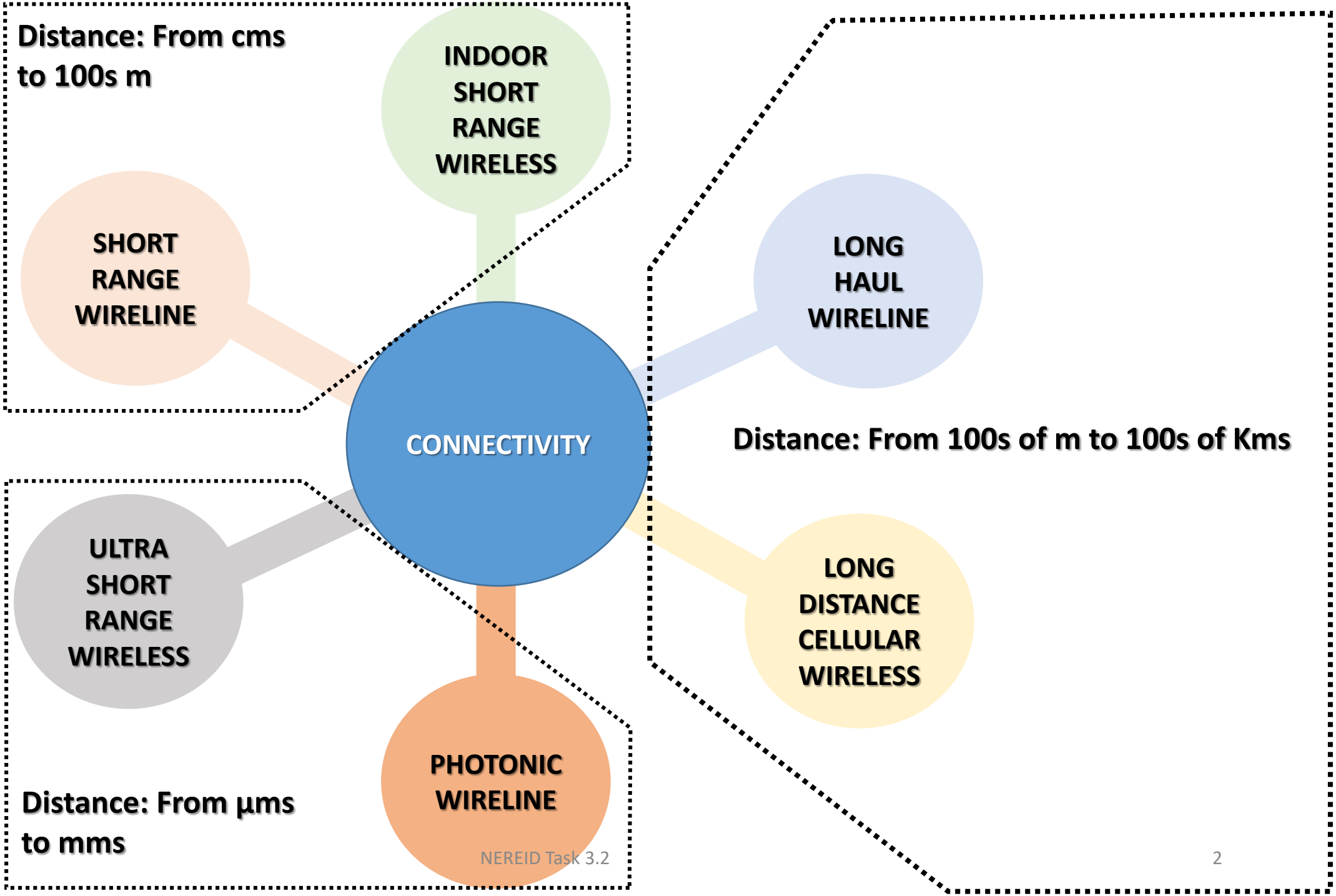
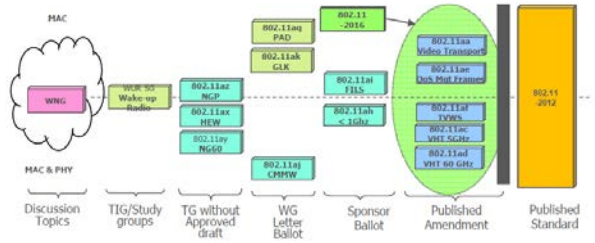
NEREID

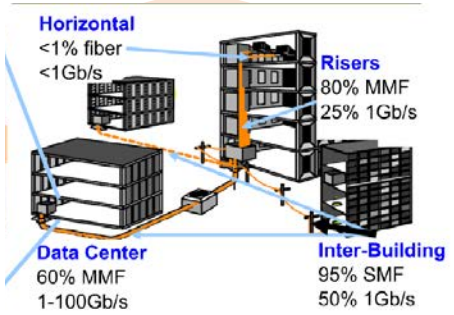
Task 3.2

CONNECTIVITY ROADMAP BUILDING


Distance: From cms to 100s m
INDOOR SHORT RANGE WIRELESS
SHORT RANGE WIRELINE
LONG HAUL WIRELINE
CONNECTIVITY
Distance: From 100s of m to 100s of Kms
ULTRA SHORT RANGE WIRELESS
LONG DISTANCE CELLULAR WIRELESS
PHOTONIC WIRELINE
Distance: From µms to mms

Distance: From cms to 100s m

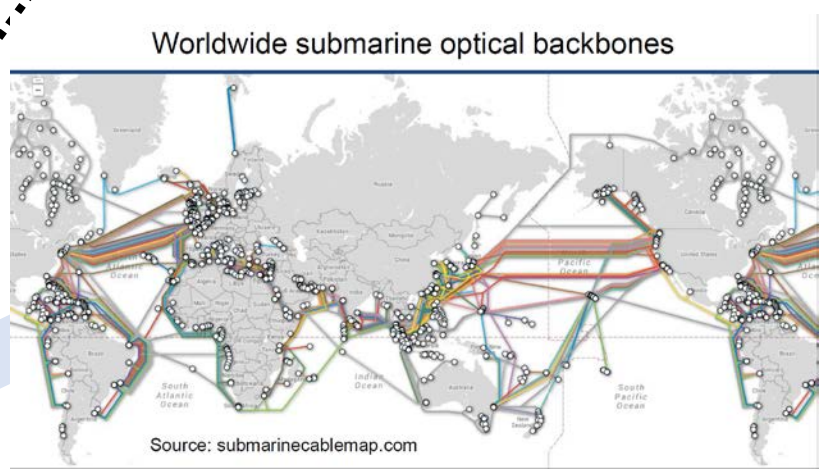




INDOOR SHORT RANGE WIRELESS

SHORT RANGE WIRELINE

LONG HAUL WIRELINE



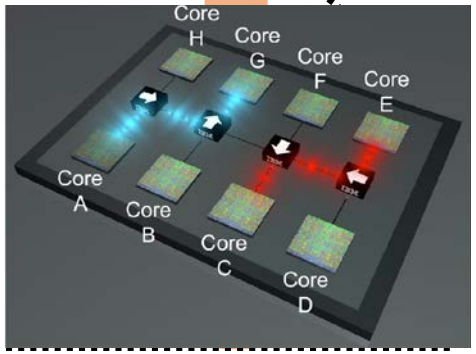
Distance: From 100s of m to 100s of Kms

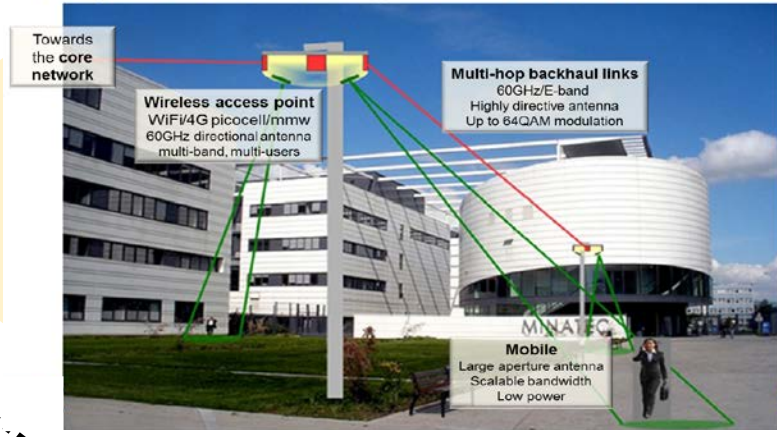
CONNECTIVITY

ULTRA SHORT RANGE WIRELESS

Distance: From µms to mms

PHOTONIC WIRELINE





LONG DISTANCE CELLULAR WIRELESS

5G+ Roadmap

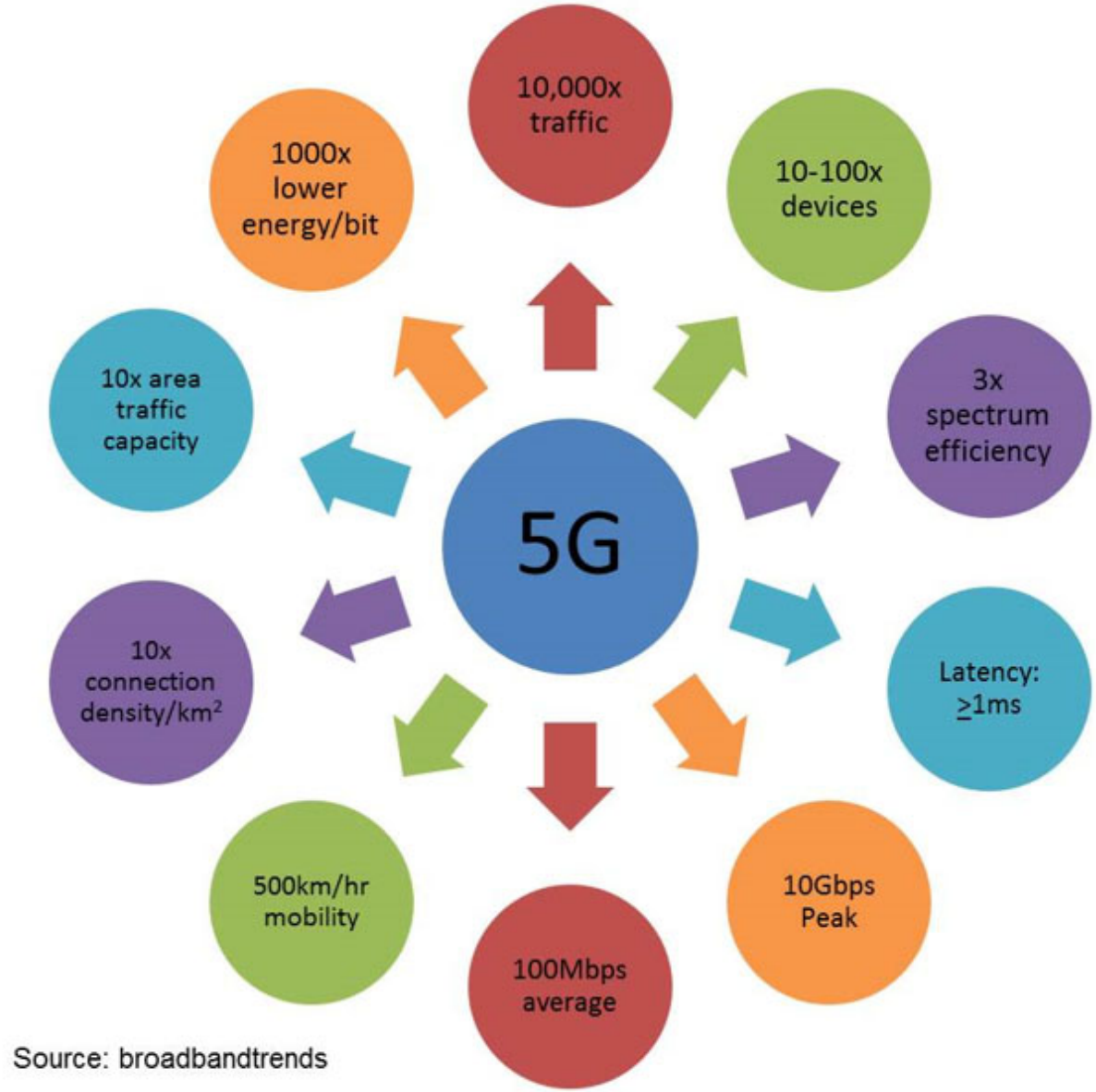
Dr. Emilio Calvanese Strinati

Smart Devices, Telecommunications & Security Scientific and Innovation Program Director

