

Signaling Overhead is a 5G Bottleneck and Advanced WLAN will make it in Hot Spots

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1. **Spectrum Efficiency and Overhead in LTE DL**
2. **5G RAN Architectures & Key Technologies**
3. **The 5G Control Plane Bottleneck**
4. **The 5G Design Error**
5. **Conclusions**

Spectrum Efficiency and Overhead in LTE DL

P. Mogensen et.al.: LTE Capacity compared to the Shannon Bound , IEEE 65th Vehicular Technology Conference 2007-Spring, 1234 - 1238

„Performance of a 10 MHz LTE DL including effects of system bandwidth efficiency and SNR efficiency, calculated for both, AWGN and TU channel, including features of advanced antenna techniques and **fast time and frequency domain packet scheduling (FDPS)** is

- **0.83** on link level (overhead is 17%)

- **0.57** for SISO / **0.54** for MIMO on system level (total OH is **43/46%**).”

Dedicated & Common Control Channel OH (system level) reduce BW efficiency by 26 to **29 %** in addition.

Impairment	Link: <i>BW eff</i>	System : <i>BW eff</i>
BW efficiency	0.9	0.9
Cyclic Prefix	0.93	0.93
Pilot overhead	1.0	0.94
Dedicated & Common control channels	N.a.	0.715
Total	0.83	0.57

<-- ~ 29 %

Even larger OH is expected for LTE-A (4G) and 5G.

The large signaling OH results from packet switching. Can channel switching for massive streaming services reduce OH - how much ?

AWGN = Additive White Gaussian Noise TU = Typical Urban

System Level Spectrum Efficiency for SISO / MIMO

P. Mogensen, et.al.: LTE Capacity compared to the Shannon Bound, IEEE 65th Vehicular Technology Conference 2007-Spring, 1234 - 1238

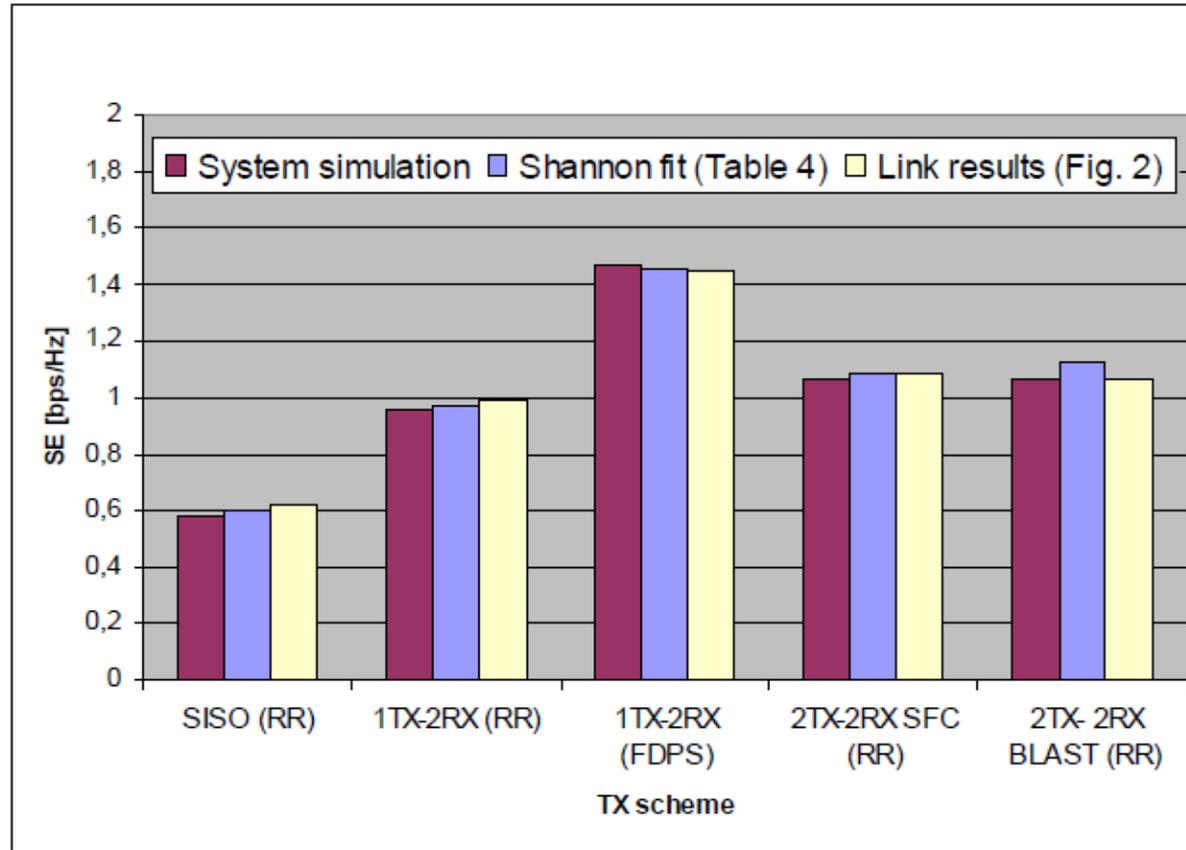


Fig. 6. Comparison of cell Spectral Efficiency from “Shannon Fit” parameters, results from semi-static “system simulations” and using the raw link simulation results. Macro cell case#1 .

