5G: Your questions answered

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Introduction

- Announcements with regards to the launch of new LTE / 4G* networks are now coming on a weekly basis from every corner of the world. Operators in the more advanced markets are even in later stages of LTE-A (a.k.a. "the real 4G") network deployment.

- It is but natural for speculations to start discussing on the next technology which is being billed as ‘5G’ or the "fifth generation mobile wireless technology" for the moment.

* Even though the term 4G is widely used with LTE networks, it does not satisfy the requirements laid out by IMT-Advanced. Hence we refer to LTE-Advanced as the actual 4G.

What is '5G'?

- There is no consensus on what '5G' is at the moment. Different parties identify it in a way that suits their needs and at the same time justify the need of '5G' with a use case that is causing an issue for an operator at the moment.

- METIS, the EU funded organisation, defines '5G' as a technology that supports:
  - 1000 times higher mobile data volume per area
  - 10 times to 100 times higher number of connected devices
  - 10 times to 100 times higher typical user data rate
  - 10 times longer battery life for low power MMC
  - 5 times reduced End-to-End latency

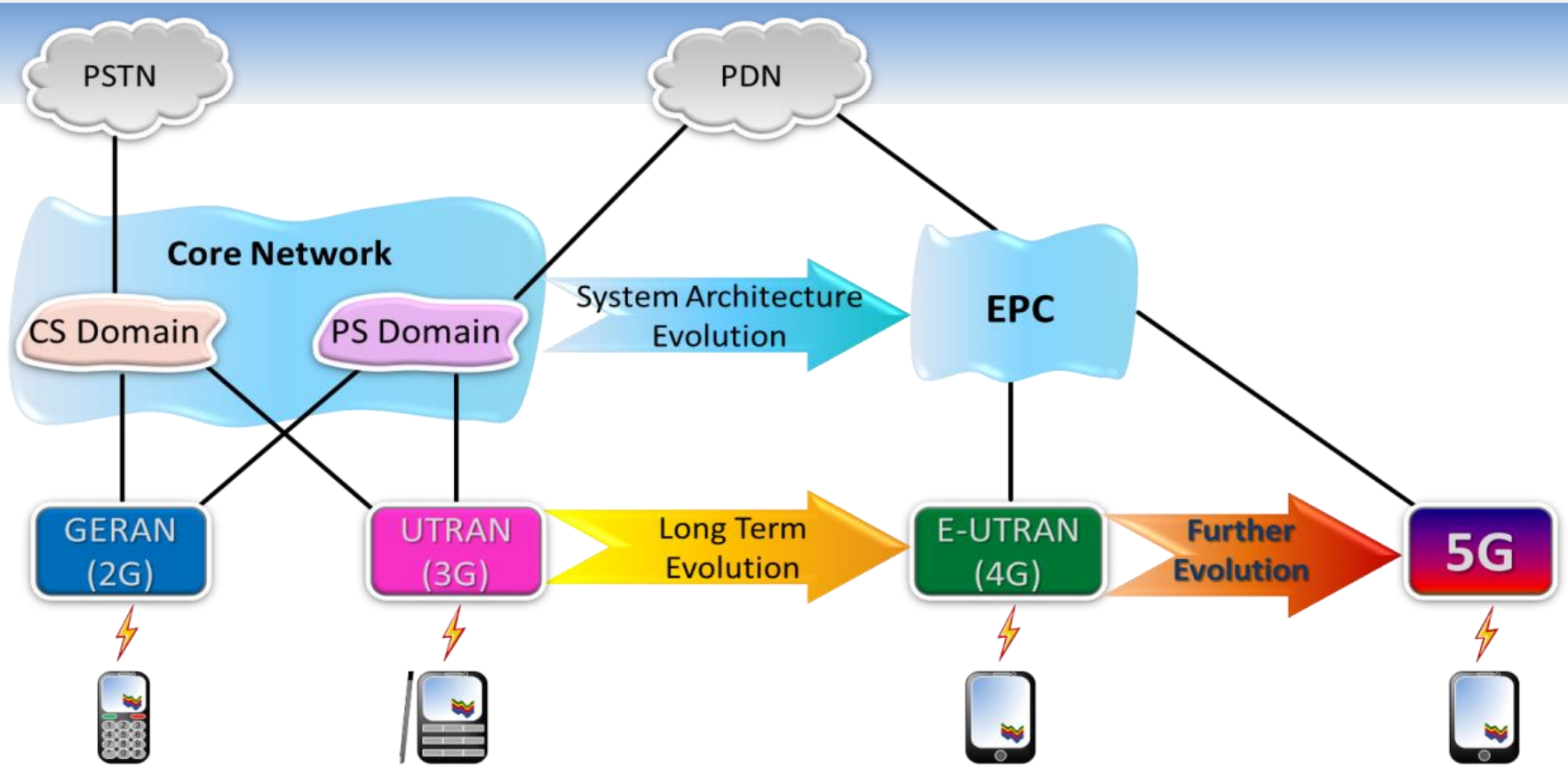
Who is talking '5G'

