5G

What to expect and where to start

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Technology & Innovation Research
Outline

Why
The human possibilities of 5G

What
5G key technologies

When
5G success factors

Nokia
Geared to lead in 5G
How 5G will blend into everyday’s life

Is it possible to coordinate millions of sensors in a cell?
Only if the system of network and devices work efficiently

Can I trust machines that act autonomously?
Only if they interact absolutely reliable and fast enough

Can I update my operating system instantly?
Only if sufficient bandwidth on demand is guaranteed
5G will expand the human possibilities of the connect world

Throughput

- >10 Gbps peak data rates
- 100 Mbps avg. goodput

Latency, Reliability

- <1 ms latency
- 10 000 x more traffic

# of Devices; Cost; Power

- M2M ultra low cost
- 10 years on battery

Cost; Power

- 10-100 x more devices

(M2M) Wide area

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

3D video – 4K screens

- Gigabytes in a second

Mission critical broadcast

- MBps transferred in an instant
- Mission-critical wireless control and automation

Work and play in the cloud

- Augmented reality

Industry & vehicular automation

- Self Driving Car

Smart city cameras

- Voice

Sensor NW

- Augmented reality

M2M

- Voice

Voice

- Throughput

Throughput: 5G
What 5G is NOT

Myth #1
5G = millimeter wave only

Myth #2
5G = utilizes above 6 GHz only

Myth #3
5G = will use totally new access

Myth #4
5G will be fully specified by 2018

What 5G is ...

5G might have one UDN access technology leveraging mmW to complement other lower band wide area/cellular access technologies

5G will use existing and new IMT spectrum below 6 GHz as well as above 6 GHz (WRC2019)

5G is expected to leverage OFDM and cyclic-prefix single carrier for best massive-MIMO and beamforming support as well as cost and energy efficiency

3GPP 5G releases 14 and 15 last into 2018/19 World Radio Conferences takes place in 2019 IMT process for “5G” runs till 2020. First commercial 5G deployments in 2020
5G system vision
A symbiotic integration of novel and existing access technologies

5G Wide area deployments
Scalable service experience anytime and everywhere

- 4G ‘massive mobile data and M2M’
- 3G ‘voice, video and data’
- 2G ‘high quality voice and M2M’
- Wi-Fi ‘best effort data’
- Fixed access

Zero latency and GB experience – when and where it matters

5G Ultra dense deployments
Integration enabling seamless user experience and efficient operation with cloud and SDN technologies as underlying principles

For end user:
5G will provide ubiquitous connectivity as well as high and consistent user experience

Unified solution
For operator:
a tight integration enabling simplified network mgmt of the whole access portfolio and gradual introduction of 5G

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### 5G technologies under study

<table>
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<tr>
<th>Spectrum access and efficiency</th>
<th>Deployment</th>
<th>Reliability – Flexibility – Scalability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massive MIMO and massive beam forming</td>
<td>Multi-RAT integration</td>
<td>New waveforms and modulations</td>
</tr>
<tr>
<td>3..6 GHz: Spectral efficiency (MIMO), &gt;&gt; 6 GHz more about path gain (BF)</td>
<td>5G is integrating novel and existing radio access technologies</td>
<td>Must be justified by gains, compatibility with MIMO essential</td>
</tr>
<tr>
<td>Centimeter-Wave and Millimeter-Wave Spectrum access, for dense deployments</td>
<td>Radio virtualization</td>
<td>Flexible Networking</td>
</tr>
<tr>
<td></td>
<td>Parts of radio will be virtualized, need for specialized L1 HW may still persist</td>
<td>Local gateway/services Per-service tailored feature set (mobility, QoS, latency etc.)</td>
</tr>
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</table>
5G is to optimize below 6 GHz access and enable above 6 GHz access
Expanding the spectrum assets to deliver capacity and experience

