Feeling the (Pain of) Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, …

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Expectation Always Grows with Success!

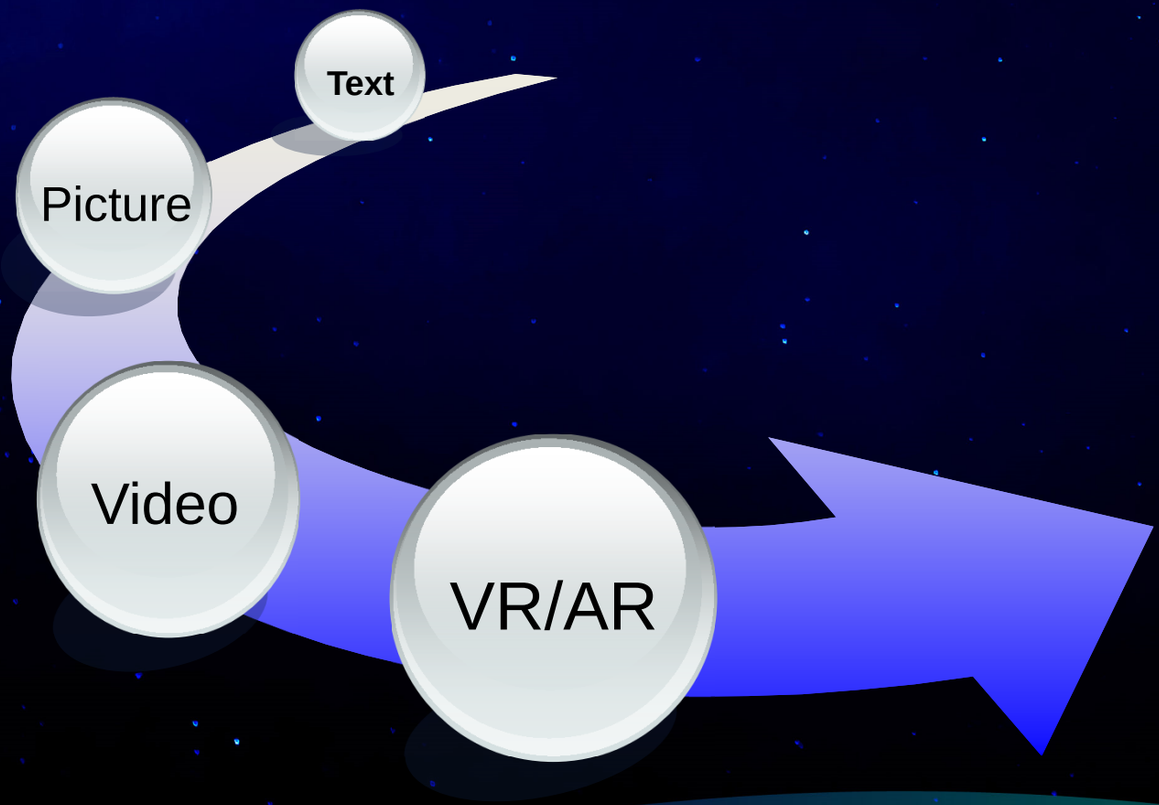
Expectation for runners:

- **When you run 100 meters in 10 seconds, you are expected to run it in 9.5 seconds**
- **When you reach 9.5 seconds, you are expected to run it in 9 seconds**
- **You will always be expected for something newer and harder!**

Expectation for the Internet

- **TCP/IP was initially expected to send/receive “lettergrams”**
- **When the Internet can successfully support “textual” applications, it is expected to support “image applications”**
- **When the internet can support “voice applications”, it is expected to support “video” applications**
- **When the internet can support video applications, it is expected to support “immersive experience” applications. But can it really support it?**

Evolution of Internet Applications



AR/VR: New Way to Live, to Play, to Work, to Share, to Design, to Experience, to Go beyond the Screen

Source: Modification of https://www.youtube.com/watch?v=aThCr0PsyuA

Can the Internet Support any New Applications?

New Requirements

- **High Throughput (1-10Gbps)**
- **Low Latency (1ms)**

Obstacles

Physics

- ❖ Light speed: 300km/ms

Protocols

- ❖ 40-year old design

Real Transport: 100km/ms

Economics

- ❖ CapEx
- ❖ OpEx

Emerging Technologies

mmW | 5G | IoT | V2X | ION | SDN | NFV | MEC

Panelists

- **Tommy Svensson:** Challenges and Opportunities with mm-wave Communications in 5G
- **Valerio Frascolla:** Mobile Edge Computing, a key building block for 5G networks
- **Eugen Borcoci*:*** Centralized SDN control in distributed IoT environment - is it possibly an efficient cooperation ?

Thank you

www.huawei.com

Panel on Communications on ICN & SPACOMM

Topic: Feeling the (Pain of) Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

SDN, NFV, MEC.. in IoT Environment?

Eugen Borcoci
University POLITEHNICA Bucharest
Electronics, Telecommunications and Information Technology Faculty (ETTI)
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NexComm Conference, 23-27 April, Venice

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

Facts:

