Air interface evolution towards 5G

Presenter: Klaus I. Pedersen, Nokia Networks
5G will enable very diverse use cases with extreme range of requirements

- >10 Gbps peak data rates
- Massive Broadband
- 100 Mbps whenever needed
- 10-100 x more devices
- M2M ultra low cost
- 10 years on battery
- Massive machine type communication
- Ultra reliability
- <1 ms latency

- 10 000 x more traffic
- Capacity for everyone
- 3D video / 4K screens
- Work in the cloud
- VR gaming
- Industry 4.0
- Autonomous driving
- Remote control of robot
- Mission critical broadcast
- Sensor NW

- # of Devices | Cost | Power
- Critical machine type communication
- (Low power) Wide area
- Crowd
- Ultra-dense
- Outdoor

- A trillion of devices with different needs
- GB transferred in an instant
- Mission-critical wireless control and automation
5G is to enable above 6 GHz & optimize below 6 GHz access
- 5G to be initially deployed below 6 GHz due to band availability

**WRC**

- 2015: Some additional bands <6GHz to be identified – in time for 2020 deployments
- 2019: Expected to identify >6GHz bands – too late for 2020 deployments

**Bands**

- 3…6 GHz unpaired band is candidate for first 5G deployments.
- Ready for > 6 GHz unpaired bands
- Easily extensible to paired bands, also under 3 GHz

- 100-200 MHz carrier bandwidth supported
- High degree of spectrum flexibility required (fragmented spectrum)
- Carrier aggregation / dual connectivity, also with LTE bands
## Lean Carrier Design

Lean carrier = no unnecessary transmission of wideband control data.

- Less inter-cell interference
- Lower BTS power consumption
- Lower UE and IoT device power consumption with narrowband AD converter

### Transmission activity in empty cell

<table>
<thead>
<tr>
<th></th>
<th>LTE</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current solution</td>
<td>Continuous transmission of common reference signals</td>
<td>No unnecessary transmissions in empty cell</td>
</tr>
</tbody>
</table>

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Flexible Frame Structure

Solutions

- Flexible frame size
- Flexible control channel
- Beamforming optimized
- Flexible TDD asymmetry

Benefits

- Latency <1 ms
- Efficient mux of users with diverse requirements.
- More efficient interference management
- Higher beamforming gain

Flexible trade-offs between enhanced spectral efficiency, low latency and increased reliability.

Practical LTE latency 10-20 ms

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Example of flexibility in terms of variable TTIs

**Fundamentals:**
- Short RTT calls for a short TTI size.
- The relative control overhead is larger for short TTI sizes.
- Longer TTI allows higher TBS, better time diversity, efficient FEC.

**Low cost MTC use case:**
- Scheduled on moderate BW with longer TTI size
- Low BW and long TTI is attractive from cost and coverage p.o.v.

**MCC use case:**
- Short TTI size to meet latency requirements.
- TTI size adapted according to latency constraints.

**MBB use case:**
Start TCP sessions with short TTI size to quickly overcome the slow-start phase, followed by using medium size TTI to minimize control overhead.

**Broadcast use case:**
Scheduled with long TTI size to maximize FEC gains from time-diversity.

**Observation:** A flexible frame structure with dynamic adjustment of TTI size per user is one possibility.
## Waveforms – Flexibility for Different Services

<table>
<thead>
<tr>
<th>Use case</th>
<th>Optimization target</th>
<th>Waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile broadband synchronous transmission</td>
<td>Spectral efficiency</td>
<td>Similar solution as in LTE like OFDMA and SC-FDMA</td>
</tr>
<tr>
<td>TDD beamforming optimization</td>
<td>Same waveform in uplink and downlink for beamforming</td>
<td>Uplink and downlink harmonization</td>
</tr>
<tr>
<td>Base station power efficiency</td>
<td>Low RF requirements (peak-to-average-power)</td>
<td>Single carrier solution for high bands in downlink (Zero Tail is similar to single carrier)</td>
</tr>
<tr>
<td>Small packet asynchronous transmission</td>
<td>Low overhead for small packets</td>
<td>Other solution could be considered</td>
</tr>
</tbody>
</table>

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## Overview of New Waveform Options

