

5G: The Nervous System of the Digital Society and Digital Economy

Dr David Soldani

VP European Research Centre, Huawei
Visiting Professor, University of Surrey, UK

<https://de.linkedin.com/pub/dr-david-soldani/a/6a0/336>



EU Main challenges from European Commission



Leadership in supplying/deploying ICT infrastructures and services



Know-how, competencies and capabilities, especially in SW and HW



Jobs generation in the ICT sector and contribution to more than 3% GDP



Investments for a renewed industrial landscape (internal and external)

5G Vision

“The smart phone is the extension of what we do and what we are, the mobile is the answer to pretty much everything”

Eric Smith, Google, MWC 2010



“The advanced 5G infrastructure is expected to become the nervous system of the Digital Society and Digital Economy”

Günther Oettinger, European Commission, MWC 2015

2020

“Bearer Graph”

→ Nervous system of the Digital Society and Economy



2010

“Client Server”

→ Bit pipe and Free Communication Services

Convergence of:
1. Cloud computing
2. UE Computing power
3. Connectivity at high speed



European Commission main investments and targets



€12.5B /€ 80B European funds: Horizon 2020 investment in ICT Research in 2014–2020



From the lab to the market: from electric cars, to robots → help care for elderly generation



€5.5 B PPP: 5G, Robotics, Photonics, Factory of the Future, HPC, Big Data (and Security)



Open access for *true innovation*: sharing knowledge and reaping the benefits of big data

Main 5G initiatives ongoing globally



EU

- 5G PPP in Horizon 2020
- Framework Program 7, e.g. METIS and 5GNow projects
- [White Papers](#)



UK

- 5GIC at University of Surrey
- <http://www.surrey.ac.uk/5gic>



US

- 4G Americas : [White Papers](#)



China

- IMT-2020 (5G) Promotion Group
- 863 Research Program
- Future Forum : [White Paper](#)



Japan

- 5G Promotion Forum (ARIB)
- [White Paper](#)



Korea

- 5G Forum as PPP
- [White Paper](#)

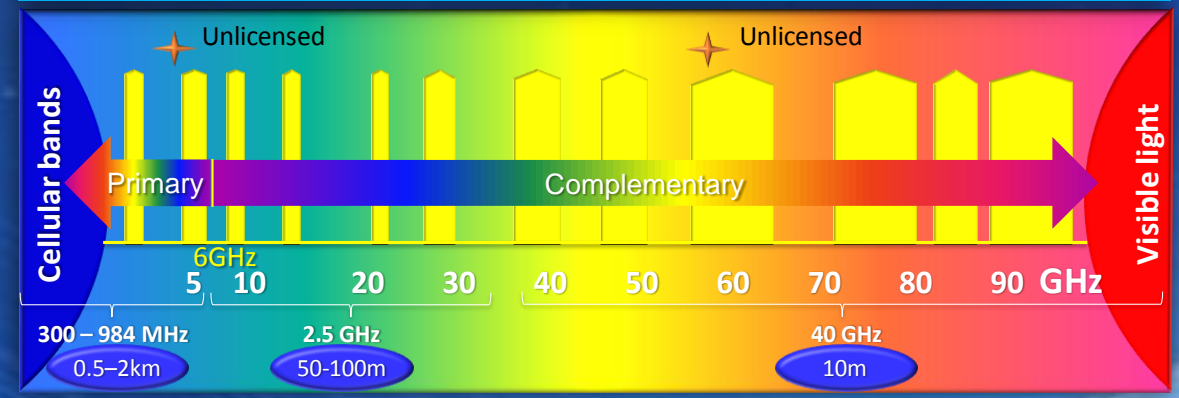
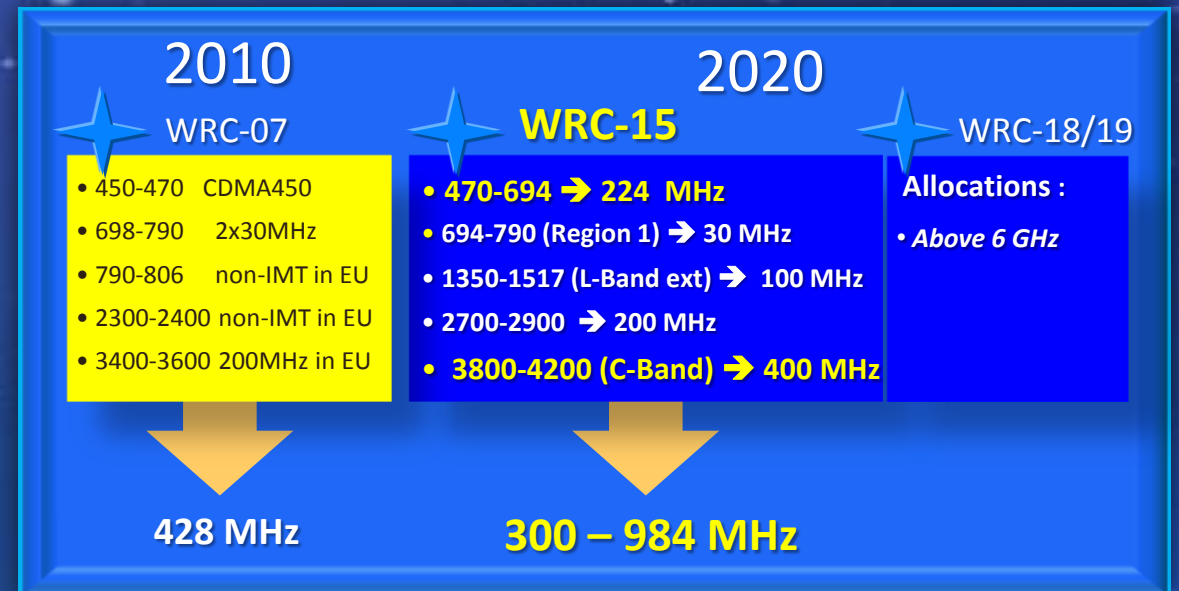
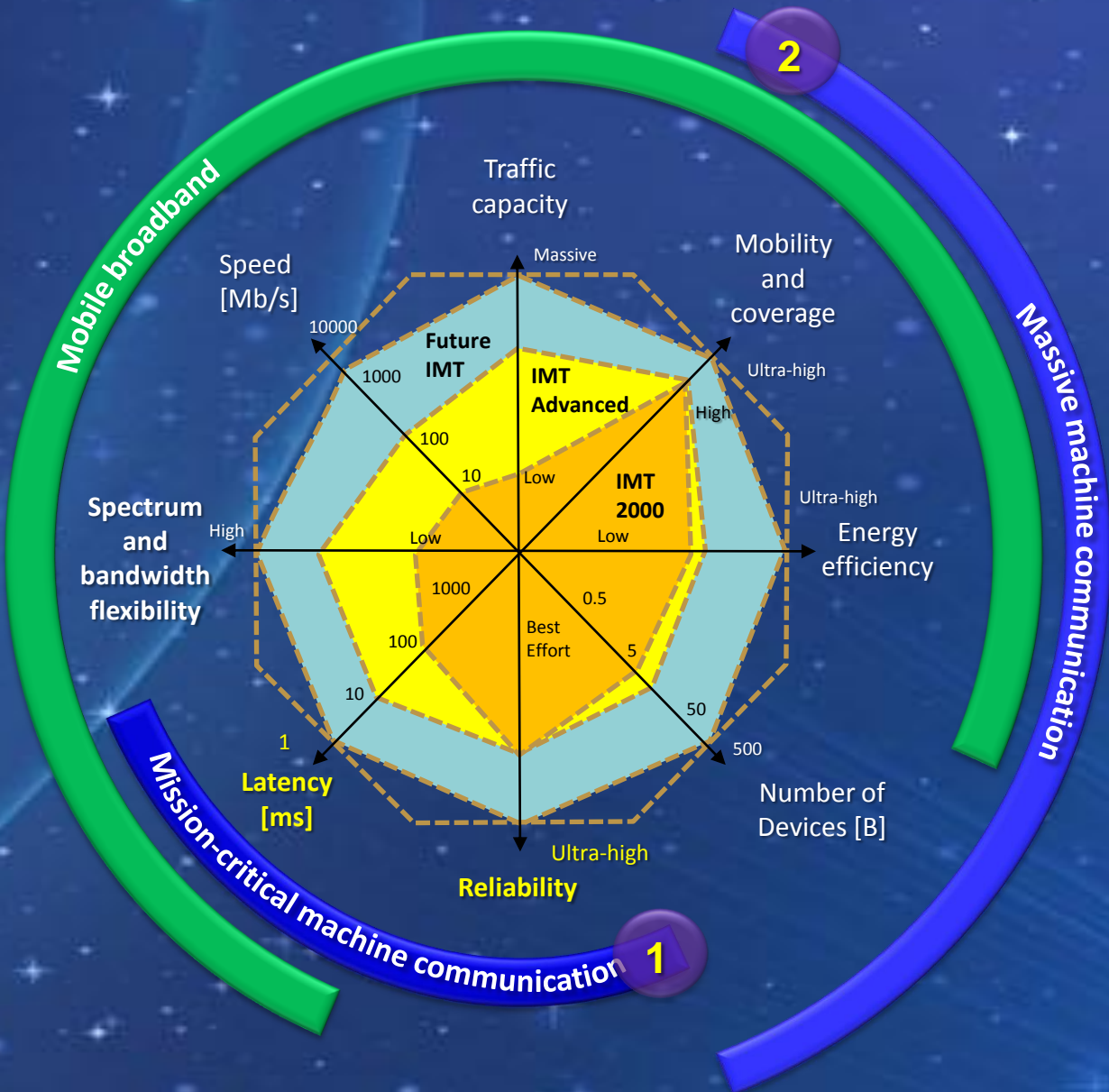


NGMN

- [White paper](#)

Key recommendations and capabilities

3

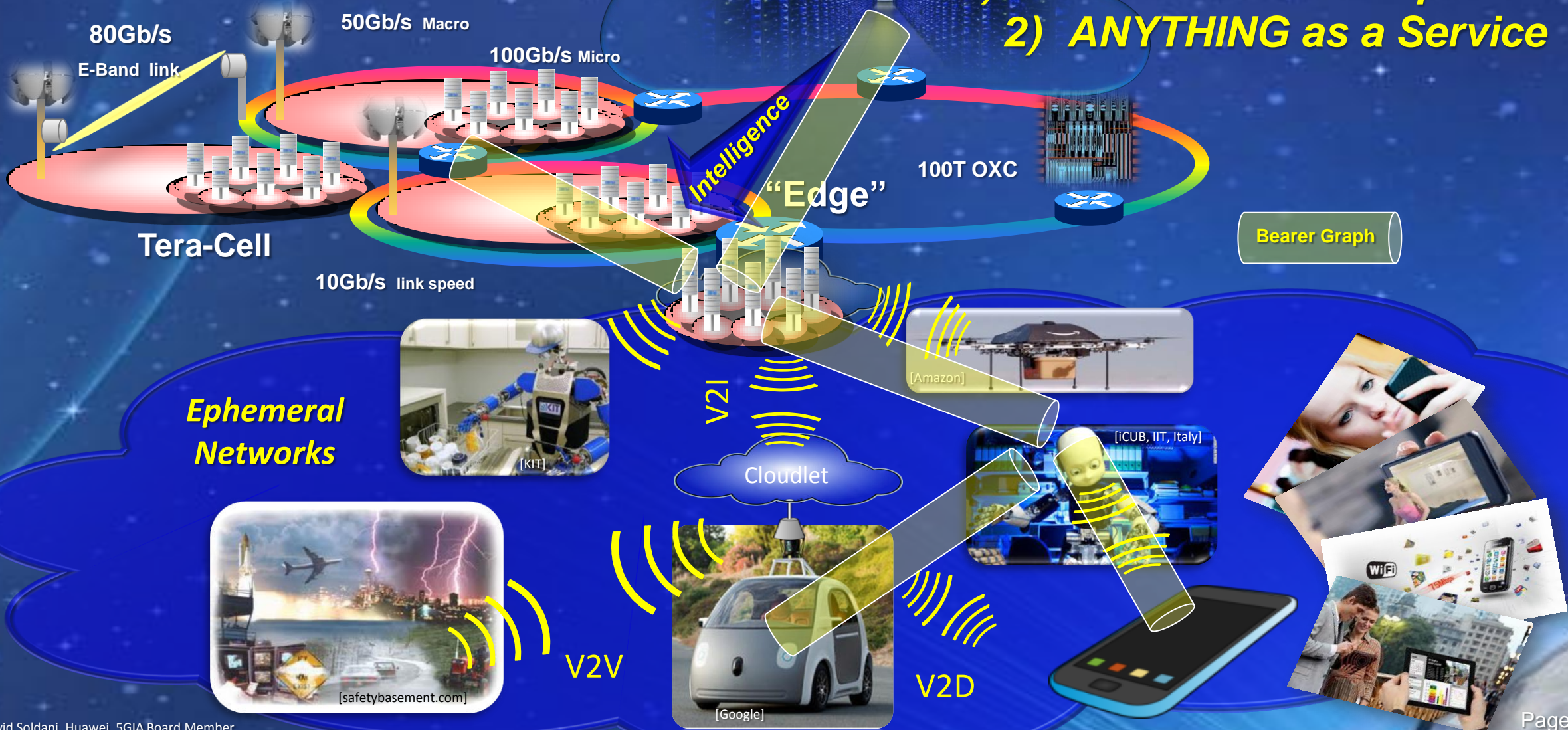


- MNO-CA: Commercial Spectrum for Infotainment
- MNO-ITS: Government Cellular Spectrum (Safety), e.g. < 3 GHz
- VDC: Direct Spectrum for ITS or Infotainment: e.g. 3.5 or 5.9 GHz

What is our (multitenant) 5G network and services vision?

- 1000x higher wireless area capacity and 10G true immersive experience
- 100 billions of connections and 5x lower E2E latency (1ms target)
- 90% energy saving per provided service

1) **FULL Immersive Experience**
2) **ANYTHING as a Service**



What are the fundamental enabling technologies?