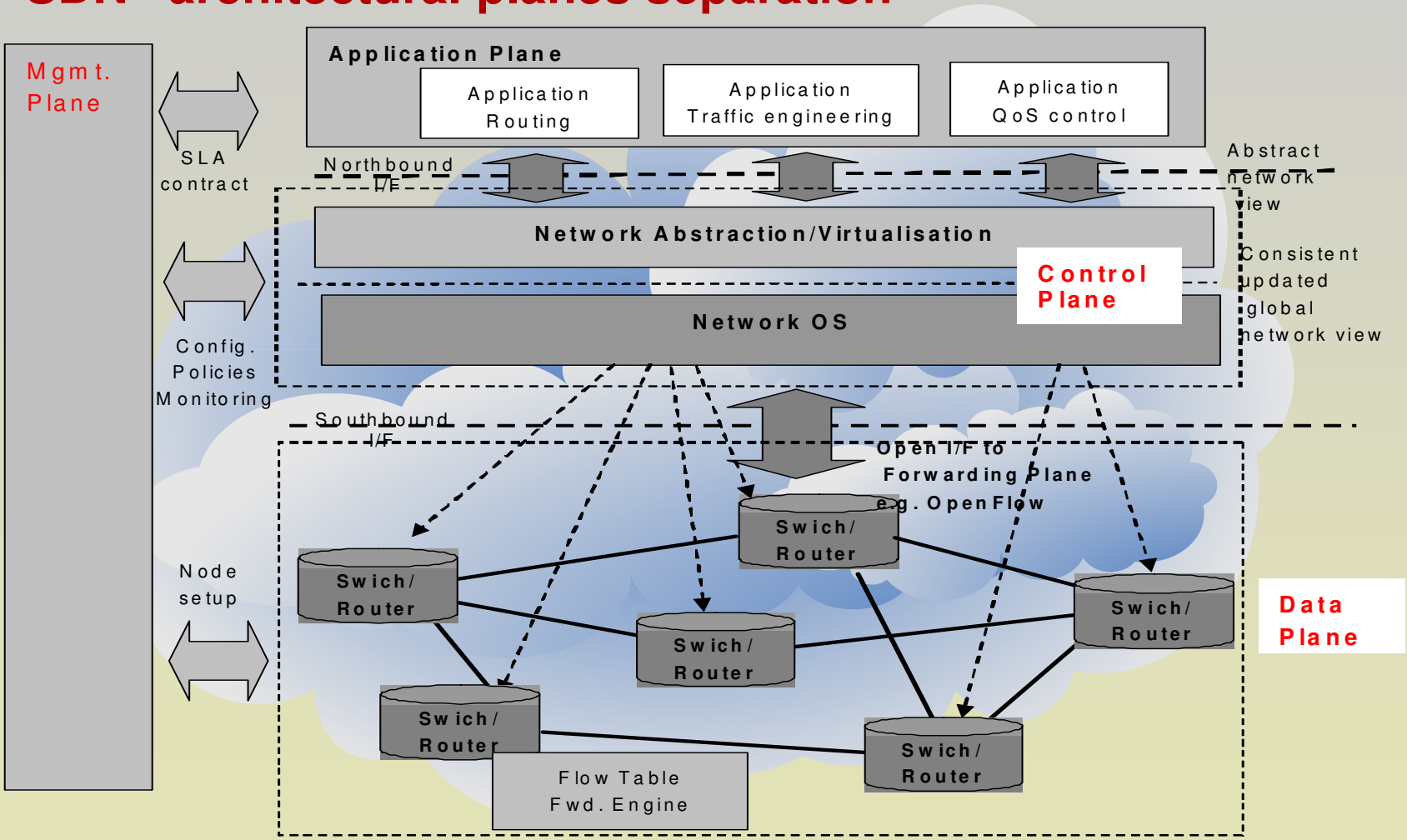
- **Internet and Telecom convergence → Integrated networks: Future Internet**
- **Novel services, applications and communication paradigms**
  - **Internet of Things (IoT) and Smart cities, M2M and Vehicular communications, Content/media oriented communications, Social networks,**
  - **Internet of Everything (IoE), etc.**
- **Novel, emergent technologies** are changing networks and services architectures :
  - ***Supporting technologies***
    - ***Cloud Computing***
    - ***Fog/Edge Computing /Mobile Edge Computing /Cloudlets***
    - ***Software Defined Networks (SDN)***
    - ***Network Function Virtualization (NFV)***
    - ***Advances in wireless technologies: 4G-LTE, LTE-A, WiFi, 5G***

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **Software Defined Networking (SDN)**
  - **SDN – applicable in Clouds, WANs, IoT, vehicular, 5G**
- **SDN concepts and advantages:**
  - **Control Plane (CPI) and Data Plane (DPI) separation**
  - **centralized logical control and view** of the network
    - underlying network infrastructure is abstracted to applications
    - common APIs (northbound I/F)
  - Open I/Fs Southbound I/F CPI (controllers - DPI elements)
    - E.g. OpenFlow
  - **Network programmability**: by external applications including network management and control
  - **Independency of operators** w.r.t. network equipment vendors
  - Increased network reliability and security

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- SDN –architectural planes separation



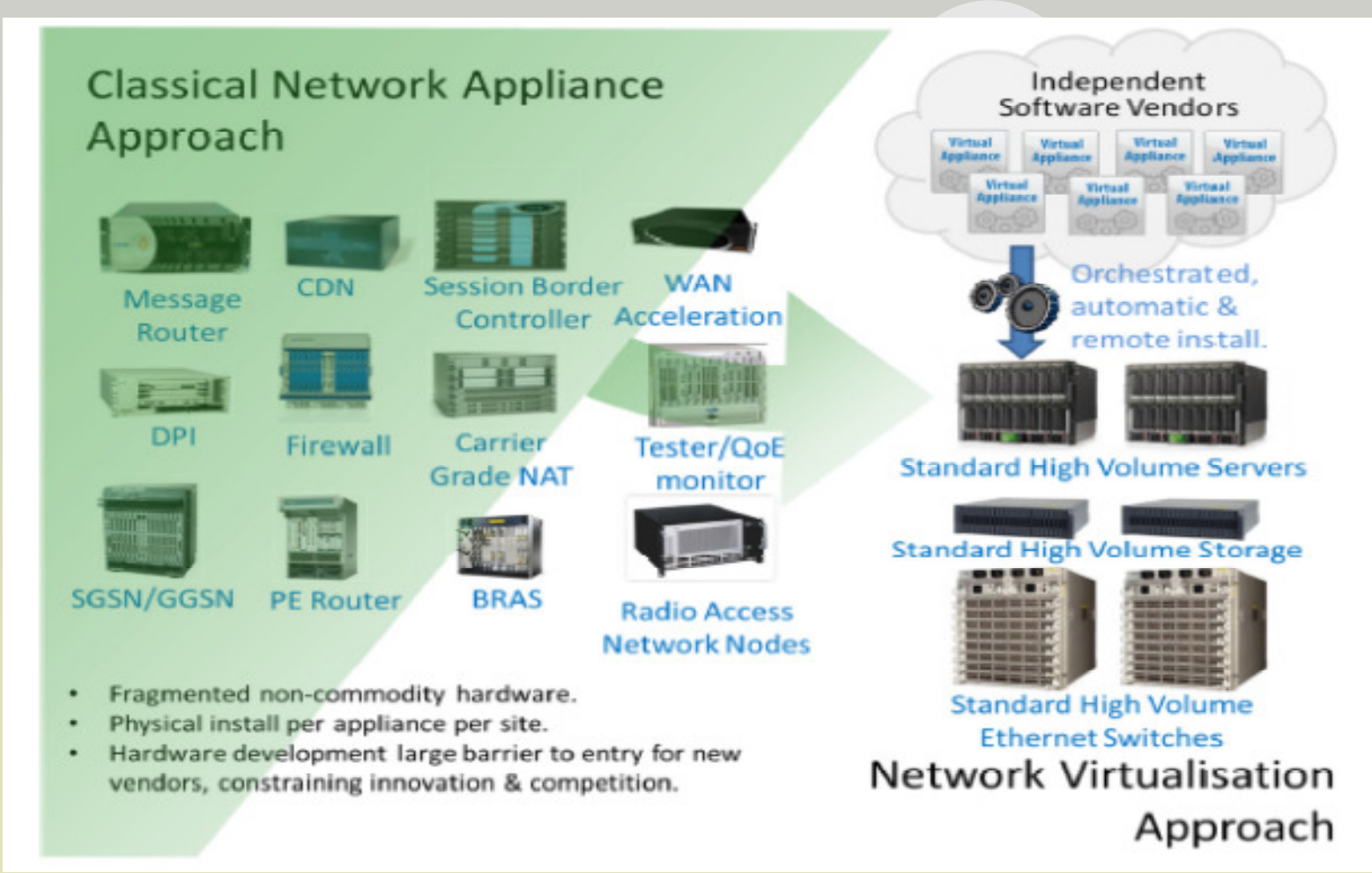
NexComm Conference, 23-27 April, Venice

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **Network Function Virtualization (NFV)**
  - Using COTS computing HW to provide **Virtualized Network Functions (VNFs)**
    - Sharing of HW and reducing the number of different HW arch.
  - **High flexibility in assigning VNFs to HW**
    - better scalability (hope)
    - decouples functionality from location
    - enables time of day reuse
    - **Virtualization-** → flexibility and resource sharing
  - **Rapid service innovation** through SW -based service deployment
  - Higher **operational efficiencies**
  - **Reduced power consumption**
    - (VNF migration, instantiation, …)
  - **Standardized and open I/Fs**: between VNFs infrastructure and mgmt. entities

