergency communications
- Waste mgmt.
- Traffic steering & management

THE FUTURE IS NOW
- Communication
- Virtual 3D presence

PERSONAL ROBOT
- Personal robot
- 8k Video beamer
- Real time work in cloud

PERSONAL ROBOT
- Personal robot
- 8k Video beamer
- Real time work in cloud
Heterogeneous use cases – diverse requirements

5G

"Unlimited experience"
100 Mbps whenever needed

"For everything"
>10 Gbps peak data rates

"Instant action"
10 000 x more traffic

Extreme Mobile Broadband

10-100 x more devices

Massive machine communication

M2M ultra low cost

Critical machine communication

10 years on battery

<1 ms radio latency

Ultra reliability

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5G for people and things | Key to the programmable world
Versatile radio

Unlocking spectrum assets

Dynamic resource usage

Configurability

Massive MIMO

Multi-connectivity

Extreme Mobile Broadband

Critical machine communication

Massive machine communication

Slim Radio

1ms Radio

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Unlocking new spectrum assets | The Foundation for 5G

Leveraging all bands, ranging from ~400MHz - 100GHz

Lower frequencies translate into continuous coverage for high mobility and reliability cases

Higher frequencies translate into higher capacity and massive throughput

Different characteristics, licensing, sharing and usage schemes

Carrier BW: \( n \times 20\text{MHz} \times 100\text{ MHz} \times 1-2\text{GHz} \)

Duplexing: FDD, TDD

Cell size: Macro, Small, Ultra Dense

Coverage vs. Capacity

10 years 100 Mbps 10-100 x 10,000 x ultra low >10 Gbps <1 ms

Leading channel modeling know-how
Channel measurements from 3-73GHz

Leading METIS I & II spectrum work package

Worlds 1st Wide Area Single Frequency Network trial in UHF band

Worlds 1st Licensed Shared Access demos/trial

Nokia Solutions and Networks 2015
Tokyo Bay Summit 2015 - Lauri Oksanen
Multi-Connectivity | Perception of infinite capacity

One System of versatile radios collaborating perfectly together

Throughput

~3x higher area throughput
Gradual introduction leading to smooth migration/transition
Cost and energy efficient deployment
Fulfilling coverage & capacity demands and business needs

Extreme mobility robustness and ultra reliability

Improved performance
Split of control and user plane transmission across layers/technologies

4G/5G real-time radio resource prototype

- 10,000 x
- >10 Gbps
- 100 Mbps
- <1 ms
- 10-100 x
- ultra low
- 10 years
Native massive MIMO | Let the capacity follow the demand

SE improvement @ lower bands
Compensating path loss with high Beamforming gain (with large number of antennas) @ high bands

<table>
<thead>
<tr>
<th>Massive MIMO gain LTE@2GHz</th>
<th>Cell Avg.*</th>
<th>Cell Edge*</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 Tx Rx</td>
<td>~200%</td>
<td>~130%</td>
</tr>
<tr>
<td>64 Tx Rx</td>
<td>~200%</td>
<td>~700%</td>
</tr>
</tbody>
</table>

Different frequency ranges requires different phased array architecture
Applicable for both macro and small cells

Higher carrier frequency \(\rightarrow\) smaller antenna arrays

16 controllable antenna elements
e.g. 16, 32, 64, 256, ...

Phased Array Research
Cooperation with top industry and univ.

74GHz mmWave Indoor & Outdoor trials with NTT DOCOMO

Active massive antenna demo with Mitsubishi

10Gbps with National Instruments

* Note: vs. LTE Rel. 12
Configurability | One versatile radio for many deployments

Flexible radio parameter setting for tailored use cases and QoE

Diverse use cases

Diverse deployments

Sub frame lengths

Scalable carrier bandwidth

OFDMA-based waveform

10 years 100 Mbps 10-100 x 10,000 x ultra low >10 Gbps <1 ms

For all use cases
E.g. different sub-frame lengths for different latency requirements

E.g. different subcarrier spacing for different deployment needs

For all deployment
E.g. different frequency bands (above and below 6GHz), macro and SC
E.g. aggregation of (fragmented) bands or cells