→ The nervous system of the true Digital Society and Digital Economy

Sensing



© Temistocle Lucarelli | Dreamstime.com

Edge computing



© Italianestro | Dreamstime.com

Networking

5

<Match, Action> ≤ 1ms

2

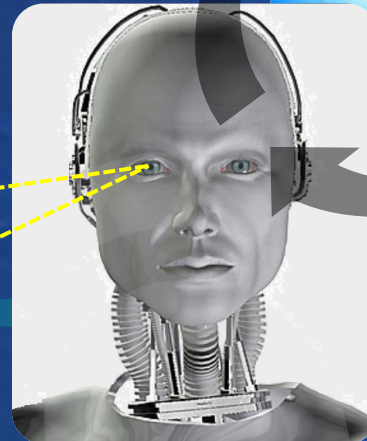


Rendering



© Mopic | Dreamstime.com

Controlling & Orchestrating



© Lightslab | Dreamstime.com

Acting



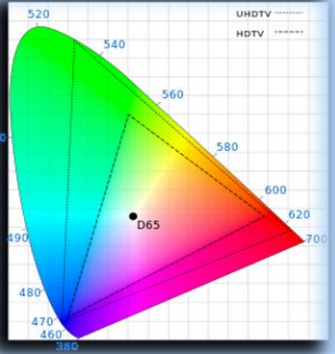
Geometry
Identity

(Cyber world)

Looking at “Full Immersive Experience” ...

8K= 2x4K pixels
4K = 2x2K pixels
2K = 2048 x 1080 pixels

8K UHD



4K SHD

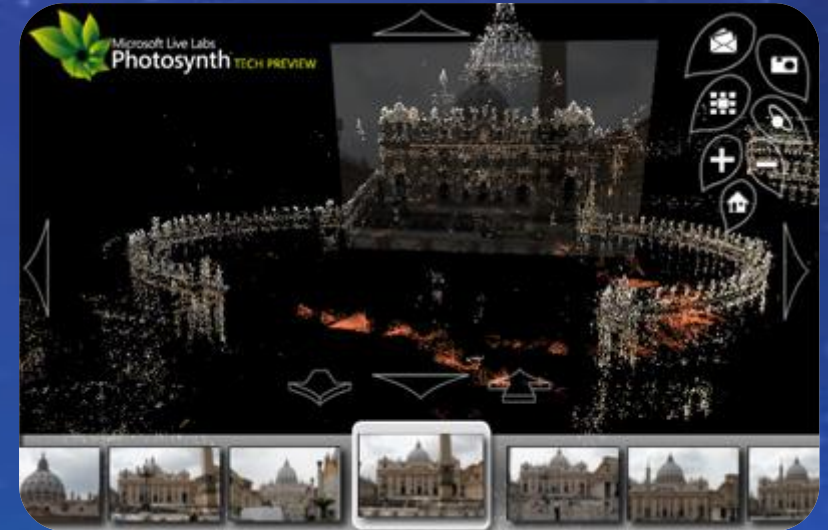
FHD

SD

http://en.wikipedia.org/wiki/Ultra_high_definition_television



Holovizio Lightfield Display [Holografika]



3D reconstruction obtained from a number of pictures captured from **collaborating** different viewpoints [Microsoft Photosynth]



Huawei audio lab with **22.2 channels** system



The Stanford **multi-camera** system



Pope election in 2005 and 2013 – Comparison
<http://www.text100.com/hypertext/2013/04/homo-numericus/>

Example: movie projectors tomorrow (lasers)

→ 30-50 Mb/s for a single view transmission and Zero-Latency (adaptive) interaction client-server *

*) For luminance (brightness), chrominance (color), resolution, view point, etc. adaptation



2-8K → 30-50 Mb/s/view (compressed)

<http://spectrum.ieee.org/consumer-electronics/audiovideo/lasers-coming-to-a-theater-near-you>

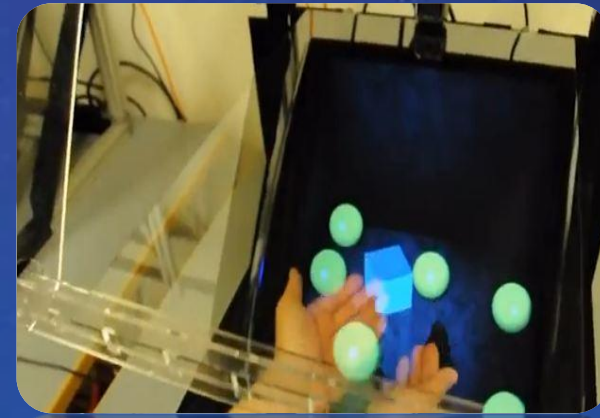
Example: Holographic rendering / soundfield audio reproduction

Media MIMO

- Multi-camera capture
 - 3D sensing of the scene
- “Retina display”
 - >100 deg vision (multiple views)
- Spatial sound experience
 - Multi-zone soundfield



[www.bridgat.com]



[Microsoft Holodesk]

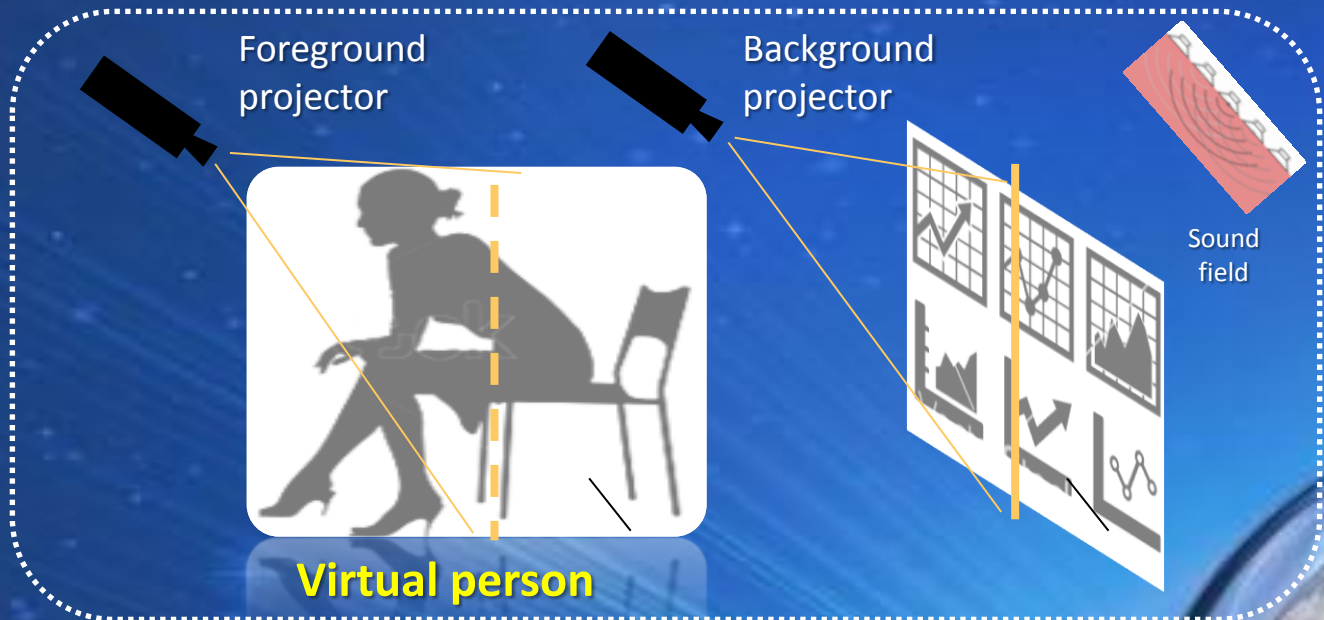


[Multi-camera system]

→ Up to 1Gb/s for real full parallax holography



Real person



Virtual person

Looking at the “Second Machine Age”...

Focusing on leveraging technologies around machine intelligence, big data and connected networks

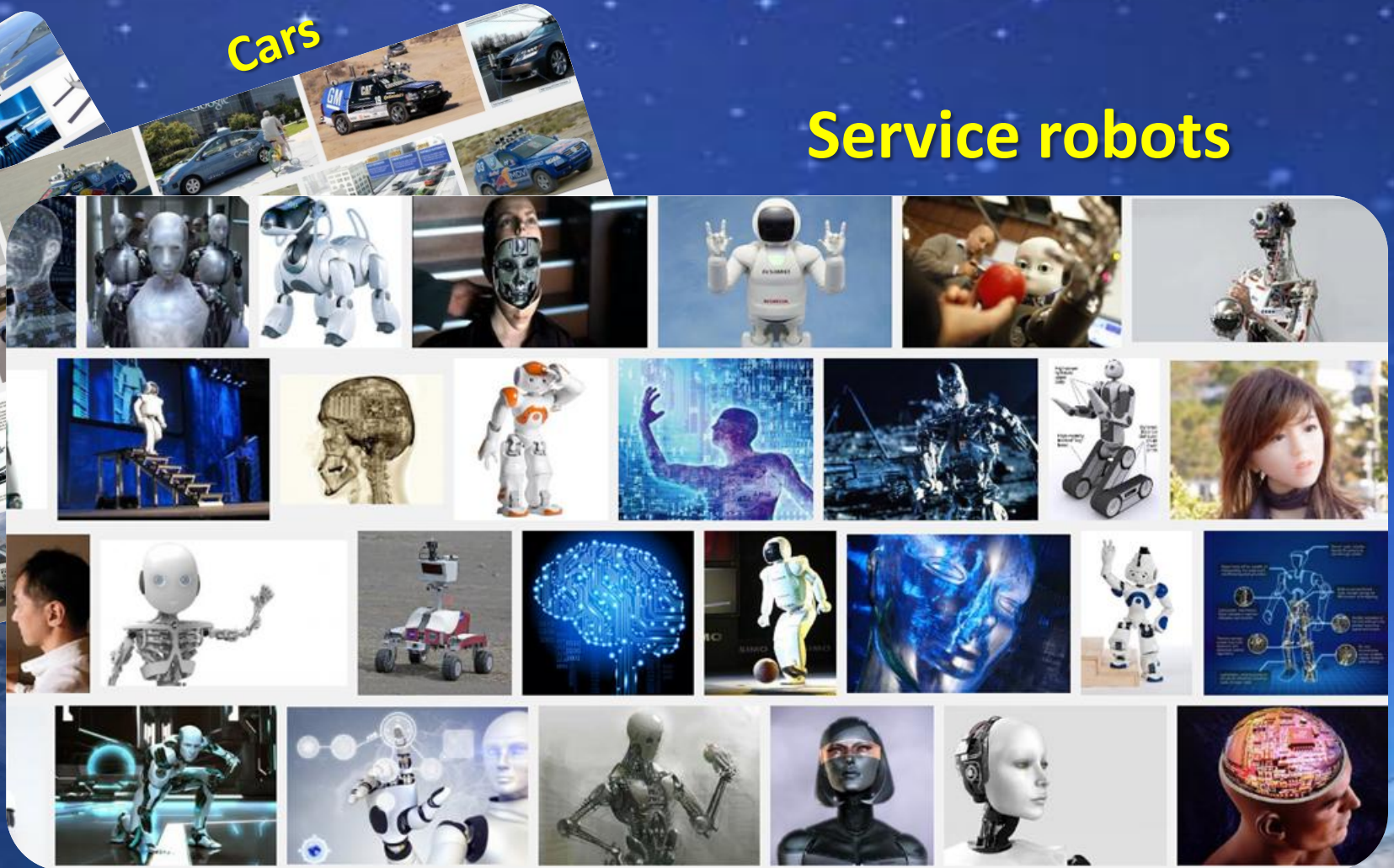
http://www.uk.cappgemini.com/resource-file-access/resource/pdf/dtr5_29thnov_final.pdf



Drones

Cars

Service robots



“
The Second Machine Age is the time when machines are now able to take over a lot of cognitive tasks that humans can do.
”

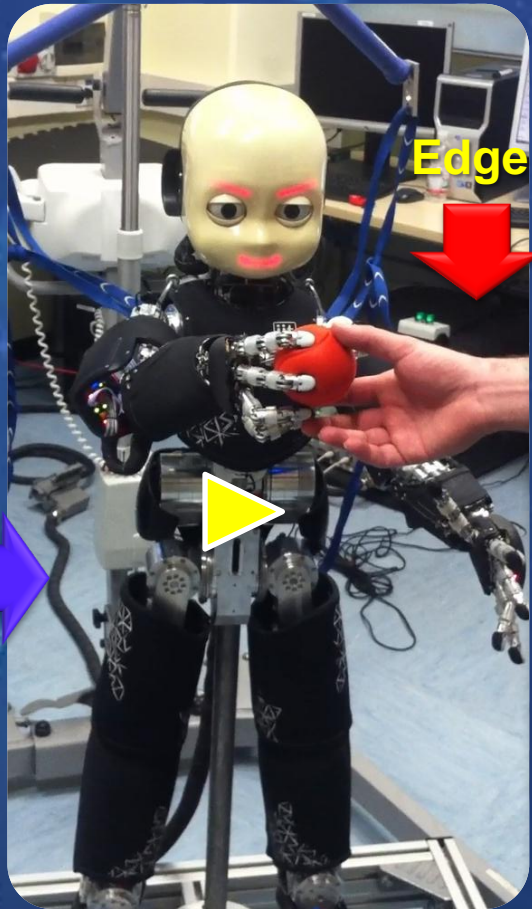
[Erik Brynjolfsson and Andrew McAfee, MIT Center for Digital Business]

Example: The *iCub* robot platform (www.iit.it)

→ **5.000 sensors!**

For massive deployment by 2030

1. 100% Plastic Robot (iit): 3D printing + Graphene
2. Battery self powering: new generation batteries
3. Wireless connectivity: 5G



[iit, Genova, Italy]