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

NFV vision (source : ETSI)



Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

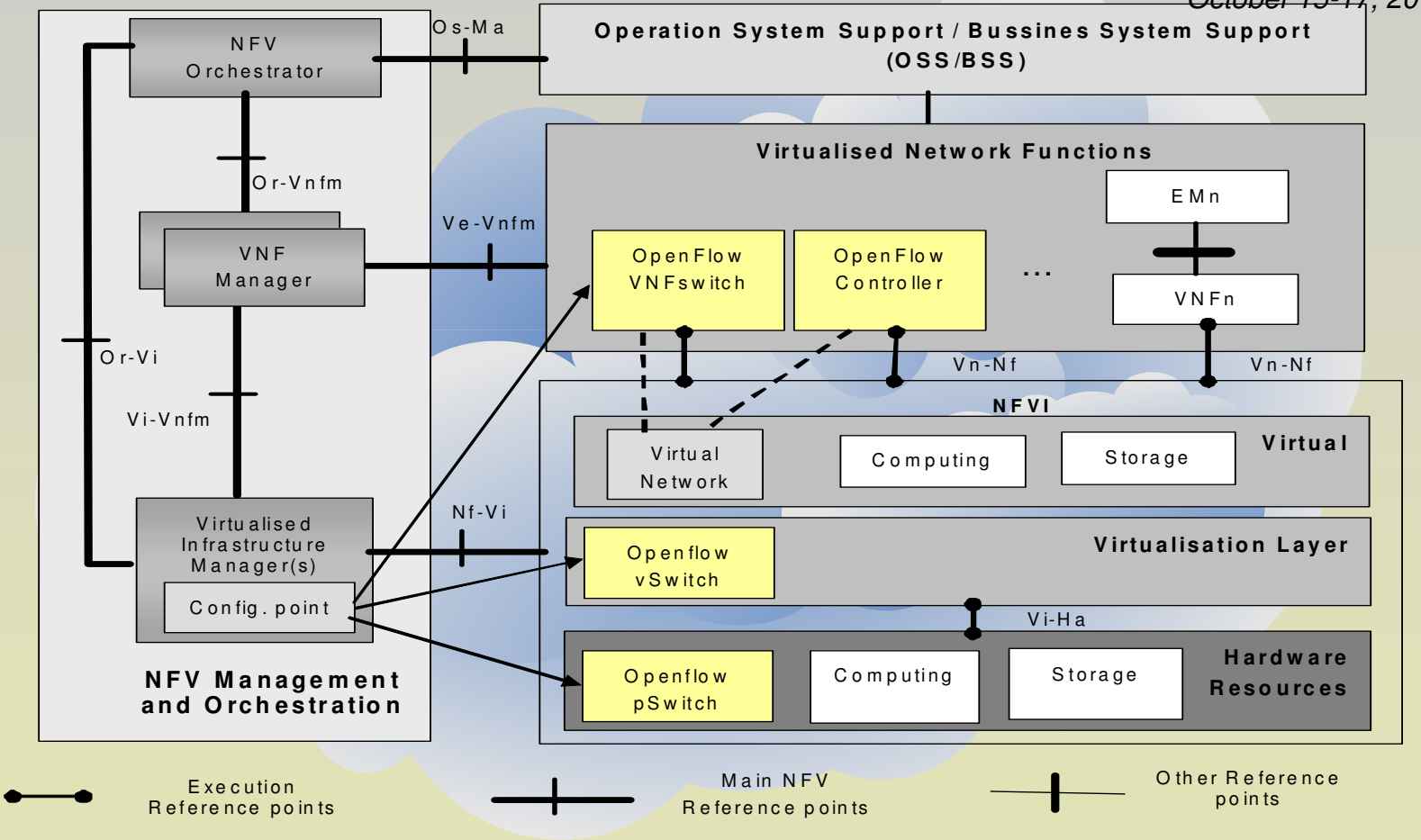
- **SDN and NFV –complementary (orthogonal?)**
  - SDN - **horizontal** separation in planes
  - NFV - **vertical** separation : HW/SW (applicable in both CPl and DPl)
  - They can be developed together
    - NFV provides functionalities
    - SDN provides “Tools”

- Cooperation
  - ETSI
  - ONF
  - IETF
  - ….

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **SDN and NFV –are complementary- example**

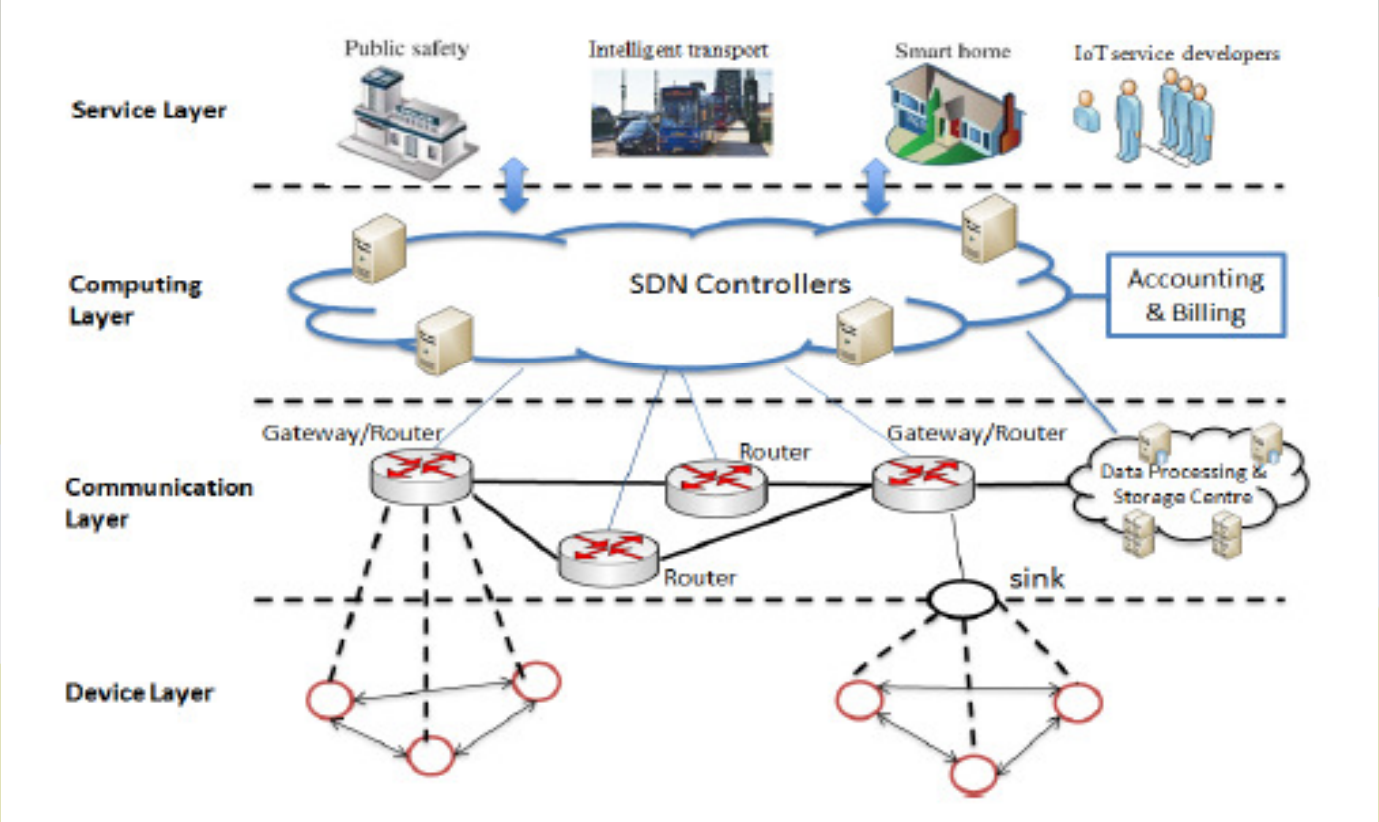
Source: "SDN and OpenFlow World Congress", Frankfurt, October 15-17, 2013