CEA-LETI

emilio.calvanese-strinati@cea.fr

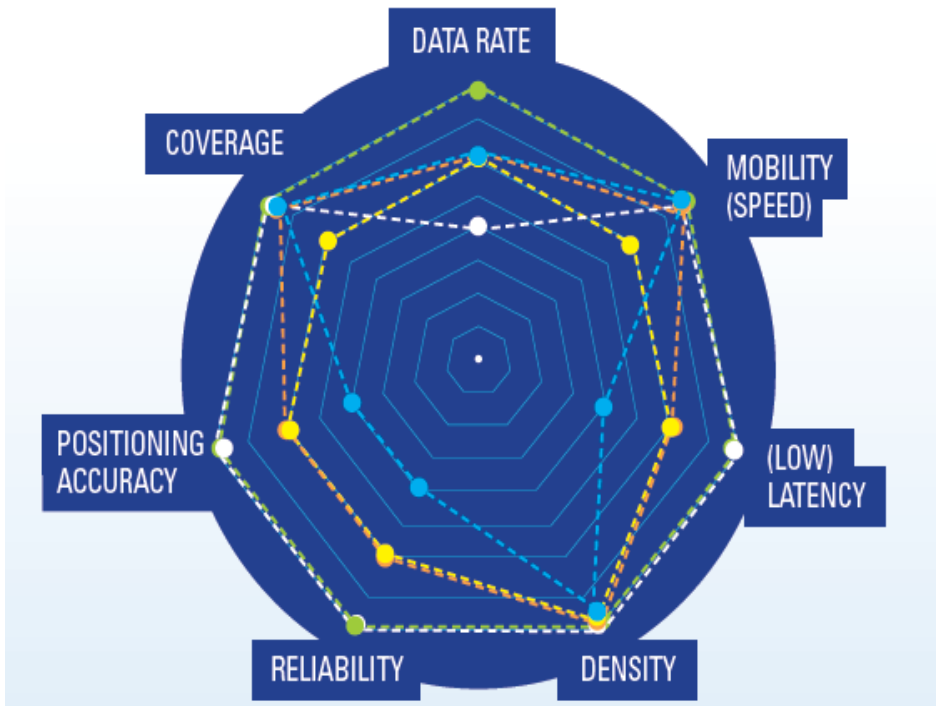
5G: THE PROMISE OF SCALABLE & EXTREME VARIATION OF REQUIREMENTS



Source: broadbandtrends

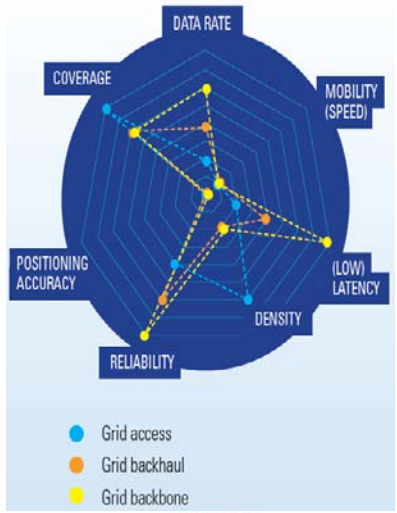
CHANGING THE COSTUMER: SPECIFIC KPIS PER VERTICAL

AUTOMOTIVE

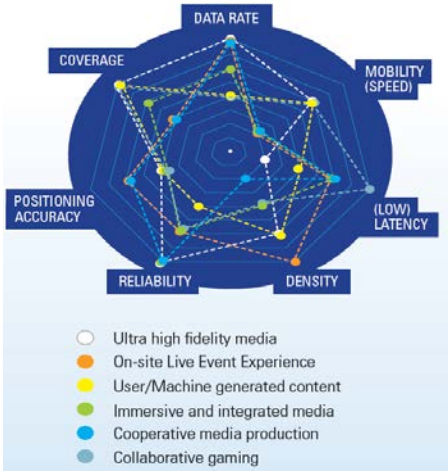


Source: 5G PPP

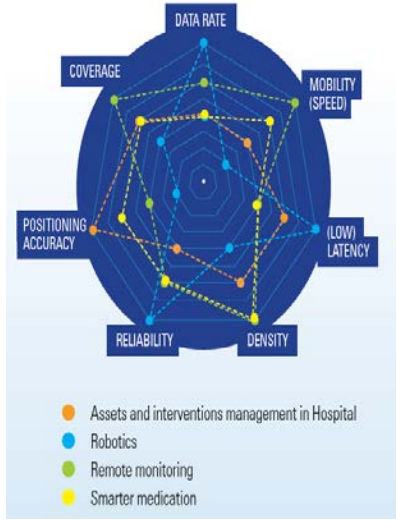
ENERGY



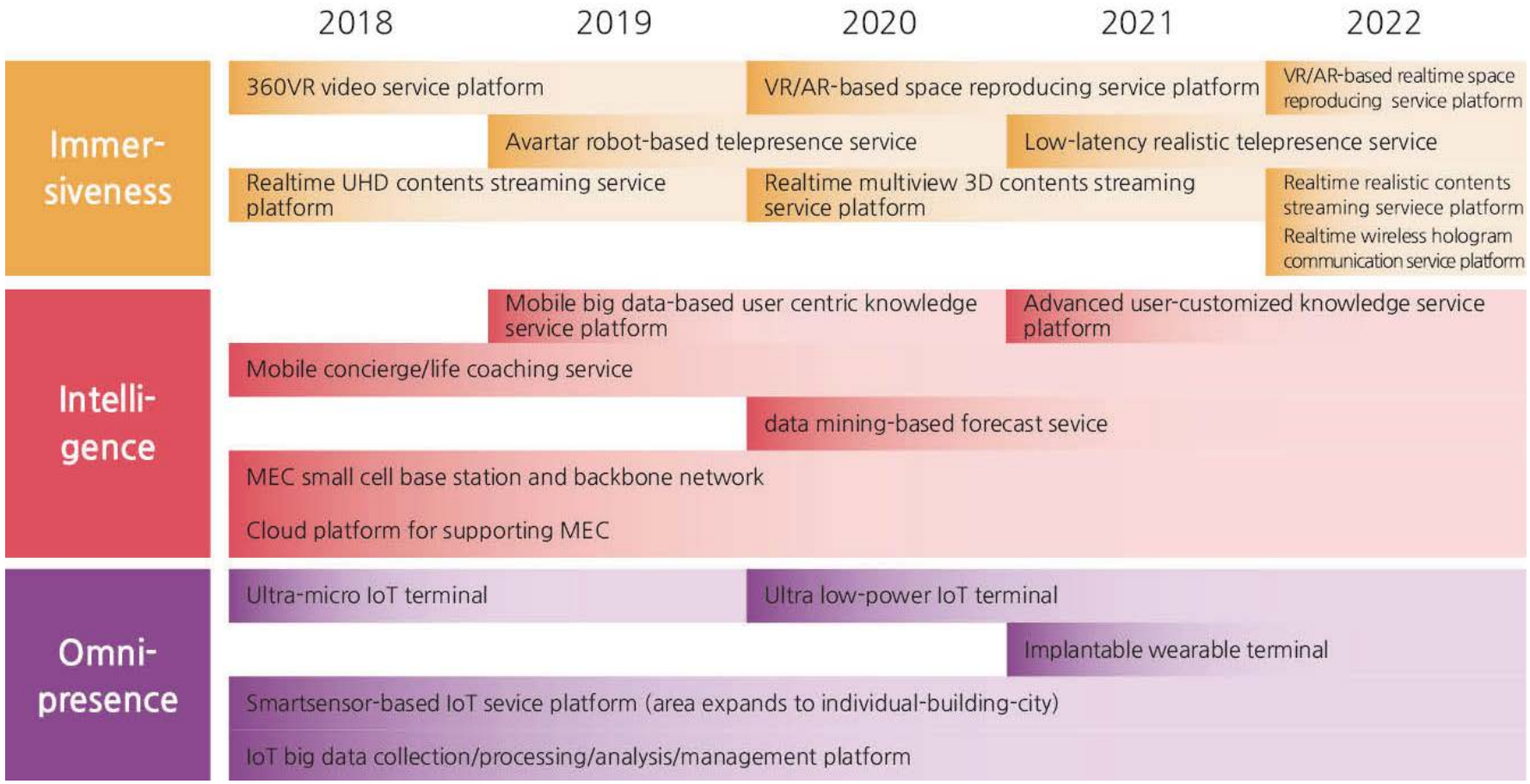
MEDIA & ENTERTAINMENT



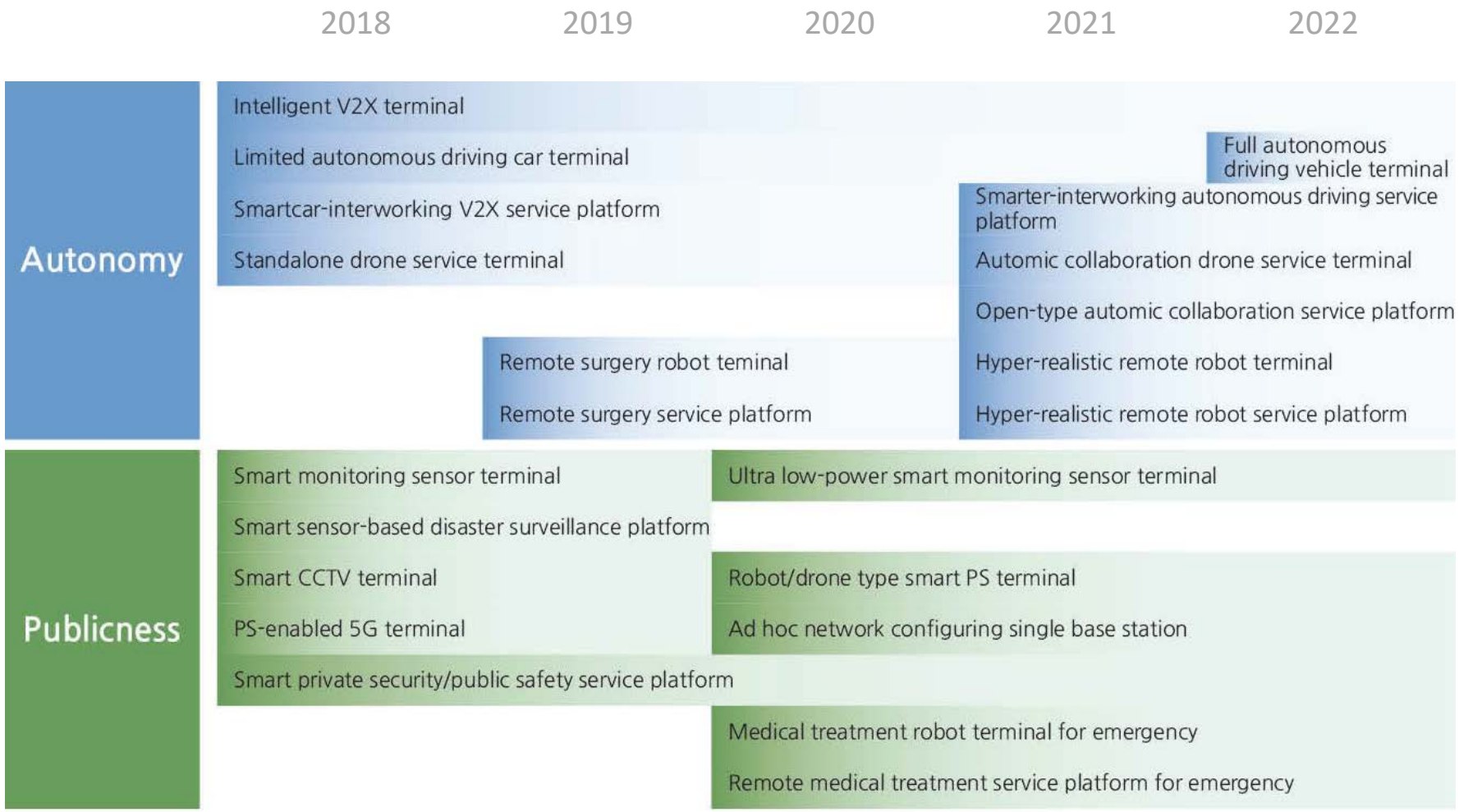
e-HEALTH



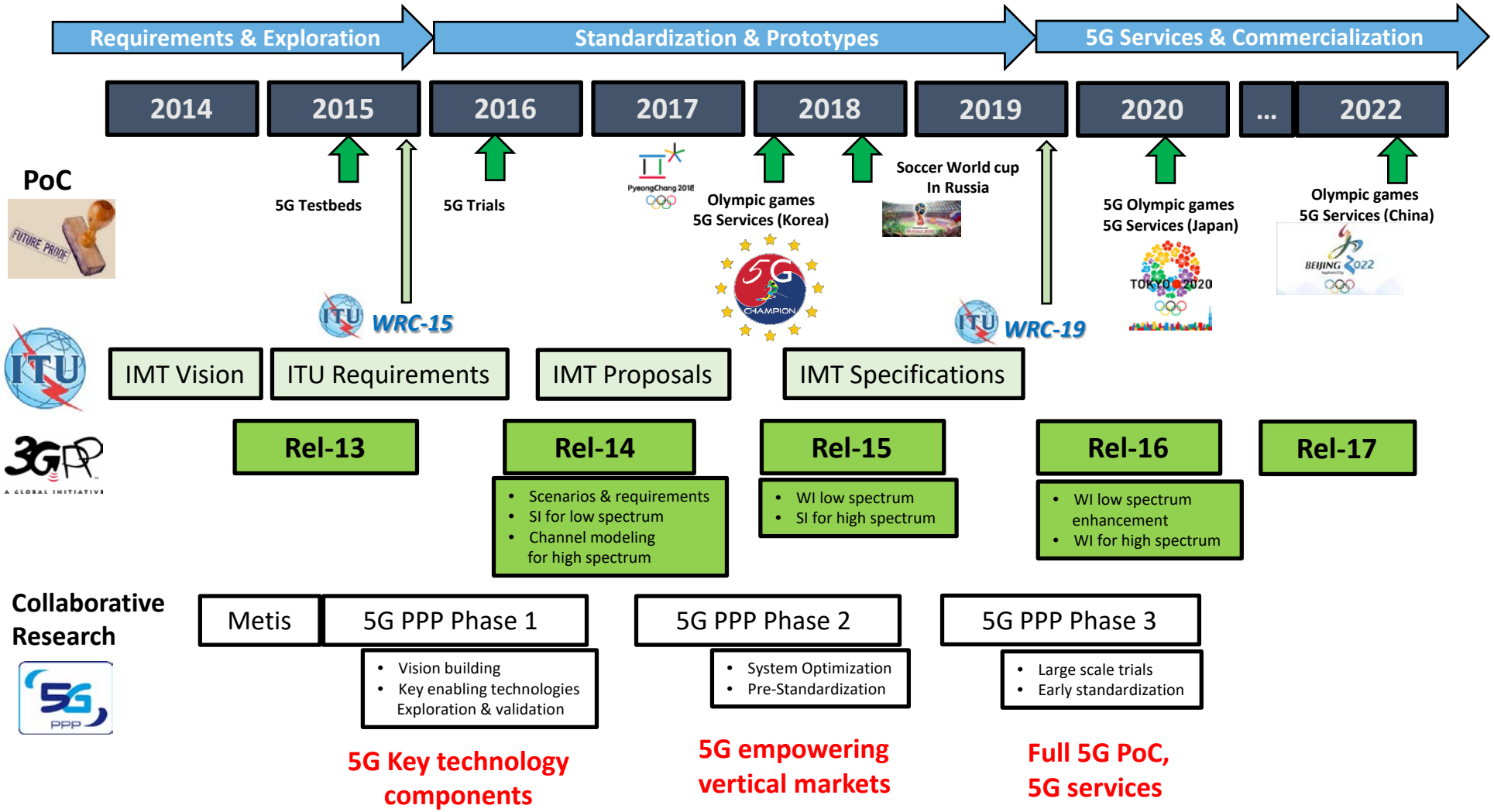
ROADMAP ON MAJOR 5G SERVICES & PRODUCTS



ROADMAP ON MAJOR 5G SERVICES & PRODUCTS



RACE TO 5G SERVICES



3GPP TIMELINE

- There will be two phases for the 5G normative work
  - **First 5G release / Release 15:** specification will be completed by Sep. 2018, addressing the more urgent subset of the commercial needs