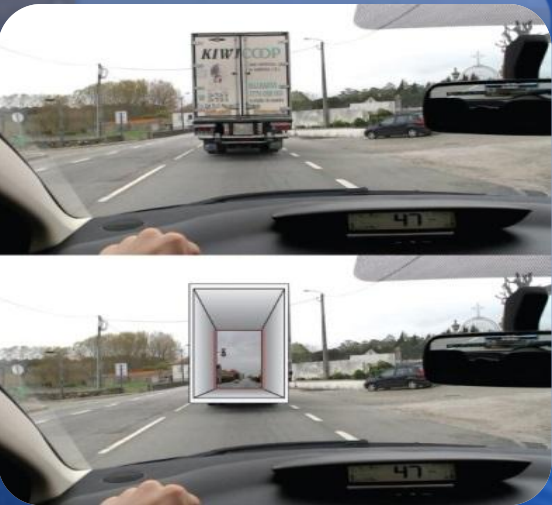
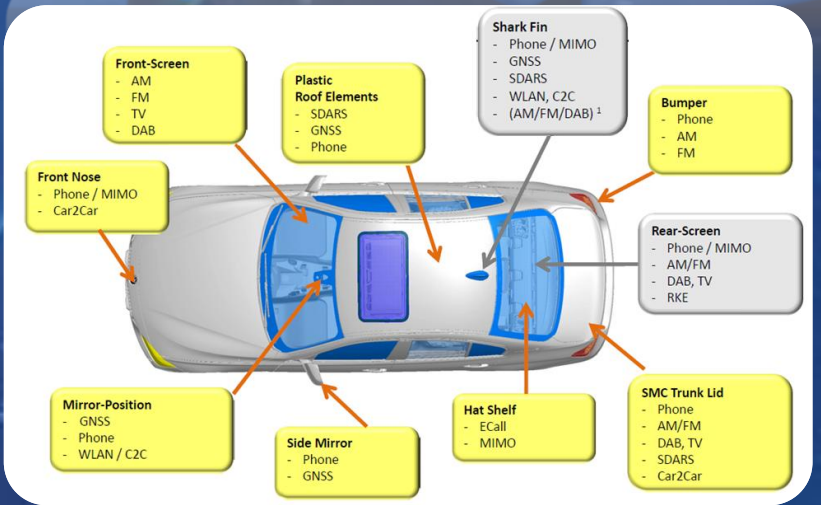
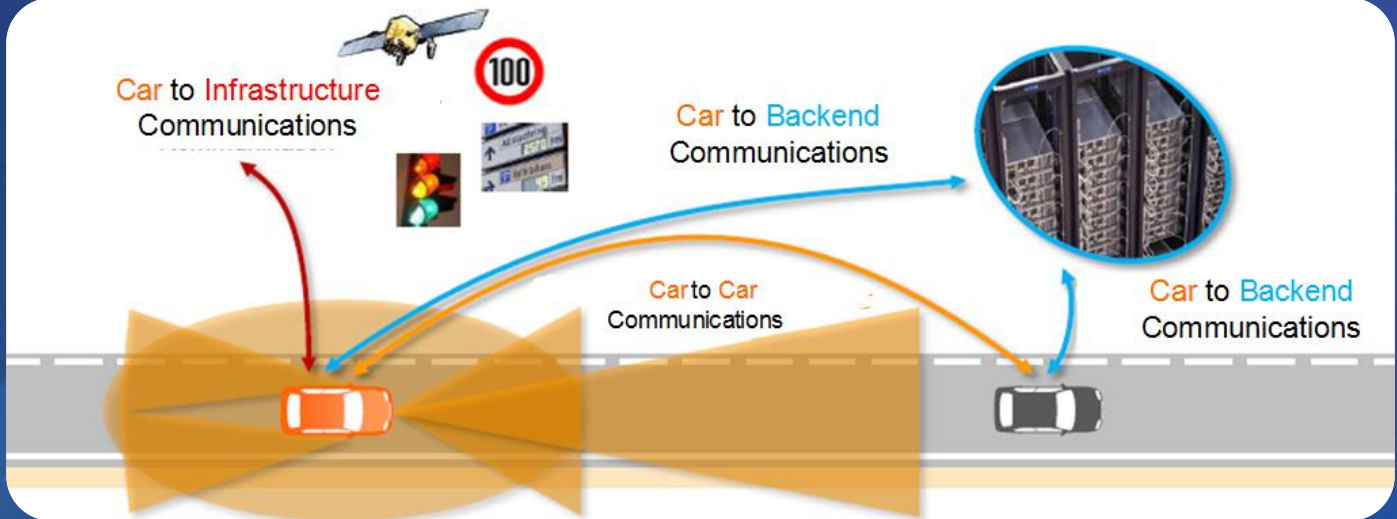


Sensor	Specs	Bandwidth
Cameras	2x, 640x480, 30fps, 8/24bit	147Mbit/s uncompressed
Microphones	2x, 44kHz, 16bit	1.4Mbit/s
F/T sensors	6x, 1kHz, 8bit	48kbit/s
Gyroscopes	12x, 100Hz, 16bit	19.2kbit/s
Tactile sensors	4000x, 50Hz, 8bit	1.6Mbit/s
Control commands	53DoF x 2-4 commands, 100Hz/1kHz, 16bit	3.3Mbit/s (worst case), 170kbit/s (typical)

→ **Force control: latency requirement = 1-5 ms**

Example: Future Car Communications

➔ New Antenna Concepts for MIMO, Integration of 11p and LTE/5G, Mobile Edge Computing



Communication requirements

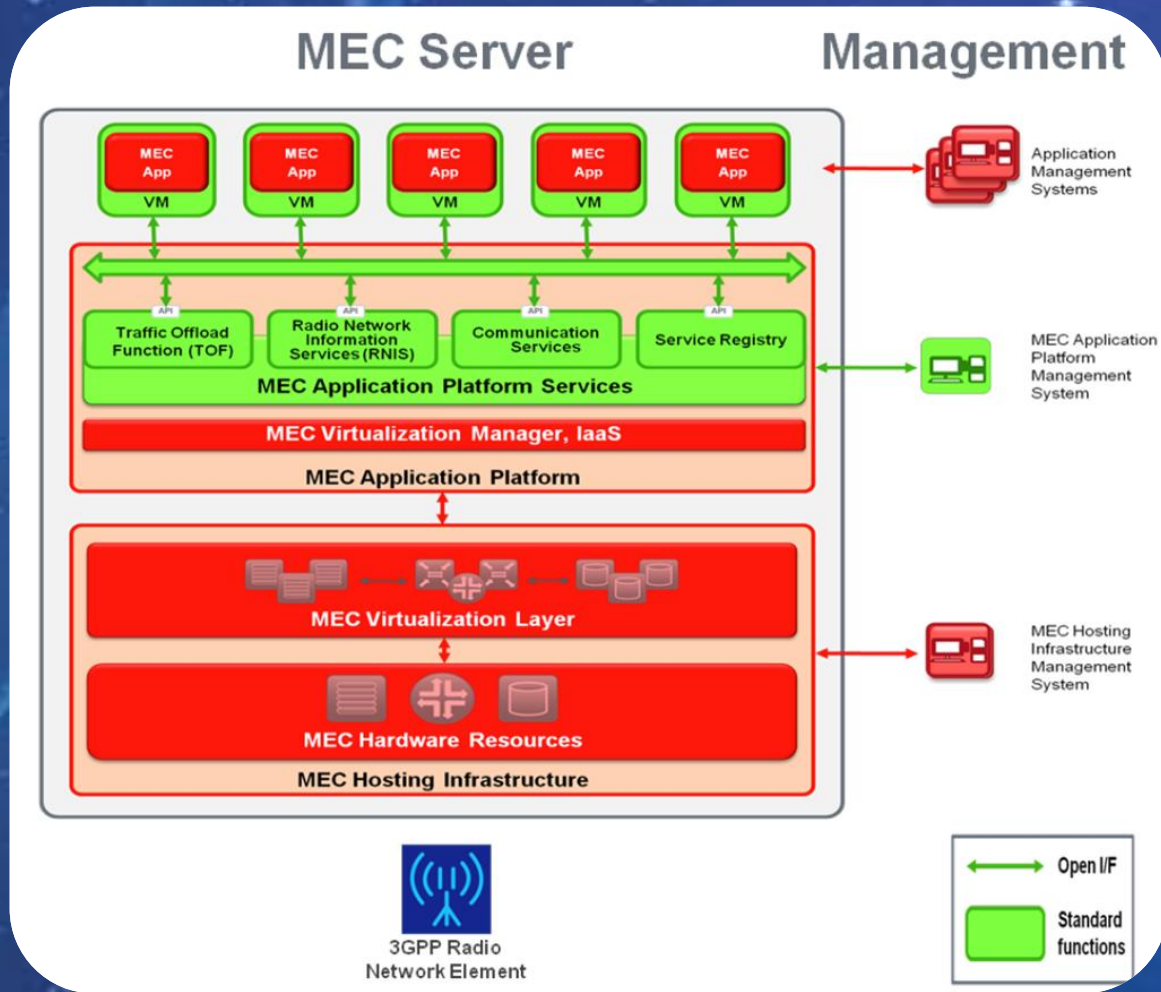
- Better connection than smart phone
- Reliable and low latency for future advanced driver assistant systems (ADAS) and autonomous driving (AD)
- High data volumes (>200Mb/s) at low latencies for future cooperative automatic driving functions (V2V)
- Support performance up to maximum speed (500km/h relative)
- Any network operator, regardless vehicle occupants' contract (safety information)

[Kathrein Automotive]

[Markus Dillinger, Huawei]

Looking at “Mobile-Edge Computing” ...

Enable applications and services (Layer 4 and above) to be hosted ‘on top’ of network layer benefitting from being in proximity to prosumer and from receiving local radio-network contextual information



Main characteristics

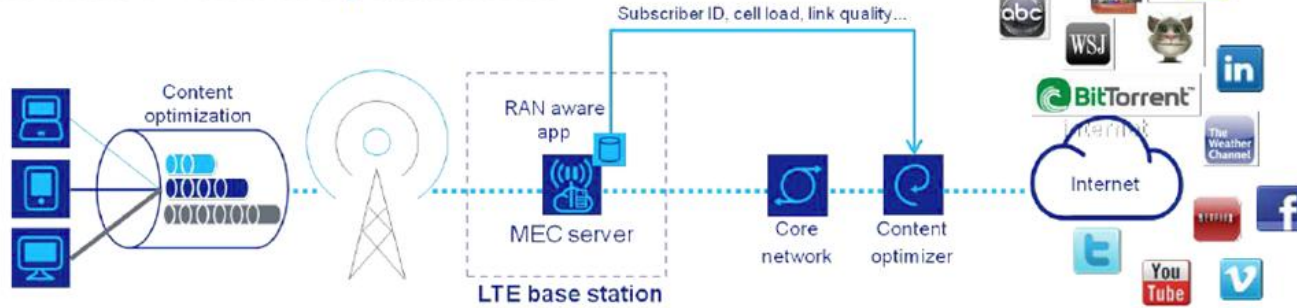
- On-Premises
- Proximity
- Lower latency
- Location awareness
- Network context information

[A. Neal, et al. “Mobile-Edge Computing,” [Introductory Technical White Paper](#), Sept. 2014]

Example: use cases

Context and proximity benefits!

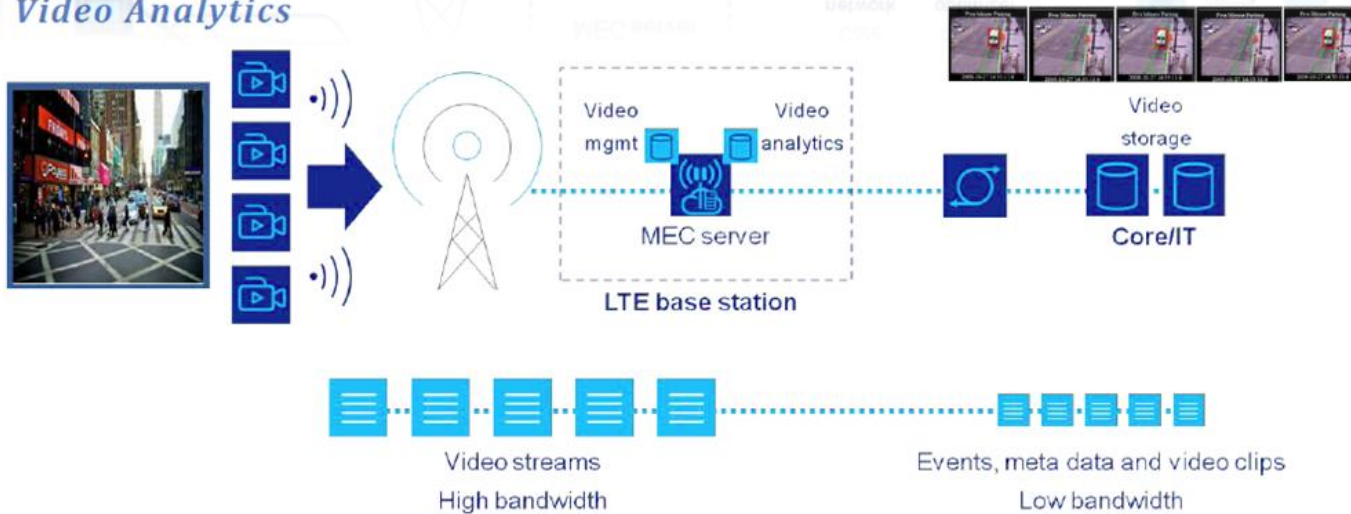
RAN-aware Content Optimization



Exposing cell/subscriber radio information

- Enable dynamic content optimization
- Improve QoE, network efficiency for new service and revenue opportunities