NexComm Conference, 23-27 April, Venice

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

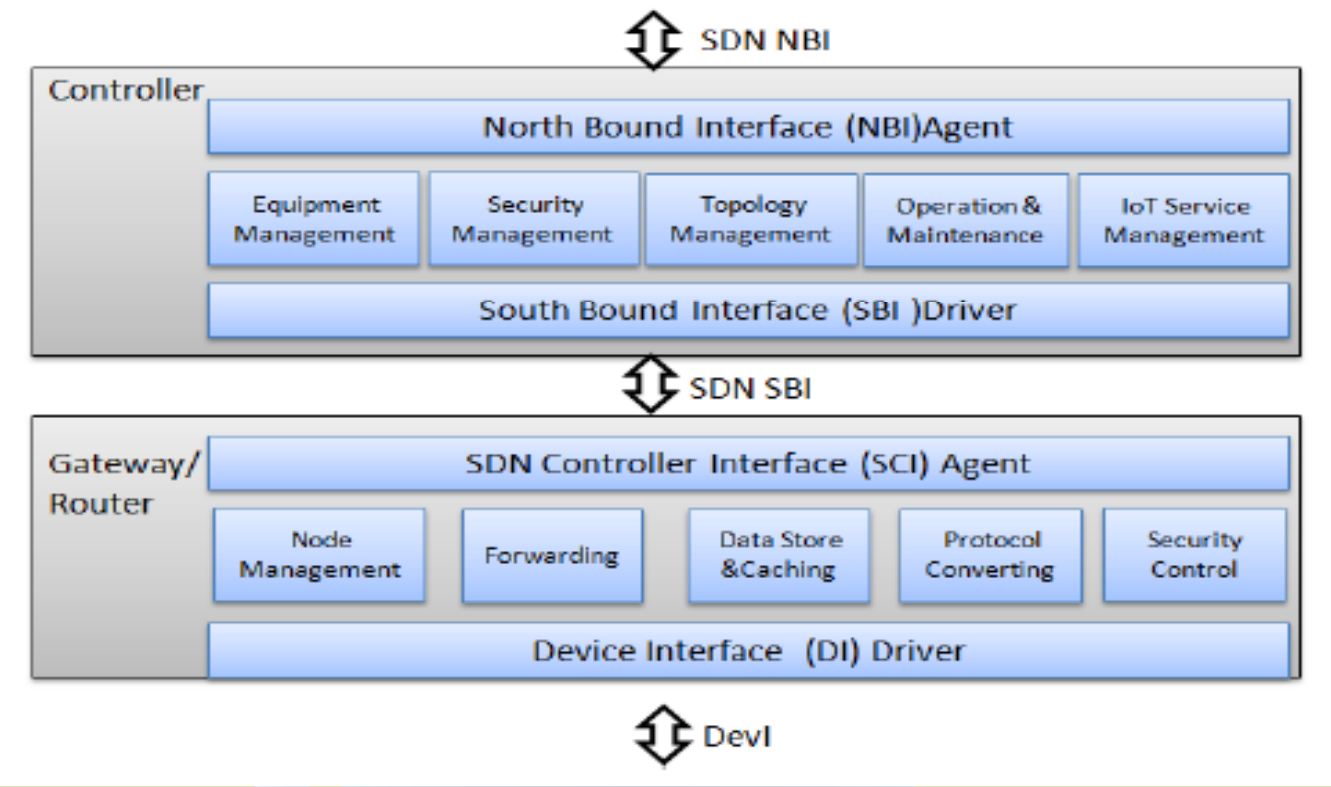
- **SDN control of IoT- example 1**



Source: Y.Li, et.al, "A SDN-based Architecture for Horizontal Internet of Things Services", ICC Conference, 2016

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

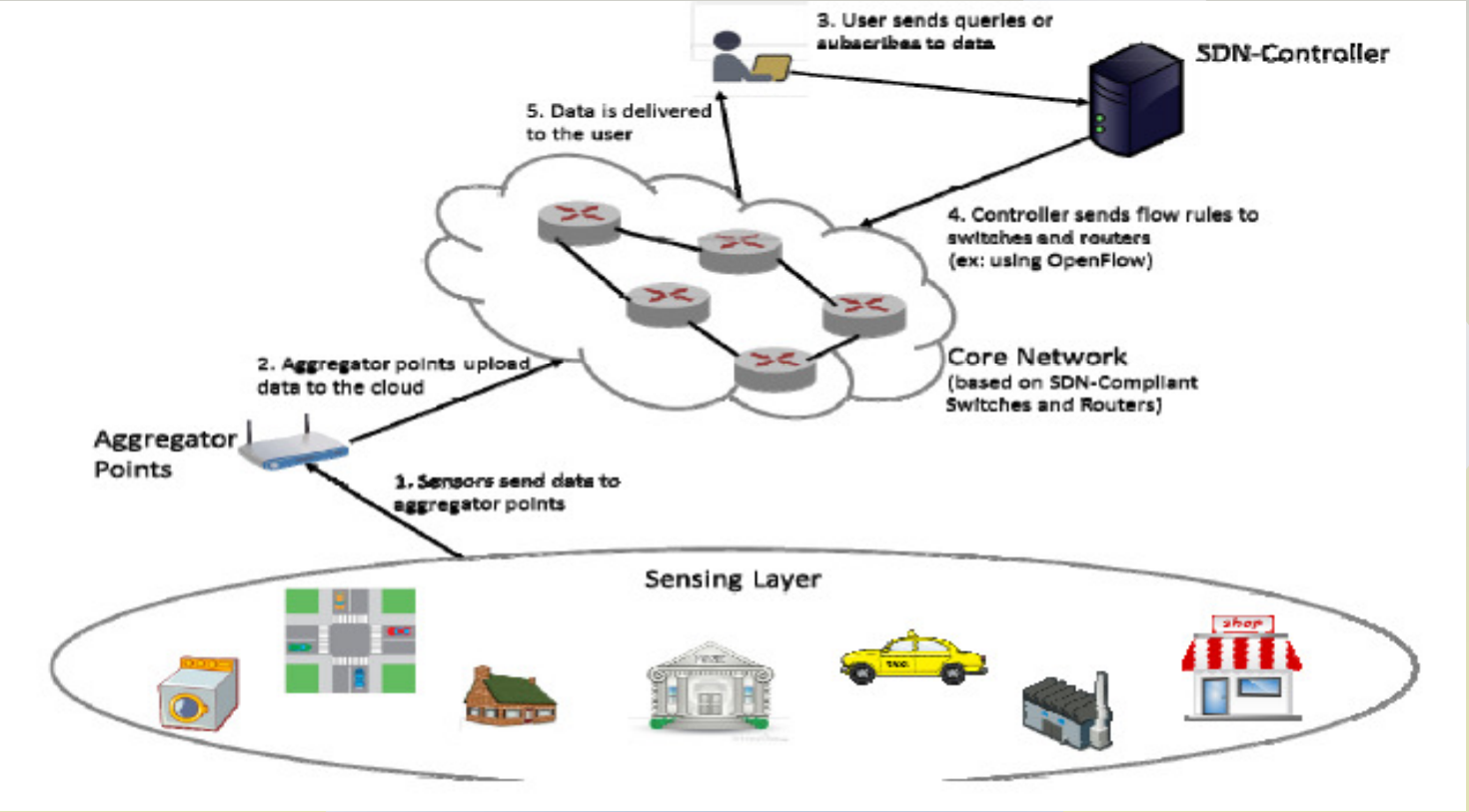
- SDN control of IoT- example 1 (cont'd)
- Functional modules of the controller and gateways