<table>
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<tr>
<th>Availability LOS</th>
<th>Spectrum availability</th>
<th>Antenna technologies</th>
<th>Interference conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell size LOS/NLOS</td>
<td>mmWave local area (e.g. 70-90 GHz)</td>
<td>~1 GHz carrier bandwidth High data rates</td>
<td>Low Rank MIMO/BF efficient beam steering More noise limited (70-90GHz)</td>
</tr>
<tr>
<td>cmWave solid area (&lt; 30 GHz)</td>
<td>Several ~100 MHz</td>
<td>High Rank MIMO higher data rates</td>
<td>Interference coordination/rejection</td>
</tr>
<tr>
<td>Below 6GHz wide area (&lt;6.5GHz)</td>
<td>Low latency support with flexible air interface</td>
<td>High Rank MIMO, limited by the size of antennas Carrier aggregation essential</td>
<td></td>
</tr>
</tbody>
</table>

| Different spectrum licensing, sharing and usage schemes | |

- **Cell size LOS/NLOS:**
  - 10 cm (3 GHz)
  - 1 m (300 MHz)
  - 1 m (300 MHz)

- **mmWave local area:**
  - ~1 GHz carrier bandwidth
  - High data rates

- **cmWave solid area:**
  - Several ~100 MHz

- **Below 6GHz wide area:**
  - Low latency support with flexible air interface
  - High Rank MIMO, limited by the size of antennas
  - Carrier aggregation essential
5G radio interface technologies

Ultra Dense Networks

Throughput

Ultra Reliable Networks

Latency; Reliability

Critical Machine Time Communication

Massive Machine Type Communication

Ultra Deep Networks

Connection Density

Latency

# of Devices; Cost; Power

Gigabytes in a second

10Gbps, 4K screens

Workplace in the cloud

Augmented reality

Industry & vehicular automation

Mission critical broadcast

Self-Driving Car

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5G technology summary

1. Spectrum (below and above 6 GHz)
2. New tailored Radio Interface Technologies
3. Optimized for low latency, reliability and throughput
4. Architectural evolution with multi-technology integration
5. Design for Flexibility, Reliability and Scalability
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## What is needed to make 5G a true global success?

**Growth and Enabler of societal innovation**

<table>
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<tr>
<th>Flagship of Digital Agenda</th>
<th>Cross region collaborative research and pre-consensus</th>
<th>Market driven competition and consolidation</th>
<th>Legislation on Net Neutrality</th>
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</thead>
<tbody>
<tr>
<td>Drive global standardization</td>
<td>More globally harmonized spectrum (for LTE and 5G)</td>
<td>Data Protection for information centric networks</td>
<td>Fair rules for standard essential patents</td>
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5G from research to standards

**Release 13:** Clean LTE-A evolution release
5G research progressing outside 3GPP

**Release 14:** The 5G study phase
leading to Rel-15 work item phase

**Release 15:** The first phase of ‘The Real 5G’;
completion between 2018 and 2020

“5G starts early 2016 in 3GPP with Release 14 and then into Release 15”

“ITU-R processes for IMT2020 run in parallel in close sync”

Note: Future 3GPP release timing uncertain
**Success factors**

**Summary**

1. Pre consensus building among players during explorative research and requirements phases.
2. Global regulatory approach and aim for harmonized spectrum incl. its timely availability.
3. Focused standardization in 3GPP without reducing attention and bandwidth for LTE work.
4. Early sharing of technology feasibility and evaluation results to avoid design at the \(\text{Edge}\).
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The Nokia way for the 5G Marathon
“If you want to go fast, go alone but if you need to go far, go together”

Outside in 5G
- Collaborative research e.g. 5G PPP, 863 5G
- Customer collaborations e.g. DOCOMO, CMCC, ...
- Drive regulatory and industry work e.g. ITU-R

Inside out 5G
- University collaborations e.g. NYU, TUD, Aalto etc.
- Holistic systems research, prototyping & development
- Leverage One Nokia e.g. Technologies and HERE