  - **Second 5G release/ Release 16:** specification to be completed by Mar. 2020, for the IMT 2020 submission and to address all identified use cases & requirements

Different architecture options being evaluated

- Decisions as to which option will be standardized will be taken in 2017

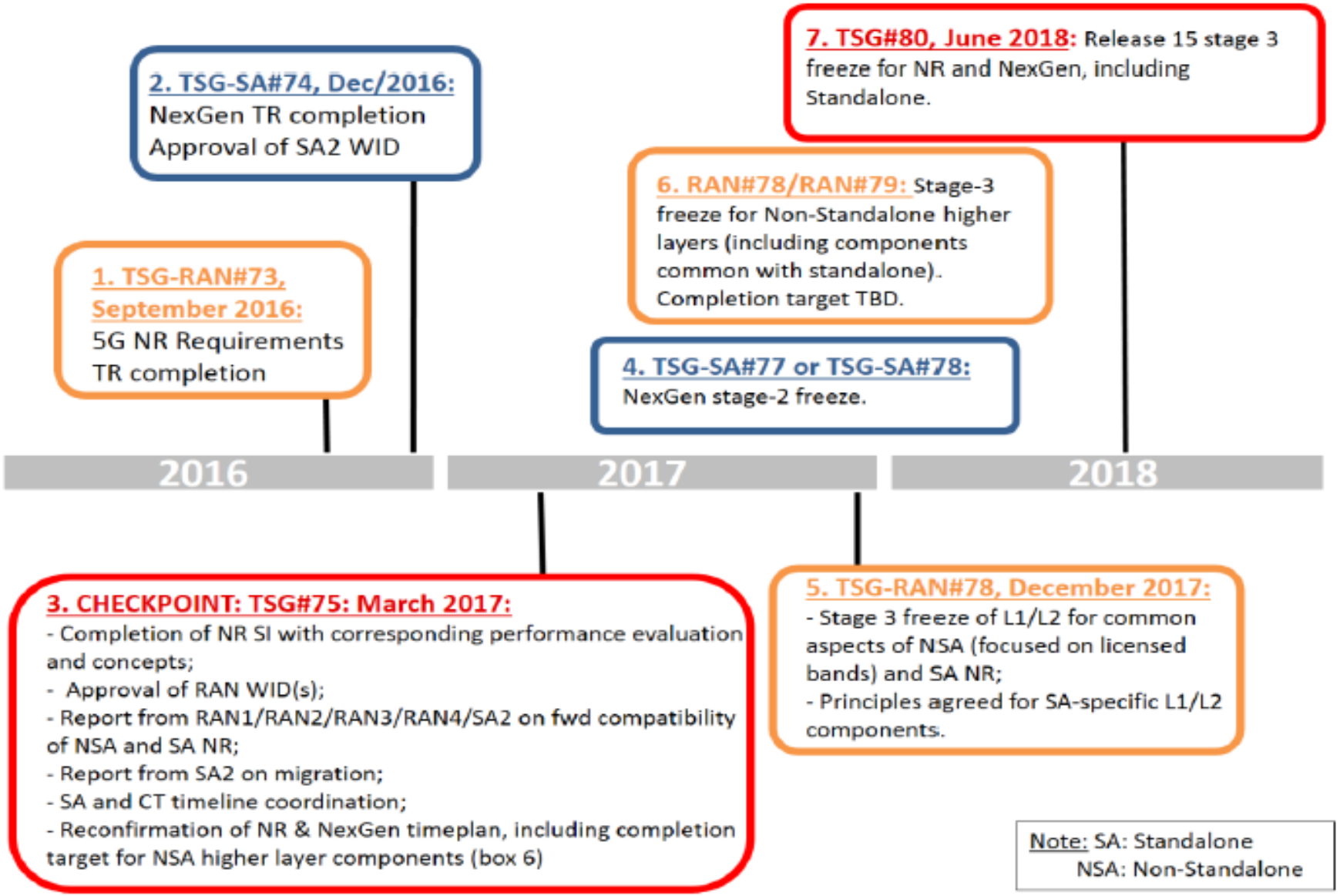
Use cases

- Enhanced Mobile Broadband
- Some Low Latency and High Reliability capabilities

Frequency ranges below 6GHz and above 6GHz

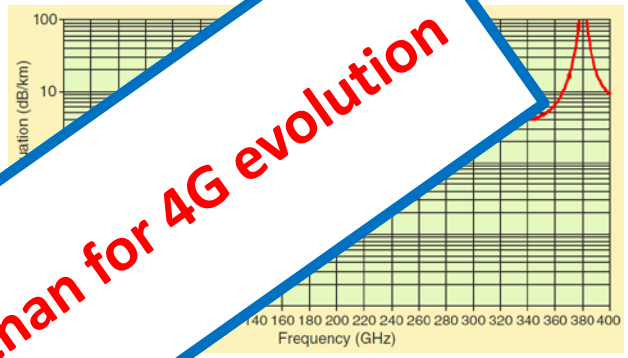
Forward compatibility between scenarios

RELEASE-15 WORKPLAN

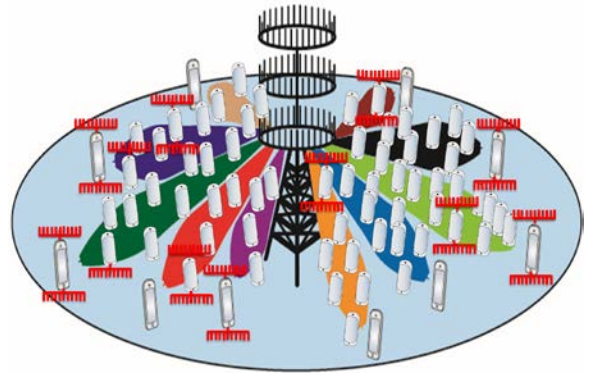


TOMORROW 5G AND LTE EVOLUTION

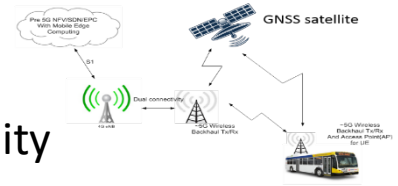
- Many more spectrum bands & types
  - From below 1 GHz to mmWave (up to 90 GHz)
  - Licensed, shared and unlicensed spectrum sharing
  - FDD, TDD, half Duplex



