5G Networks Revolution and the Activities of EC (and Individual EU Member States) to Support their Deployment

"Mobile Connected World" (MCW) Conference

Athens, May 30th 2018

Dr. Ioannis Tomkos (itom@ait.gr)

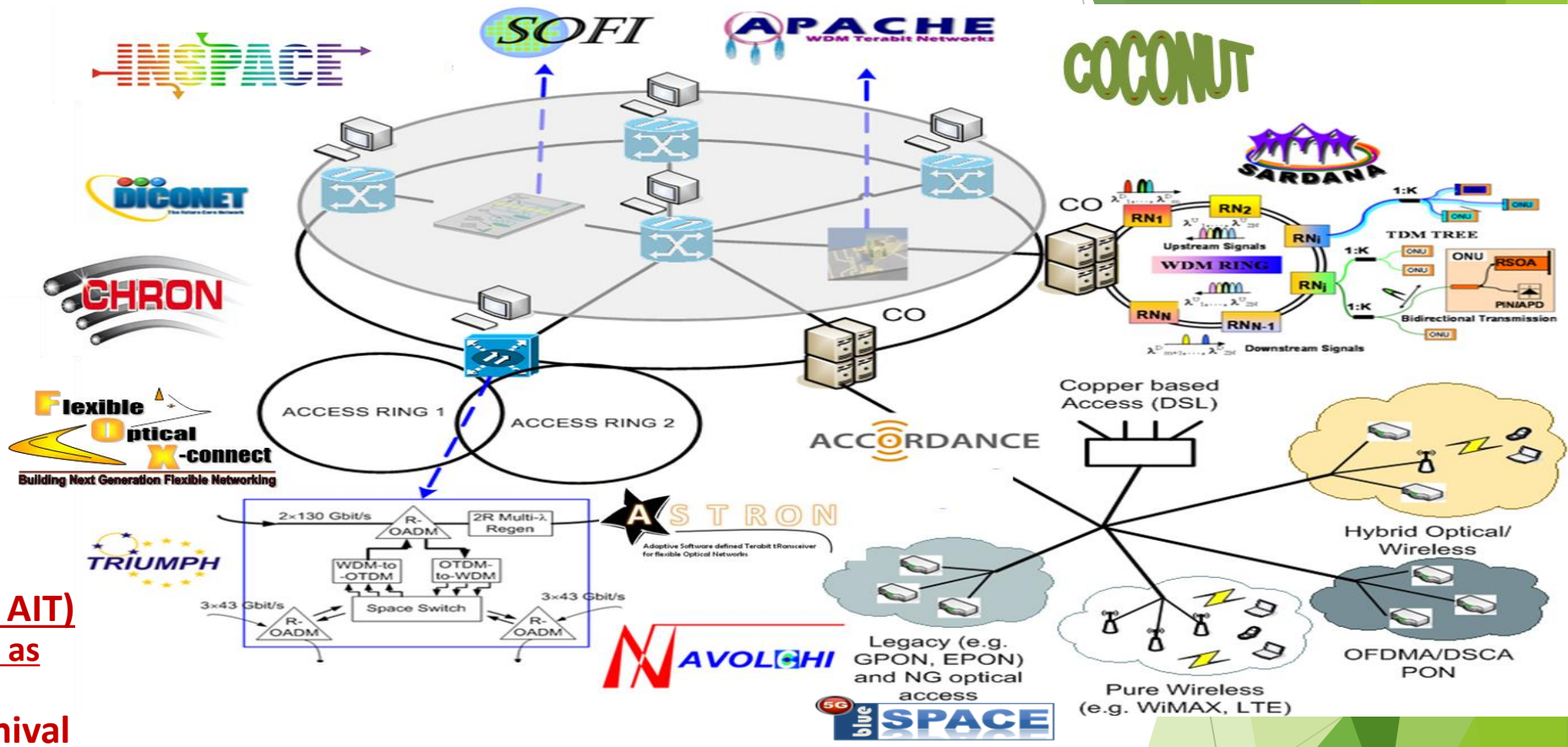
AIT's NOC Research contributions on Broadband Networks

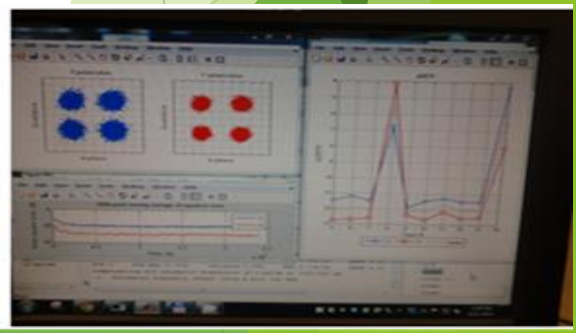
Scope:

Research on ***architectures, transmission subsystems and photonic technologies*** for high-speed telecommunication systems applicable in ***backbone core/metro networks, access networks & datacenter interconnection***

Results (2003-2018):

- ☑ **Participated in 25 research projects (bringing over 10ME to AIT)**
  - ☑ **Led 9 EU research projects as Technical Manager**
- ☑ **Over 150 publications in archival scientific *journals and magazines (110 IEEE)***
- ☑ **Over 450 publications in international (300 IEEE) conferences *and workshops***
- ☑ **Over 7850 citations (h_i=42)**
- ☑ **Many awards & distinctions**