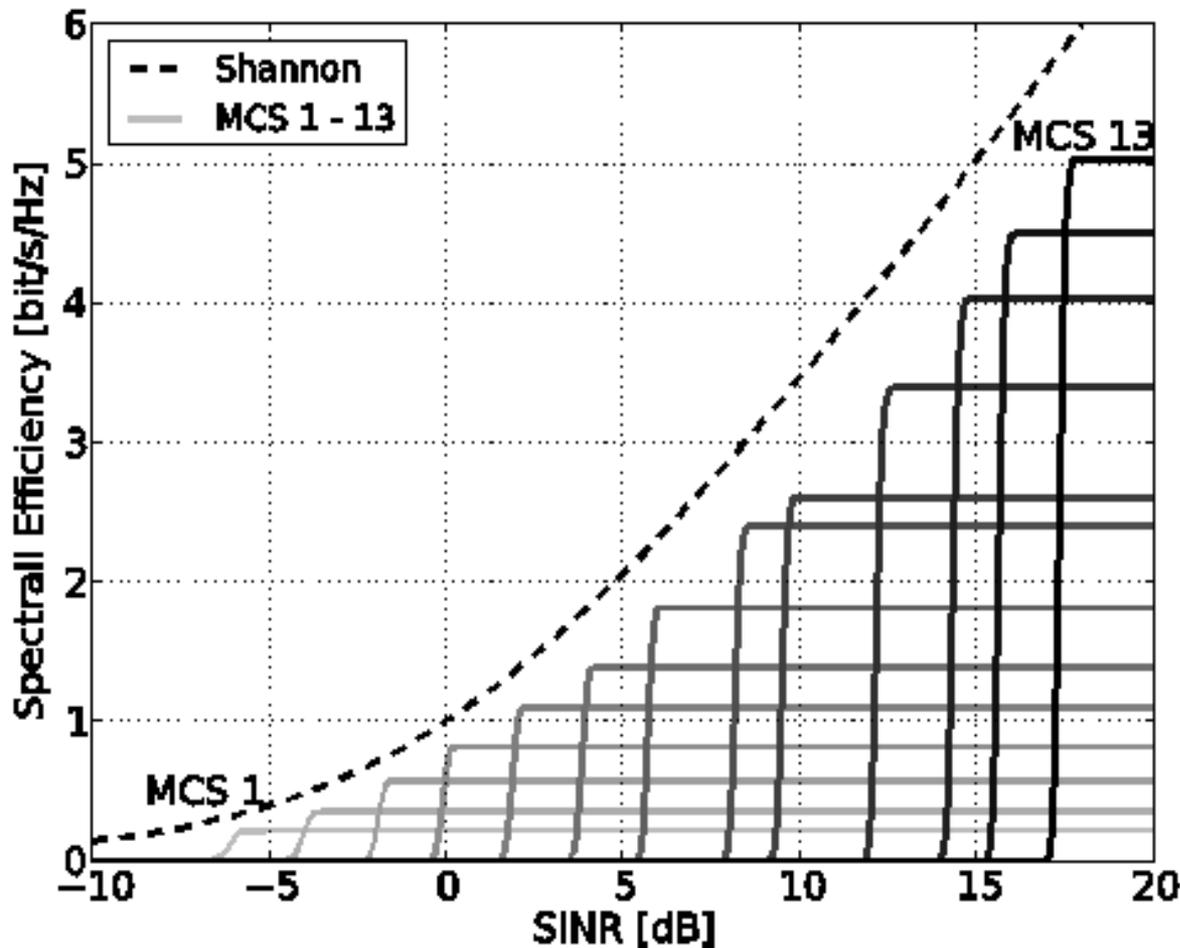
SE with link adaptation

SE in LTE DL for FDPS is about 1.4. (<1.0 in UL).

Fast Time and Frequency Domain Packet Scheduling (FDPS).