Source:Y.Li, et.al, "A SDN-based Architecture for Horizontal Internet of Things Services", ICC Conference, 2016

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

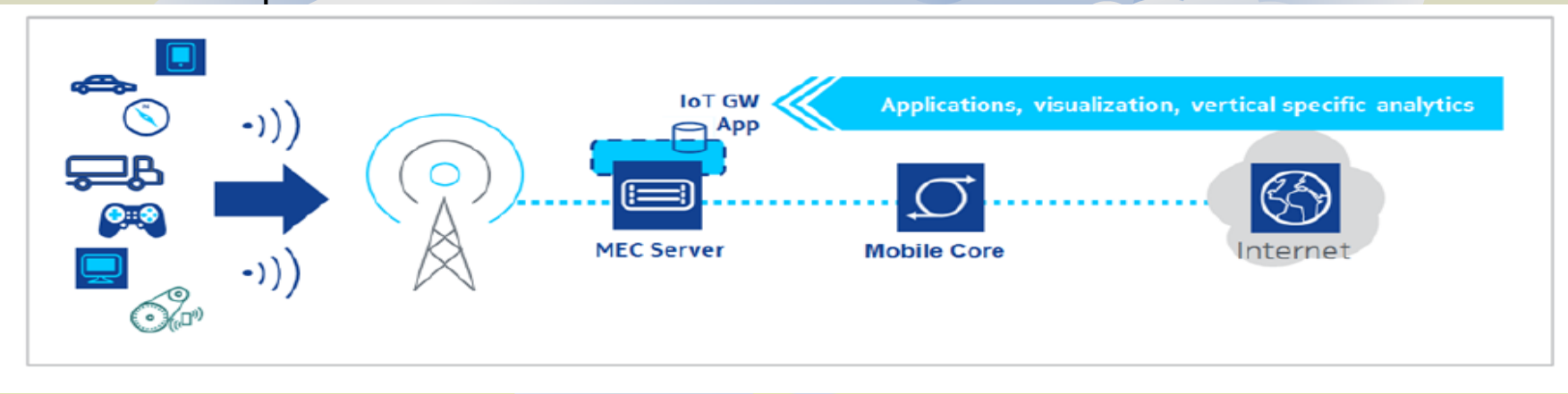
- **SDN control of IoT- example 2 (ICN-style architecture)**



Source: Amr El-Mougy, et.al., "Software-Defined Wireless Network Architectures for the Internet-of-Things", LCN 2015, Florida, USA

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **MEC Use Cases example- IoT**
- Internet of Things (IoT)
  - IoT devices: Often limited (processor, memory capacity)→ need for messages aggregation , security , low latency ..
  - r.t. capability → grouping of sensors and devices is needed for efficient service.
  - Possible Solutions:
    - IoT manipulated close to the devices (e.g., MEC server)
    - This also provides an analytics processing capability and a low latency response time.



Source: Yun Chao Hu et.al., "Mobile Edge Computing A key technology towards 5G" ETSI White Paper No. 11 September 2015, ISBN No. 979-10-92620-08-5

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **Conclusions**
- Significant effort exist towards convergence/cooperation
  - **Technologies**
    - SDN- NFV
    - SDN- NFV- 4G-5G
    - CC- EC/Fog- 5G
    - EC/Fog-MEC- Cloudlets
    - CC-SDN-NFV- IoV
    - CC-SDN-NFV- IoT
    - **Issues: eliminate parallelism and overlapping between standardization efforts……**
  - **Different functional and business aspects**
    - Management and control
    - Slicing and virtualization
    - Security, privacy
    - Scalability
      - Interoperability
    - Seamless deployment characteristics
    - Support for apps and services
  - **New business models**
  - ……

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- Thank you !

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

References

1. ETSI- Network Functions Virtualization – Introductory White Paper, https://portal.etsi.org/nfv/nfv_white_paper.pdf
2. ETSI GS NFV 002 v1.2.1 2014-12, NFV Architectural Framework
3. ONF, “OpenFlow-Enabled SDN and Network FunctionsVirtualization,” https://www.opennetworking.org/images/stories/downloads/sdn-resources/solutionbriefs/sb-sdn-nvf-solution.pdf;
4. https://www.sdxcentral.com/sdn-nfv-use-cases/
5. M.Mendonca, et. al., A Survey of Software-Defined Networking: Past, Present,and Future of Programmable Networks, 2014, http://hal.inria.fr/hal-00825087
6. Y.Li, et.al, "A SDN-based Architecture for Horizontal Internet of Things Services", ICC Conference, 2016
7. Amr El-Mougy, et.al., “Software-Defined Wireless Network Architectures for the Internet-of-Things”, LCN 2015, Florida, USA
8. Yun Chao Hu et.al., "Mobile Edge Computing A key technology towards 5G" ETSI White Paper No. 11, September 2015, ISBN No. 979-10-92620-08-5

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **Backup slides**

Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, ...