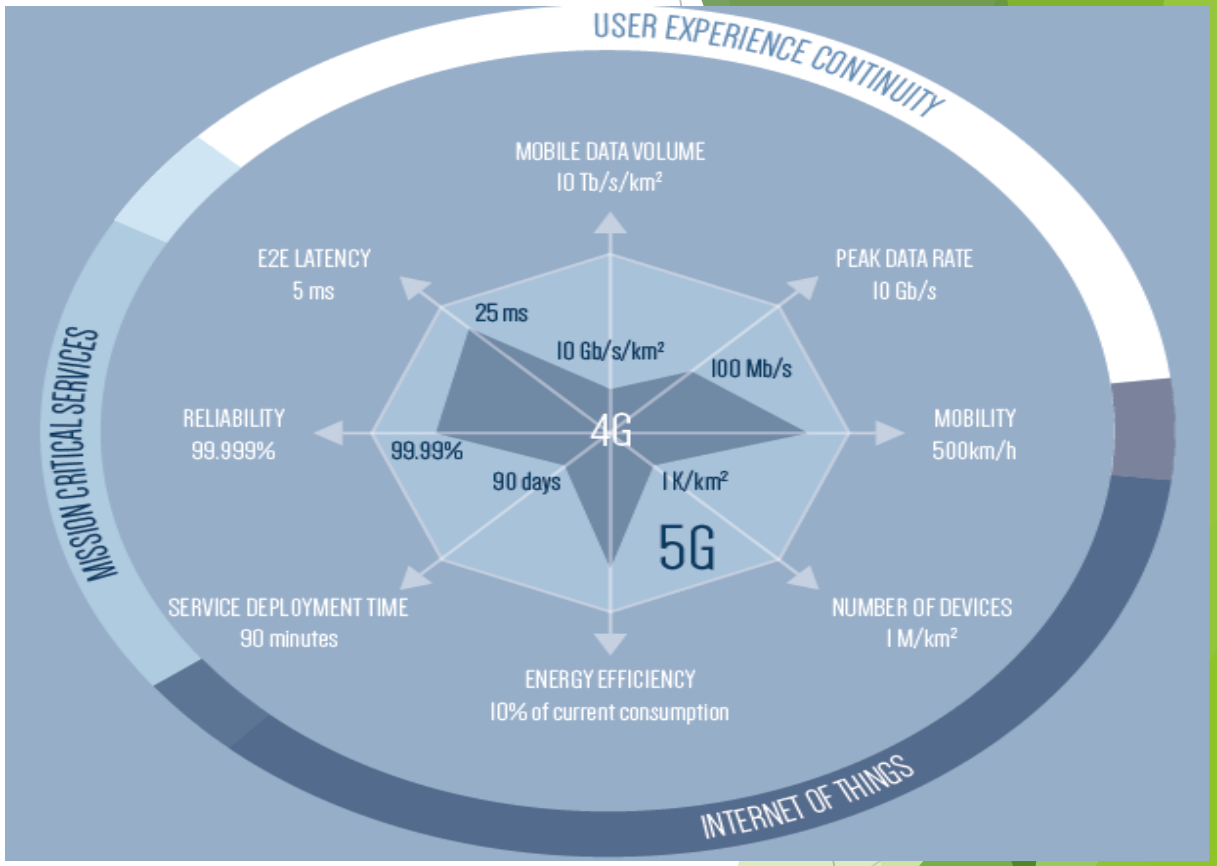
Presentation Overview

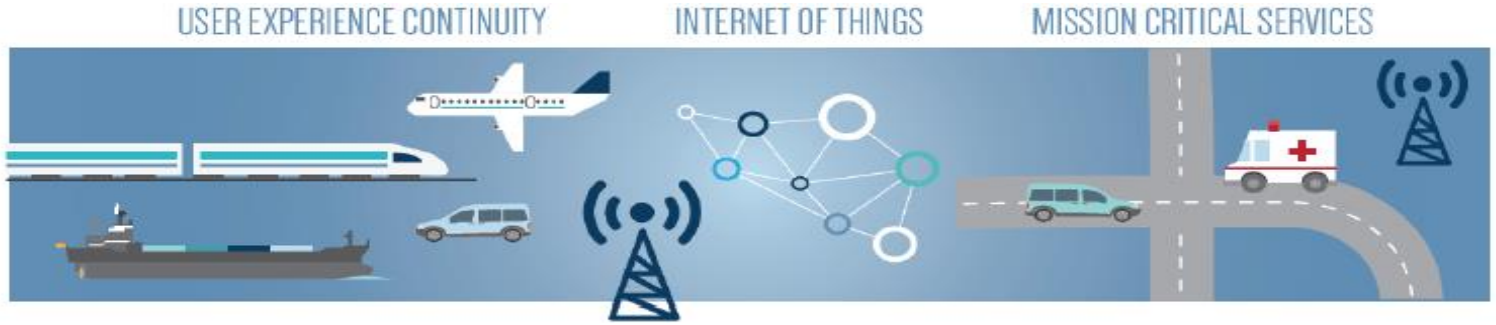
- What we define as “5G networks”
  - 5G network definition according to applications/use-cases/targeted markets
  - 5G network definition according to architecture and technologies used
    - Radio Access Network (RAN)
      - Cloud-RAN
    - Optical front-haul (FH) and back-haul (BH) Network
      - Small-cells architecture
    - Core Backbone Network
      - IP over software-defined (SDN) virtualized (NFV) Optical Networks
- “5G for Europe Action Plan”
  - Where the EU countries stand at the moment with respect to the 5G Plan?
  - EU 5G Public Private Partnership (5G-PPP)
  - 5G Pan-European Trials Roadmap
  - How Greece (and the local ecosystem) is/can be positioned

5G Applications

5G enables new applications and supports efficiency and sustainability

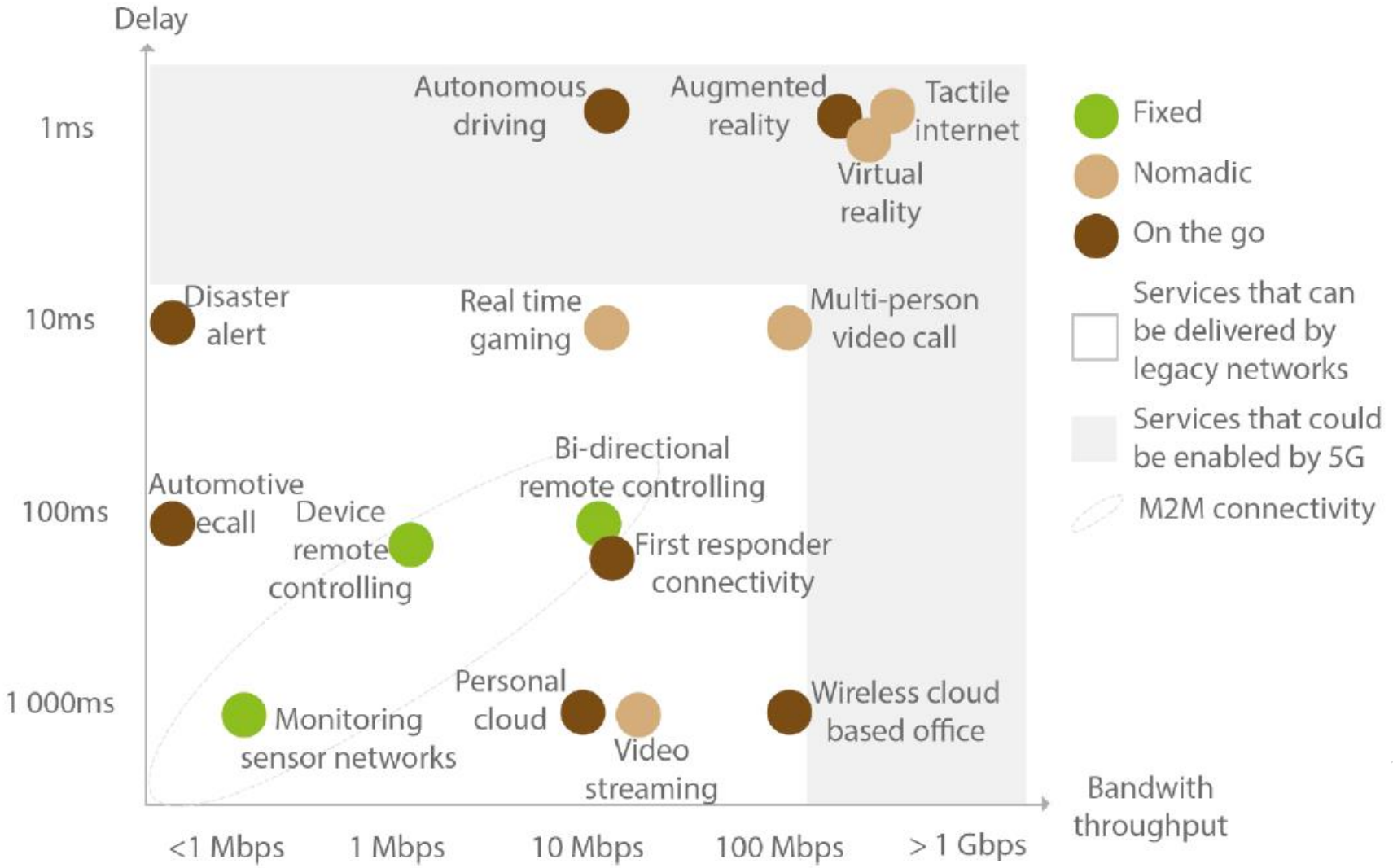
- **5G will provide an order of magnitude improvement in performance in the areas of more capacity, lower latency, more mobility, increased reliability**
  - 5G infrastructures will be also much more efficient in terms of
    - energy consumption
    - service creation time
    - hardware flexibility
  - *5G will also boost the development of other new technologies*, too, such as "autonomous vehicles", "virtual/augmented reality", and the "Internet of Things", among others.