**SE in LTE (3.9 G) is
→ ~ doubled by MIMO
→ surprisingly small.**

Spectral Efficiency vs. SINR for various Modulation and Coding Schemes in LTE



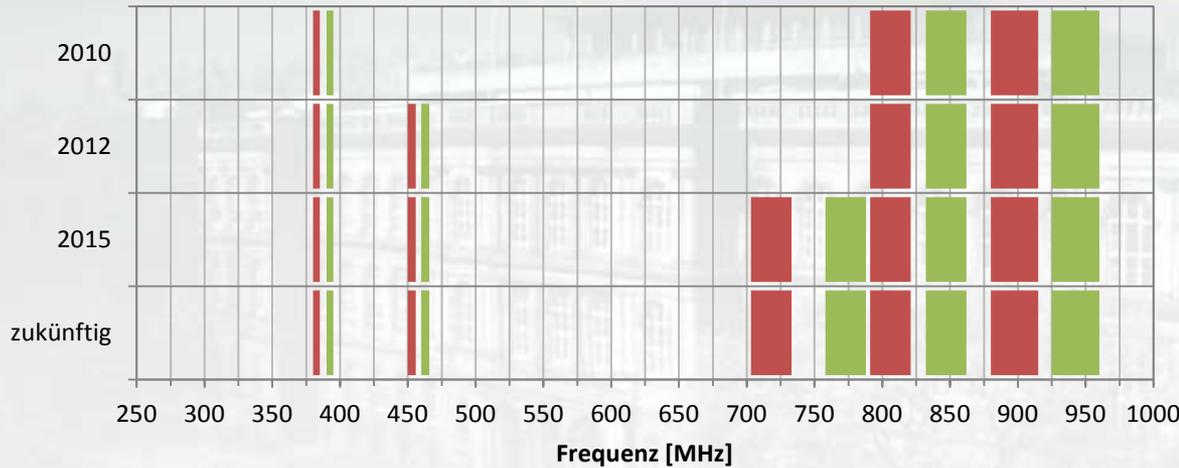
LTE mean spectral efficiency (SE) is ~ 1 bit/s/Hz

-> mostly low MCSs are used in general.

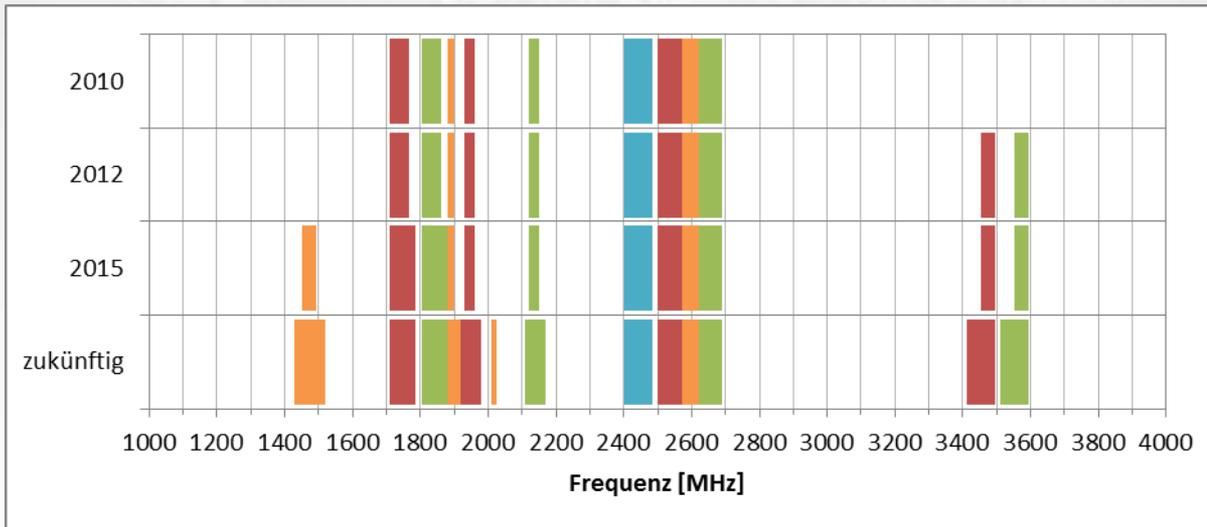
Control channels need low BER -> small MSC