- Everyone is talking about '5G'. Since '4G' is stable and working its way slowly from standards to deployments, everyone is looking for a new past time to keep busy.

Why is there a need for 5G?

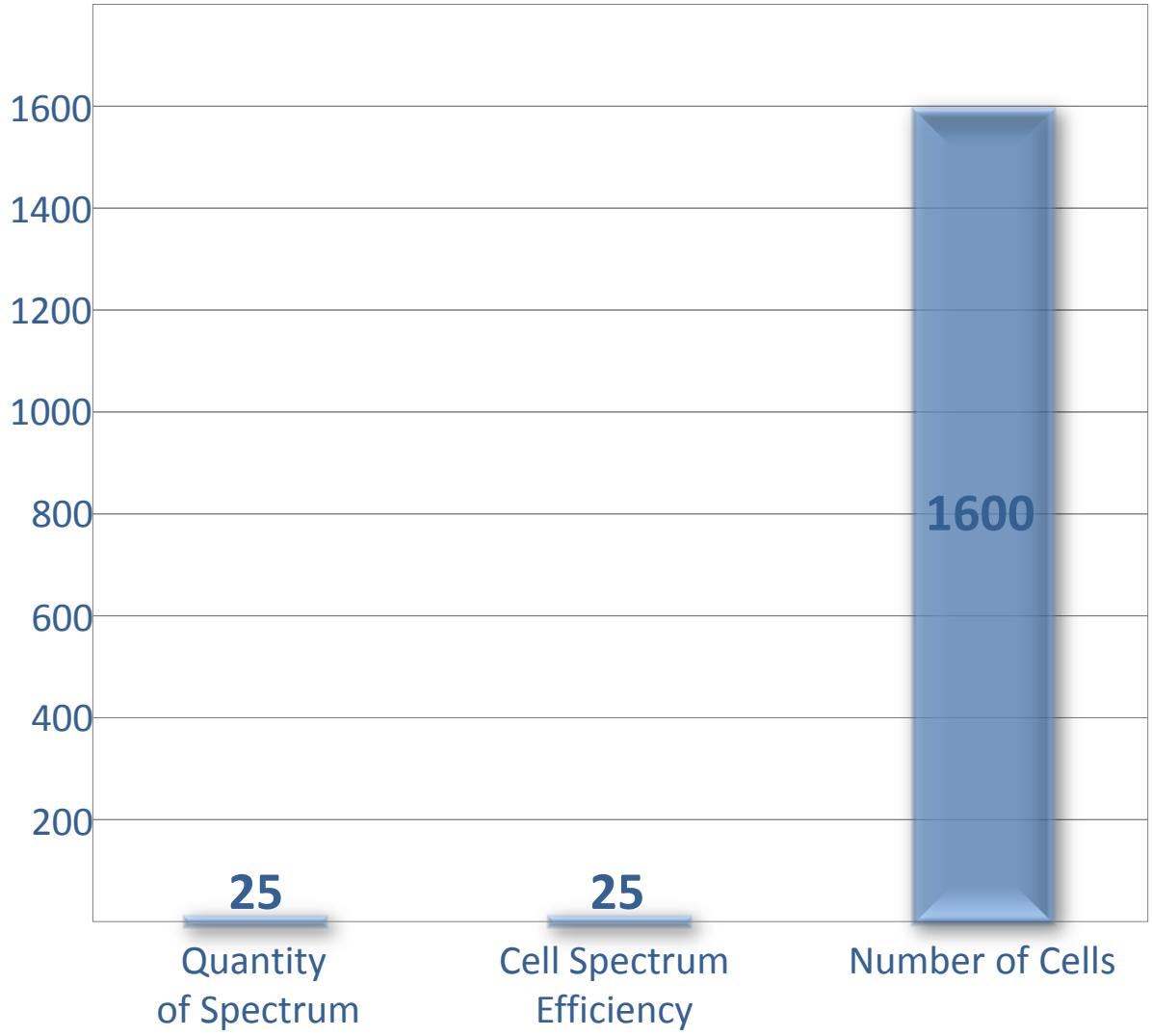
- While the operators are already facing many challenges with their current '3G' networks, not all of them have been addressed by the '4G' networks. The main challenges facing mobile operators that '5G' needs to address are:
  - Even better speeds (peak rates of up to 10Gbps)
  - Perfect cell-edge coverage
  - Extremely low latency (round trip time of roughly 1ms)
  - Significant volume of information /channel capacity (Ultra HD video)
  - Capability to handle large number of connected devices without any concerns (tens of thousands of devices per access node)
  - Interference management in HetNet scenarios
  - New deployment architectures (Mesh networks)
  - Low power consumption / Energy saving