Source: *5G Infrastructure Association: Vision White Paper, February 2015,*

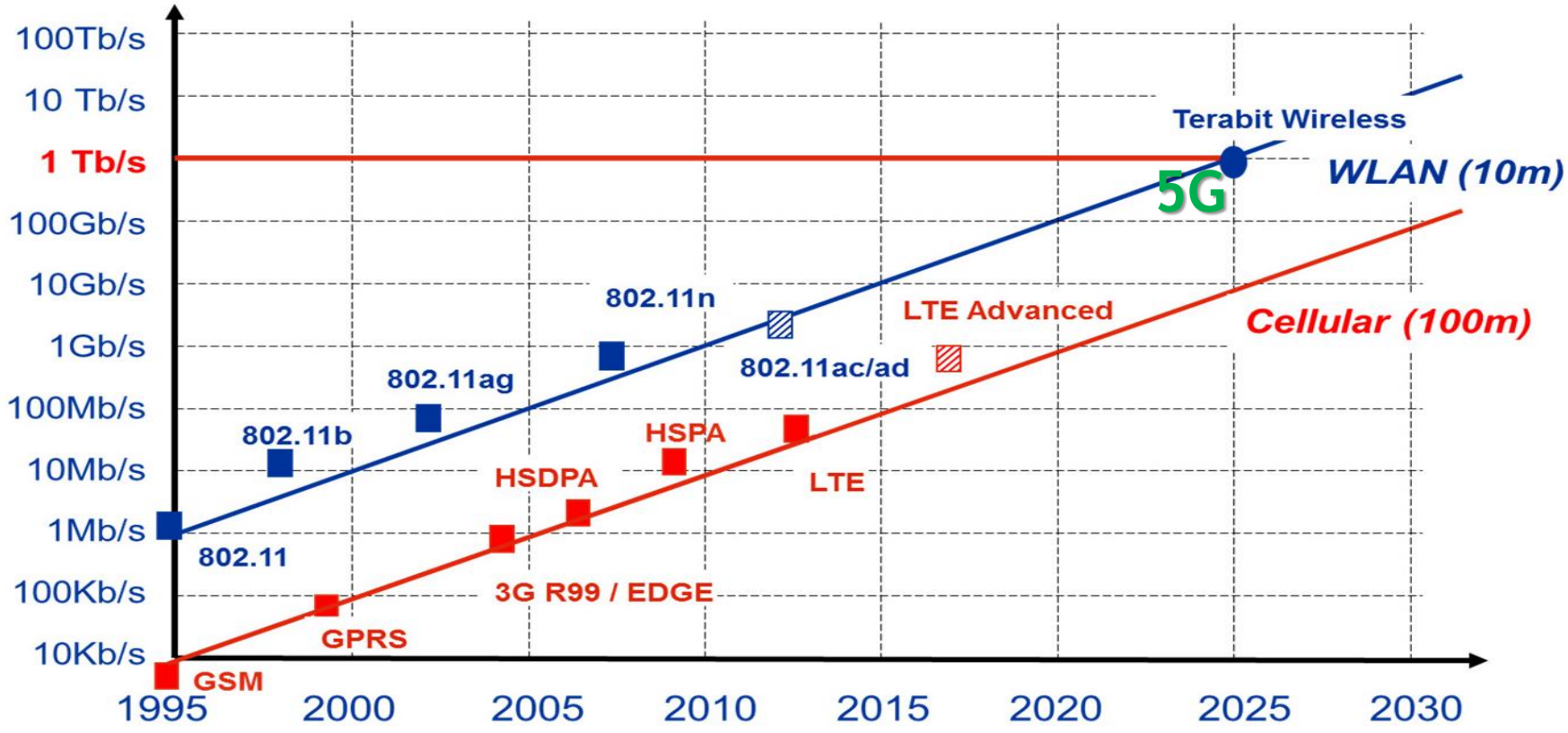
Bandwidth & latency requirements for upcoming applications



Source: GSMA Intelligence

Evolution of «Over-the-Air »
Capacity needs: towards Tb/s!