ITU-SG5: Cell Spectral Efficiency of IMT-2020 (5G) shall be 3x that of 4G

German Frequency Allocations to Mobile Broadband / Wireless Services

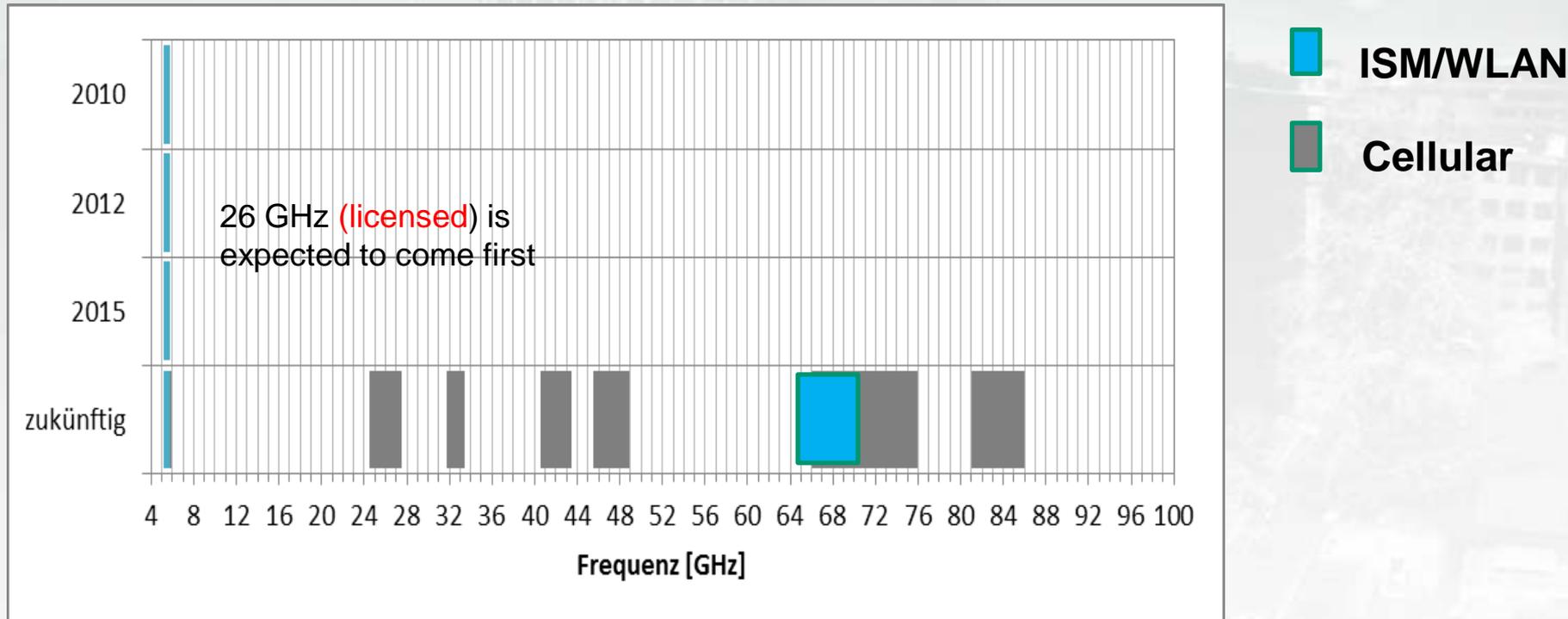


- UL
- ■ DL
- ■ TDD-unpaired
- ■ ISM Band (wireless)
- ■ 5G candidate bands.



~ **950 MHz** Spectrum licensed for **all network operators** in Germany **together**.

WRC-19: Candidate Frequency Bands for 5G (>= 2025)



WRC-19

- is expected to identify further spectrum beyond 6 GHz
- most probably **will identify about 3 to 5 GHz for 5G at 26 and 50 GHz**

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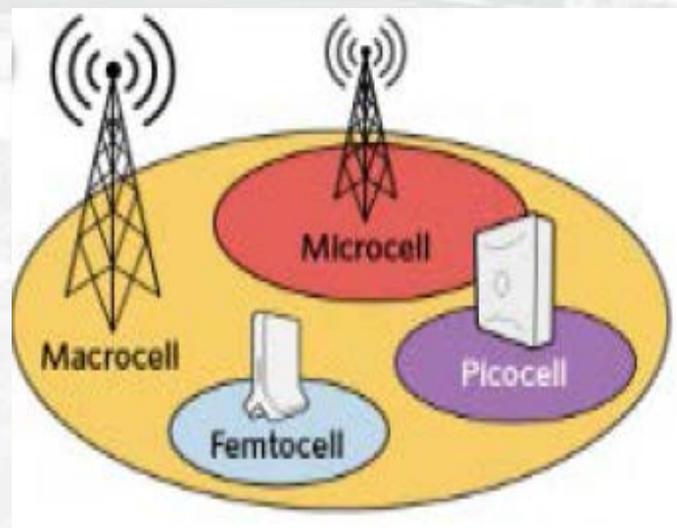
Heterogeneous (multi-tier) Networks built from different RAT Standards

Small Cells are extremely costly in terms of

- CAPEX (capital expenditure)
- OPEX (operations expenditures)

Typical parameters in 2020:

BS type	Coverage radius (m)
Macro cell about	400
Micro cell about	200
Pico cell about	40
Hot spot about	10



Heterogeneous networks (HetNet)

- combine macro, micro, pico and femto cells to meet the local capacity requirements
- in part operate in different frequency bands using different *Radio Access Technologies*
- May use Phantom Cells for robust C-plane signaling.