Will 5G be Evolution or Revolution?



The major focus for the time being is on the access network and air interface technology. While '3G' relied on WCDMA and '4G' relies on OFDMA/SC-FDMA, '5G' is focussing on new air interface technology that promises to be better than the current technology. We believe that as of the moment, there may be no significant changes needed in the core network.

Why ‘access network’ and ‘air interface’?



The last million fold capacity increase in the mobile network was achieved as shown in the picture. Since the quantity of spectrum is not expected to increase significantly, increase in spectrum efficiency and the number of cells (smaller cells) is the only real way to increase network capacity.

What are the key technologies for '5G'?

- The key technologies that are being discussed for '5G' are as follows:
  - Non-Orthogonal Multiple Access (NOMA)
  - Filter Bank Multicarrier (FBMC)
  - Millimetre frequencies/waves
  - 3D Massive MIMO
  - Cognitive radio spectrum sensing techniques
  - Super wideband spectrum
  - smaller cells and ultra dense HetNets.
  - Multi-technology carrier-aggregation

- Once research picks up steam, we would hear about many more new technology concepts for '5G'

What is Non-Orthogonal Multiple Access (NOMA)?

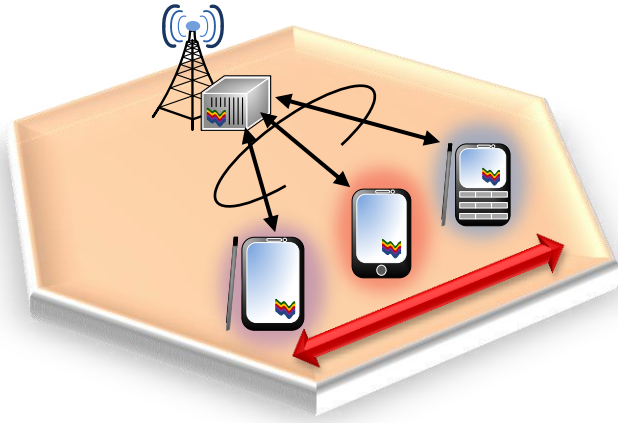
NOMA is one of the most promising technologies that is strongly supported by important mobile operators and it is assumed that it will play a central role in the 5G networks.

NOMA increases the sum cell capacity (when compared to orthogonal systems) by sharing both time and frequency resources among the users.

NOMA is a combination of OFDMA with superposition and interference cancellation techniques. Although current technology would limit NOMA due to processing power shortage, in 10 years time, signal processing capability should be more sufficient.

New path loss profile is been used with NOMA, which utilizes path loss difference for user multiplexing purposes and is proved more efficient than OFDMA.

Interference cancellation at the receiver increases throughput while it assists robustness.