Flexible radio parameter setting for tailored use cases and QoE

Diverse use cases

Diverse deployments

Sub frame lengths

Scalable carrier bandwidth

OFDMA-based waveform

Same for uplink & downlink

5MHz → 2GHz

Adjusted to latency requirements

Ultra-dense (Low power) Wide area Crowd Outdoor Indoor

10,000 x >10 Gbps 100 Mbps <1 ms 10-100 x ultra low 10 years

Latency

Throughput

50%

+30%
5G for people and things | Key to the programmable world
System of systems

- Efficient mobility provisioning
- Fast traffic forwarding
- Dynamic experience management
- Service-determined connectivity
- Extreme Mobile Broadband
- Critical machine communication
- Massive machine communication

Network Slicing
Network Slicing | Made-to-order use case support with virtual sub-networks

Multiple independent instances on one physical network

- Full automation and self-optimization
- Optimized service delivery for heterogeneous use cases and businesses
- Common composable network functions
- Enabling NaaS business model for all kinds of industries

**Cognitive**
Dynamic network level control & orchestration

**Programmable**
Software-defined functions for

**Mobile Edge computing**
Content & processing where it's needed

- 10,000 x
- >10 Gbps
- 100 Mbps
- <1 ms
- 10-100 x
- ultra low
- 10 years

*5G Novel Radio Multiservice adaptive network Architecture

Leader of 5G PPP project NORMA* to design the 5G multiservice architecture

**5G ready**
Nokia AirFrame datacenter

Programmable SDN based x-Haul
Any-to-any meets point-to-point => many to many connectivity

- Shortest and optimal path for U-plane routing
  e.g. critical M2M
- Support for new network services
  that require relocatable low latency and high reliability
  (multi-connectivity) services
- Higher resilience against disconnect from core
- many-to-many type of connectivity
  e.g. for V2X where the combination of low latency and full mobility is key
- C and U plane separation demo with SKT
- Mobile Edge Computing trial for Car to Infra

- Service-determined connectivity | Latency, resilience and FMC

- Features:
  - Latency: <1 ms
  - Relocatable low latency and high reliability
  - Mobility on demand
  - Traffic routed through core
  - Shortest and optimal path
  - Low-latency virtual networks
  - Many-to-many type of connectivity
  - Higher resilience
  - 10 years
  - >10 Gbps
  - Broadband Internet

- Technologies:
  - 5G AP / MCA-U
  - Local packet forwarder
  - Local Anchor
  - Local service or application
  - Broadband Internet
  - MEC applications, local service chains
  - Centralized IP Anchor
  - Local switching to near-by UE
  - Traffic passed through local service or application
  - Pass through local service or application
  - Local content/server
  - Mobility on demand
  - Alternative local termination, with mobility support

- Benefits:
  - Local switching to near-by UE
  - Pass through local service or application
  - MEC applications, local service chains
  - Broadband Internet
  - Centralized IP Anchor
  - Traffic routed through core
  - Local switching to near-by UE
  - Low-latency virtual networks
  - Mobility on demand
  - Alternative local termination, with mobility support

- Applications:
  - Car to Infra"
Dynamic Experience Management | Superior quality at less resources

Automated QoE optimization of each application session

- Full QoE awareness of application sessions
- Immediate QoE degradation prediction
- Root cause analysis
- Decision making powered by self-learning

- Immediate action before problems arise

4 x QoE compared to today

→ 100% Successful sessions in congested networks

+20-30% capacity

Unique Nokia solution available today – even more important in the heterogeneous 5G environment

Live demo quality optimization for video services at MWC 15

- 4 x QoE
- >10 Gbps
- 100 Mbps
- <1 ms
- 10-100 x
- ultra low
- 10 years

Seconds

10,000 x

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Collaboration partnership on the journey to 5G

- 2020 Olympics
- 2019 WRC19
- 2018 Phase 1 standard
- 2017 3GPP work item
- 2016 3GPP 5G study begins
- 2015 Field testing, WRC2015
- 2014 Delivery of mmWave Demo