- More diverse deployment scenarios and N
  - Device-to-device, mesh, relay
  - From wide are to hotspots



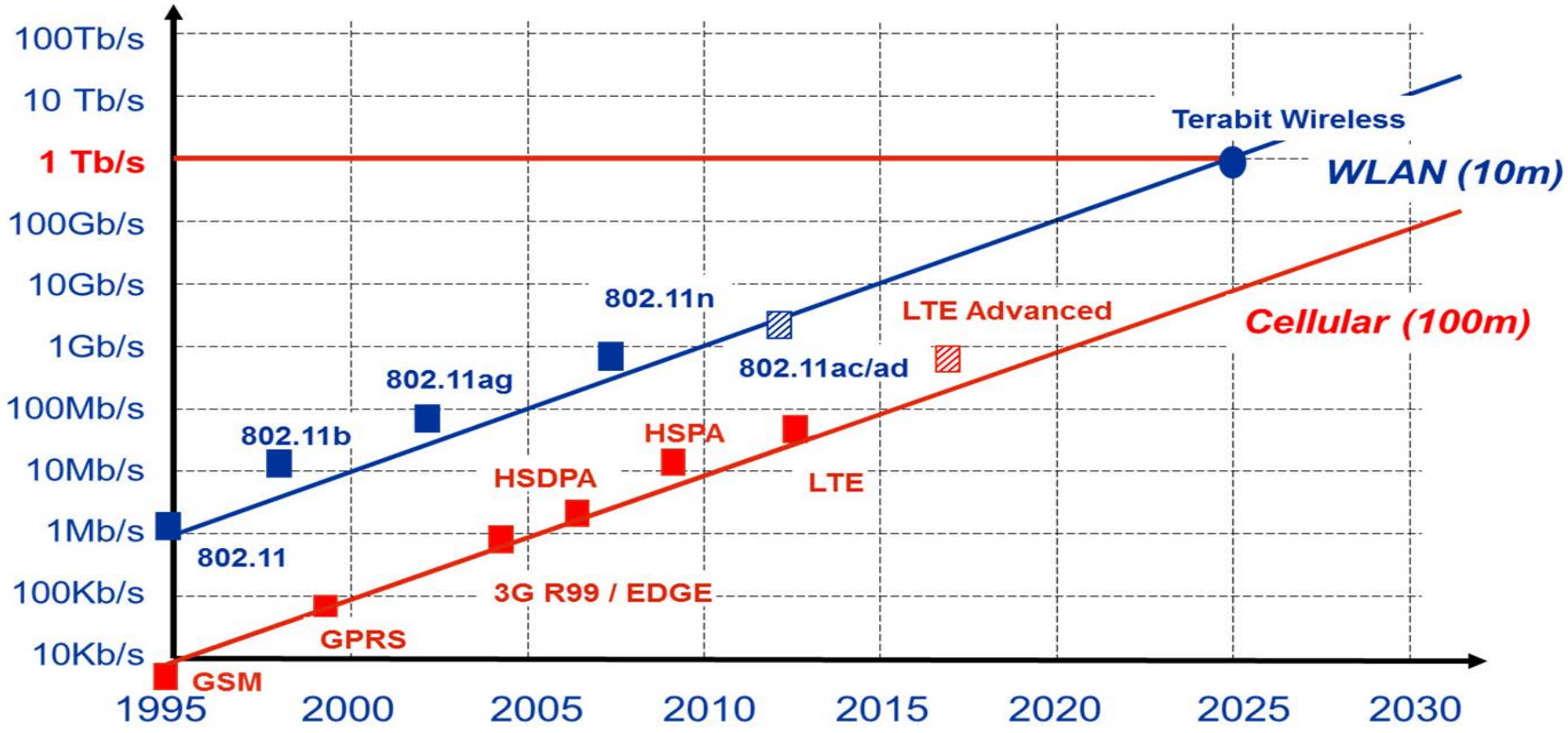
- Advanced wireless techn
  - OFDM adapted t
  - Massive MIM
  - Robust n
- Ext e cases (including dedicated for vertical markets)
  - rrow band
  - ical and nominal traffic
  - H bility (500 Km/h) to no mobility



The roadmap to 5G is significantly more complex than for 4G evolution

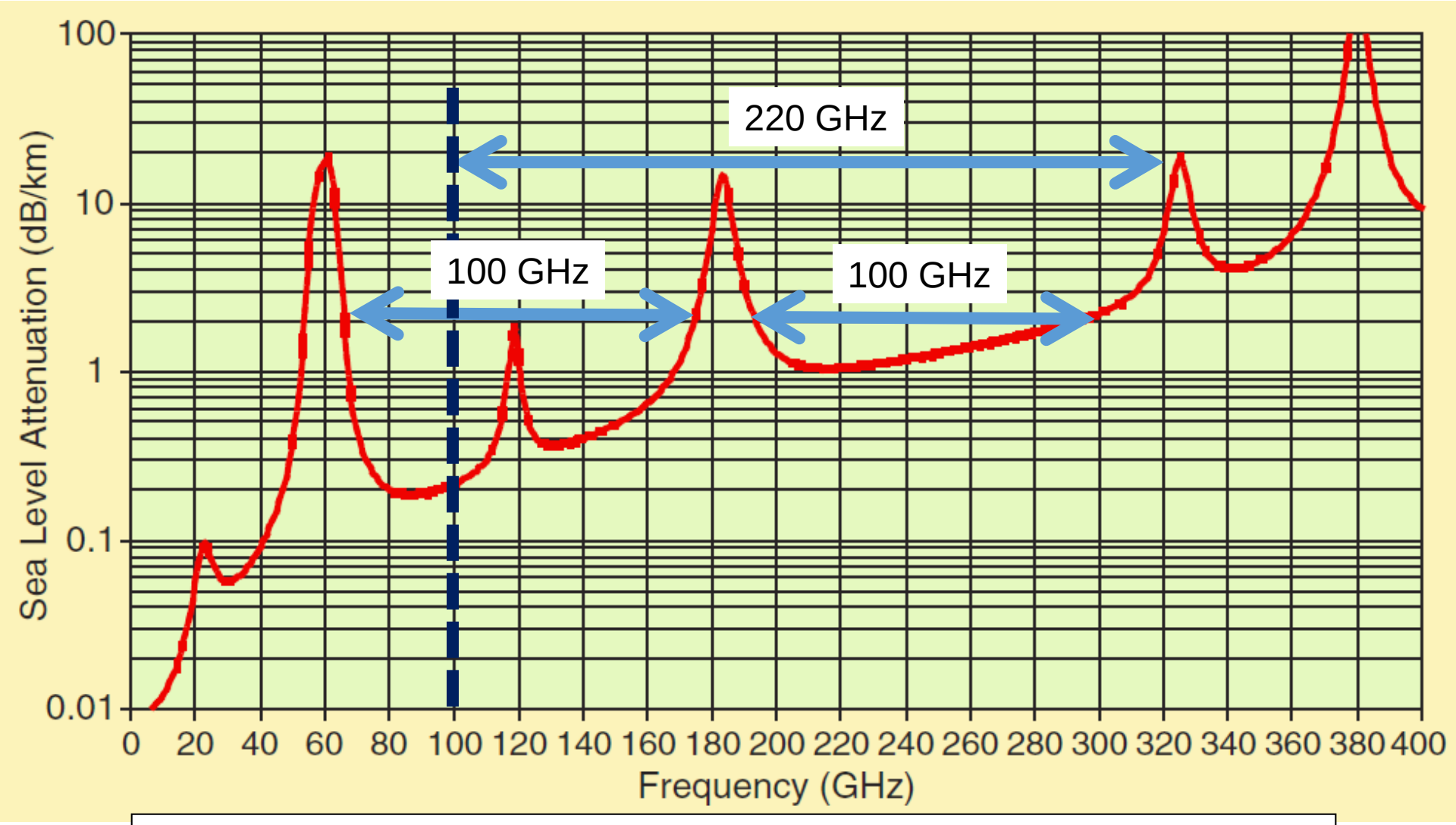
FUTURE CAPACITY NEEDS: TB/S (WIRELESS)

Applications and services beyond 2020 will require **1Tb/s wireless** connections