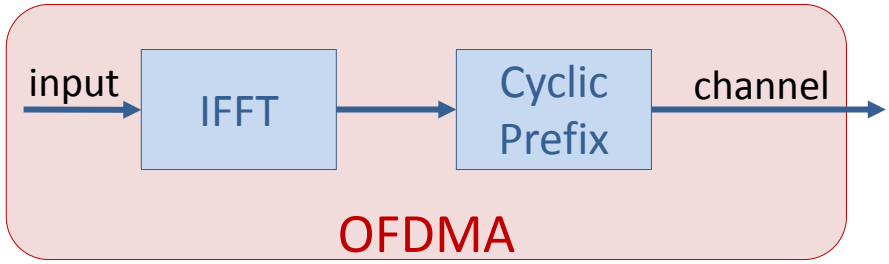


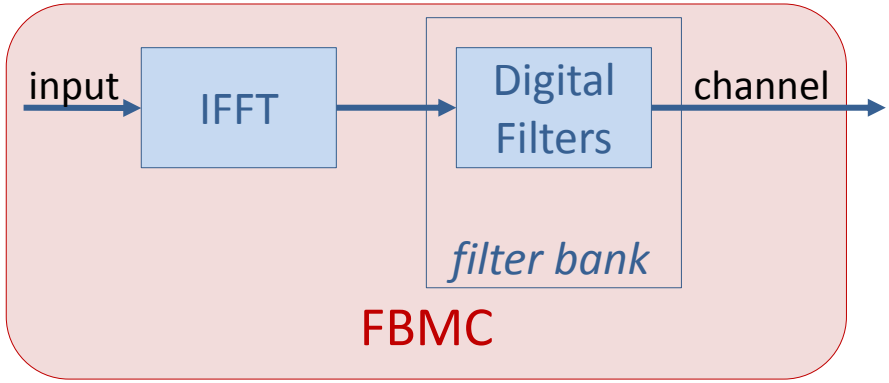
Picture source: NTT Docomo

What is Filter Bank Multicarrier (FBMC)?

FBMC is an alternative approach to OFDMA since it has a higher spectral efficiency

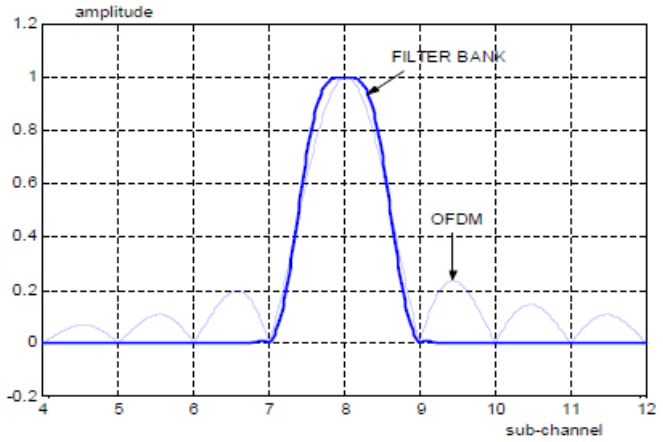
FBMC uses common FDMA without subcarrier overlap while lack of sidelobes allow increased spectral efficiency.





Comparing OFDM and FBMC

Sub-channel frequency response



→ no sidelobes with the filter bank

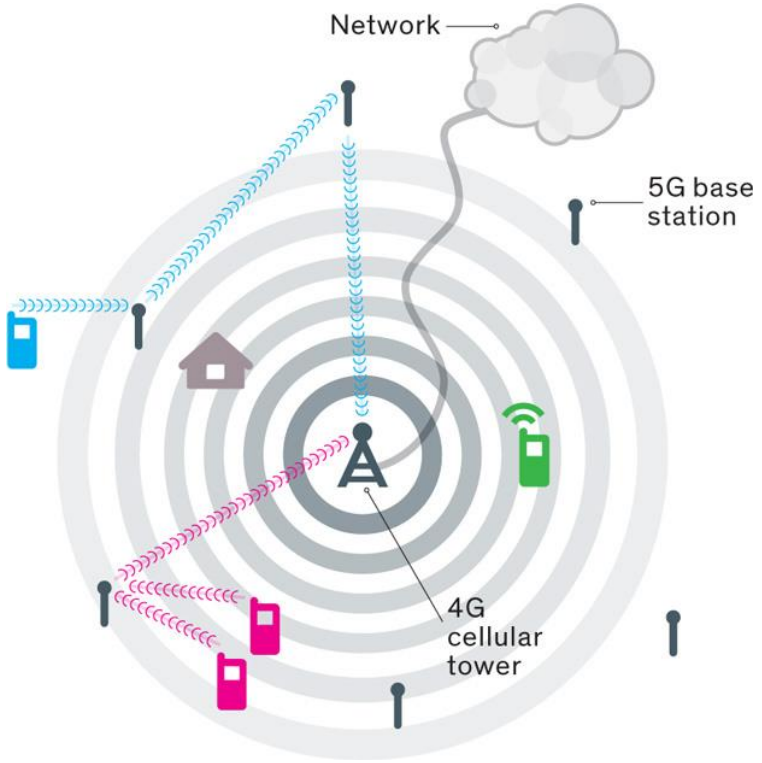
→ no cyclic prefix : increased spectral efficiency