- **List of Acronyms**

- BS Base Station
- BSS Business Support System
- CC Cloud Computing
- CCN Content Centric Networking
- COTS Commercial-off-the-Shelf
- EC Edge Computing
- EPC Evolved Packet Core
- ETSI European Telecommunications Standards Institute
- FC Fog Computing
- FCN Fog Computing Node
- IoT Internet of Things
- LTE Long Term Evolution
- MEC Mobile Edge Computing
- M&O Management and Orchestration
- MME Mobility Management Entity
- NF Network Function
- NFV Network Functions Virtualization
- NFVI Network Functions Virtualization Infrastructure
- NO Network Operator
- NP Network Provider
- NS Network Service
- OSS Operations Support System
- SDN Software Defined Network
- SLA Service Level Agreement
- SP Service Provider

Intro to Panel on "Feeling the Pain of Convergence: mmWave, 5G, SDN, NFV, IoT, ION, MEC, …"

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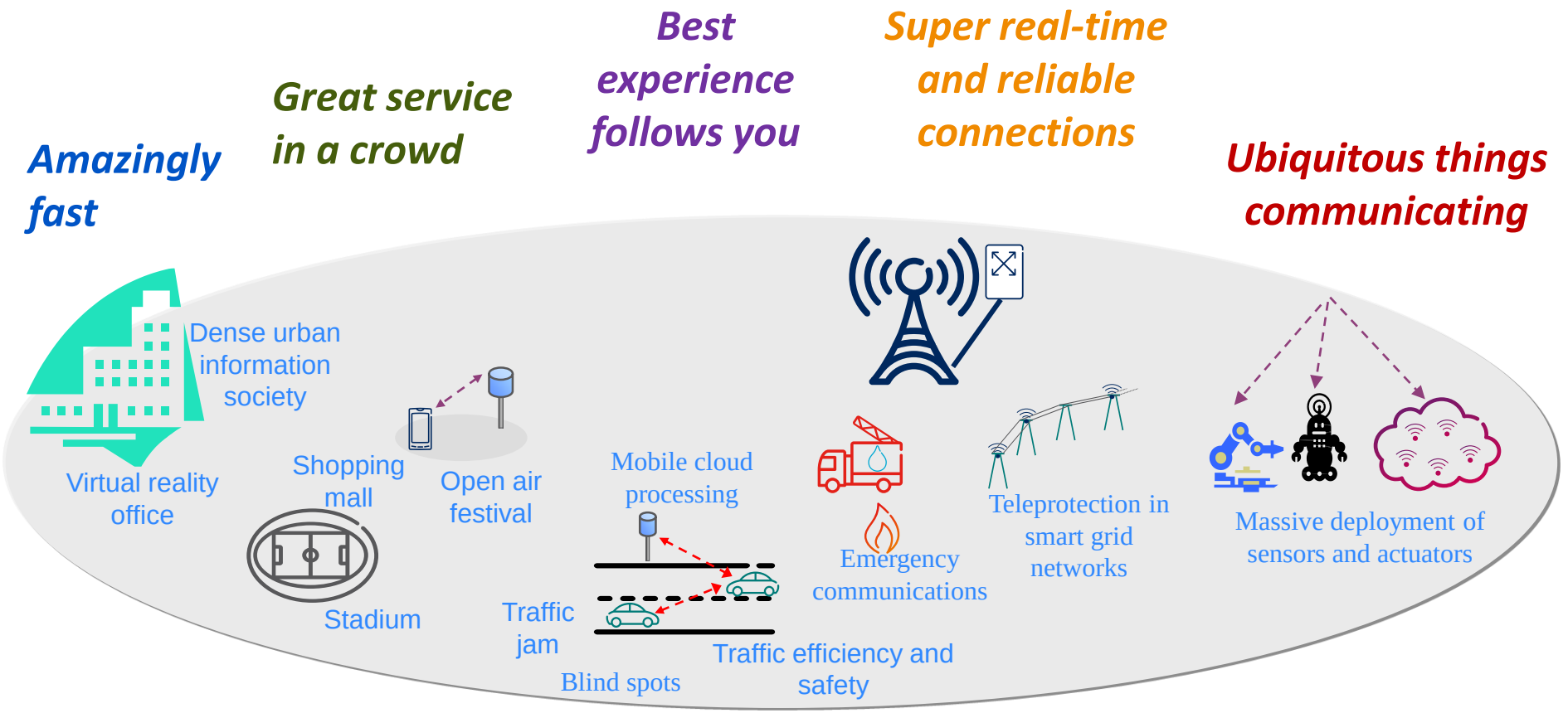
CHALMERS

METIS Scenarios and Test Cases



Source: METIS Deliverable D1.1 "Scenarios, requirements and KPIs for 5G mobile and wireless system", https://www.metis2020.com/

Additional use cases has been proposed by NGMN Alliance, 'NGMN White Paper,' Feb. 2015 (available online https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf)