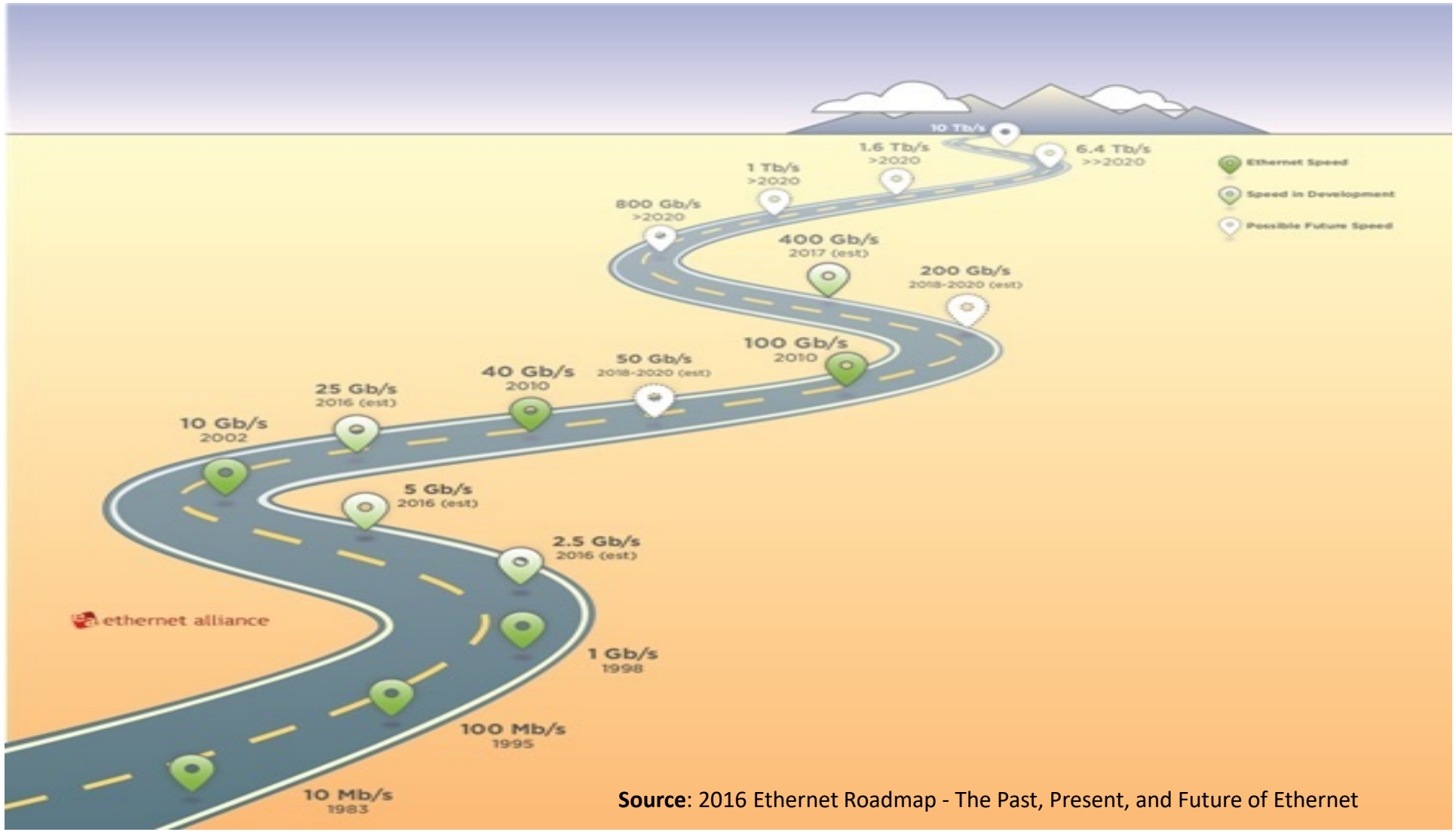
Reference: G. Fettweis, System Concept for 1 Gbit/s and Beyond, Tutorial IEEE 802 Plenary, Vancouver, November 2005

NEW SPECTRUM: ABOVE 90 GHZ FOR 1TB/S



Jonathan Well, „ Faster Than Fiber: The Future of Multi-Gb/s Wireless,“ IEEE Mircrowave Magazine, May 2009, pp. 104-112

