Old stuff refurbished for 5G:

60 GHz, FD-/TDMA, Beamsteering, Interference Management, Spatial Multiplex, Spread Spectrum, S-Aloha Access, Packet-Switching, Multi-Hop Relay, D2D, Self-Organization, Small Cells, Mobile Broadband, etc.

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FFV Workshop, Dresden, Oct. 21, 2016
1. 5G-Parameters

2. 5G Phases and Frequency Spectrum

3. Frequency Spectrum for IEEE 802.11 WLAN

4. Hot Spots, Small Cells, Het Nets are Answers to Scarce Spectrum for 5G

5. Old Stuff refurbished for 5G

6. Conclusions
Parameters and Key Technologies of 5G Phase-2 Systems

5G

Key Technologies

- Tech. for Above 6 GHz
- Adv. Coding & Modulation
- Adv. MIMO & BF
- Enhanced D2D
- Adv. Small Cell
- Interf. Management
- Flat Network
- Multi-RAT Interworking
- Mobile SDN

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Road Map for 5G Introduction

WRC: WRC-15 → WRC-18/19

3GPP: Rel-13 → Rel-15 → Rel-16 → Rel-17


5G Standards

Initial 5G Commercialization

ITU Document 5D/TEMP/390-E

ComNets
• 1.427 - 1.518 MHz
• 3.4-3.6 GHz (In Germany in total 50 MHz per mobile operator).
• TV bands (470-690 MHz) were not opened for mobile service.

WRC-19 will allocate bands **beyond** 28 MHz for mobile service. WRC-23 will consider TV-bands, anew.

But: IEEE 802.11ad (multi-Gbps @ 60 GHz) exists since 2012! (and will take the big share of 5G traffic in mmWave bands)
WRC-19: Candidate Frequency Bands for 5G (>= 2025)

WRC-19
- is expected to identify further spectrum beyond 6 GHz.
- most probably will identify less than a 5 GHz of this für 5G

Spectrum pre-ferred by NGMN for shared use (not matching WRC-19 candidate bands):

a. 6 – 20 GHz (e.g. 5.9 - 8.5 GHz, 9.9 - 10.6 GHz)
b. 20 GHz – 30 GHz (e.g. 21 - 23.6 GHz, 24.5 - 29.5 GHz,
c. 30 – 86 GHz (e.g. 31.8 - 33.4 GHz, 40 - 43.5 GHz, 66-76 GHz, 81-86 GHz,
• **5G Phase 1 Technique:** introduced in 2018/20 using spectrum below 6 GHz assigned by WRC-15. This system will be called „5G“.

• **5G Phase 2 Technique:** introduced in between 2025 and 2030 using frequency spectrum assigned by WRC-19 above 6 GHz

• From **2030** on system technique known as „6G“ will be used.
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IEEE 802.11ad:

Channel | Center frequency
---|---
1 | 58.32 GHz
2 | 60.48 GHz
3 | 62.64 GHz
4 | 64.8 GHz

.11ah: WLAN in ISM Band at 900 MHz. Radio range / Data rate are larger / smaller than at 2.4 / 5 GHz.
Inhalt

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6. Conclusions
Small Cells result are extremely costly in terms of
- CAPEX (capital expenditure)
- OPEX (operations expenditures)

**Typical parameters in 2020:**

<table>
<thead>
<tr>
<th>BS type</th>
<th>Coverage radius (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro cell</td>
<td>400</td>
</tr>
<tr>
<td>Micro cell</td>
<td>200</td>
</tr>
<tr>
<td>Pico cell</td>
<td>40</td>
</tr>
<tr>
<td>Hot spot</td>
<td>10</td>
</tr>
</tbody>
</table>

Heterogeneous networks combine macro, micro, pico and femto cells to meet the local capacity requirements.

Macro- / Micro-, Pico- and Femtocells in part operate in different frequency bands and are based on different frequency bands *and* Radio Access Technology (RAT) Standards.
mm-Wave supported 5G System

Millimeter Wave Hotspots for Backhaul & Access

The Technology Solution for 5G Small Cell Access and Backhaul
- Capacity growth beyond what emerging Small Cell and Spectrum Sharing solutions can provide
- 100x – 1000x growth!

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Summary:

System design of a LCRN is presented and a distributed organization is described to create a virtual TDM trunk carrying approx. 30Erl. of full-duplex traffic. Channel transmission rates of 16 and 64kbit/s are used for voice and data, respectively. Stations of the LCRN function as relays to extend the effective distance between transmitters and receivers to a multiple of a single line-of-sight connection. Stations may adapt their radio power dependent on the traffic needs and the transmission characteristics observed. The paper describes the transmission techniques used as well as the main protocol functions and the most important management tasks (e.g. joining/leaving the system, channel management, signalling, routing etc.).
Key Concepts of LCRN #2

- Mobile Broadband (3 MHz IF bandwidth) at 60 GHz, (1985)
- S-Aloha; FD-/TDMA for both, control and data channels (1985)
- Spread Spectrum (link gain) (1985)
- Packet Switching with short address carried in packets (1985)

Fig. 2 from LCRN 1985 paper

Single slot: 16 kbit/s (voice)
Multi-slot: 64 kbit/s (data)
Cell radius: 500 m (LOS)
Coordinated beam steering with interference avoidance
Peak data rate grows by factor 100 in 10 years (Moore: VLSI processing power doubles in 18 months).

Key Concepts of LCRN #3

- Mobile Broadband @ mm-waves (60 GHz) 1985
- S-Aloha; FD-/TDMA for control & data channels 1985
- Spread Spectrum (link gain) 1985
- Packet Switching (short address in packet 1985
- Dynamic Beam Steering 1985
- Spatial multiplexing
- Multi-hop Relay & D2D Communications 1985

1985: LCRN paper

Re-use of radio resources (ti)
- within same cell
- on multi-hop route.
Key Concepts of LCRN #4

- Mobile Broadband at mm-waves (60 GHz) 1985
- S-Aloha; FD-/TDMA for both, control and data channels 1985
- Spread Spectrum (link gain, color code) 1985
- Packet Switching with short address carried in packets, 1985
- Dynamic Beam Steering, 1985
- Multi-hop Relay & D2D Communications, 1985
- Self-organizing Mobile Ad-Hoc Network (MANET) 1985
- LCRN was IPR protected (Priority 1983)*
- LCRN was the template for GPRS**
- LCRN was further developed to be real-time supportive and to be WLAN IEEE 802.11 compatible***

*) DE 00000 3337 648, ...647, ...646, ...644, ...643 (5 Patents)

1985: LCRN paper

**) B. Walke: The Roots of GPRS. IEEE Wireless Communications, October 2013, 2-23

***) R Zhao, B Walke, GR Hiertz: An efficient IEEE 802.11 ESS mesh network supporting quality-of-service, IEEE Journal on Selected Areas in Communications 24 (11), 2005-2017
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Conclusions

Most functional and architectural characteristics of 5G systems were proposed 33 years ago, already: 60 GHz, FD-/TDMA, Beamsteering, Interference Management, Spatial Multiplex, Spread Spectrum, S-Aloha Access, Packet-Switching, Multi-Hop Relay, D2D, Self-Organization, Small Cells, Mobile Broadband, ..

Exponential growth of signal processing power allowed for ever more complex algorithms and operation of higher frequency bandwidth.

LCRN in 1983 was a mobile broadband system: Today it would transmit at > 16 Gbit/s per radio channel (Moore’s Law).

LCRN was the fertilizer for GPRS*, UMTS and, especially LTE-A/pro

Thank you!