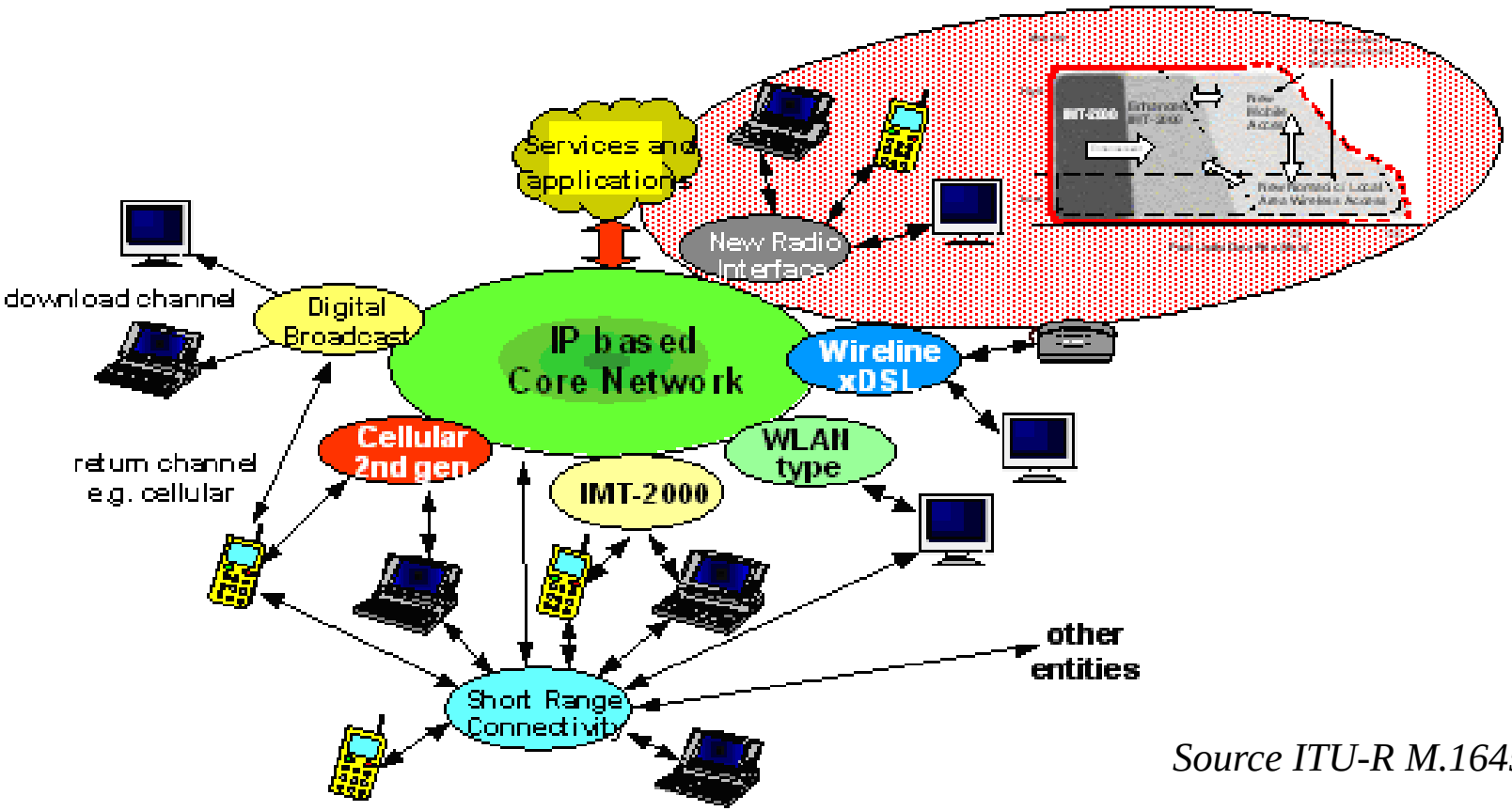
METIS Overall Technical Goal

A system concept that, relative to today, 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 Massive Machine Communication (MMC) devices,
- 5 times reduced End-to-End (E2E) latency.

Source: METIS Deliverable D1.1 "Scenarios, requirements and KPIs for 5G mobile and wireless system", https://www.metis2020.com/

Recap: ITU-R Vision for Systems Beyond 3G



Source ITU-R M.1645

Integrate existing and evolving access systems on a *packet-based* platform to enable cooperation and interworking.

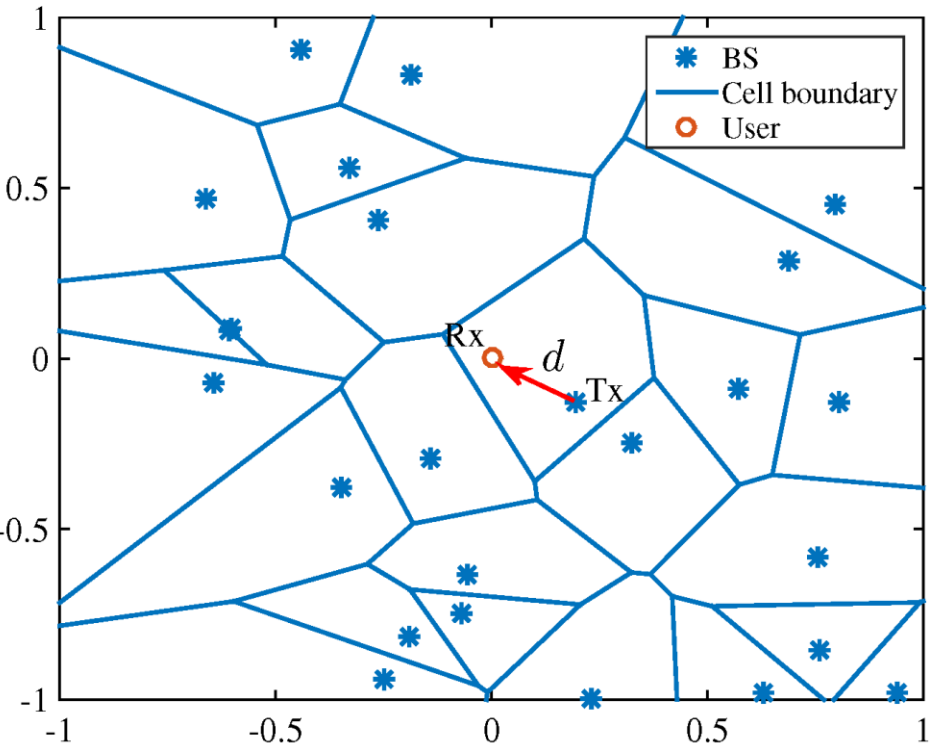
"Optimally connected anywhere, anytime"

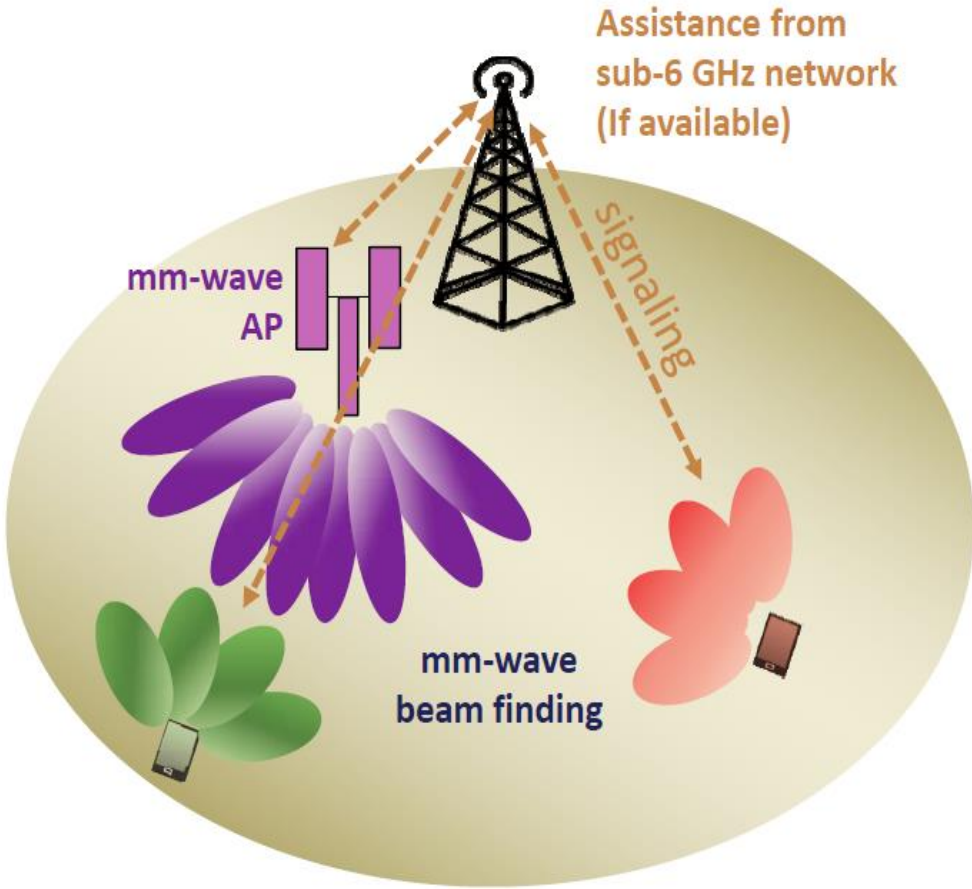
We have done it once already – On the terminal side!