Picture source: FBMC physical layer – principle by Maurice Bellanger, Phydyas

What is Millimetre frequencies/waves?

Extremely High Frequency covers 30GHz to 300GHz and the waves have wavelength of 10 to 1mm, hence they are called millimetre waves (mmWaves)

5g Beam Scheme: Steerable millimeter-wave beams could enable multigigabit mobile connections. Phones at the edge of a 4G cell [blue] could use the beams to route signals around obstacles. Because the beams wouldn't overlap, phones could use the same frequencies [pink] without interference. Phones near the 4G tower could connect directly to it [green].



Source: Ariel Bleicher, "*Millimeter Waves May Be the Future of 5G Phones*", June 2013, http://spectrum.ieee.org

What is 3D Massive MIMO?

Massive MIMO is composed of many (maybe hundreds) of inexpensive low-power antenna components that are used to increase throughput and channel efficiency.

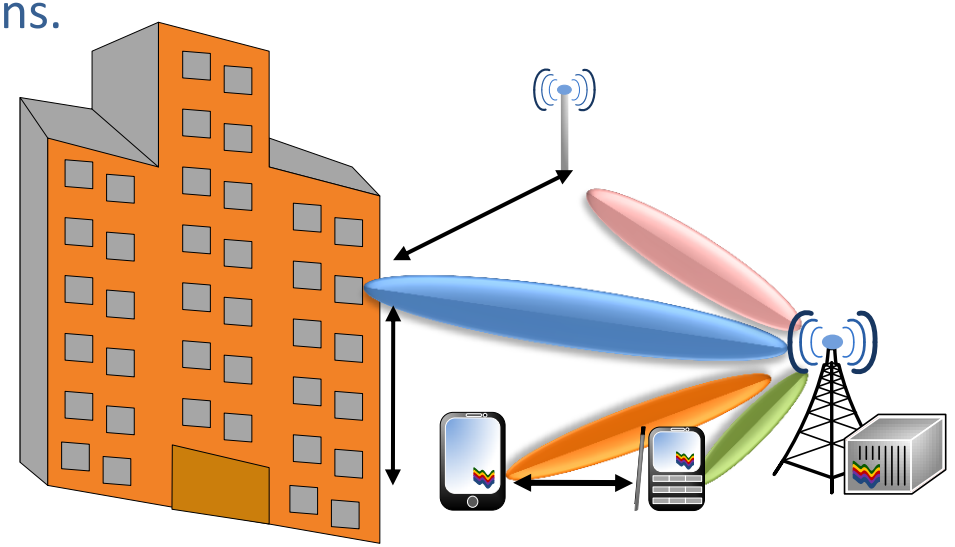
Massive MIMO benefit from reduced latency, increased significant cell channel capacity and a simplified MAC layer.

3D beamforming is often referred to as the 3D MIMO pointing out the ability to produce separate beams on three dimensions (horizontal and vertical) at the same time.

Massive MIMO enables 3D beamforming, as due to the large number of antennas, independent beams can be formed pointing towards various directions.

3D beamforming helps suppress inter-cell interference.

Multiuser MIMO (MU-MIMO) support.