Video Analytics



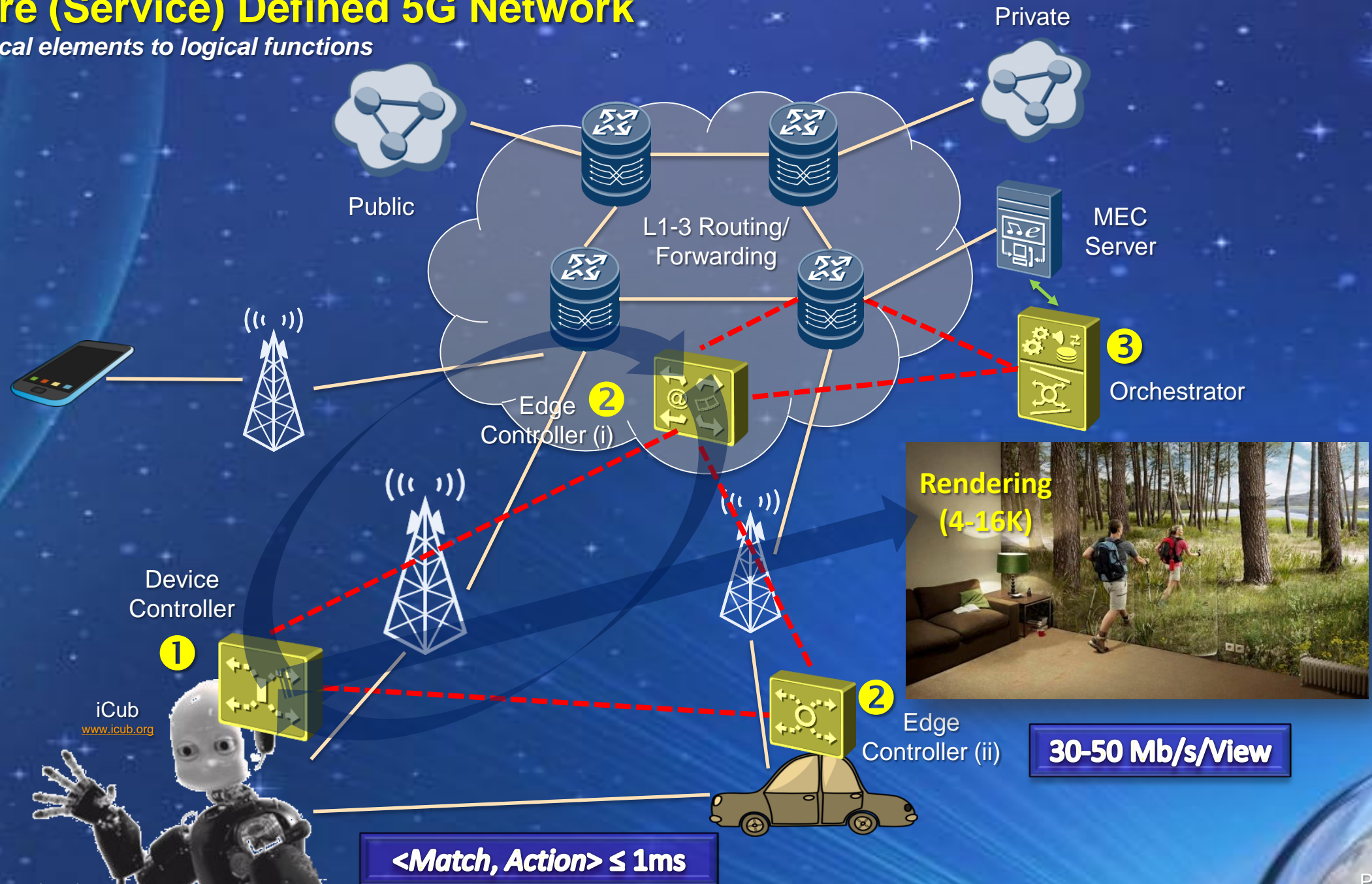
Transcoding and storing video streams

- Detect and notify specific configurable events e.g. object movement, lost child, abandoned luggage, etc.
- Send low bandwidth video metadata to the central operations and management server for **database searches** for safety, public security to smart cities, etc.

[A. Neal, et al. "Mobile-Edge Computing," [Introductory Technical White Paper](#), Sept. 2014]

Software (Service) Defined 5G Network

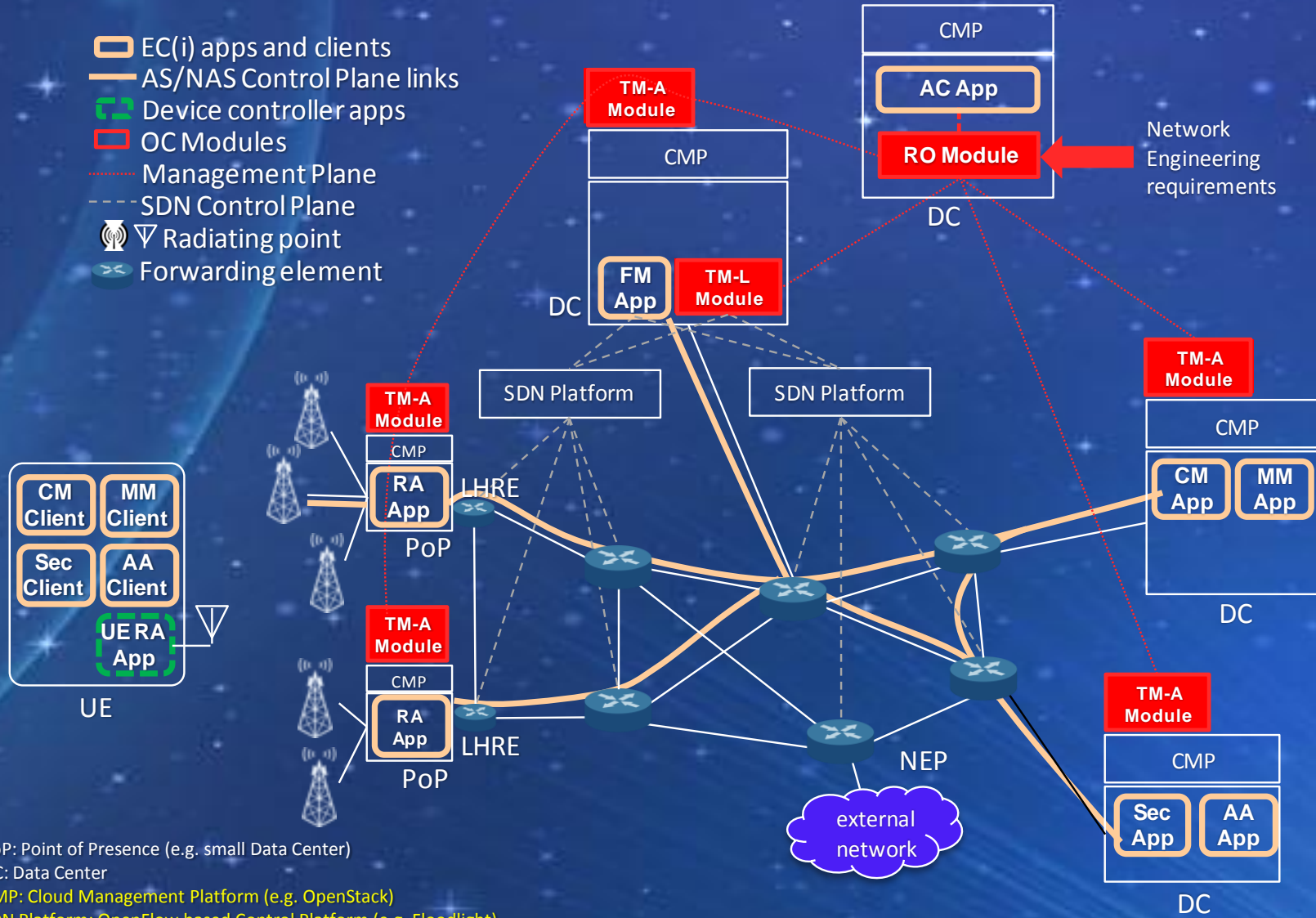
→ From logical elements to logical functions



5G Plastic Architecture: how to realize that?

→ Unified Connection, Security, Mobility and Routing management without tunneling protocols

- EC(i) apps and clients
- AS/NAS Control Plane links
- Device controller apps
- OC Modules
- Management Plane
- SDN Control Plane
- Radiating point
- Forwarding element



PoP: Point of Presence (e.g. small Data Center)
 DC: Data Center
 CMP: Cloud Management Platform (e.g. OpenStack)
 SDN Platform: OpenFlow based Control Platform (e.g. Floodlight)
 LHRE: Last Hop Routing Element
 NEP: Network Entry Point

Orchestrator

- RO (Resource Orchestration):** embedding decisions of EC (i) Apps and their virtual links
- TM-A (Topology Management - Apps):** enforces/maintains embedding of the EC (i) Apps
- TM-L (Topology Management - Links):** enforces/maintains embedding of links between EC (i) Apps: **Control Plane**

Edge Controller (i) (EC)

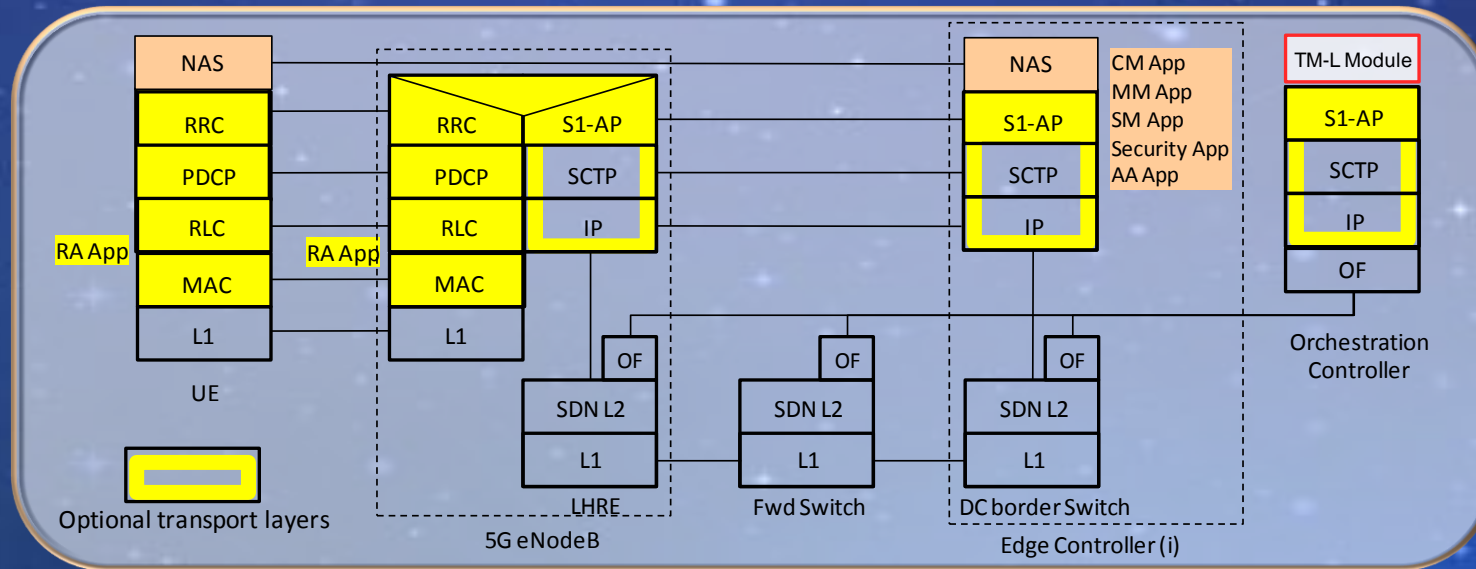
- CM** (Connection Management) App
- MM** (Mobility Management) App
- Security** App
- AA** (Authorization and Authentication) App
- RA** (Radio Access) App
- AC** (Admission Control) App: determines the embedding of the virtual links to implement the data flows
- FM** (Flow Management) App: maintains the virtual links determined by the AC App: **Data Plane**

Network Engineering requirements

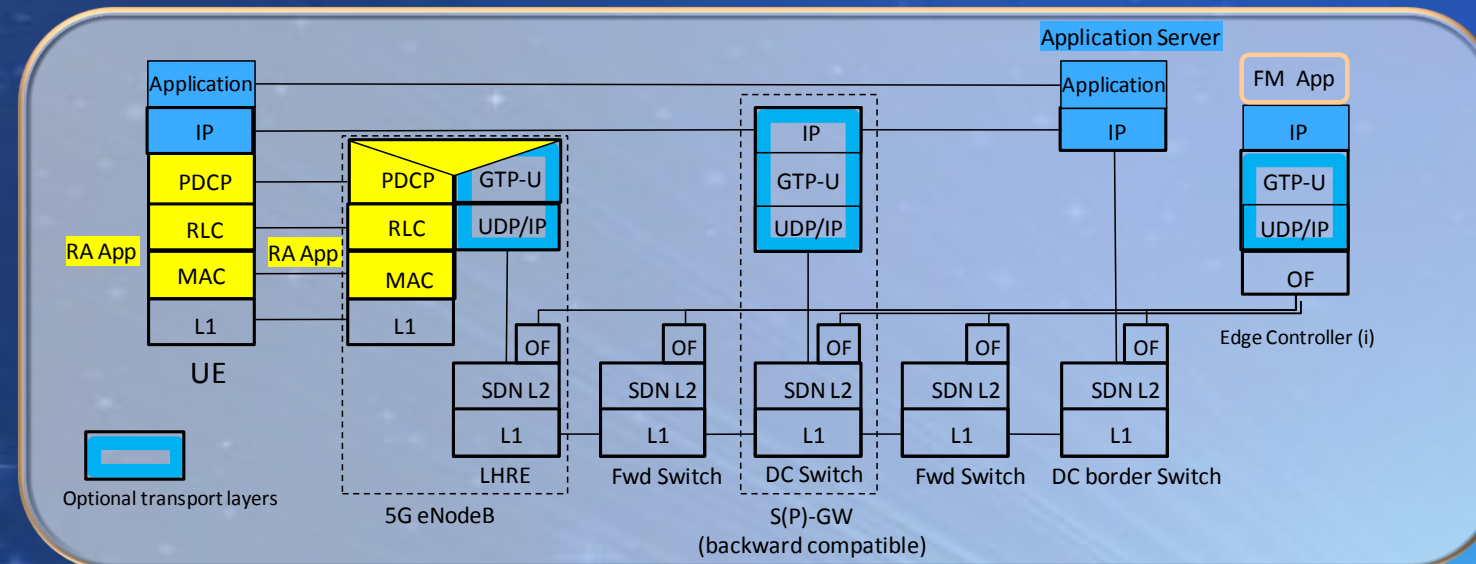
[R. Guerzoni, R. Trivisonno, D. Soldani, "SDN-Based Architecture and Procedures for 5G Networks," 1st International Conference on 5G for Ubiquitous Connectivity, November 26–28, 2014 Levi, Finland]