<table>
<thead>
<tr>
<th>OFDM</th>
<th>SC-FDMA</th>
<th>LTE solution</th>
<th>New waveforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Low transceiver complexity</td>
<td>- Low amplifier requirements</td>
<td>• Downlink OFDM</td>
<td>• Lower emissions</td>
</tr>
<tr>
<td>- Simple MIMO</td>
<td>- Advanced receiver required</td>
<td>• Uplink SC-FDMA</td>
<td>• Less Cyclic Prefix overhead</td>
</tr>
<tr>
<td>- Frequency domain</td>
<td>- Limited frequency scheduling</td>
<td>• OFDM fine for synchronous transmission also in 5G</td>
<td>• Some gain for asynchronous transmission like IoT</td>
</tr>
<tr>
<td>scheduling</td>
<td></td>
<td></td>
<td>• Flexibility for different subcarrier spacings</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Good to have same solution in uplink and downlink</td>
</tr>
<tr>
<td>ZT-DFT-OFDM (Zero Tail)</td>
<td>FBMC (Filter Bank Multicarrier)</td>
<td></td>
<td></td>
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<tr>
<td>- Lower out of band</td>
<td>- Lower out of band emissions</td>
<td></td>
<td></td>
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<tr>
<td>emissions</td>
<td>- Similar performance as SC-FDMA</td>
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<td></td>
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<tr>
<td></td>
<td>- No Cyclic prefix overhead</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- MIMO extension difficult</td>
<td></td>
<td></td>
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<tr>
<td>GFDM (Generalized</td>
<td>UFMC (Universal Filtered)</td>
<td></td>
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<tr>
<td>Frequency)</td>
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<td>• High receiver complexity</td>
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<td>• Robust to frequency offset</td>
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UE Agnostic Massive MIMO and Beamforming

**UE agnostic MIMO**
Network capacity can be upgraded with base station MIMO without new 3GPP definitions and without new devices. This solution applies for any frequency bands.

**Massive MIMO**
Large number of antenna ports (>32) can be utilized at high frequency bands to boost the link performance and minimize interference. Grid-of-beams (GoB). Hybrid eNB antenna architectures.
Small Packet Efficiency – Massive MTC access

Solutions

• Contention based transmission
• Coding scheme enhancements
• Session on demand

Benefits

• Lower synchronization requirements
• Faster decoding for small packets
• Minimized signalling overhead

- LTE: more than 10 radio signalling messages required for call setup, and additional signalling for call release
- LTE: uplink synchronization, capacity request and resource allocation required
- Potential for improvements!
Mission Critical Communication (MCC) – Ultra Reliability

Ultra reliable communication:
Successfull transfer of a payload of $B$ bits within a time of $T$ seconds with high probability (e.g. 99.999%).

Possible enablers (examples):
- Diversity and redundancy
- Short TTI sizes, robust control CH
- Efficient error correction coding
- Active interference management
- Cell densification

SINR statistics for different MIMO options:

- $1 \times 1$
- $2 \times 2$
- $4 \times 4$

Cumulative Distribution

Instantaneous SINR [dB]

~40 dB
Example of SINR Outage Performance

Results for a traditional three-sector macro scenario

SINR target at 0 dB is a reasonable value for reliable low data rate communication.

Reaching the 0 dB SINR target with high reliability (10^-5 outage) requires both high order microscopically macroscopic and macroscopic diversity.

Interference cancellation and/or resource partitioning helps as well.
Multi-Node and Multi-Technology Aggregation

5G can be aggregated together with LTE both from different sites and from multiple bands

Multi-site aggregation

• Smooth 5G introduction
• Simpler refarming
• Higher user data rates

Multi-band aggregation
A symbiotic integration of novel and existing access technologies
Nokia 5G system vision

Scalable service experience anytime and everywhere

<table>
<thead>
<tr>
<th>5G</th>
<th>Wide area and Ultra-Dense deployments</th>
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| Zero latency and GB experience – when and where it matters

<table>
<thead>
<tr>
<th>4G</th>
<th>Massive mobile data and M2M</th>
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<tbody>
<tr>
<td>3G</td>
<td>Voice, video and data</td>
</tr>
<tr>
<td>2G</td>
<td>High quality voice and M2M</td>
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<tr>
<td>Wi-Fi</td>
<td>Best effort data</td>
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<td>Fixed access</td>
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5G for people and things
New performance levels 2020+

“It is dangerous to put limits on wireless” (1932)
-Gugliemo Marconi