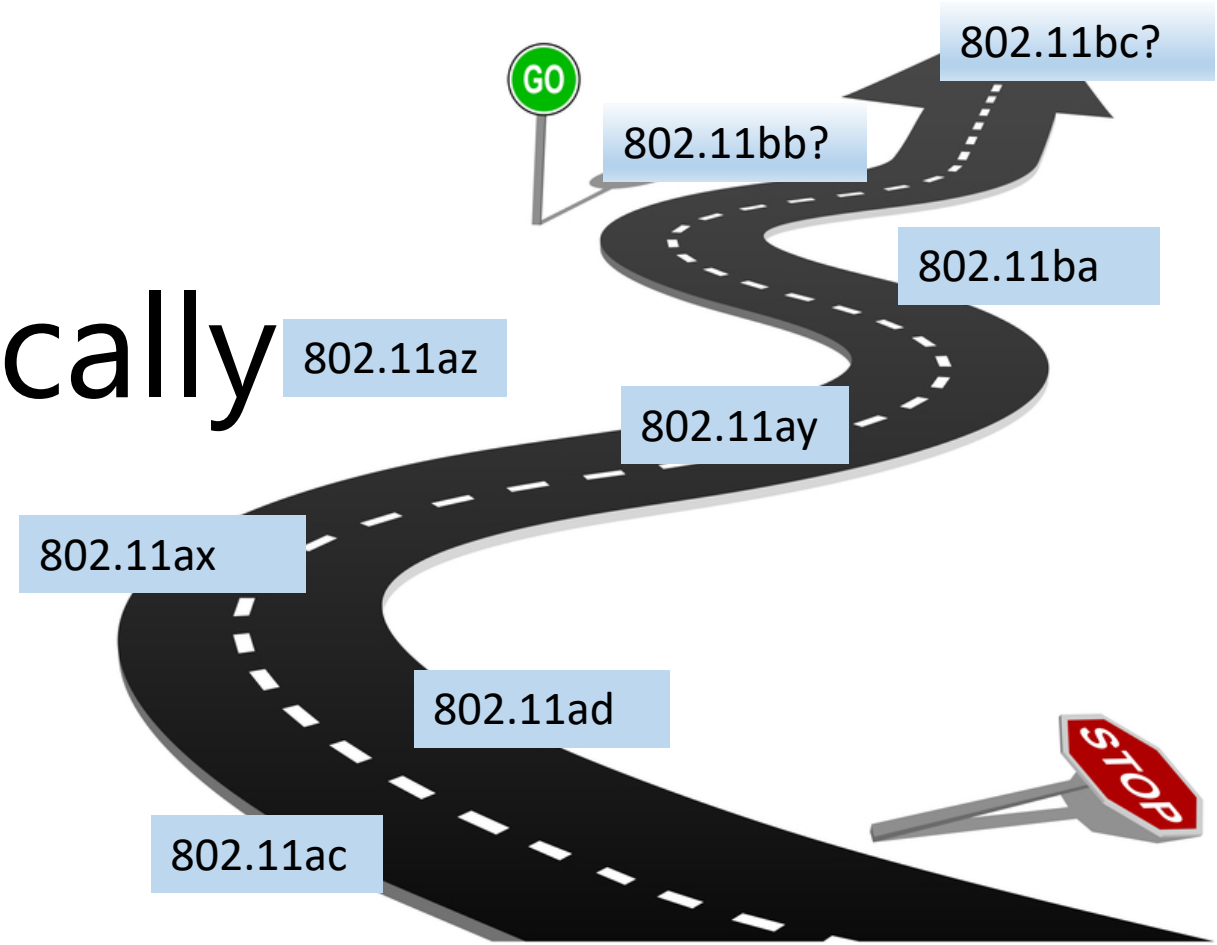
FUTURE BACKHAUL NEEDS



Source: 2016 Ethernet Roadmap - The Past, Present, and Future of Ethernet

802.11 challenges

technically & politically

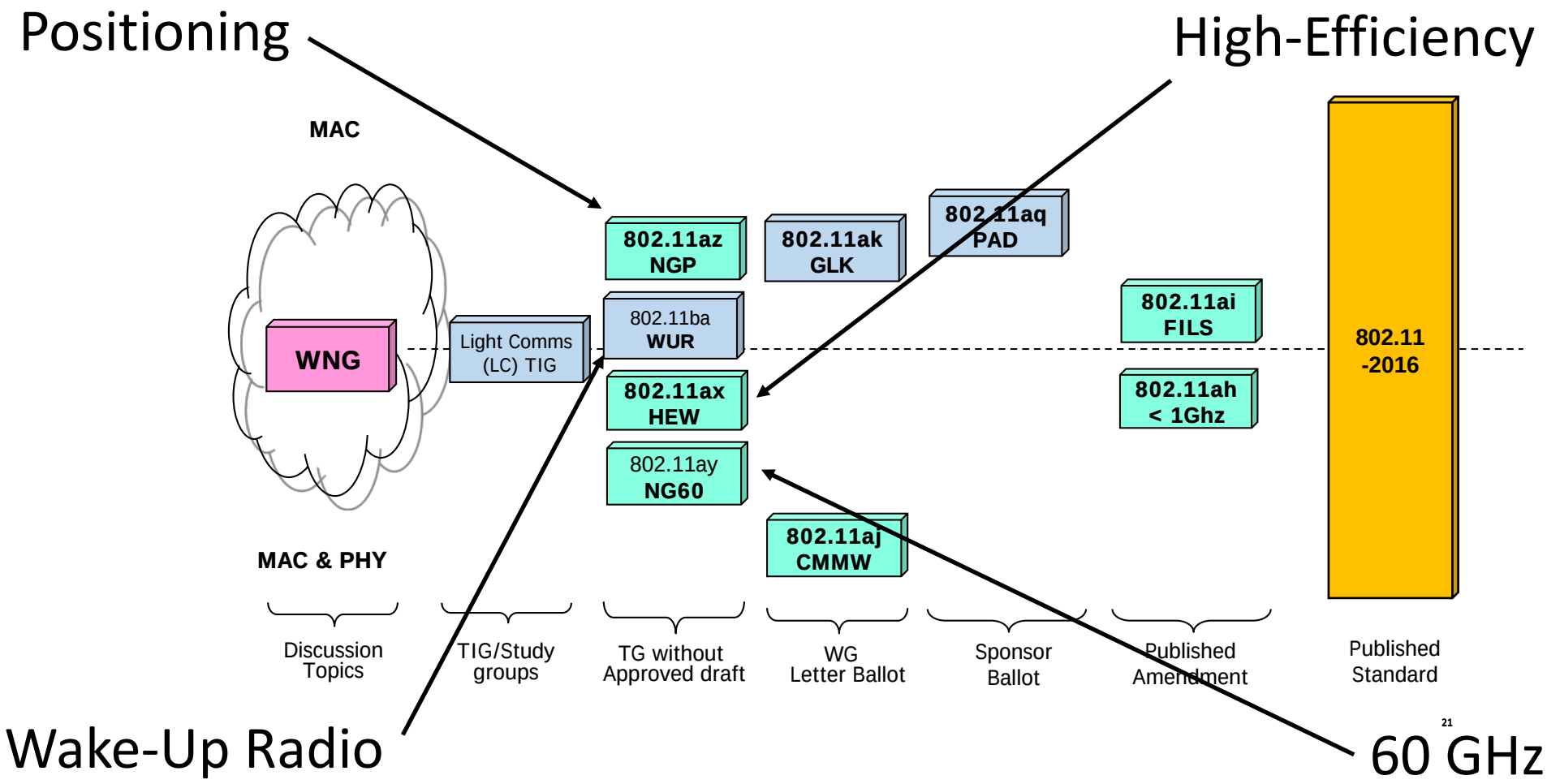


Leif Wilhelmsson
Ericsson Research

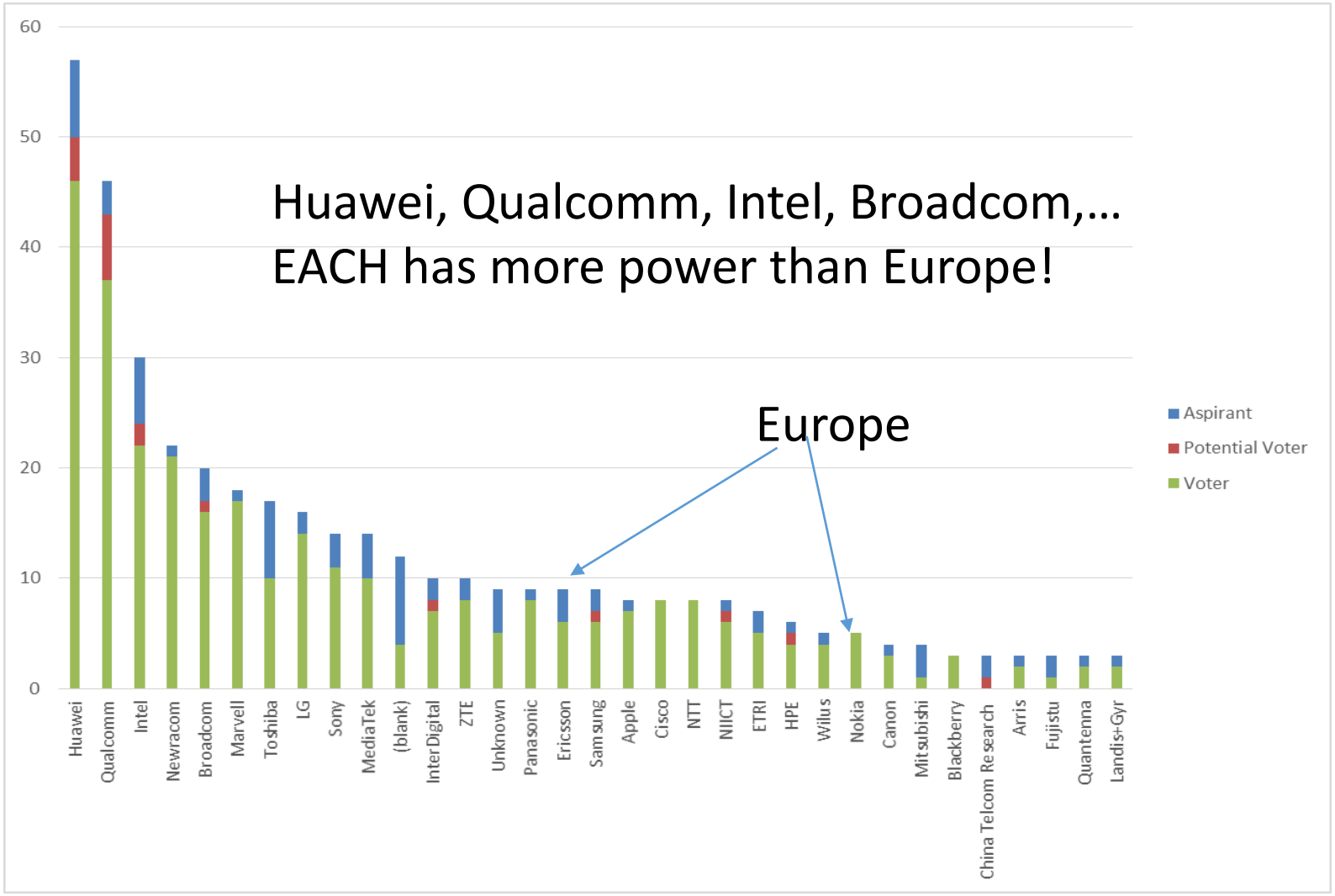
Outline

- Current Activities
  - Technically
  - “Politically”
- Expected Future Activities
  - Technically
  - “Politically”
- Take-aways

Current Main Activities - Technically



Current Main Activities - “Politically”



Expected Future Activities - Technically

"802.11ax++"

- mmW (60 GHz and higher?)
- Massive MIMO
- New spectrum
- Better support for IoT
- Coexistence with non-802.11
- Visible Light Communications

"802.11ay++"

"Green field"

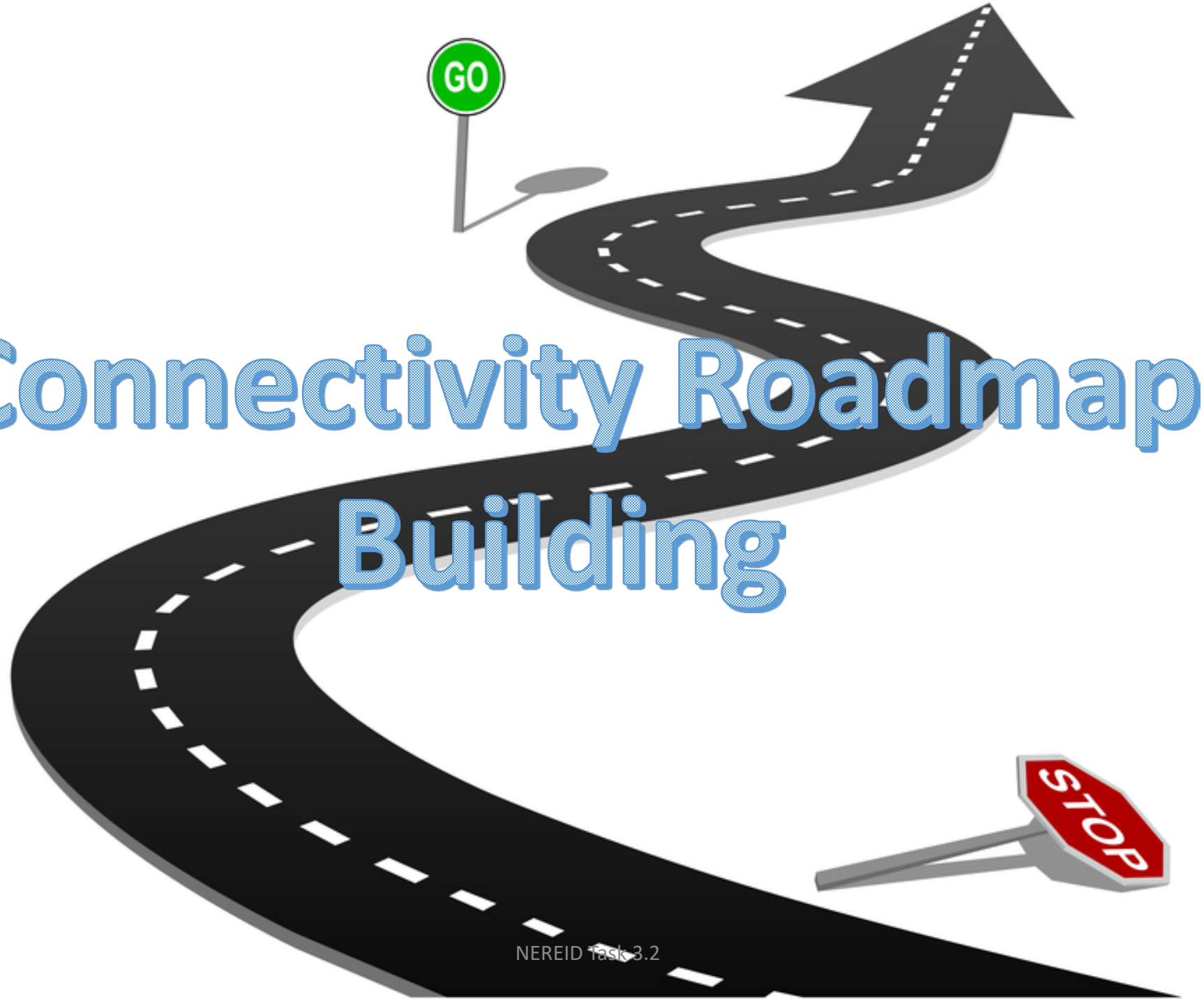
Expected Future Activities - Politically

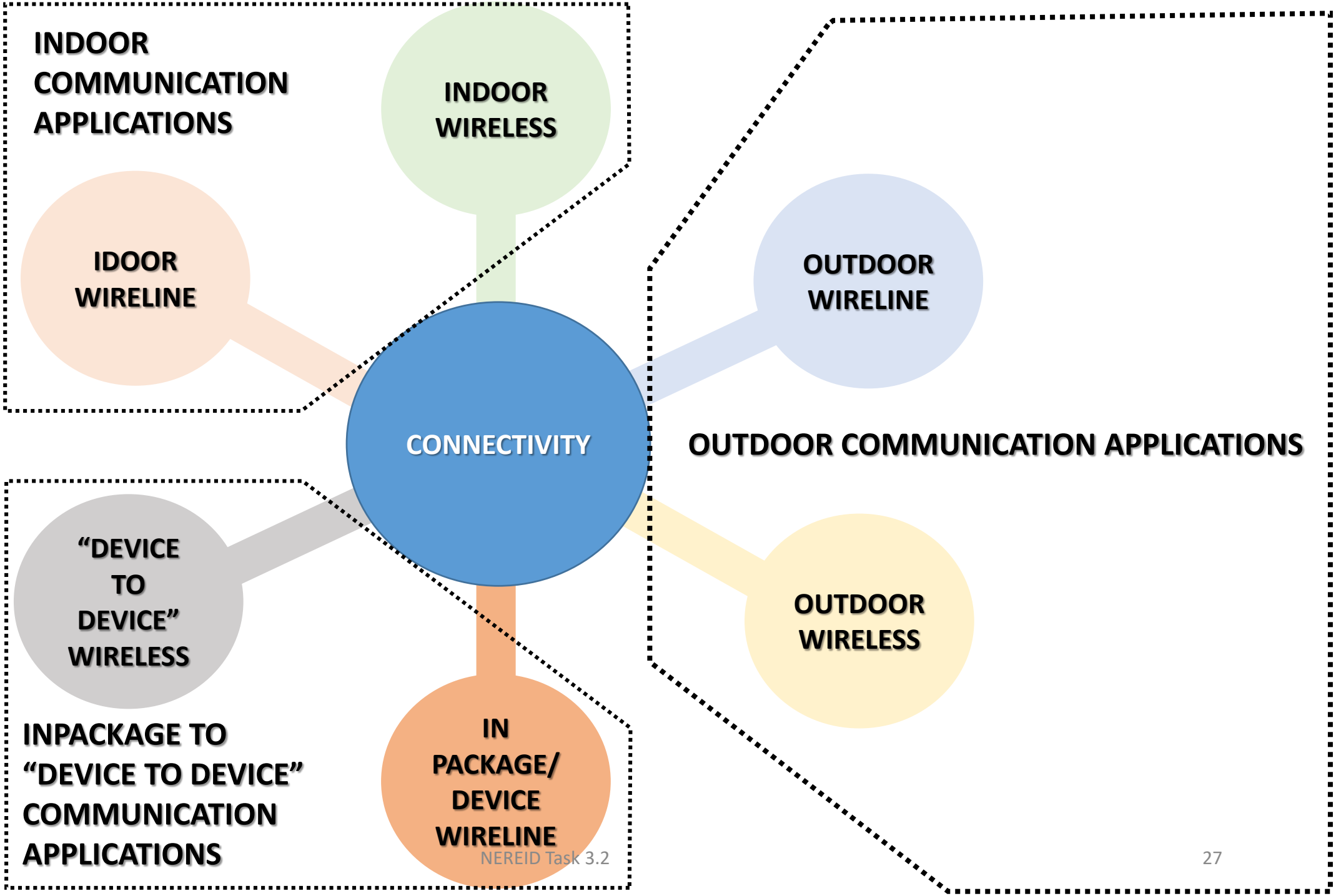
- IEEE 802.11 will have to deal with that unlicensed will be used by other major technologies as well
  - The huge advantage of having a band on their own for free is history
  - Must be competitive with MuLTEfire and 3GPP
  - Must show it can coexist with other technologies. Now it is only the other way around, other standards must not interfere with Wi-Fi
- Europe needs to determine if they are OK with standing at the side-line watching, and if not determine how to engage

Take-Aways

- In terms of wireless data traffic, IEEE 802.11 is the largest carrier. It is in a sense disruptive is that some thing not so good, suddenly became good enough at a lower price
- One important key to the success is the free bands. Another that the key players have teamed up
- IEEE 802.11 and e.g. 3GPP are moving from complementary towards being more competitive (spectrum and feature-wise)
- From a European perspective, it does not seem good that IEEE 802.11 standardization is happen in rooms where we are not present