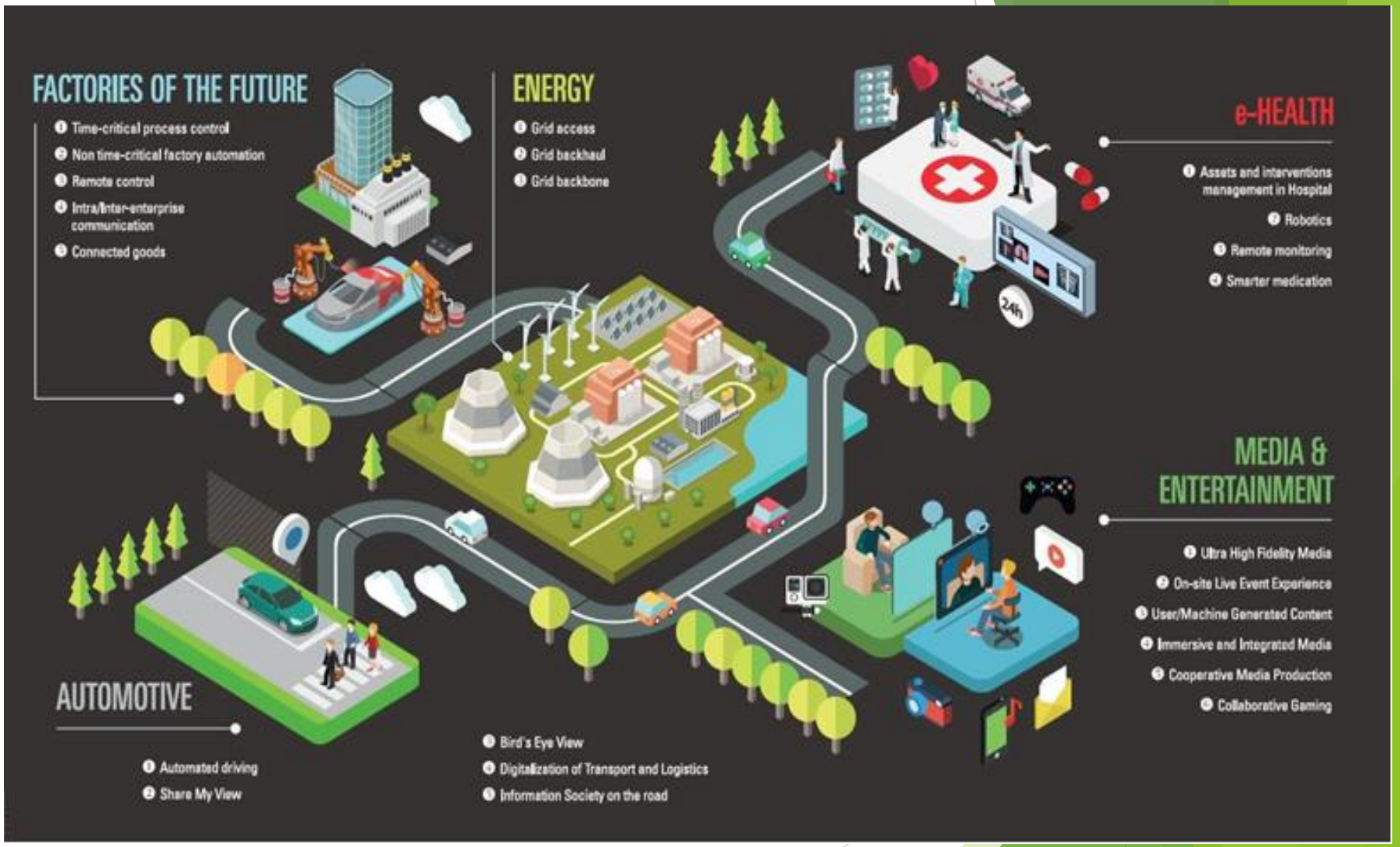
Applications and services might require **1Tb/s wireless** connections soon (i.e. by 2025-2030)! - which can only be offered over very short distances over the air



Reference: Prof. G. Fettweis, System Concept for 1 Gbit/s and Beyond, Tutorial IEEE 802 Plenary, Vancouver

5G is an enabler for Vertical Industries

1. Automotive
2. eHealth
3. Energy
4. Media & Entertainment
5. Factories of the future



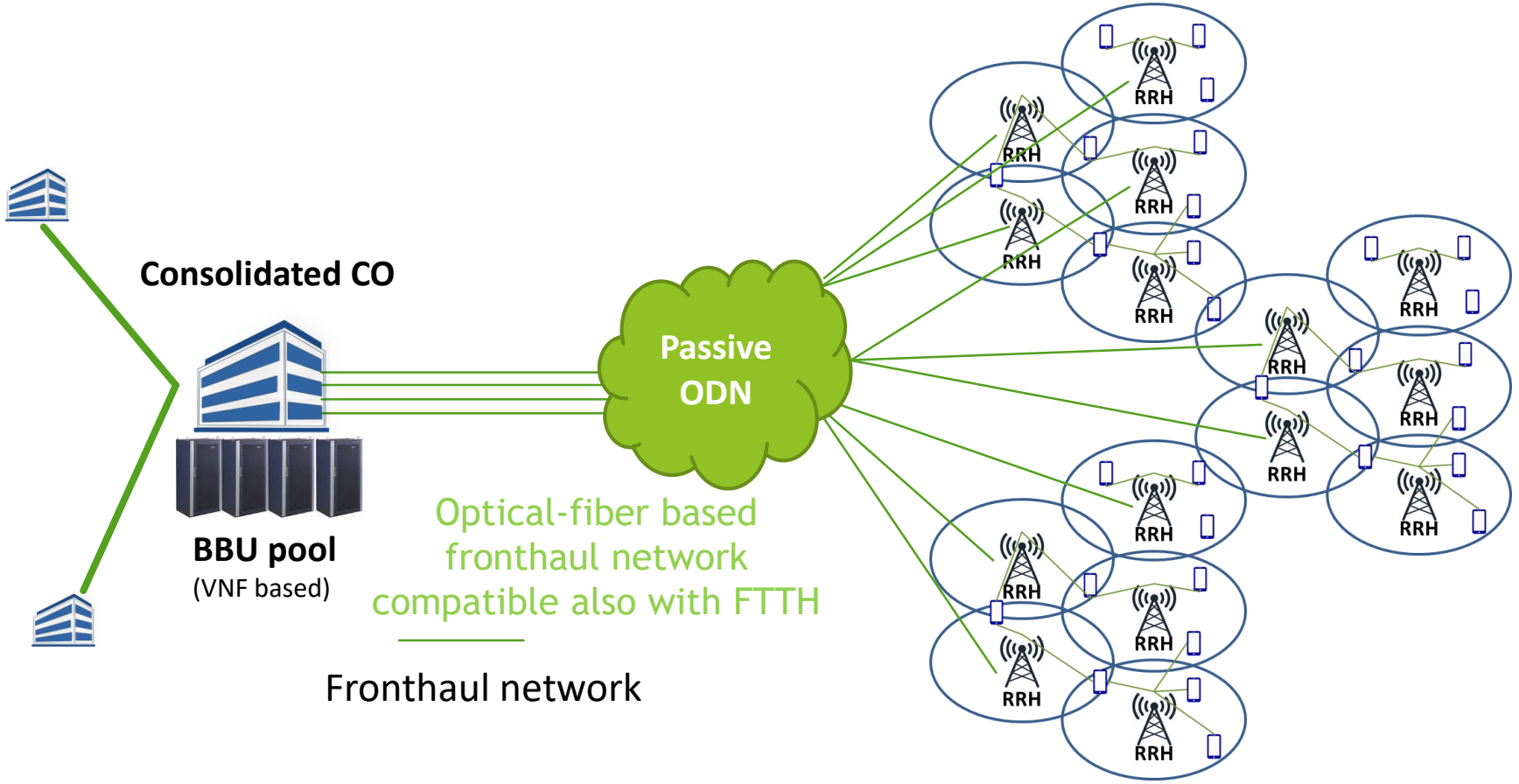
Details in: https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-use-cases-and-performance-evaluation-modeling_v1.0.pdf

5G Network Architecture & Technologies

Which are the key technology innovations that will enable the 5G revolution?