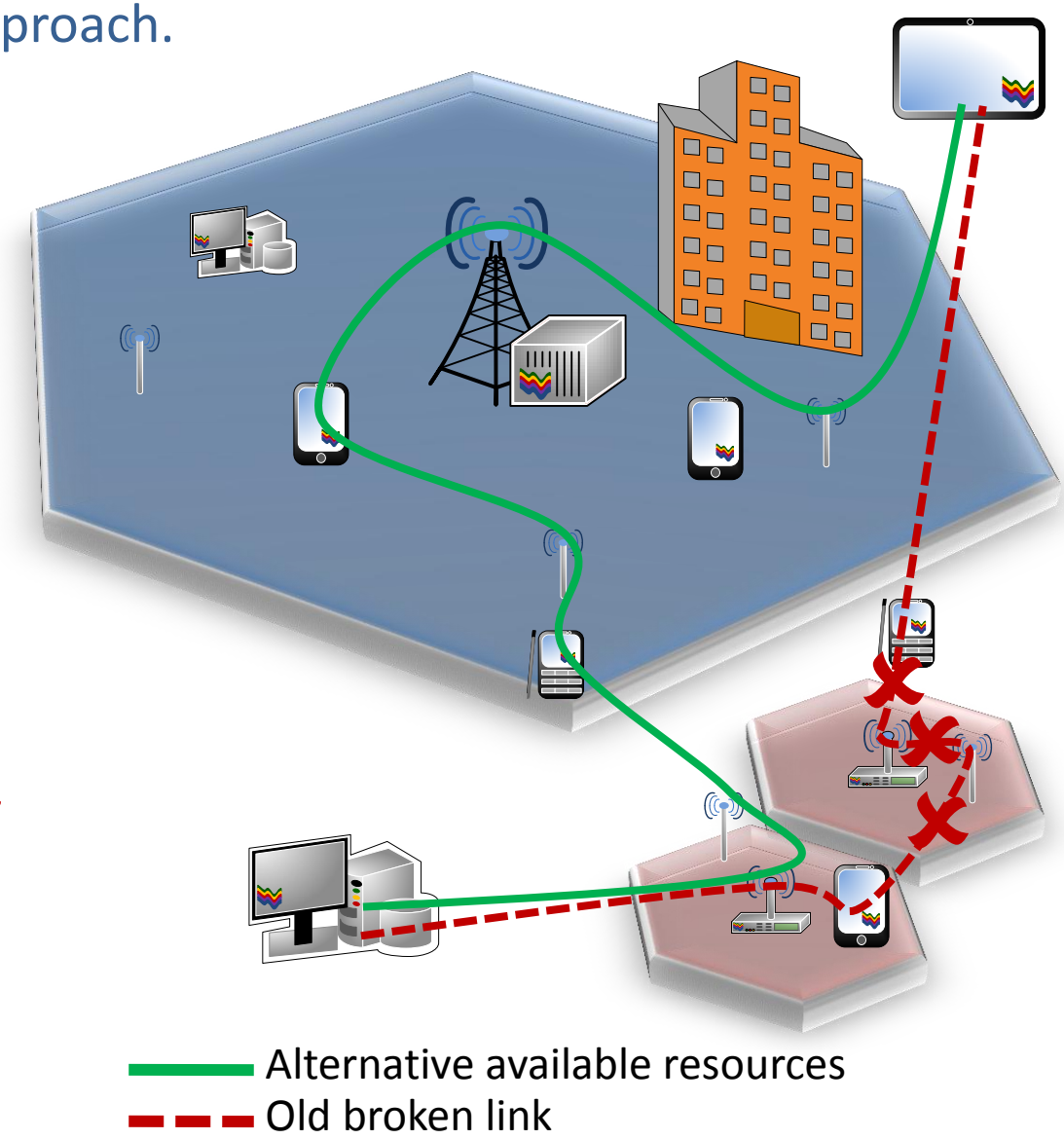
What are Cognitive radio spectrum sensing techniques?

The most important property of cognitive radio is its ability to dynamically select the best wireless channel in a given location. Spectrum sensing is used to facilitate scarce radio spectrum and initiate a carrier aggregation approach.

A cognitive radio system will utilize available spectrum on non-interference basis for the UE by *Continuous Spectrum Sensing*.

When UE needs to return to the spectrum then system should be prepared to allocate is with alternative resources and for that reason there is an ongoing *Monitoring for Empty Alternative Spectrum*.

Cognitive radio systems *Monitor the Type of Transmission* for interference mitigation purposes. Transmission carrying similar type of traffic are ignored for interference avoidance.



What is the Super Wideband Spectrum?