C-plane signaling via narrow antenna beams is difficult to achieve: HetNet with C-plane/U-plane Split result in „Phantom Cells“

Capacity enhancement of LTE / LTE-A towards LTE-B(eyond) by

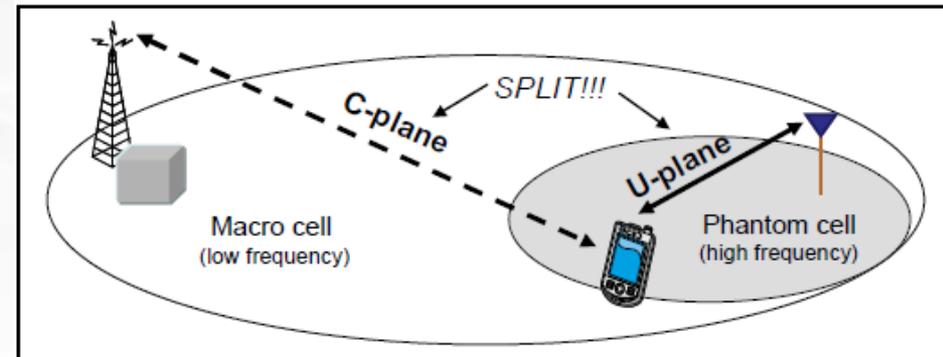
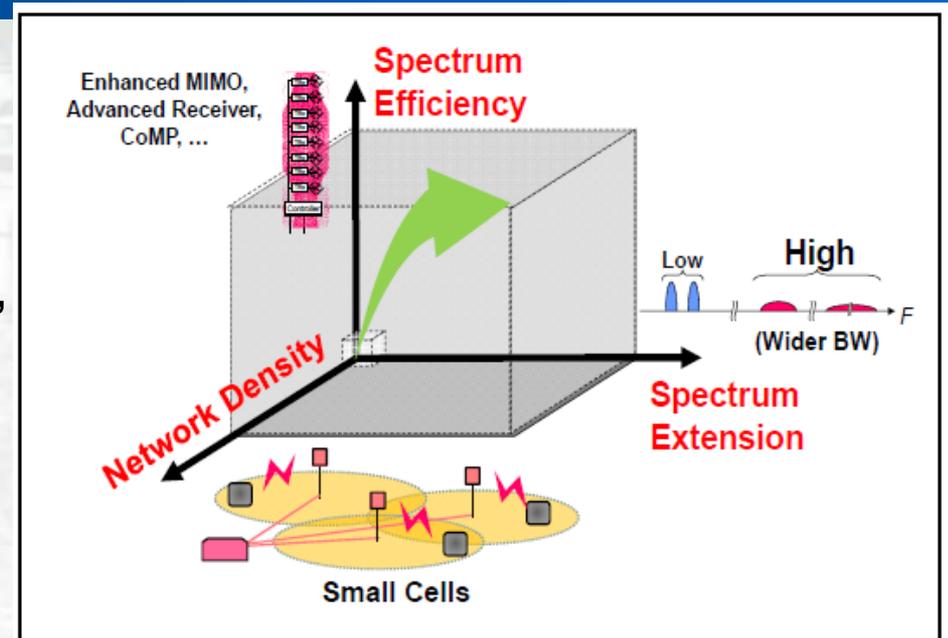
- Spectrum efficiency (**beamforming, massive MIMO, CoMP**, adv. receivers)
- Spectrum extension (carrier aggregation,
- Network density (HetNet).

Co-channel deployment of macro-/small cells, where remote radio heads and relays share frequencies of macro cells cause difficult mutual interference.

Spectrum < 2,5 GHz is fully loaded. Capacity extension is possible at > 3,5 GHz, where propagation loss is higher but much more spectrum is available.

C-plane / U-plane split applies spectrum at < 2,5 GHz in macro cell to control user data transmission in small cells at >3,5 GHz.

H. Ishii, Y. Kishiyama, H. takahasshi: A novel architecture for LTE-B, GLOBECOM Workshop on Emerging technologies for LTE-A and Beyond 4G, Anaheim 2012



Macro-BS beam covers Phantom Cell

Phantom Cells based on individual nodes

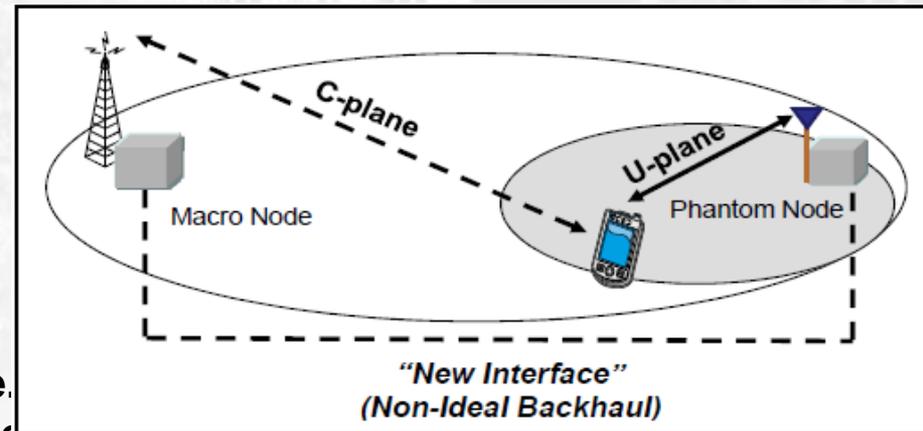
Signaling is provided by macro cell beam covering at least part of a Phantom cell.