- At the moment, it's not yet clear which technologies will do the most for 5G in the long run, but a few early favorites have emerged:
  - **On the architecture side:**
    - cloud-based centralized network offering resources virtualization
    - small cells,
    - optical fiber based back-haul and front-haul
  - **On the radio access side:**
    - millimeter waves,
    - beamforming
    - massive MIMO

Targeted C-RAN architecture model for 5G



- The 5G networks will be capable of advanced software-defined functionality and virtualization using SDN and NFV
- More processing is performed at the CO.
  - Physical BBUs are removed and the BBU sites are consolidated in an edge cloud (mini-DC) located at the CO.
  - Actual BBUs can be replaced by virtual BBUs implemented with VNF.
    - Some HW functions may still be needed at the RRH (encryption, HARQ, FEC, Beam forming)

Spectrum options for 5G

Low-bands sub-1GHz

- Offers coverage
  - Up to 35km but typically <2-5km in urban scenarios
  - Primarily considered for massive - machine-to-machine communications

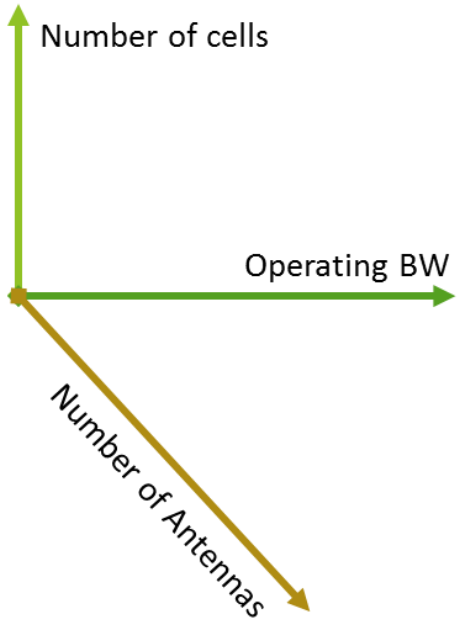
Medium-bands sub-6GHz

- Offers capacity and moderate coverage
  - More than 100MHz per operator
  - Coverage drops to a few hundreds of meters in urban deployments

High-bands mmWave (26GHz)

- Offers high capacity and small coverage
  - High throughput hotspots
  - 2GHz of bandwidth per operator

Capacity increase options

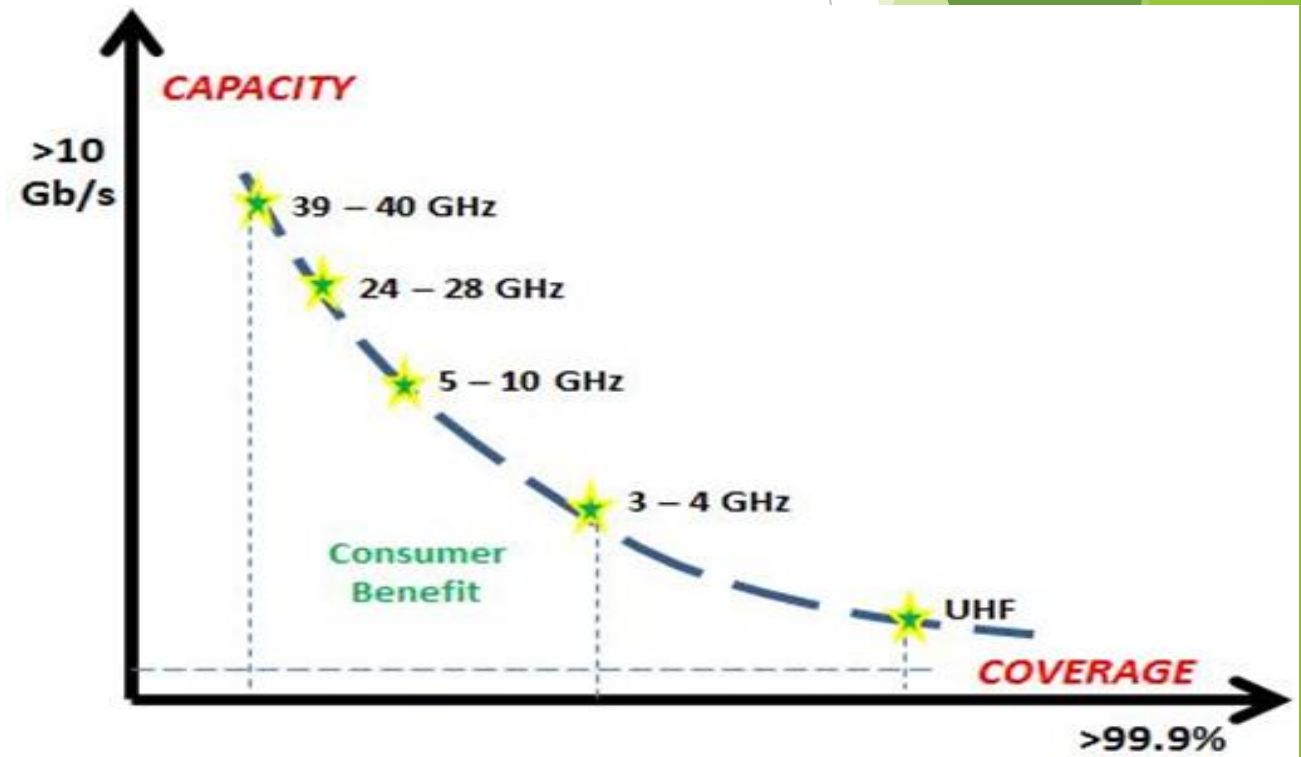


- Operating bandwidth (BW)
  - For sub-6GHz: 100MHz per operator (typically 3-4 operators)
  - For 26GHz (expected to be defined in EU): at 2-3.25GHz
- Number of antennas
  - 10s to 100s

$$C_{total} = BW \times \log_2(1+SINR) \times N_{cells}$$

Millimeter waves for higher bandwidth

- We are approaching a “brick-wall”, since more people and devices are consuming and producing more data than ever before, while at the same time we keep using more or less the same bands of the radio-frequency spectrum (i.e. essentially up to 6GHz).
  - That means that even with higher-spectral efficiency transmission systems (e.g. based on OFDM technology), we will have problems to meet the demand needs.
- One way to get around that problem is to simply transmit signals on new frequency bands that have never been used for mobile services before!
- That’s why providers are experimenting with broadcasting on millimeter waves, at frequencies higher than 20GHz (going up to 300GHz)
- Until now, only operators of satellites and radar systems used millimeter waves for real-world applications.
  - More recently, some wireless network providers have begun to use them to send data between stationary points, but using millimeter waves to connect mobile is an entirely new approach!