Backwards compatibility to current and future 3GPP releases

LTE Current and future *Control Plane*



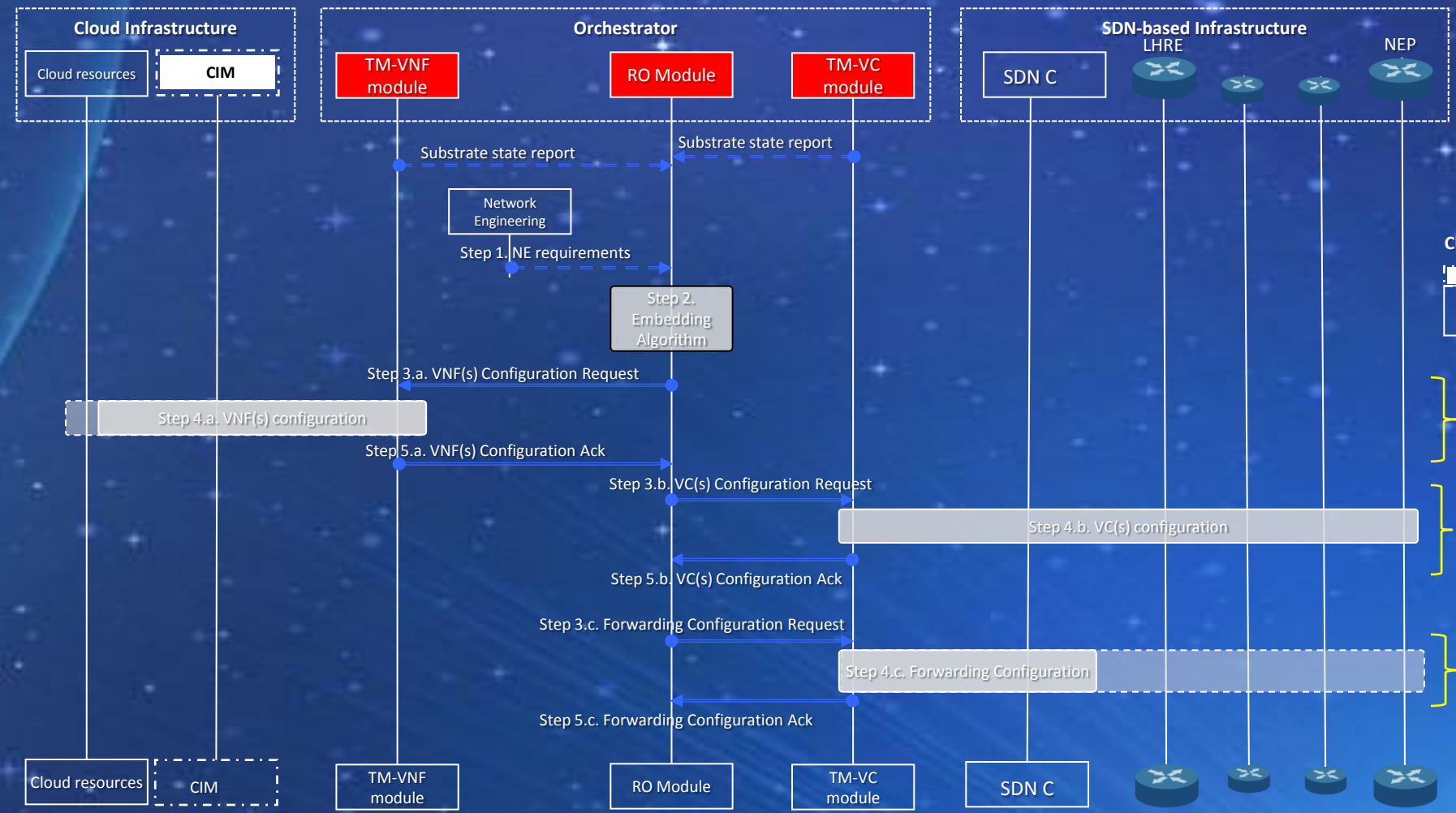
LTE Current and future *User Plane*



Control and Data Plane instantiation procedure

- Compliancy with ETSI NFV MANO architecture

Control Plane Instantiation



Cloud Infrastructure:
 CIM Cloud Infrastructure Manager
 Cloud Resources

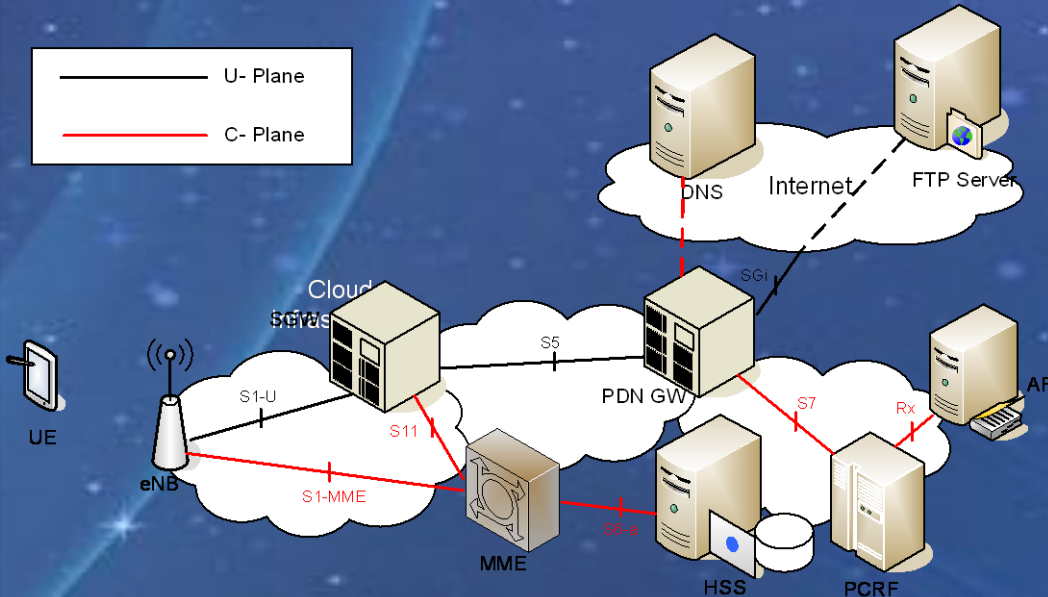
Virtualized Network Function (VNF) Instantiation

Virtualized Connection (VC) Instantiation

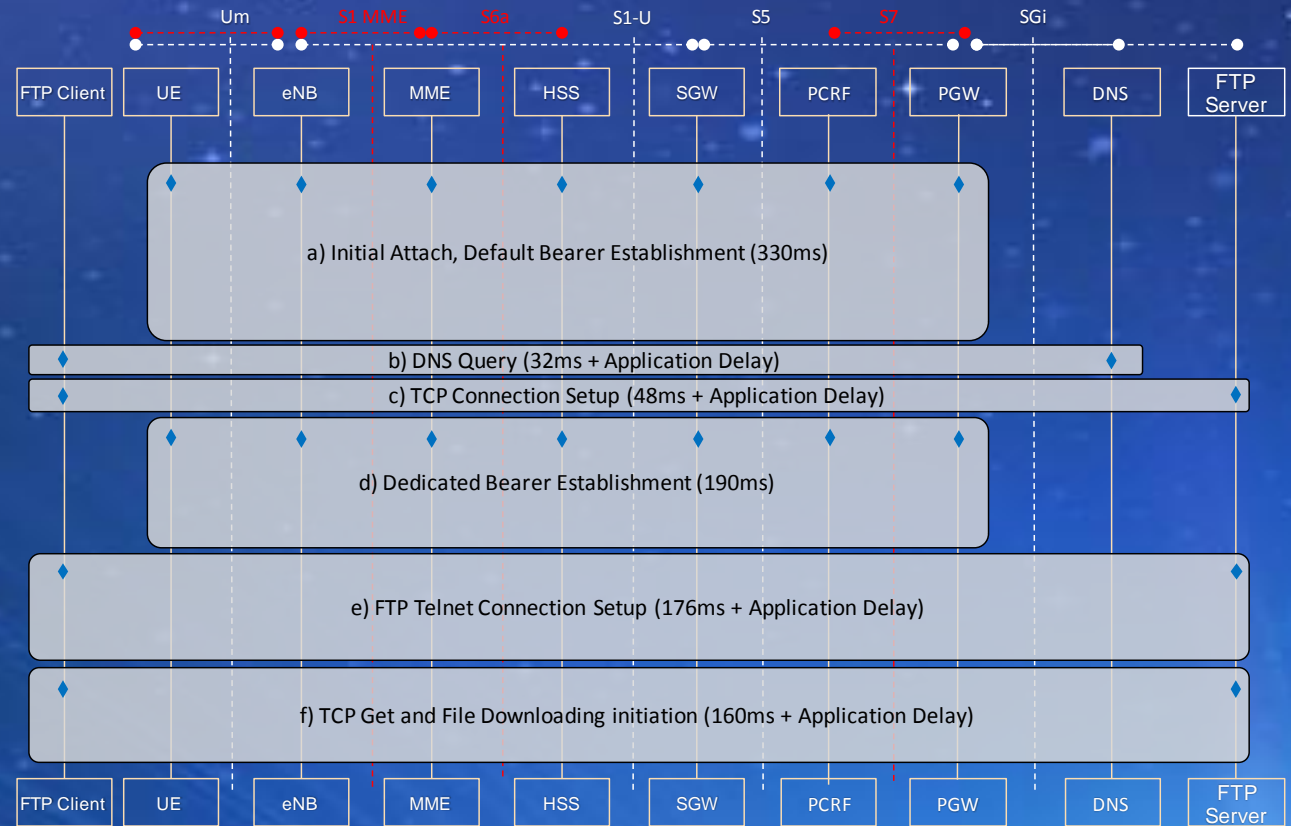
Data Plane Instantiation

[R. Guerzoni, R. Trivisonno, Huawei]

Reference 4G Architecture



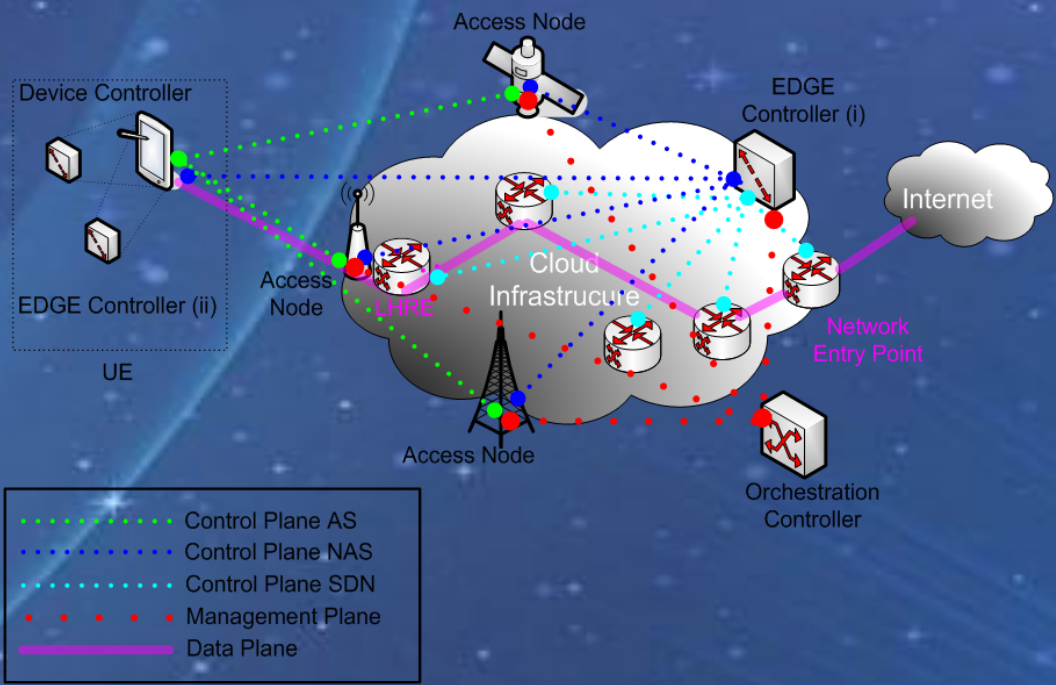
End to End Latency Contribution to FTP Session



[R. Trivisonno, R. Guerzoni, I. Vaishnavi and D. Soldani, "SDN-based 5G mobile networks: architecture, functions, procedures and backward compatibility," Transactions on Emerging Telecommunications Technologies, 2015]

Towards 5G Zero Latency: end to end latency reduction

SDN Based 5G Architecture



4G		5G		
Phase	Delay (ms)	Techniques	Improvement (ms)	%
Initial attach, default bearer establishment	~315	Always-attached strategies	-200	-60
		SDN-based mobile core	-20	-5
		Always-on data plane	-40	-10
Dormant to active transition	9.5	Implement 5G requirements	Air interface delay: 1	-60
U-plane latency	16	SDN-based mobile core (Direct communication)	E2E delay: 5 (TBA)	-30
Dedicated bearer establishment	176	SDN-based mobile core	-20	-10
		Always-on data plane (Direct communication)	-140 (TBA)	-75

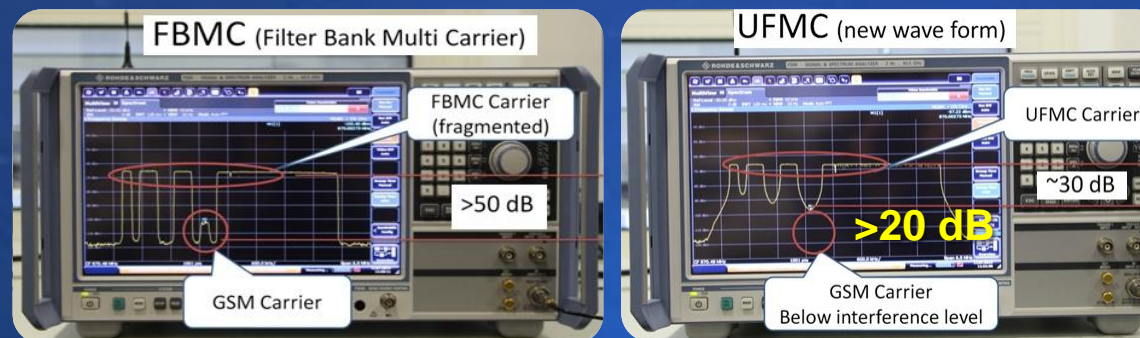
[R. Trivisonno, R. Guerzoni, I. Vaishnavi and D. Soldani, "SDN-based 5G mobile networks: architecture, functions, procedures and backward compatibility," Transactions on Emerging Telecommunications Technologies, 2015]

Filter-Bank Multi-Carrier (FBMC) for 5G Air Interface (METIS WP2)



- Suitable for MBB and MTC, Flexible spectrum usage and low complexity/OFDM (TX~ the same; RX < 2x)
- Significantly outperforms OFDM and UFMC with very small interference leakage