- The capacity of a channel in the presence of noise is the maximum data rate a channel can carry with vanishingly small error probability. The channel capacity is proportional to SNR and bandwidth. In order to satisfy the 5G demand to achieve multiple Gbps of data transfer, more bandwidth is required

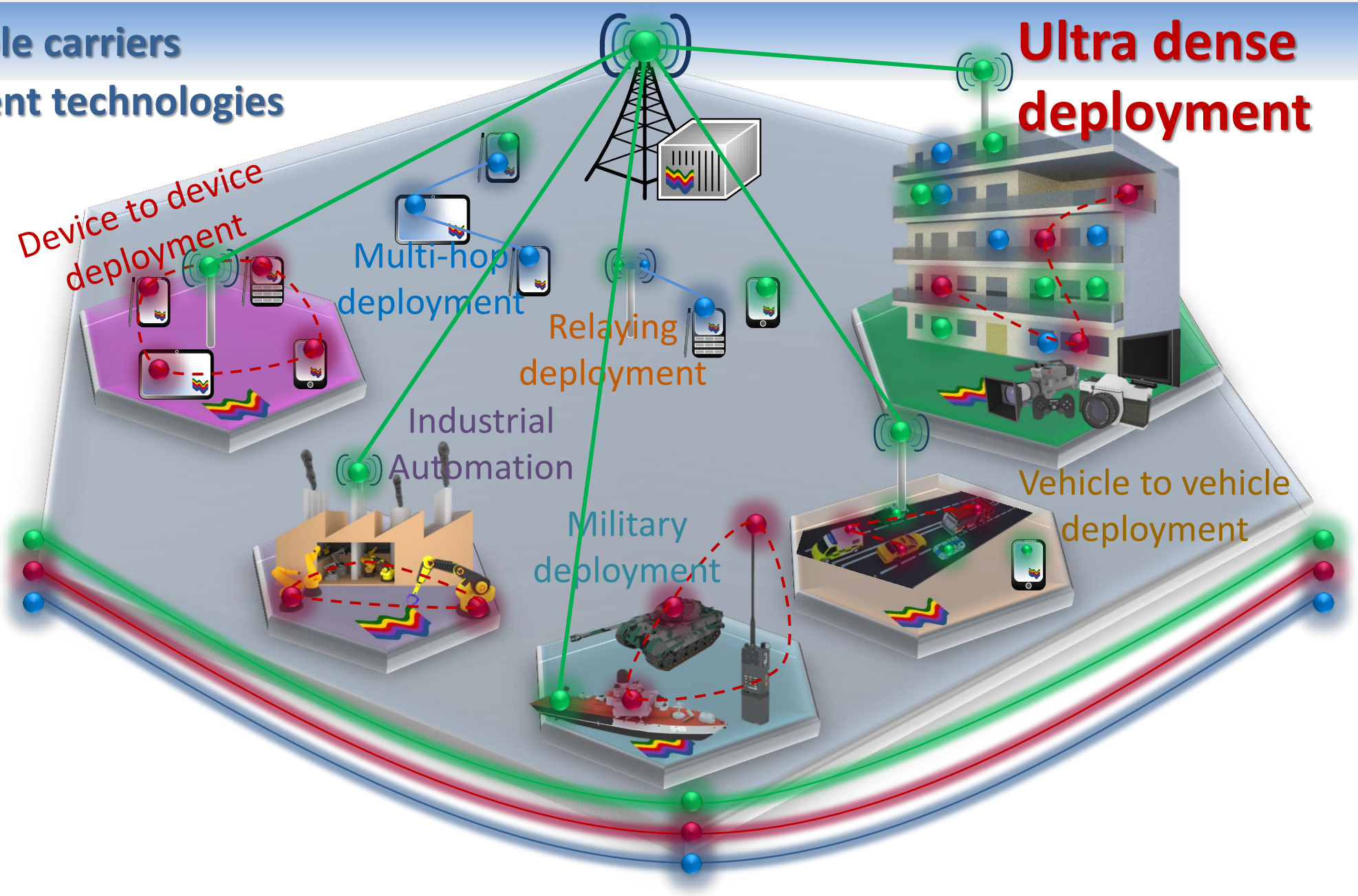
- The higher the carrier frequency, the larger the bandwidth, the higher the channel capacity. Also there is availability in the higher frequency which makes contiguous wideband possible.