Small-cells for better coverage

- There is one major drawback to millimeter waves, though, since they can't travel through buildings or obstacles and they can be absorbed by foliage and rain.
  - That's why 5G networks will likely augment traditional cellular towers with another new technology, called "small cells".
    - Small cells are smaller (or even "miniature" base stations; in that case they are called "fempto-cells") that have limited coverage (which require minimal power to operate).
  - To provide adequate coverage, these small-cells need to be placed every 250 meters or so, throughout cities. Thus network carriers should install thousands of these stations in a city to form a dense network that acts like a relay, receiving signals from other base stations and sending data to users at any location.
    - While traditional cell networks have also come to rely on an increasing number of base stations, achieving 5G performance will require an even greater infrastructure and a much larger number of base stations.
      - Luckily, antennas on small cells can be much smaller than traditional antennas. This size difference makes it even easier to stick cells on e.g. light poles and atop buildings.
- The number of small cells required to build a 5G network may make it hard to set up in rural areas. In such cases, the network should be augmented with macro-cells and base stations that operate at lower frequencies (i.e. sub-6GHz)

Beamforming

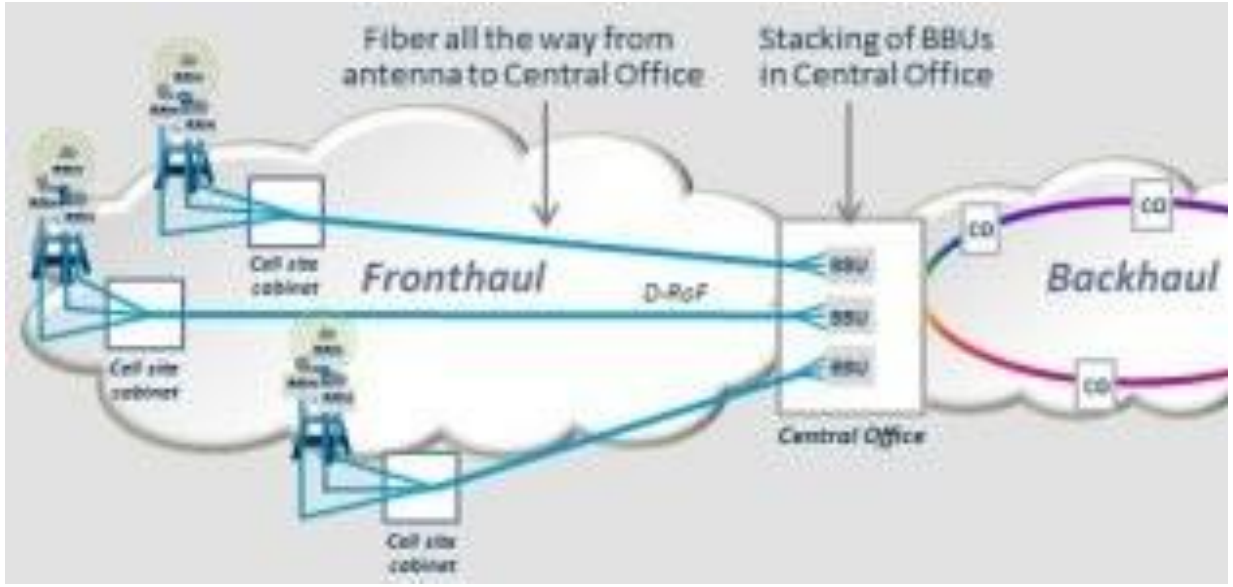
- Beamforming is a traffic-signaling system for cellular base stations that *identifies the most efficient data-delivery route to a particular user and it reduces interference for nearby users in the process*.
  - There are several ways for 5G networks to implement it; e.g. based on electronic or photonic techniques and devices
- Beamforming can help massive MIMO arrays make more efficient use of the spectrum around them, since the primary challenge for massive MIMO is to reduce interference while transmitting more information from many more antennas at once.
  - At massive MIMO base stations, signal-processing algorithms plot the best transmission route through the air to each user. Then they can send individual data packets in many different directions, bouncing them off buildings and other objects in a precisely coordinated pattern.
  - By choreographing the packets' movements and arrival time, beamforming allows many users and antennas on a massive MIMO array to exchange much more information at once.
- For millimeter waves, beamforming is primarily used to increase the coverage since at those frequencies cellular signals are easily blocked by objects and tend to weaken over long distances.
  - In this case, beamforming can help by focusing a signal in a concentrated beam, talking even about "pencil-beams", that points only in the direction of a single user.

Massive MIMO

- Today's 4G base stations have only about a dozen ports for antennas that handle all cellular traffic: eight for transmitters and four for receivers.
- 5G base stations can support over a hundred ports, which means many more antennas (which can fit on a single or multiple array per base-station). With more antennas, a base station could send and receive signals from many more users at once, increasing the capacity of mobile networks by one or even two orders of magnitute.
  - This technology is called massive MIMO (Multiple Inputs – Muliple Outputs).
    - In general MIMO describes wireless systems that use two or more transmitters and receivers to send and receive more data at once. MIMO is already found on some 4G base stations.
    - Massive MIMO takes this concept to a new level by featuring dozens of antennas on a single array. So far, massive MIMO has only been tested in labs and at a few field-trials, which have demonstrated new records for spectrum efficiency (i.e. a measure of how many bits of data can be transmitted to a certain number of users per second, when utilizing a certain number of frequency units).
- However, installing so many more antennas to handle cellular traffic also causes more interference among the signals requiring very advanced signal processing approaches to reduce the impact of interference.

Optical fiber-based front-haul

- For a potential 5G mobile network deployment scenario utilizing 200-MHz carrier aggregated signals, 64x64 M-MIMO and 3 directional sector antennas, there is a requirement for 240(!) 10Gbps CPRI (option 7) front-hauling interfaces to connect the remote radio units (RRU at the antenna site) with the centralized basedband units (BBUs) in cloud radio-access networks (C-RAN).
  - That brings the total front-haul data capacity requirement to a staggering 2.4Tbps
- It is not possible to achieve such front-haul connectivity requirements effectively with wireless technology… Instead we need to start using optical communication links for the front-haul connections.



RRH: Remote Radio Head
BBU: Base Band Unit
D-RoF: Digital Radio over fiber (CPRI/OBSAI)

- *So we all need to understand that 5G networks will be developed to support mobile users, but the network infrastructure itself will not be mobile, neither is will be based only on wireless technologies!*

Why are we talking about "5G revolution"?

- Standards are not ready yet (3G PPP, ETSI, etc…) or focusing on evolutions of legacy solutions
- Regulation is not in favor yet (i.e. spectrum, drones, … for instance)
- Technology is not mature or too costy (i.e. mmW at 90 GHz+)
- 5G discussion bodies has chosen different paths and priorities (Ex. VLC)
- The need for such technology may not be here yet…
- We just simply do not how to do it now!!! … but the "evolutionary" approach can severely limit the potential of 5G

5G for Europe Action Plan

How Greece is/can-be positioned?

5G for Europe Action Plan

- The 5G Action Plan is a strategic EU initiative which concerns all stakeholders, private and public, small and large, in all Member States, to meet the challenge of making 5G a reality for all citizens and businesses by the end of this decade.
  - Very high-capacity networks like 5G will be a key asset for Europe to compete in the Global market, with worldwide 5G revenues for mobile operators expected to reach €225 billion annually by 2025.