Small cells (Phantom cells) are not conventional cells since they lack

- primary/secondary synchronisation signals (PSS/SSS)
- Cell specific reference signals (CRS)
- Master/system info block (MIB/SIB)
- ..

Radio resource control (connection and mobility management) is done by macro cell.

If Phantom cells are established as separate nodes, baseband processing can be done there. Then, a cable based **new interface** is required between



C-plane signaling still remains to be carried on spectrum $< 2,5$ GHz.
(A novel RAN architecture is required for node based phantom cells.)

H. Ishii, Y. Kishiyama, H. takahasshi: A novel architecture for LTE-B, GLOBECOM Workshop on Emerging technologies for LTE-A and Beyond 4G, Anaheim 2012

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The 5G control Plane Bottleneck - 1

5G Phase-2-System (> 2025), operated above 6 GHz will

- have 3-times spectral efficiency compared to 4G
- use e.g. **3 GHz of ~ mm-wave spectrum** (e.g. 26 and 50 GHz) and **~ 950 MHz in cm-wave spectrum** (0,7 – 2,5/3,5 GHz).

Comparing 4G to 5G, there is an increase of

- 3 in spectrum available for 5G
- 3 in expected spectrum efficiency.

Accordingly, the capacity may **increase up to ~ 9-fold**.

5G (>6 GHz) will mostly be based on distributed antenna system & massive MIMO (spatial mux & beam forming). No omnidirectional coverage is possible there.

At least part of Control Plane signaling (mobility management, association control, random access, resource assignment , etc.) **requires omnidirectional DL transmission carried on cm-wave spectrum.**

Signaling capacity increase is less than 9-fold. It must be robust.

The 5G control Plane Bottleneck - 2

- Massive MIMO need perfect CSI but suffer from more severe pilot contamination, and from significant hardware impairments increasing signaling overhead (SO) beyond that of LTE.

MTC for D2D comms. requires sophisticated interference coordination (-> SO increases).

Geo localization of UEs will be required, increasing SO.

→ **Dedicated & Common Control Channel OH (system level) will increase** compared to 4G **say 35%** (29% in 4G) equivalent to >1,05 GHz bandwidth out of a total of 3 GHz.

Assume

- Multi-tier networks (HetNet) will be operated:

- Phantom cells with control signaling in cm-band, data in > 5 GHz band
- Licensed-assisted access operation (cellular signaling for WiFi band data)
- GPRS/LTE-Narrow Band-IoT used for device management in MTC.

- 50% of 1,05 GHz = 500 MHz ~ control plane SO carried on cm-waves

The 5G control Plane Bottleneck - 3

Where to carry the current U-plane traffic that will be replaced by 5G signaling traffic in bands < 2,5 GHz ?

Excessive large number of small cells operated > 2,5 GHz would be required for this.

Phantom Cell is a very costly solution. Alternatives ?

How, else can C-plane traffic be carried that needs larger reach than U-plane traffic?

-> swiping small ceels with C-plane traffic beams in time domain instead of omni-signaling increases SO since same info is transmitted multiple times in sequence.

Consequences for research in 5G/6G:

Modeling and analysis of 5G systems is urgently required to investigate and develop techniques to circumvent this problem.

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5G Design Error: Competition with WLAN in its original service domains

Most traffic increase in 5G compared to 4G is video streaming et similar, mostly consumed/originating in hot spots. User sit and watch and don't need mobility support and AAA.

WLAN instead of LTE-A/B is preferable under „no-data-limit“ flat rate billing (NDL-FR), e.g. IEEE 802

- .11ac (wide channel, MIMO) at 5GHz outdoors,
- .11ad / 11ay (MIMO, 512 QAM) at 60 GHz indoors,
- **.11.ax. OFDMA, 1024 QAM at 2,4 & 5 GHz (and beyond), in- and outdoors.**

WLAN at ≥ 5 GHz is attractive, too, since **less complex / less cost than 5G**.
Remember Ethernet pushed-out Token Ring.

TDD outperforms FDD in channel-state information (CSI) precision.

ISM band coexistence of 5G DL and WLAN by License Assisted Access (LAA) operation (TR36.889, TS36.213) is complex and **senseless under NDL-FR**. Better make use of WLAN, there.