Spectrum	50 dBc	40 dBc	35 dBc
LTE – OFDM	0	0	0
FBMC	762 kHz	818 kHz	827 kHz

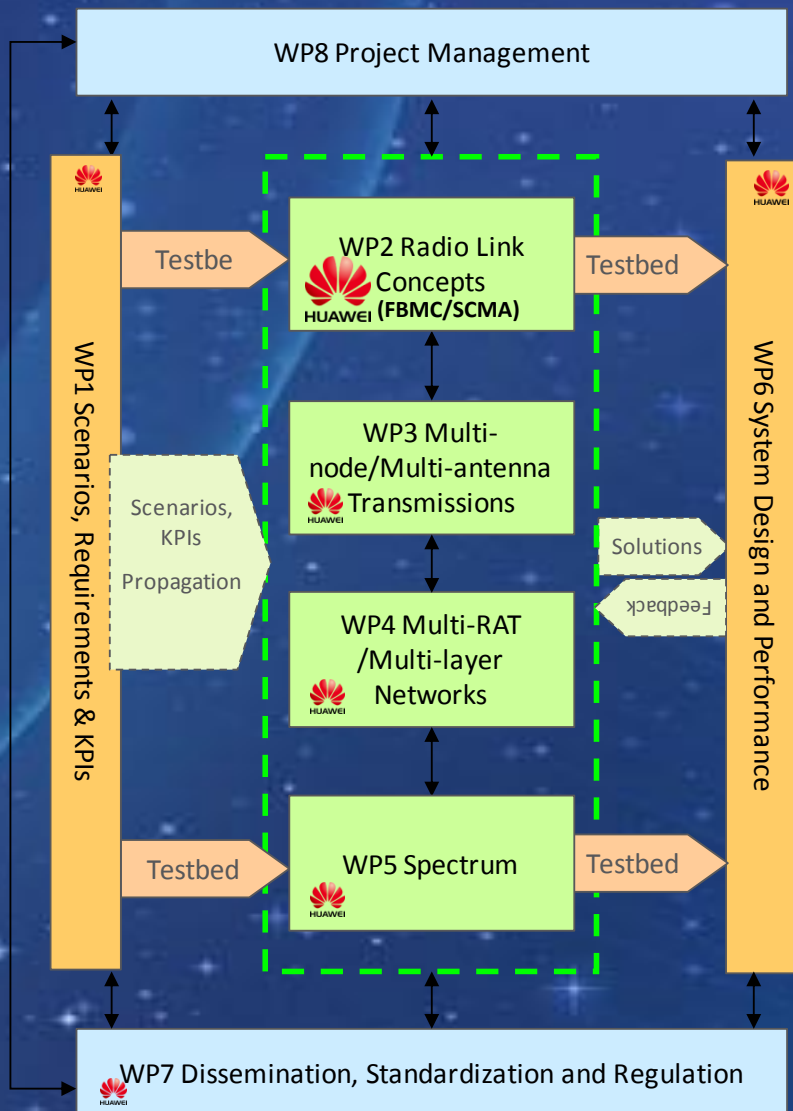


UE1

UE2

UE3

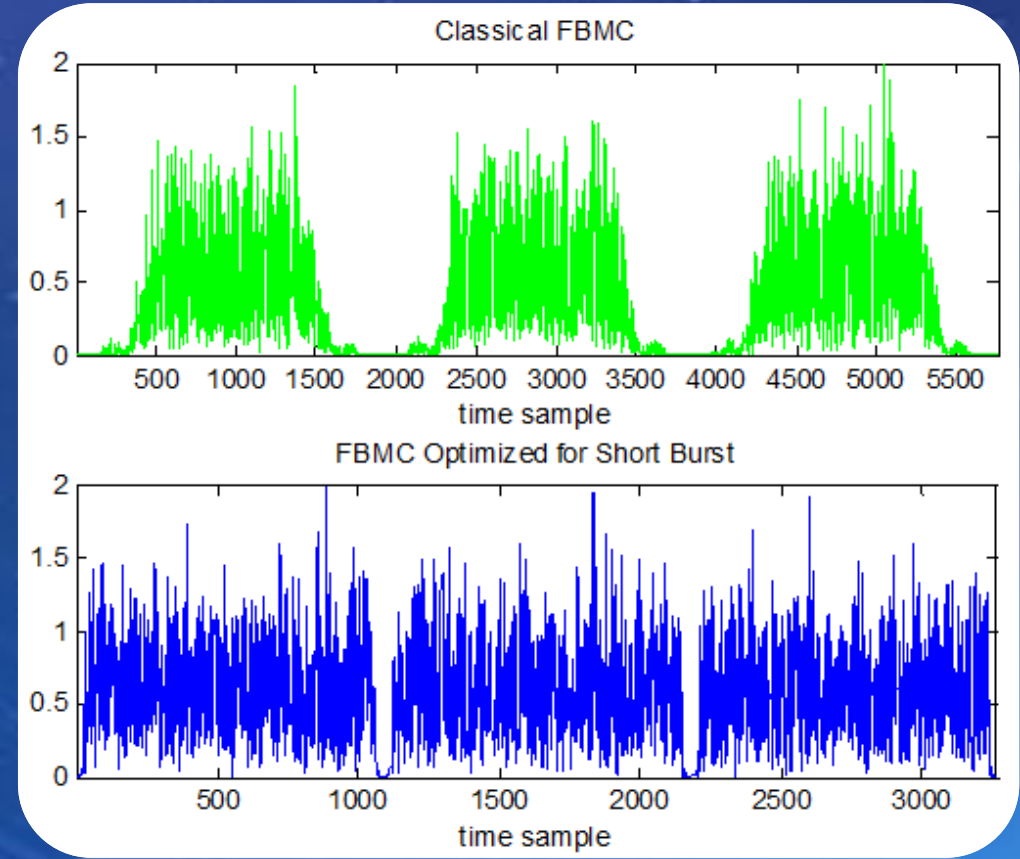
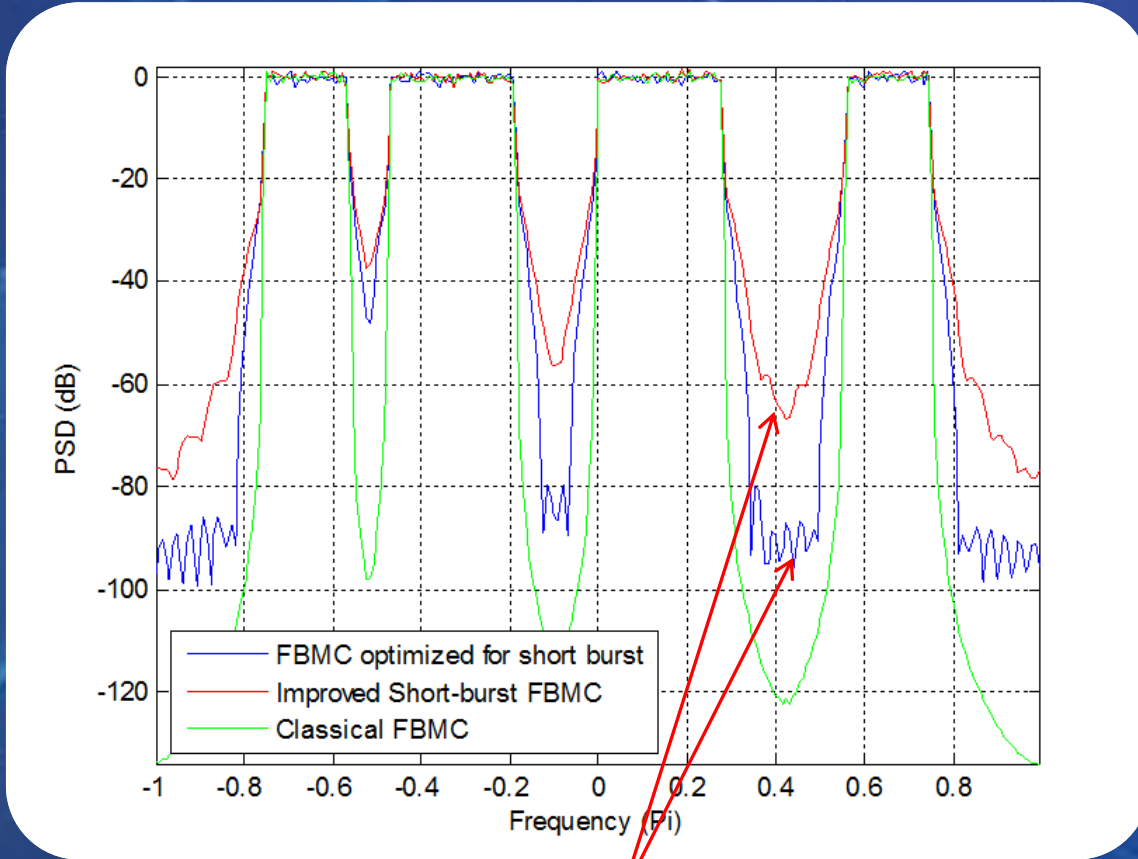
BS with RRU



FBMC: low Power Leakage and short Time Overhead for Short Burst



- Further optimization for short burst with low time overhead → MTC Communications



> 20 dB reduction in interference leakage

3.5 symbol overhead

0.25 symbol overhead

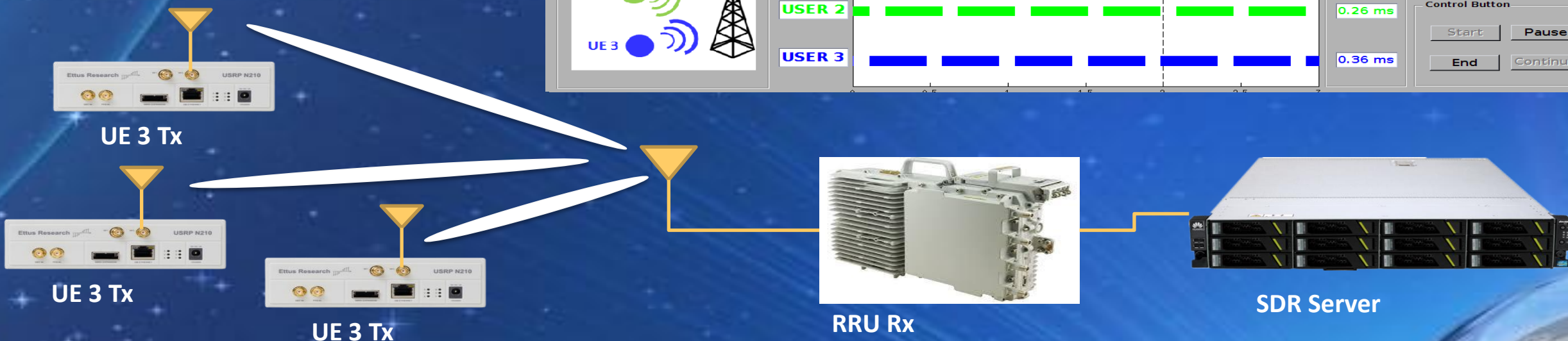
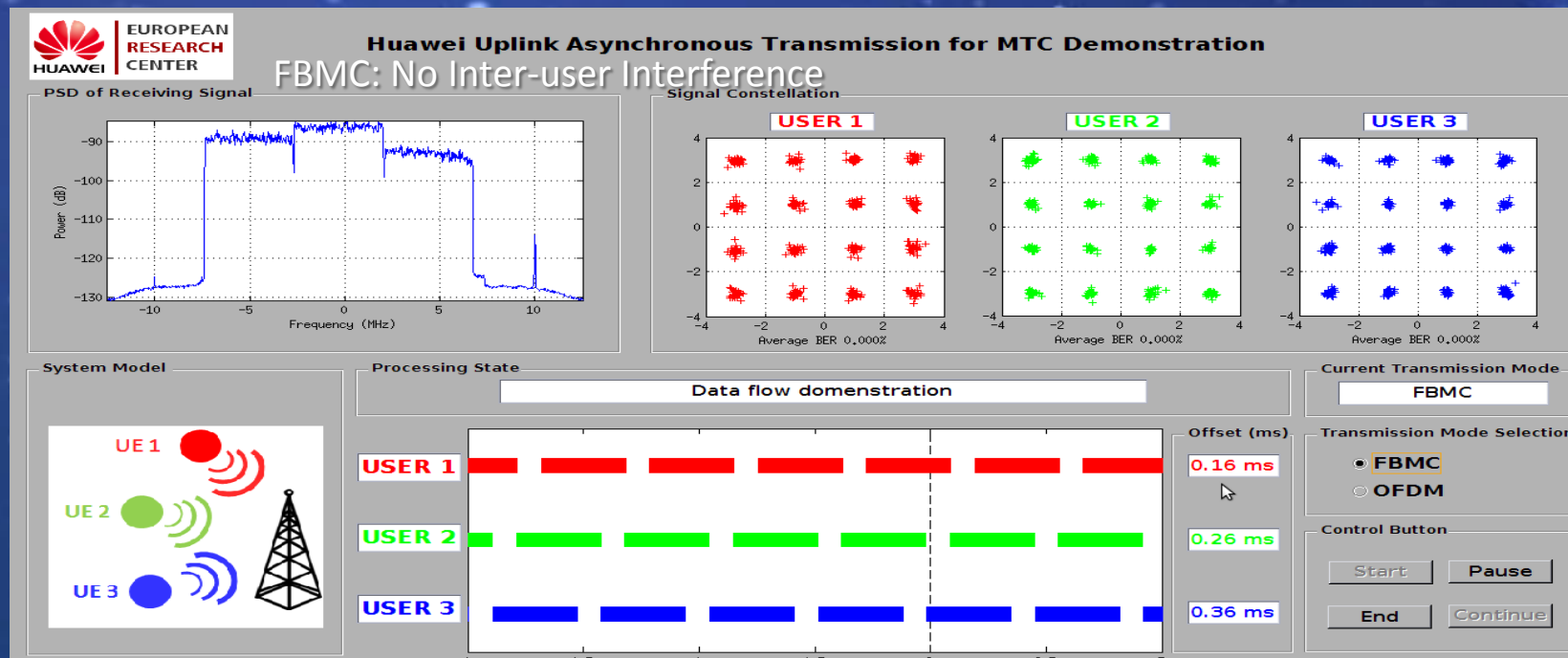


[Hanwen Cao, Nikola Vucic, Zhao Zhao, Egon Schulz, Huawei]

AFBMC: Asynchronous instant low-latency uplink



- Avoid uplink Time Adjustment (TA) as in LTE
- Enable connectionless low-latency communication
- Especially suitable for MTC packet transmission



[Hanwen Cao, Qi Wang, Zhao Zhao, Egon Schulz, Huawei]