Connectivity Roadmap Building




INDOOR COMMUNICATION APPLICATIONS
INDOOR WIRELESS
IDOOR WIRELINE
CONNECTIVITY
OUTDOOR WIRELINE
OUTDOOR COMMUNICATION APPLICATIONS
OUTDOOR WIRELESS
"DEVICE TO DEVICE" WIRELESS
IN PACKAGE/ DEVICE WIRELINE
INPACKAGE TO "DEVICE TO DEVICE" COMMUNICATION APPLICATIONS

OUTDOOR WIRELESS APPLICATIONS

Outdoor & Cellular	**Present**	**2-4years**	**4-7Years**	**8 – 15 years**
IoT Long Range	Sub GHz (10s Kms, Kbs) ultra low power (mW)	Sub GHz (100Km, Kbs) Ultra low power (<mW)	*Sub GHz (100Km, Kbs) ?* ***Toward 0 power?*** ***Hardware Security****?*	*To be completed*
Up & Dwn Links	0.7 to 3GHz (few Mbs)	0.7 to 6 GHz (10s Mbs) 60GHz (Gbs; Dynamic Beam orientation) Research in 100GHz band	***0.7 to 100GHz*** *(10 Gbs) With* ***dynamic Beam Orientation*** *Research over 100GHz bands*	*Up to THz (10s of Gbs) With Dynamic Beam Orientation*
Fix Mini Cell to Mini Cell & Fix Mini Cell to Cell Backhauling	Research Activities on mmW bands: 28GHz; 40GHz; 60GHz; 70-80GHz.	mmW bands (10 Gbs) with Beam Focussing Research in 100GHz band	*mmW to THz bands (10s of Gbs) with* ***Beam Focussing***	*mmW to THz bands (100 Gbs) with Beam Forming*
Mobile Mini Cell to Mobile Mini Cell; Mobile Mini Cell to Cell Backhauling		Research Activity on Dynamic Beam Orientation	*mmW bands (10Gbs) with* ***Dynamic Beam Orientation***	*mmW bands (10s of Gbs) with Dynamic Beam Orientation*

OUTDOOR WIRELINE APPLICATIONS

Cellular, Data Centers long Range, and Long Haul	**Present**	**2-4years**	**3-6Years**	**7 – 15 years**
Cell to Cell ;	Optical Fibers (10 Gbs / fiber)	Optical fibers (toward 40 Gbs / fiber)	*Optic fibers (**100 Gbs / fiber**)?*	*Optic (n x 100 Gbs / fiber)?*
Fix Mini Cell to Mini Cell, Fix Mini Cell to Cell		*Low cost Optical Fibers? (10 Gbs / fiber)?*	***Low cost Optical Fibers** (10s of Gbs)?* *+ Through wall Plastic Waveguide (10 Gbs)*	*Low cost Optical Fibers (100 of Gbs)?* *+ Through wall Plastic Waveguide (10s of Gbs)*
Cell to Data Centers; Data Centers Long Range	Optical Fibers (10 Gbs / fiber)	Optical Fibers (toward 40 Gbs / fiber)?	*Optical Fibers (**100 Gbs / fiber**)?*	*Optical fibers (n x 100 Gbs / fiber)?*
Long haul	Optical fibers (< 10 Gbs / fiber)?	Optical fibers (Toward 10 Gbs / fiber)?	*Optical fibers (**40 Gbs / fiber)**?*	*Optical Fibers (100 Gbs / fiber)?*

INDOOR WIRELESS APPLICATIONS

Indoor communication & Localization	Present	2-4years	3-6Years	7 – 15 years
WLAN/WPAN/WBAN	WiFi (2.4 – 5GHz; <500Mbs) BT (2.4GHz; <10Mbs) DECT (1.9GHz; <100kbs) Infrared (<10m)	WiFi (2.4 – 5GHz; < 1Gbs) BT (2.4GHz; <10Mbs) DECT (1.9GHz; <100kbs) Infrared (<10m) 802.11 ad (60GHz; > 1Gbs) LiFi (visible light; > 1Gbs) Research over 100GHz bands	***Cognitive Multi Mode Radio*** *0-6GHz + 60GHz* ***LiFi*** *(10s Gbs)* P2P over 100GHz bands Research in sub-THz band	*Cognitive Multi Mode* *WLAN over 100GHz* *LiFi (100s Gbs)??* *P2P in sub-THz band*
WSN	Ad-hoc(ISM bands; Kbs) Zigbee (2.4GHz; Kbs) BTLE (2.4GHz; Kbs)	802.11 ah, ax (Mbs, mW) Wake up systems & Protocol	*Cooperative sensing, cooperative radio* ***Toward « Zero Power »*** ***Hardware Securtiy***	*« Recycling material » for radio* *« Zero power node »* *Security / Safety / Privacy*
Localization ?	Radar (RF; < 10m) Infrared (<10m)	Radar (RF &mmW; <100m) UWB (<20m) Ultrasound (<10m)	***Radar (RF to THz)*** *UWB* *Ultrasound* *Impulse light*	*Multi physics fusion*

INDOOR WIRELINE APPLICATIONS

Indoor & Data Center Short Range	Present	2-4years	3-6Years	7 – 15 years
WLAN	Copper (100Mbs; <5m) PLC (Power line carrier) (1Mbs; 20m) Optical Fiber (few Gbs; 100m) Plastic Optical Fiber(10s of Mbs; 10m)	Copper (Lower power) PLC (10Mbs; 20m) Optical Fiber (10s of Gbs; 100m) **Graded Index POF (100s of Mbs; 10m)**	Copper (Low power HDR) PLC (100Mbs; 20m) Optical Fiber (100 Gbs; 100m) **GI-POF (1 Gbs; 10m)** mmW Plastic Wave Guide (few Gbs; <20m)	Copper (ULP HDR) PLC (n x 100Mbs; 20m) Optical Fiber (100s of Gbs; 100m) GI-POF (10 Gbs; 10m) mmW PWG (n x 10Gbs; <20m)
WSN		PLC (Kbs, 100m)	To be completed	To be completed
Data Centers Short Range	Copper (1m; <10 Gbs) Optical Fibers (10m; 40 Gbs / fiber)	Copper (1m; 10Gbs) Optical Fibers (10m; 100 Gbs / fiber)	Copper (1m; 10s of Gbs) Optical Fiber (10m; n x 100 Gbs / fiber) **GI-POF (1m; 1Gbs)** mmW PWG(1m; 10Gbs)	Copper (1m; 100Gbs) Optical Fiber (10m; 1Tbs / fiber) GI-POF (1m; 10 Gbs) THz PWG (1m; 10s of Gbs)

DEVICE TO DEVICE WIRELESS APPLICATIONS

Ultra Short Range	**Present**	**2-4years**	**3-6Years**	**7 – 15 years**
Die To Die **Package To Package**	Research on: EM Field (Mbs, mm) ES Field (Mbs, um) mmW Radio (Gbs, mm)	Data rate > 1Gbs BER 10^{-12}	**Data Rate > 10Gbs** **BER 10^{-15}**	Data Rate > 100Gbs BER 10^{-18}
NFC	RF (13MHz; Kbs)	RF (13MHz; 100Kbs)	RF (13MHz; 1Mbs) **Hardware Security**	Security / Privacy Embedded
RFID	RF (13MHz; Kbs) RF (2.4GHz; Mbs) Research: in mmW bands	RF (13MHz; 100Kbs) RF (2.4GHz; 10Mbs) mmW (60GHz; 100Mbs)	RF (13MHz; 100Kbs) RF (2.4GHz; 10Mbs) **mmW (60GHz; 100Mbs)** **Hardware Security**	Security / Safety / Privacy Embedded

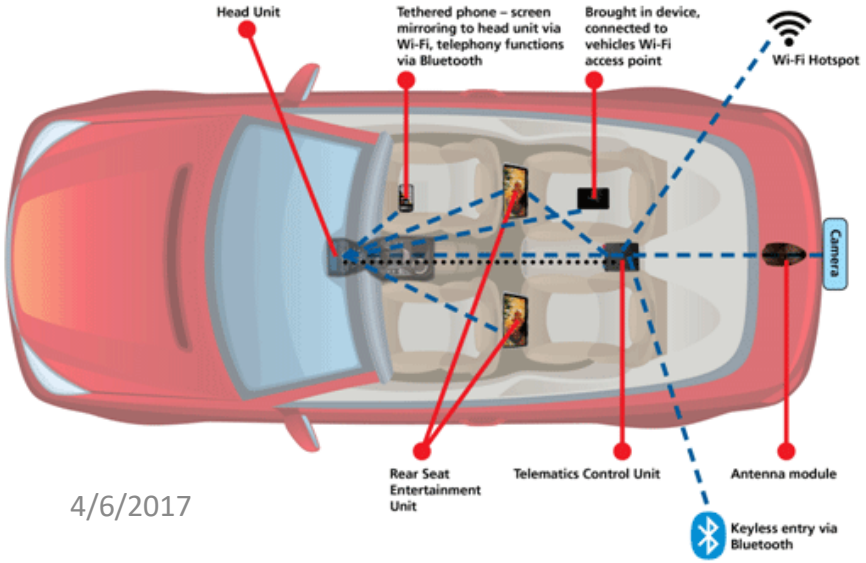
IN PACKAGE/DEVICE WIRELINE APPLICATIONS

Outdoor & Cellular	Present	2-4years	3-6Years	7 – 15 years
Die 2 Die	Copper Pilar (Gbs, 100s µm) Short Bonding (100Mbs, mm) Photonics Silicon Interposer (10s Gbs, mm)	Copper Pilar (10 Gbs, 100s µm) Photonics Silicon Interposer (100 Gbs, mm) Active Interposers (10Gbs, mm)	Copper Pilar (100 Gbs, 100s um) Photonics Silicon Interposer (Tbs, mm) **Active Interposers (100Gbs, mm)**	Toward 10 Tbs over mm Active Interposers (1Tbs, mm)
In Module	Bonding (10s Mbs, mm) Optical guide on module's substrate (10s Gbs, mms) Flip chipped + Copper (Gbs , mm)	Optical guide (100 Gbs, mms) Flip chipped + Copper (10 Gbs , mm)	**Optical guide (Tbs, mms)** Flip chipped + Copper (100 Gbs , mm)	Toward 10 Tbs over cm
IN Device	Optical guide/Fiber (10s Gbs, 10s cms) Copper (Gbs, 10s cms)	Optical guide/Fiber (100 Gbs, 10s cms) Copper (10 Gbs, 10s cms) Graded Index Platic Optical Fiber(100 Mbs; cms)	Optical guide/Fiber (Tbs, 10s cms) Copper (100 Gbs, 10s cms) **GI-POF (Gbs, 10s cms)** **mmW Plastic Wave Guide (10s Gbs, 10s cm)**	Toward 10 Tbs over 10s cms

AUTOMOTIVE CONNECTIVITY APPLICATIONS

The Automotive connectivity Market will address different communication connectivity segments:

- The Outdoor 5G, 5G+ Wireless Up and Down links in order to be connected to a Cell or a Mini-Cell with Doppler effects depending on the speed of the vehicle.
- The Outdoor 802.11p (or same kind) Wireless Car to Car links, and Car to Infrastructure links with huge Doppler effects.
- The Indoor WiFi Like and BT evolutions.
- The Indoor wireline High Data Rate Links.
- If Localization is addressed: mmW Radars; LIDAR; GPS/GALLILEO are close to the domain.