Research Propositions

Research is required on

- validity of the above made SO estimates and conclusions,
- improvements, e.g. by „channel“ instead of packet switching

Example novel technologies:

Improved location prediction of UE after a variable length (small) idle/sleep period, e.g. by use of

- DAS,
- data aggregation as used with advanced WLAN.
- Big Data, e.g. modeling of
 - class of UE mobility,
 - topography dependent radio wave propagation.

to predict optimal hand-off location.

Develop virtual omnidirectional DL transmission of C-plane traffic for mm-wave band.

Dynamic beam width (and tx-power) modulation for control plane data. Coordination of C-plane traffic across base stations.

Conclusions

Omnidirectional transmission of control signaling is inefficient if beam forming is required to cover a 5G cell.

Radio resource control for packet based cellular radio systems cause excessive broadcast signaling overhead – 35% or more.

5G could use spectrum <6 GHz for C-plane traffic in macro/micro cells, >6 GHz for U-plane traffic in micro/femto cells to compensate for high pathloss at mm-waves.

Then, 5G C-plane traffic will result in the 5G capacity bottleneck by consuming part of cm-wave spectrum, pushing out existent traffic.

Advanced WLAN in hot spots is a deadly competitor to 4G/5G. WLAN is in place at 60 GHz already; 5G in 50 GHz will be too late.

5G is too complex, costly and misaimed w.r.t. important shares of future wireless traffic, e.g. video streaming.

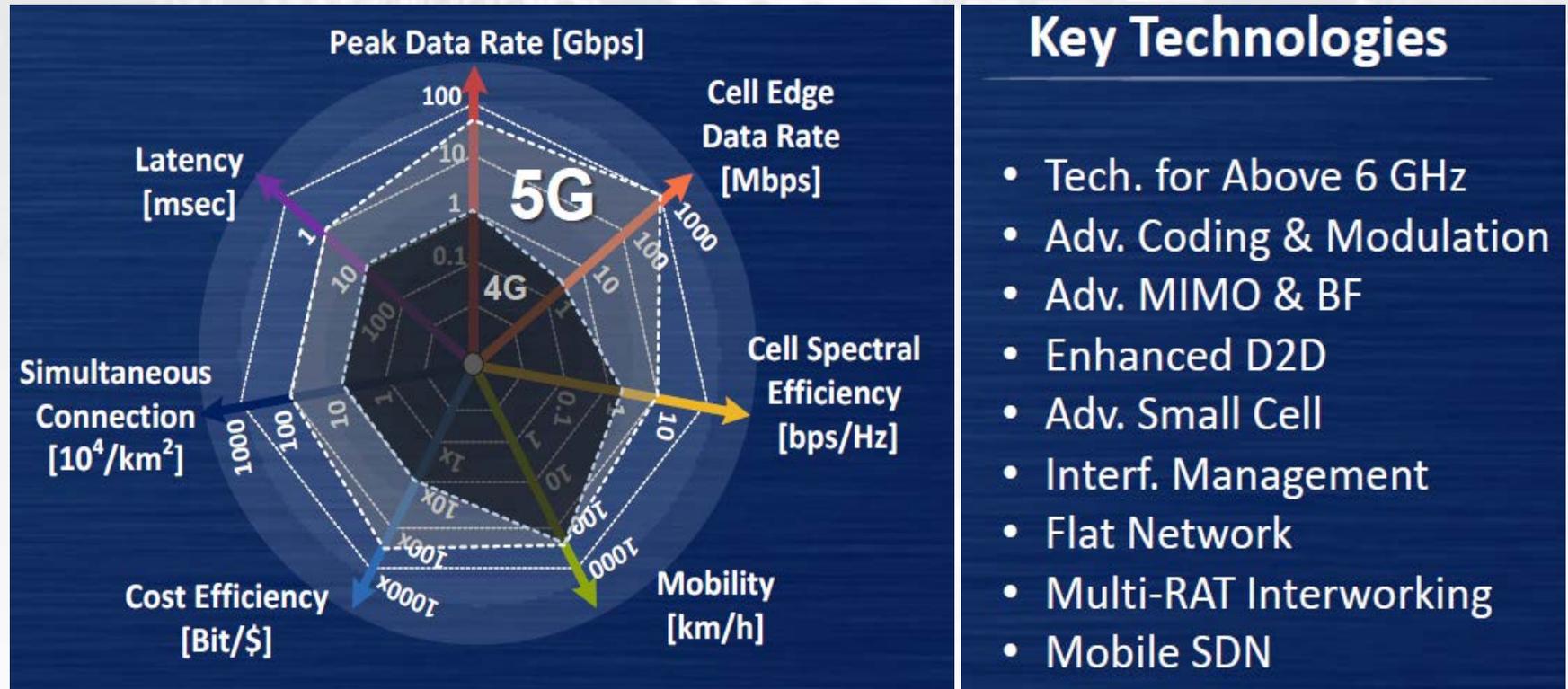


Thank you for listening!