MIMO-FBMC Transmission

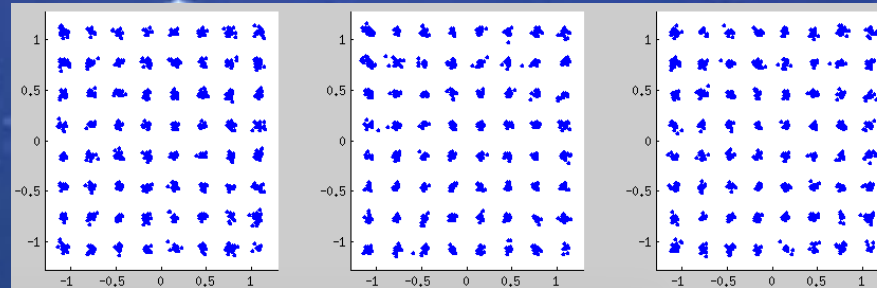


Feasibility of MIMO+FBMC was taken as an open questions in the community

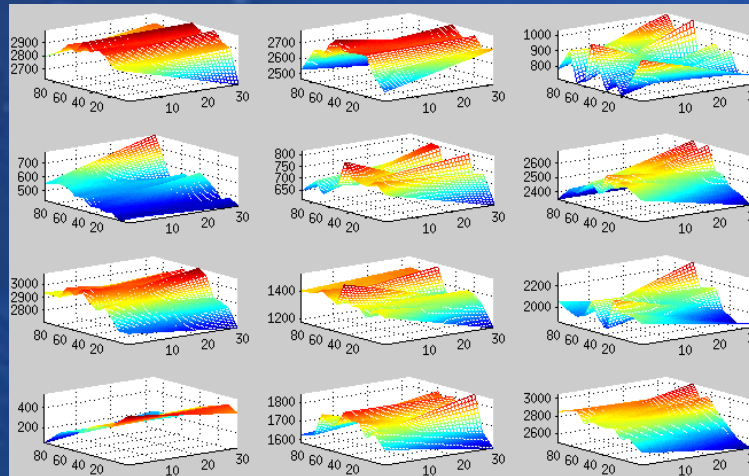
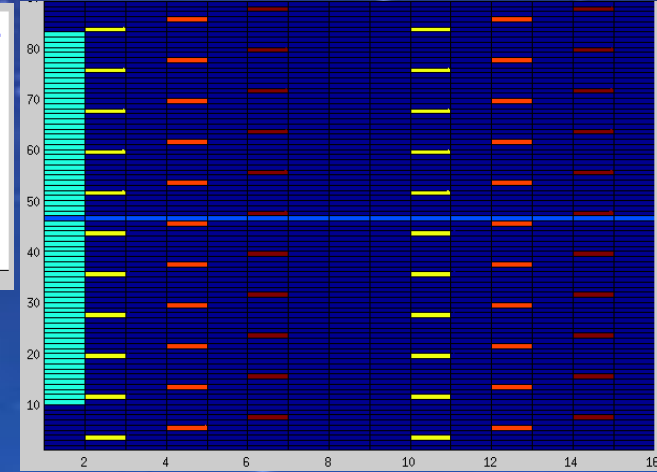
We achieved:

- *Real-world MIMO-FBMC transmission: 3 x 4*
- *Special pilot design for enabling reliable MIMO channel estimation*
- *Higher spectrum efficiency than MIMO-OFDM with comparable complexity*

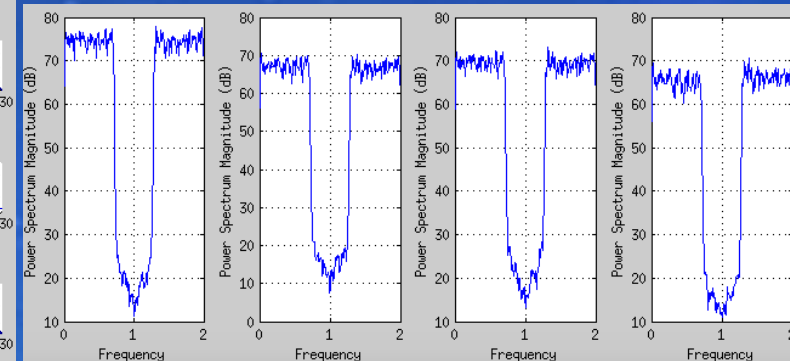
Received Constellation



PHY Resource Grid



Estimated 3x4 MIMO channels

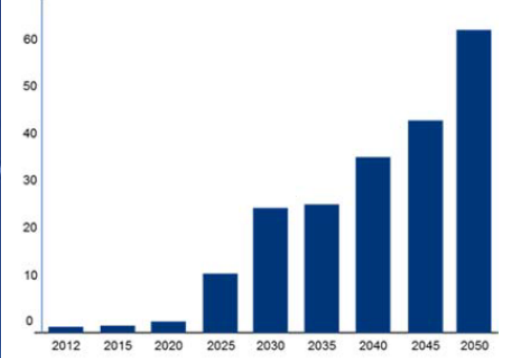


Received Power Spectrum

Global ageing: one of the greatest transformations of our time

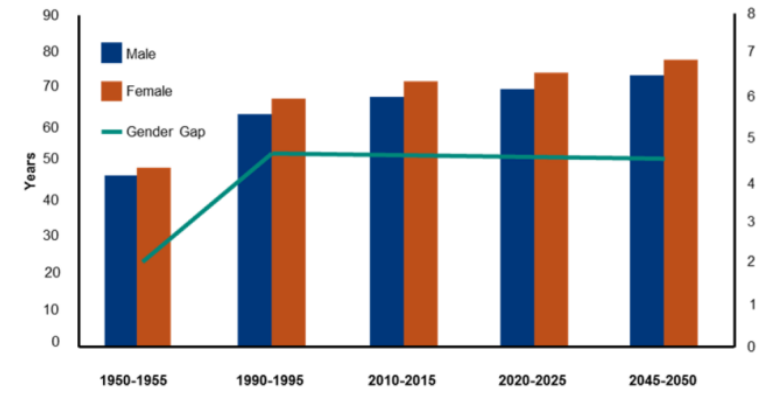
- The number of older persons (60+) : 841mn in 2013 → 2bn+ by 2050E (Source: UN) → costs up to 50% of 2010 GDP by 2050E (Source: IMF)

Chart 1: Number of countries with >30% of the population aged 60+ (2012-2050)

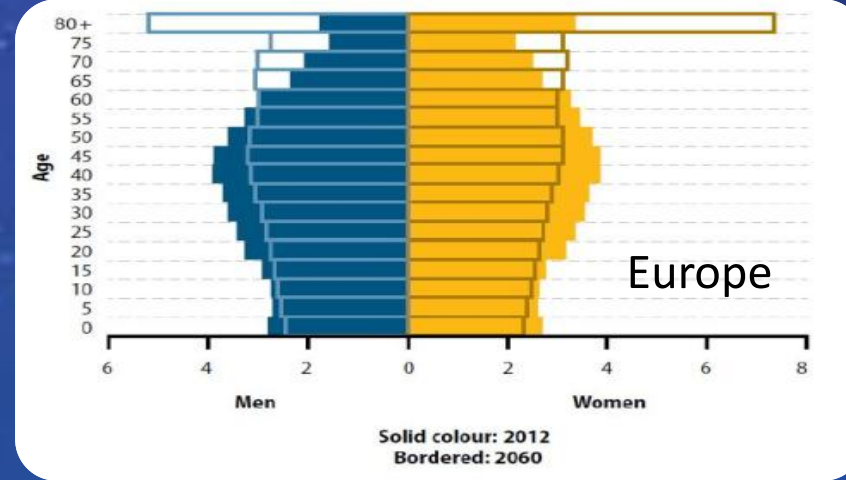


Source: UN

Chart 3: Global life expectancy at birth & gender gap

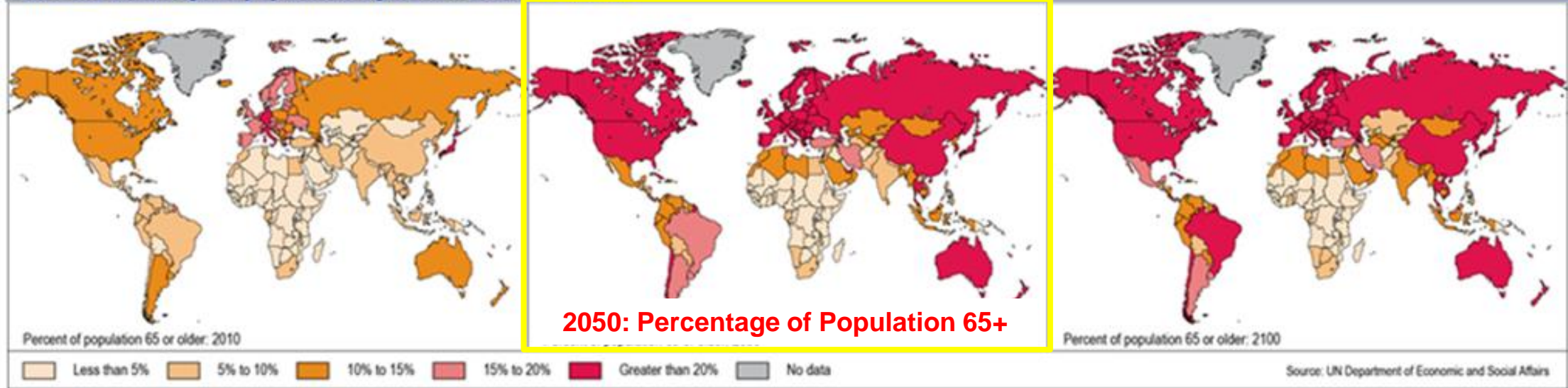


Source: UN. The vertical axis on the right side of each panel indicates the gender gap in life expectancy at birth (in years, female minus male values).



[Ambient Assisted Living Roadmap, AALIANCE2 Project – Deliverable 2.7, Sept 2014]

Chart 2: Percentage of population aged 65+: 2010, 2050, 2100



Source: UN Department of Economic and Social Affairs

Source: UN DESA

By 2050 Japan's population could drop to 107M/128M with 55M out of the workforce [10]: 40M (65+), 15M (14-)

[Merrill-Lynch report on the Longevity Economy, June 2014]

Longevity: the silver dollar*

*) Consumer markets and needs to improve the sustainability of public expenditure linked to ageing

- Public and consumer expenditure related to population ageing and the specific needs of the population over 50

- Silver Economy: **\$7 trillion per year** (3rd largest economy in the world)
- Private spending power of the elderly generation: **\$15 trillion globally by 2020**
- EU Public spending: **25% of GDP** or **~50% of Government expenditure now** → grow by more than 4% of GDP until 2060

Stakeholders

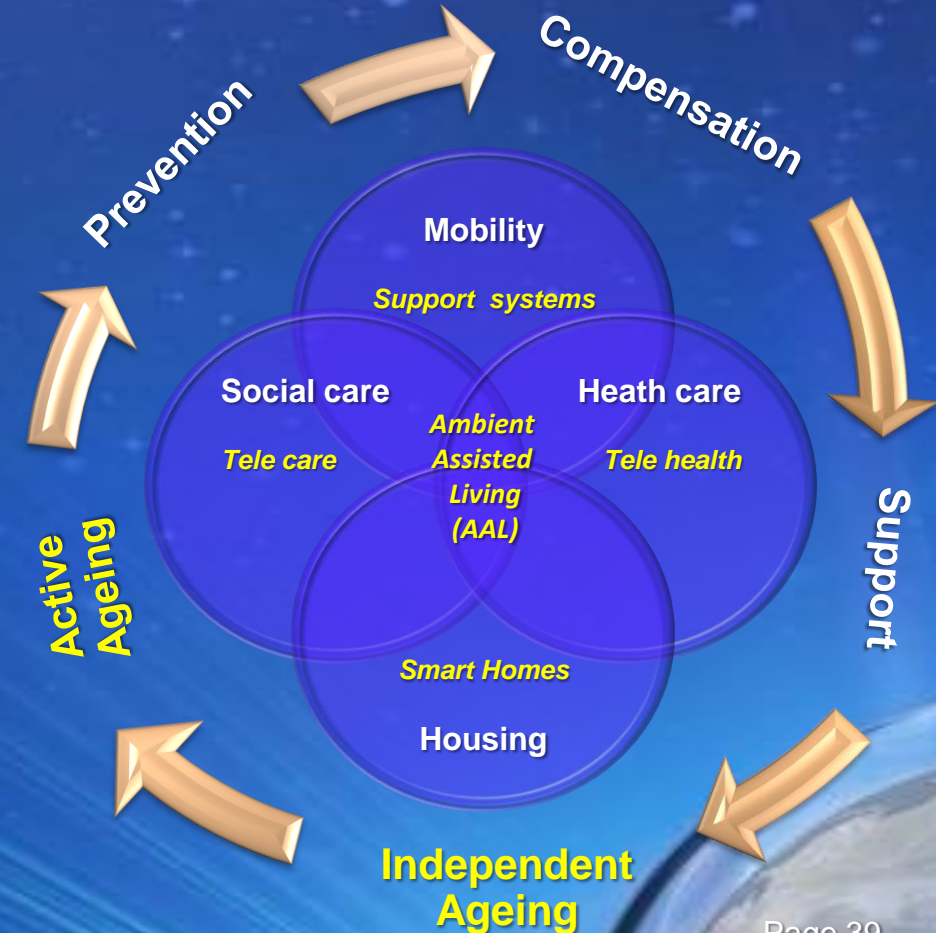
Business Model / Technologies

- **Older Person** (active, fragile and dependant)
- **Informal Caregivers** (families, caretakers, etc): 60% of requests



- **Formal Caregivers** (service provider, nurse, volunteer, etc.)