- On 14 September 2016, the Commission launched a plan to boost EU efforts for the deployment of 5G infrastructures and services across the Digital Single Market by 2020.
  - The action plan set out a clear roadmap for public and private investment on 5G infrastructure in the EU. A staff working document accompanies the action plan communication.
    - Nothing major has happened in most EU countries, including Greece

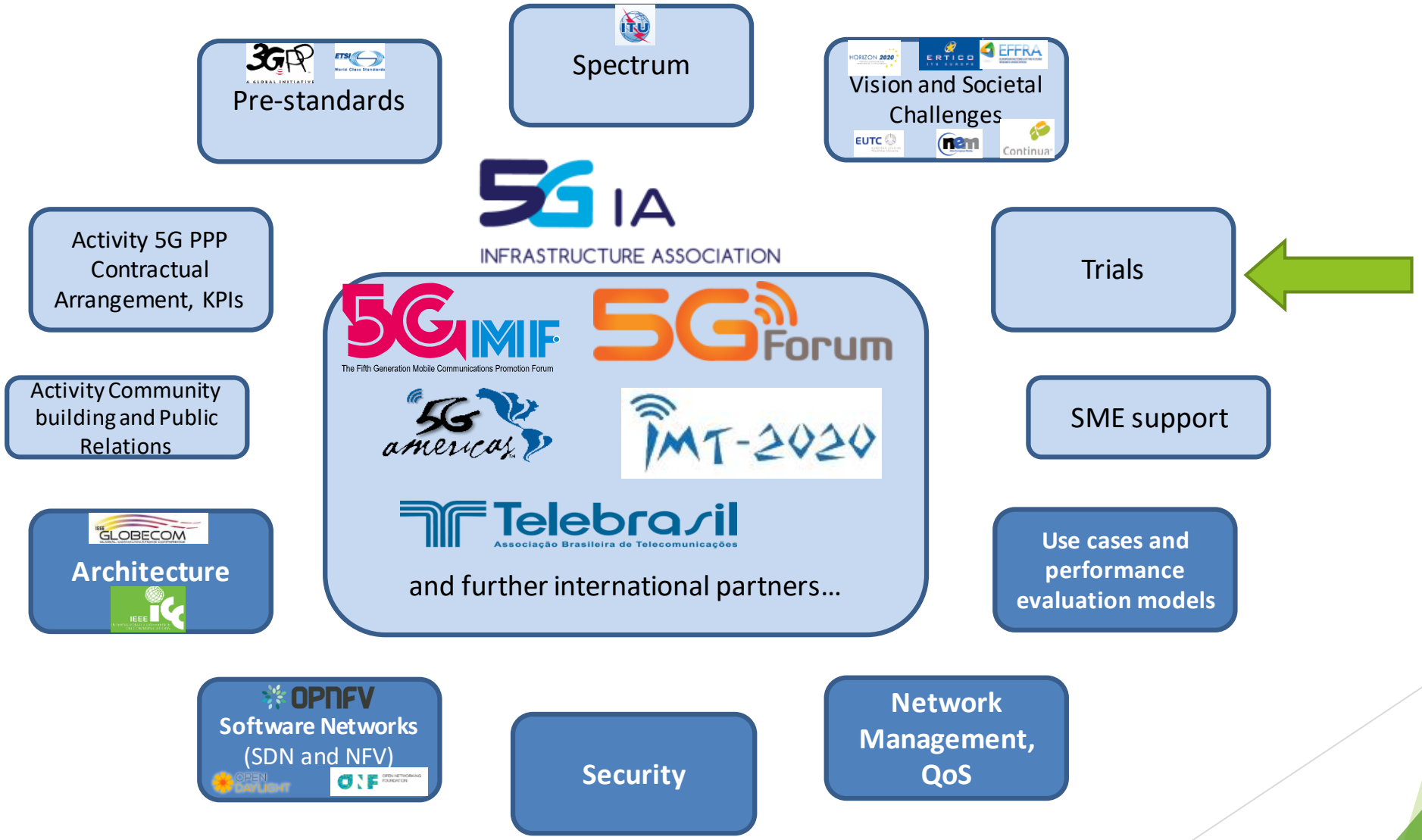
5G for Europe Action Plan

- The Commission proposed the following measures:
  - Align roadmaps and priorities for a coordinated 5G deployment across all EU Member states, targeting early network introduction by 2018, and moving towards commercial large scale introduction by the end of 2020 at the latest.
  - Make provisional spectrum bands available for 5G ahead of the 2019 World Radio Communication Conference (WRC-19), to be complemented by additional bands as quickly as possible, and work towards a recommended approach for the authorization of the specific 5G spectrum bands above 6GHz.
  - The EU Public-Private Partnership (5G-PPP) launched in 2013 has put Europe clearly in the forefront of the current research phase, as compared to other regions. The 5G Action Plan will leverage these initial research successes.
  - Promote early deployment in major urban areas and along major transport paths.
  - Facilitate the implementation of an industry-led venture fund in support of 5G-based innovation.
  - Unite leading actors in working towards the promotion of global standards.
  - Promote pan-European multi-stakeholder trials as catalysts to turn technological innovation into full business solutions.

Where the EU countries stand at the moment with respect to the 5G Plan?