Performance of 5G Phase-2 compared to 4G

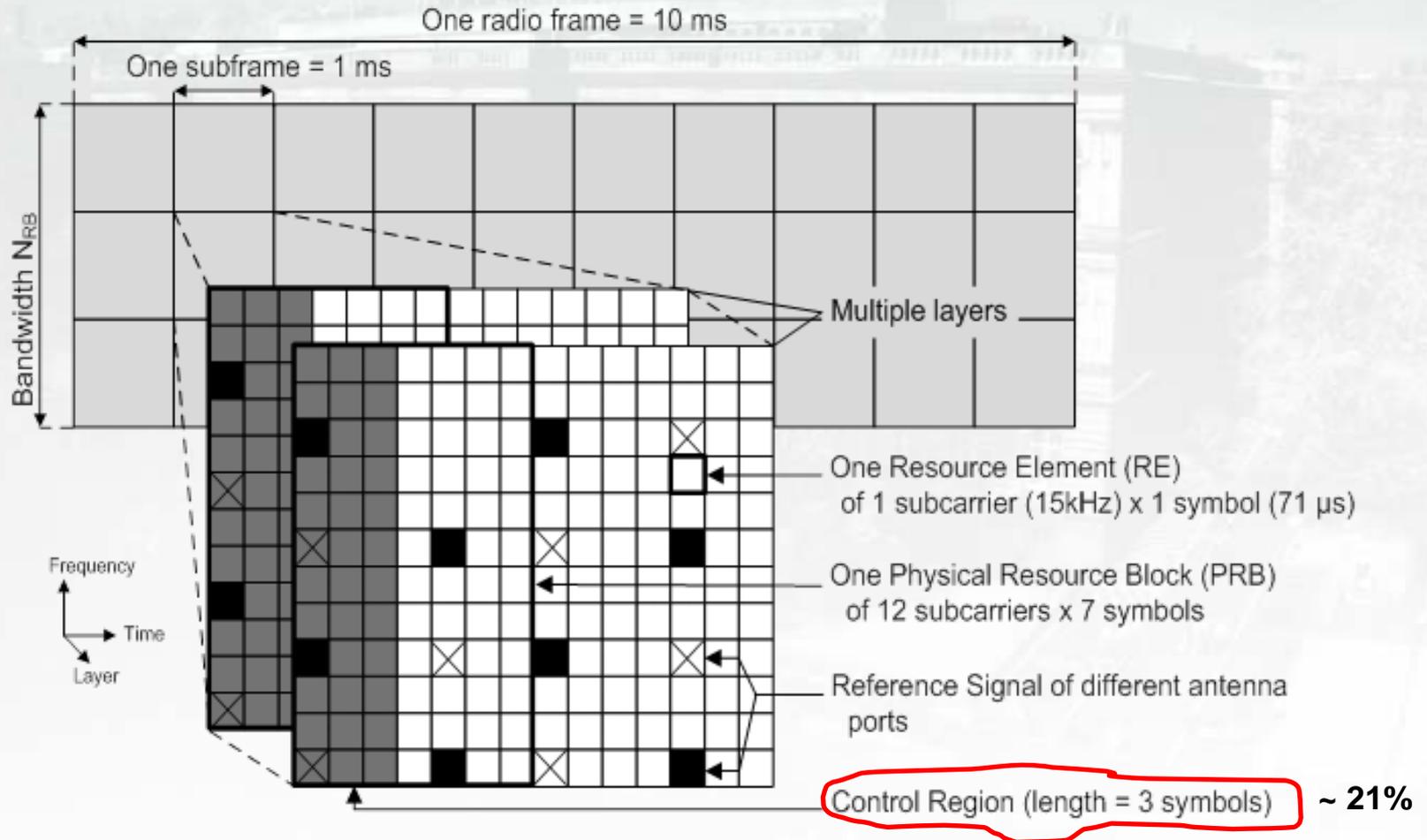
The figure shows more ambitious claims (10x) no longer valid.



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

System Control Overhead in LTE



How 6G Systems will look alike

There is a need for three versions of 5G-Phase-2 technology:

- LTE-A-like mobile data traffic, including real-time hungry Apps,
- **wireless** instead of mobile for data hungry terminals in hot spots and for IoT traffic
- MTC for industry 4.0.

5G-Phase-2 (deployed in 2025) keep „old radio“ and will add New Radio (NR) air interface with separation of indoor and outdoor service by spectrum used.

6G will apply much better dedicated radio access technologies, to meet new reliability, traffic performance and energy efficiency claims made.

Application domain-dedicated technology will solve the dilemma of mobile industry, currently not willing to say how 6G systems will perform better than 5G, besides use of optical networks.