- **Policy makers**
- **Insurances**
- **Etc.**



- **Industry**
- **Small Medium Enterprises**
- **Research institutes**
- **Etc.**

Actions in Europe: €100+B public investments in 2014-2020



EUROPEAN INNOVATION PARTNERSHIP
on Active and Healthy Ageing

Overview of the EU funding related to healthy ageing

Programme	Amount (2014-2020)
• Active and Assisted Living Research and Development Programme (AAL)	EUR 175 million
• Erasmus +	EUR 14.7 billion
• European Regional Development Fund	EUR 351,8 billion
• European Social Fund	EUR 351,8 billion
• Health Programme	EUR 449, 4 million
• Horizon 2020	EUR 77,028 billion
• EIT Knowledge and Innovation Communities (KICs)	EUR 2.7 billion from H2020
• Programme for the Competitiveness of Enterprises and small and medium-sized enterprises (COSME)	EUR 2.3 billion
• PROGRESS Programme	EUR 919.5 million
• The EU Joint Programme Neurodegenerative Disease Research (JPND)	Each country funds its own national project participants.
• The Innovative Medicines Initiative 2 (IMI2)	The EU will contribute up to EUR 1638 million from Horizon 2020

<https://webgate.ec.europa.eu/eipaha/>



**AMBIENT ASSISTED LIVING
JOINT PROGRAMME**
ICT for ageing well

Call 2015

“Living active and independently at home”

“The contribution of ICT/technologies to integrated solutions for supporting active and independent living of older adults in their homes”

- Date of publication: 26 February 2015.
- Closure date: 28 May 2015, 17h00 (CET)
- Indicative total funding (EC + Member States): **33,900,000 €**

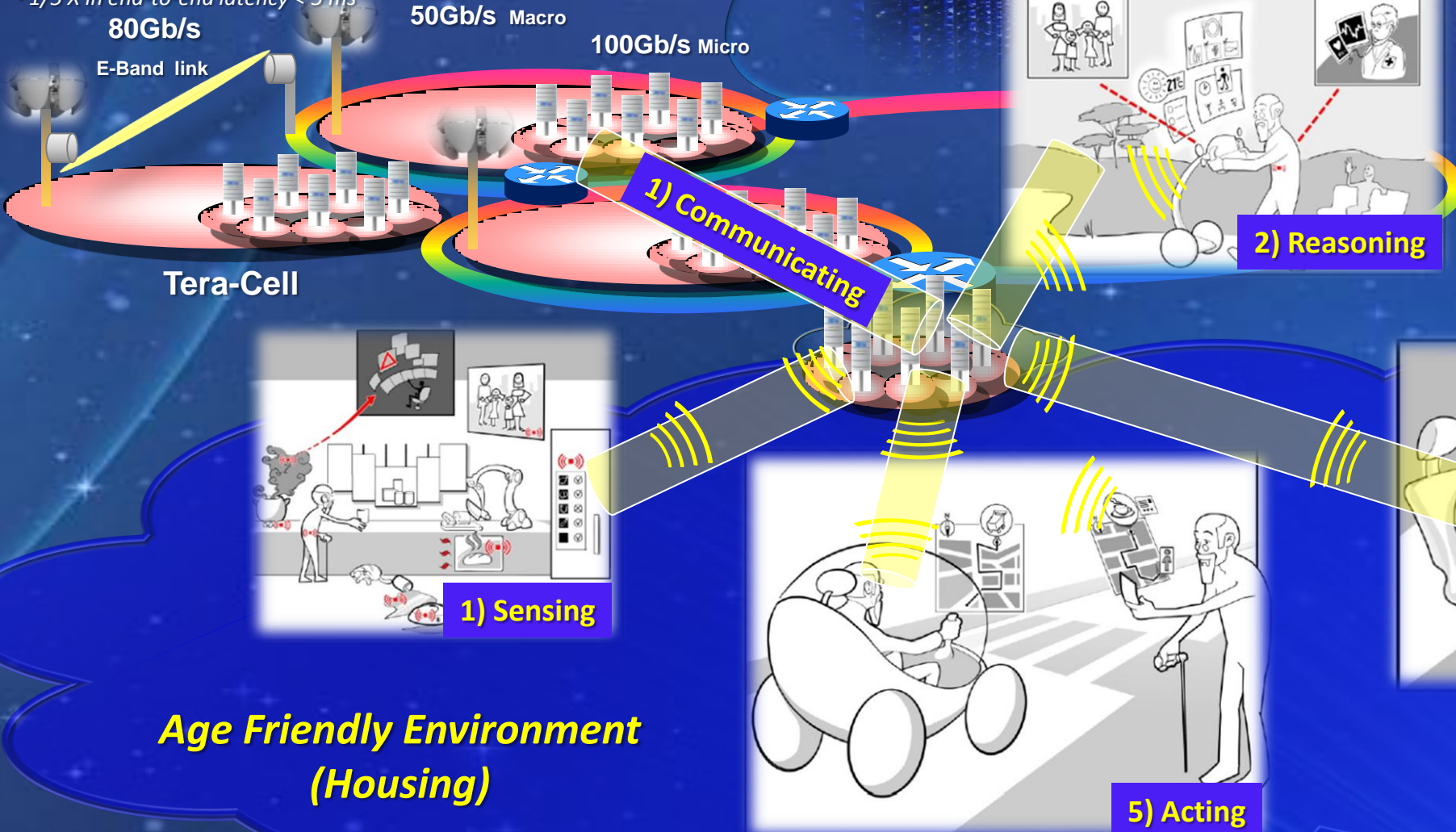


<http://www.aal-europe.eu/get-involved/call-2015/>

Vision: 5G the nervous system of the Silver Economy

- *Telemedicine, Telecare, Telehome, Mobile Health, Smart Home, IoT, service robots for better lives and reduce costs*

- 1,000 X in mobile data volume per geographical area reaching a target ≥ 10 Tb/s/km²
- 1,000 X in number of connected devices reaching a density ≥ 1 M terminals/km²
- 100 X in user data rate reaching a peak terminal data rate ≥ 10 Gb/s
- 1/5 X in end-to-end latency < 5 ms



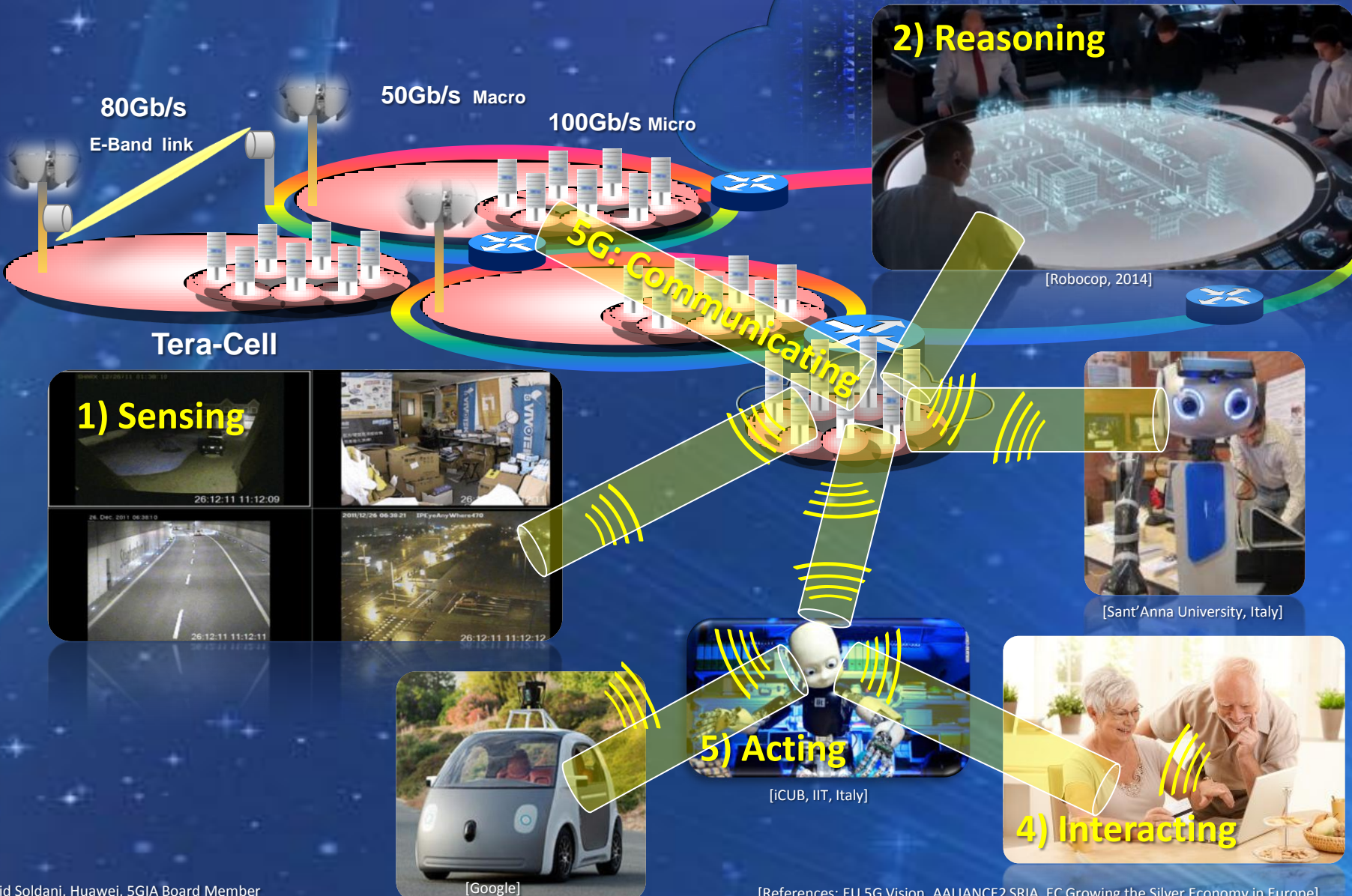
Stakeholders:

1. Older persons and caregivers
2. Service providers
3. Industry, vendors, etc.
4. Policy makers, insurance, etc.

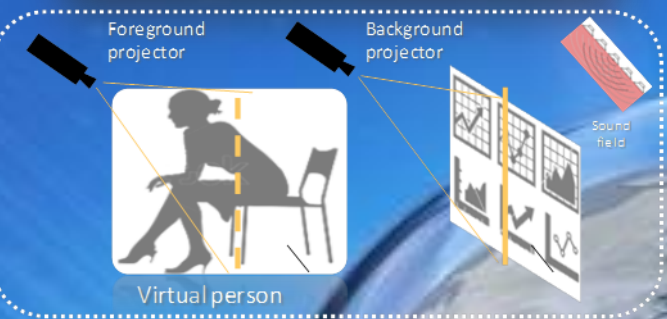
**Age Friendly Environment
(Housing)**

Use case: 5G for age-friendly and safe environments

- Houses safer and age-friendly environments in which living, several AAL technologies, like imperceptible environmental sensors, advanced processing tools for events recognition and prediction, smart electronic appliances and robots, could be adopted



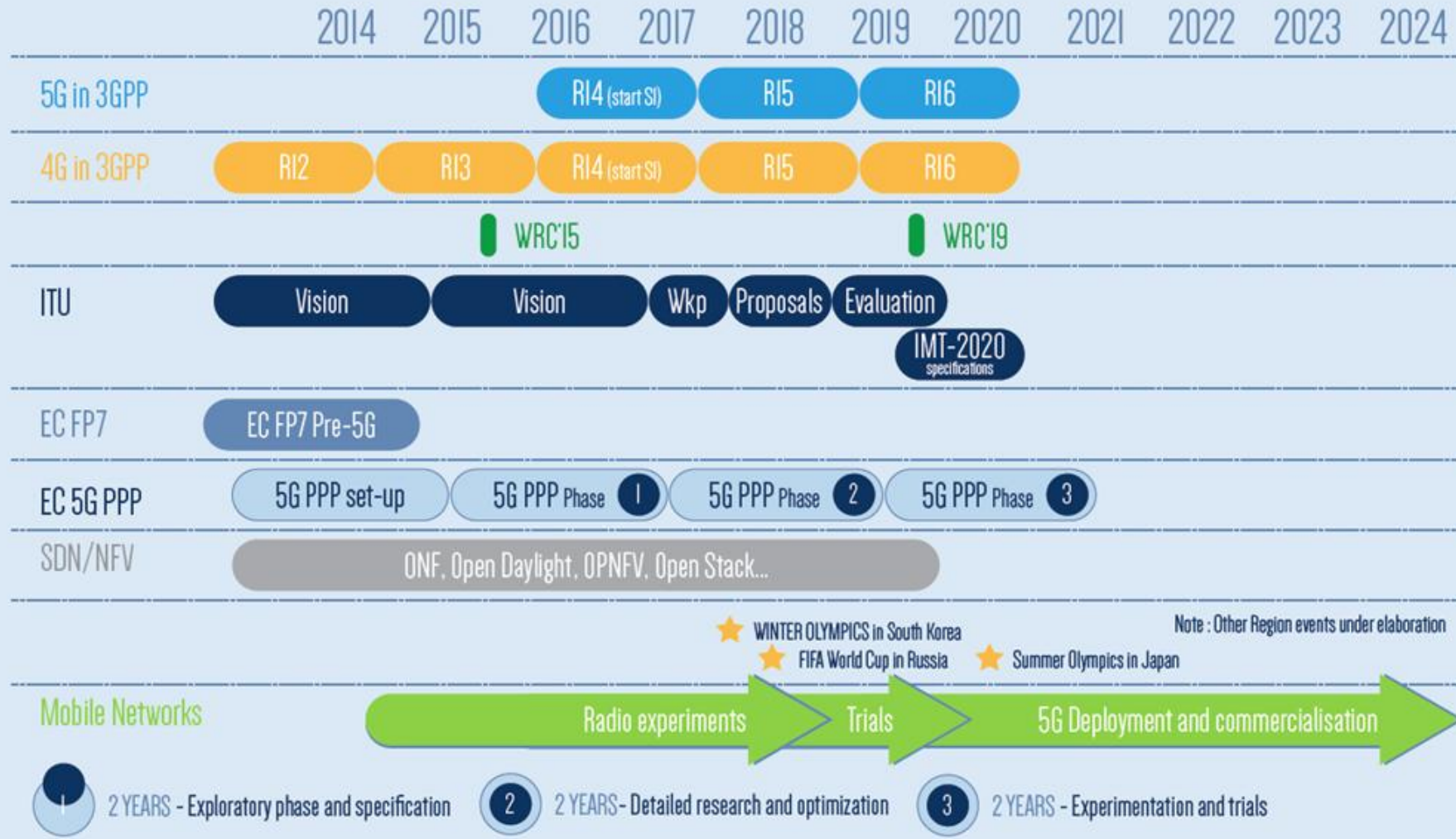
3) Rendering



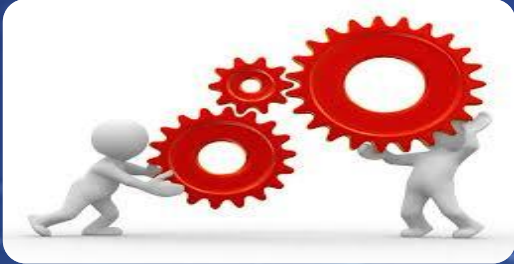
Towards "IMT for 2020 and beyond"...

More information at
www.5g-ppp.eu

Supported by the



Conclusions



5G tests and trials with Verticals essential step towards effective standardization



3GPP primary organization and others – such as, e.g., ONF and IETF – complementary



Public party crucial role in early consensus (e.g. 5GPPP), policies, regulatory processes



IP Rights shall not hinder 5G technologies adoption and market uptake



5G

Thank you

www.huawei.com

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