- Increased spectral efficiency techniques (e.g. 3D Massive MIMO) improves data speed that exceeds 10 Gbps at a relatively simple modulation scheme (such as QPSK etc) over a 1GHz super wideband channel.

What are ultra-dense Hetnets?

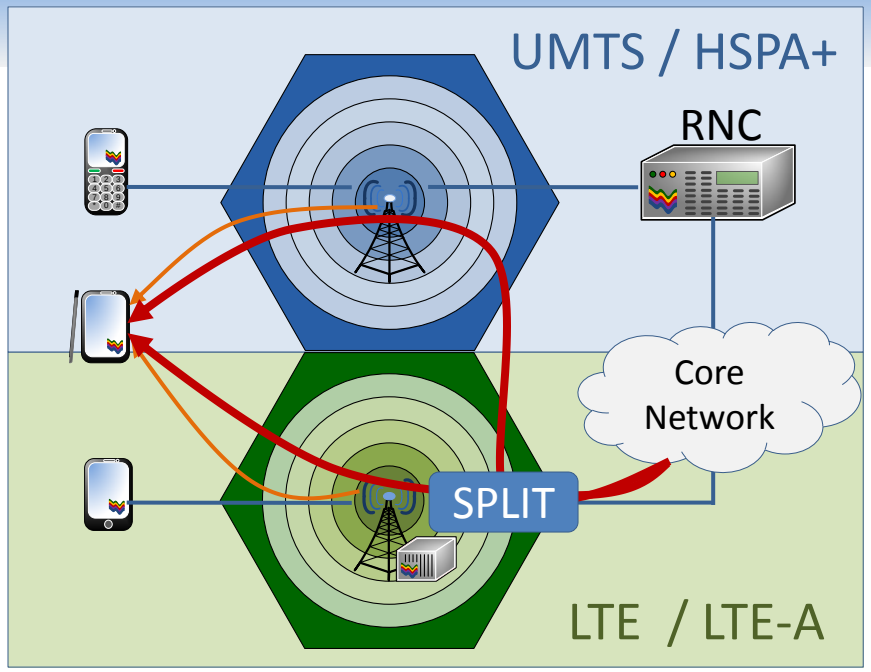
Multiple carriers

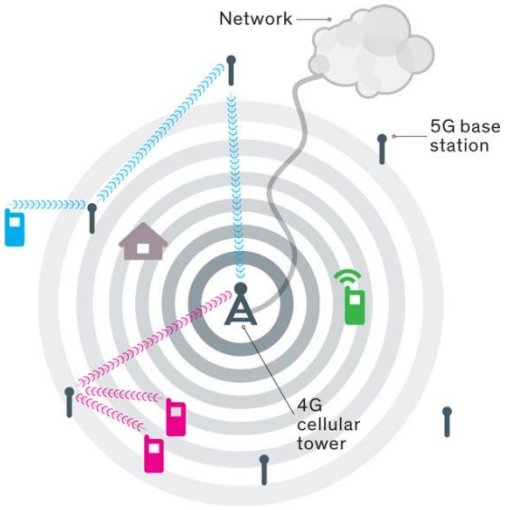
Different technologies



What is multi-technology carrier aggregation?

- Multi technology carrier aggregation is expected to be seen in 3GPP Rel. 12 specification for carrier aggregation between UMTS, LTE and LTE-A technologies.
- A future development would include carrier aggregation of non-3GPP technologies like WiFi
- For the beyond 2020 mobile communications, a carrier aggregation between any telecommunication standard is expected. Therefore every communication system should converge to 5G.
- 5G sets the HetNets principles where every powered device can get connected regardless of the connection technology used.





Bottom picture source: Ariel Bleicher, "*Millimeter Waves May Be the Future of 5G Phones*", June 2013, http://spectrum.ieee.org

When will '5G' networks be rolled out?

- While there is no specified date or deadline for '5G' technology to be rolled out, '5G' research community and equipment vendors have started proposing 2020 as probably 'the date'. Claims range from starting of development of equipment by 2020 to deployment of the network by 2020.

- Our view is that LTE-A has still got a long way to go (Release 13, 14, 15…) and it would help identify many more issues that would need to be fixed as part of 5G. As a result we think that we will see research efforts until 2017, start of standardization efforts that should go until 2020, tests until 2022, first deployments by 2025.

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