AUTOMOTIVE CONNECTIVITY APPLICATIONS

Automotive Connectivity	Present	2-4years	3-6Years	7 – 15 years
INDOOR Wireless	BT (<Mbs)	BT? WiFi? (Beam formed?) LiFi? Hardware Security?	Beam formed WiFi?? LiFi?? BT? Beam Formed mmW?? Hardware Security??	More data rate less power, less radiated power lost in the space?? High level of Security??
INDOOR Wireline	Copper (3Gbps; W) Plastic Optical Fiber (10s Mbs ; 1W)	Copper (12Gbps; W) Graded Index POF (100s Mbs; W)	Copper (24Gbps; W) GI-POF (Gbs; W) mmW Plastic wave Guides (10Gbs ; 100mW)	More data rate, less power, less weight.
Cellular Up & Down Links	4G	5G	5G+	6G
V2V – V2I – I2V; V2X	Research on: 802.11p	802.11p (6GHz, < 10Mbs; 2W) Hardware Security?	802.11p (50Mbs, 1W) mmW bands (<10Gbs; 1W) Hardware Security	High level of Security!! Less power, more data rate.
Global Positioning	GPS	GPS + Gallileo	GPS-Gallileo Combi	Less power, more accuracy
Relative Positioning	24GHz SRR; 77GHz LRR LIDAR Stereo vision (Visible, IR)	79GHz SRR; 77GHz LRR LIDAR Stereo vision (Visible, IR)	Previous sensors fusion V2X RF cross positioning	Global sensors and communication fusion

HEALTH CONNECTIVITY APPLICATIONS

The E-Health and Fitness connectivity Market will address different communication connectivity segments:

Fitness Monitoring sensors are connected to a “Mobile Web Gateway” by WBAN connectivity.

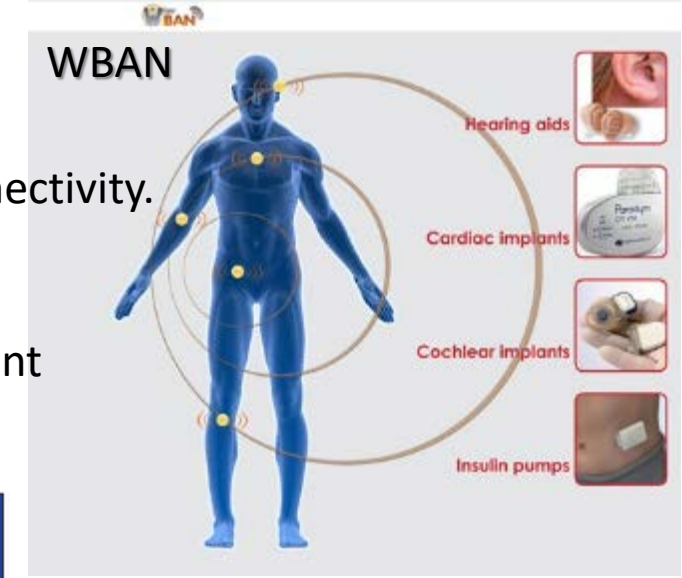
Health Monitoring sensors and actuators are connected to a « Web Gateway » by WBAN and intra-body connectivity functions through intermediate nodes or not.

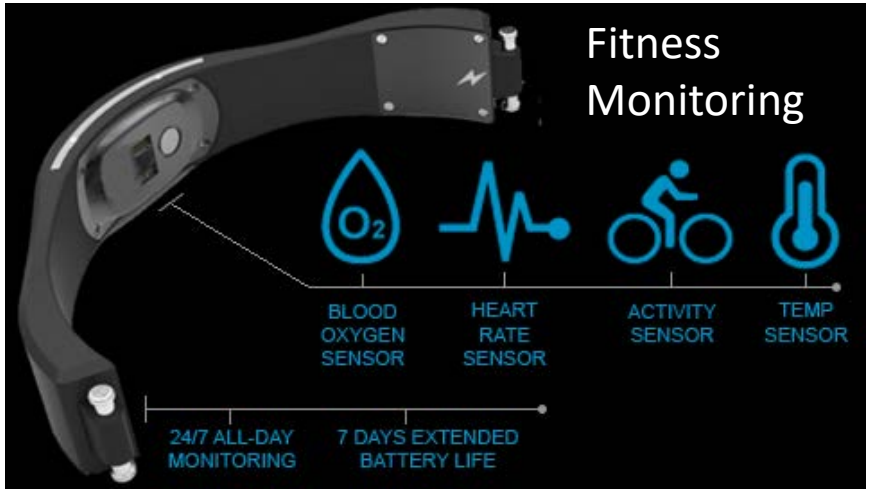
E-Medicine Links use 4G, 5G, 5G+ … networks from the first Web Gateway in the patient close environment to the Doctor office.

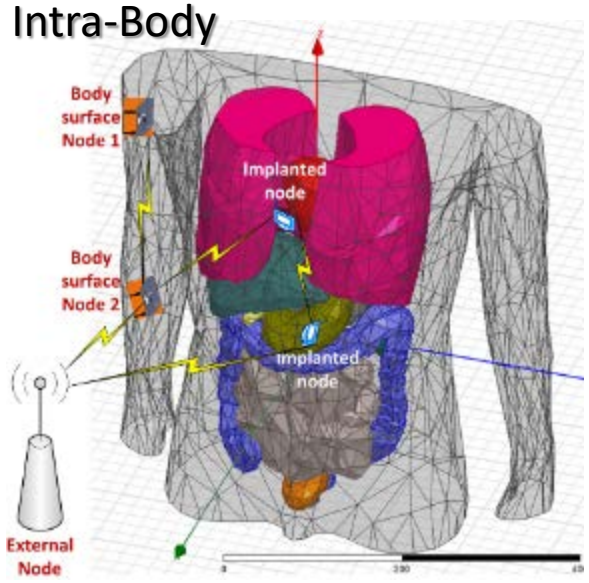
Main Challenges of such connectivity functions are:

SECURITY / CONFIDETIALITY

RELIABILITY

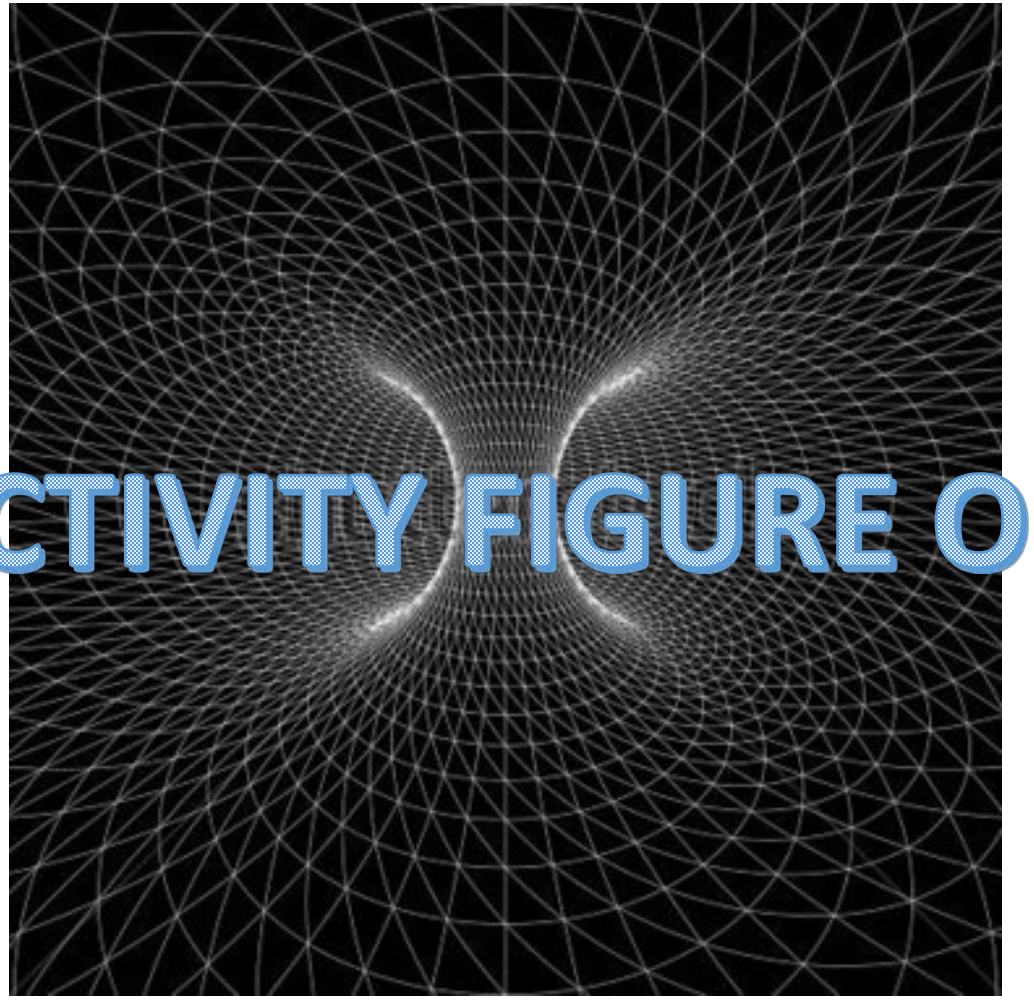






HEALTH CONNECTIVITY APPLICATIONS

Health Specific connectivity	Present	2-4years	3-6Years	7 – 15 years
WBAN	Ad-hoc(ISM bands; Kbs) Zigbee (2.4GHz; Kbs) BTLE (2.4GHz; Kbs)	Ad-hoc(ISM bands; Kbs) Zigbee (2.4GHz; Kbs) BTLE (2.4GHz; Kbs) 802.11 ah, ax (Mbs, mW)	*0.4 to 2.4 ULP cognitive evolution (Mbs, 100uW)* *Security embedded*	*Safety / Security / Privacy embedded*
Intra-Body	Ad-hoc(ISM bands; Kbs) Zigbee (2.4GHz; Kbs) BTLE (2.4GHz; Kbs)	Ad-hoc(ISM bands; Kbs) Zigbee (2.4GHz; Kbs) BTLE (2.4GHz; Kbs) UWB (<100kbs, 100uW) Ultrasonic (<Kbs, 10uW)	*UWB (<100kbs, 10uW)* *Ultrasonic (<Kbs, 1uW)* *Other ULP* *Security embedded*	*Safety / Security / Privacy embedded*



CONNECTIVITY FIGURE OF MERIT

Connectivity Functions Figure Of Merit : Connectivity-FOM

- How to evaluate the Figure of Merit of a function?
  - I would propose an approach, which will be discussed with NEREID experts in the following conference calls or meetings:
    - The industrial concern is to evaluate what is the efficiency of a function versus the cost of this function.
    - Starting from this ratio, we can try to define what the efficiency of a connectivity function is:
      - **The efficiency could be the data rate multiply by the range moderated by the error rate and divided by the power consumed**.

$$FOM = \frac{Data\_rate(Gbs) \times D^2(m) \times \frac{1}{BER}}{Psupply(W)}$$