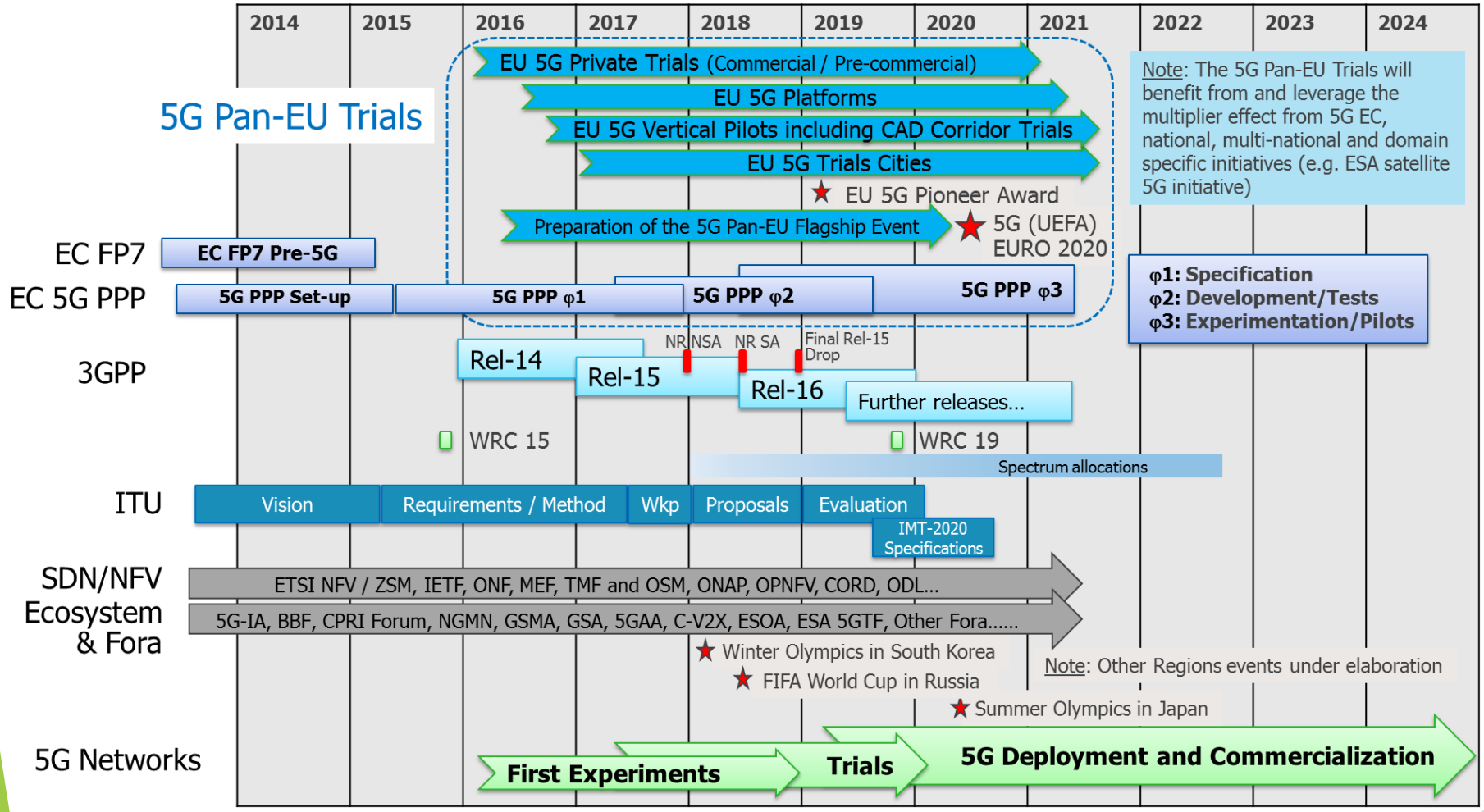
- From a preliminary study on the other EU MS on 5G initiatives, it seems that Italy is the only on that addressed the issue at National level.
  - In UK there is an initiative to sustain, with national funds, the realization of national test beds.
  - In Spain the government set 180M€ to support R&D projects on 5G and the development of ultrabroadband. Catalonia and the City of Barcelona took an initiative to promote Barcelona as a "5G City"
  - In Germany and Estonia private initiatives launched test beds on Berlin and Tallin.
  - In Sweden the local municipality of Stockolm launched an initiative to realize a testbed with Telia and Ericsson.
  - Italy launched on 16th of March 2017 a call for proposals to realize 5G infrastructures and services in 5 cities. The call closed last 20th September and the frequencies, 100MHz in 3.6-3.8 band, have been assigned for experimentation up to 2020. In particular Vodafone Italia will address Milano, Wind Tre-Open Fiber Prato and L'Aquila and Telecom Italia-Fastweb-Huawei Technologies Italia will work on Bari and Matera.
    - Next year (2018) the Italian Authority for communications will set the procedures to assign the right of use in the frequencies 694-790 MHz, 3.6-3.8 GHz e 26.5-27.5 GHz and after that will start the related procedures to assign them. Everything in Italy is moving on in compliance with the European roadmap on 5G

5G Infrastructure Association PPP



https://5g-ppp.eu/

5G Pan-EU Research & Trials Roadmap



https://5g-ppp.eu/5g-trials-roadmap/

How 5G trials can help?

- A crucial element of encouraging early investment in 5G will be to: a) identify new revenue streams which can help to provide returns for investors, and b) make the public/citizens aware about the 5G benefits.
  - 5G networks will eventually enable new services to be provided in sectors such as health and social care, agri-tech, tourism and culture, manufacturing, transport, entertainment and utilities.
- A small number of deployment pilots in EU/Greece would identify and help address practical and economic challenges relating to the deployment of next generation 5G mobile networks.
  - e.g. these could comprise one or more pilots focusing on deployment in an urban or suburban environment addressing different use cases, and one or more pilots focusing on deployment in a rural area.
- An urban pilot could provide a platform to test at scale a range of 5G “smart city” and IoT applications, such as those involving traffic monitoring, health and care, public safety and security, etc.
- A rural digital connectivity pilot could explore ways to provide the connectivity required to deliver services in sectors such as agriculture or health and care.

What “National” 5G testbed(s)/demo(s)/lab(s) can be used for?

- Demonstration/testing of 5G technologies for early promotion to future consumers/customers!
- Fulfilling the requirement of the EU “5G Action Plan”!
- Acting as an innovation catalyst!
- As a “marketing tool” for operators and vendors

Η αντίδραση του Ελληνικού Κράτους

- Ο Υπουργός Ψηφιακής Πολιτικής, Τηλεπικοινωνιών και Ενημέρωσης, Νίκος Παππάς συναντήθηκε πρόσφατα με τους CEO των εταιρειών COSMOTE, VODAFONE, WIND και τους ενημέρωσε για την υλοποίηση του Ελληνικού πλάνου.
  - Πρόσφατα δήλωσε «Ὑπογράψαμε ήδη συμφωνητικό συνεργασίας με την πόλη των Τρικάλων για την ανάπτυξη υποδομών πιλοτικού δικτύου 5G. Βρισκόμαστε ήδη στη διαδικασία προετοιμασίας του συμφωνητικού συνεργασίας με την πόλη της Πάτρας και με άλλες πόλεις».
  - «Η εμπορική ανάπτυξη του 5G θα φέρει καταιγιστικές αλλαγές σε πολλούς κλάδους της οικονομίας. Θα αποτελέσει τον καταλύτη και το απαραίτητο "όχημα" για τον ραγδαίο ψηφιακό μετασχηματισμό των κλάδων της οικονομίας και την ανάπτυξη εντελώς νέων αγορών, επιχειρηματικών μοντέλων, ευκαιριών».

- Η συμφωνία για την ανάπτυξη πιλοτικού δικτύου στα Τρίκαλα είναι το πρώτο βήμα και θα ακολουθήσουν και άλλες πόλεις, με στόχο να υπάρξει το συντομότερο δυνατόν εμπορική διαθεσιμότητα υπηρεσιών 5G σε όλες τις μεγάλες πόλεις και τους συγκοινωνιακούς άξονες της χώρας, όπως προβλέπουν οι στόχοι του Gigabit Society.
  - Οι δήμαρχοι επιλεγμένων πόλεων έχουν προσκληθεί πρόσφατα σε συζητήσεις

Summary

- “5G networks” are defined according to the new applications/use-cases/targeted markets they support & according to the new architecture and technologies used

- There is an EC mandate to implement the “5G for Europe Action Plan” across all EU Member States by 2020
  - Different Member States have reacted in different ways (others more enthusiastically/aggressive, while others less) and therefore they are at different stages of implementation
  - Greece has reacted but more actions are needed!
    - The local ecosystem needs to embrace this plan, as it can only act as a catalyst for its growth

Thank you!

Dr. Ioannis Tomkos
itom@ait.gr
+30 6973 328 329