Flexibility versus Efficiency

Picture source: http://onpr.com/choosing-the-right-smartphone-its-easy-to-decide/

From hexagonal cells to unstructured beam spaces

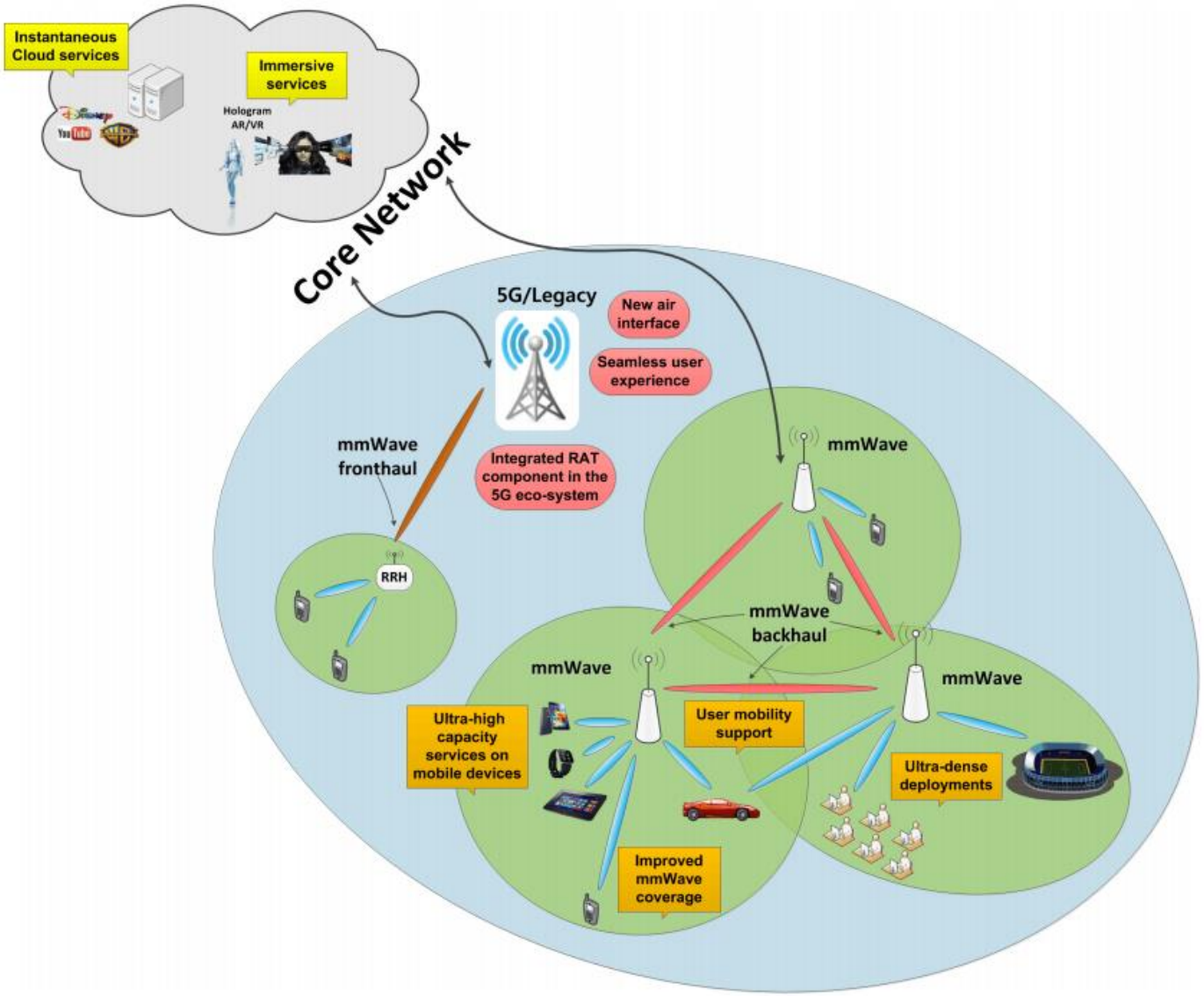




Source: mmMAGIC WP4 presentation, ETSI workshop, Sophia-Antipolis, Jan 28, 2016

mmMAGIC

Network slicing - Where should we do the computing?



Challenges and Opportunities with Demanding Verticals ”Integrated Moving Networks”

- **<u>Mutual benefits!</u>**
- **Better mobile systems efficiency**: Vehicles collect side information to improve the resource allocation and performance of the mobile network
- **More reliable V2X links**: Connect non-vehicular users to the Traffic Safety/Traffic Efficiency protocols (Pedestrians, cyclists, pets, …)
- **New disruptive business opportunities:** exploiting vehicle sensed data

The research leading to these results partly received funding from the European Commission H2020 programme under grant agreement no671650 (5G-PPP mmMAGIC project).

THANK YOU!

Find out more at https://5g-mmmagic.eu

Public deliverables: https://5g-mmmagic.eu/results/#deliverables

D1.1: “Use cases characterization, KPIs and preferred suitable frequency ranges for future 5G systems between 6 GHz and 100 GHz”, released 2015-11-30
D5.1 ”Initial multi-node and antenna transmitter and receiver architectures and schemes” released 2016-03-31
D4.1 ”Preliminary radio interface concepts for mm-wave mobile communications”, released 2016-06-30
D3.1 ”Initial concepts on 5G architecture and integration”, released 2016-03-31
D2.1 “Measurement campaigns and initial channel models for preferred suitable frequency ranges”, released 2016-03-31

mmMAGIC

6th Globecom'2017 Workshop on International Workshop on Emerging Technologies for 5G and Beyond Wireless and Mobile Networks (ET5GB)

Mon or Fri Dec 4 or 8, 2017, Singapore

Main topics:

- Novel radio access network (RAN) architectures
- Advanced radio resource management (RRM) techniques
- Emerging technologies in physical layer
- Novel services
- mmWave communications
- Energy efficiency
- Spectrum
- Prototype and test-bed for 5G and beyond technologies

Workshop Chairs:

- Wei Yu, University of Toronto, Canada
- Tommy Svensson, Chalmers U. of Technology, Sweden
- Lingjia Liu, University of Kansas, USA

Technical Program Chairs:

- Halim Yanikomeroglu, Carleton University, Canada
- Charlie (Jianzhong) Zhang, Samsung Electronics, USA
- Peiying Zhu, Huawei Technologies, Canada

http://wcsp.eng.usf.edu/5g/2017 (to appear) http://wcsp.eng.usf.edu/5g/2016

http://www.ieee-globecom.org/

From concept to deployment: the visions of the 5GCHAMPION and 5G-MiEdge projects

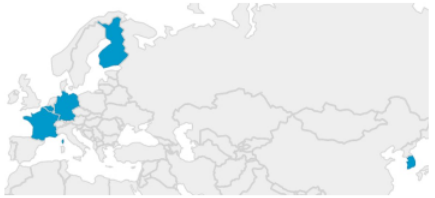
(Olympic Games are coming …)

Valerio Frascolla
Intel

2017.04.27, COCORA 2017, Venice

5GCHAMPION (www.5g-champion.eu)

- *Project name: 5G Communication with a Heterogeneous, Agile Mobile network in the Pyeongchang Winter Olympic Competition*
- *Funding scheme: FP8, Europe-Korea co-funding*
- *Duration: 2016.06 – 2018.05*
- *Key Targets:*
  - The first 5G proof-of-concept in conjunction with the 2018 Korean Winter Olympics,
  - Synergize satellite and terrestrial technologies,
  - Strong impact on Standards bodies.



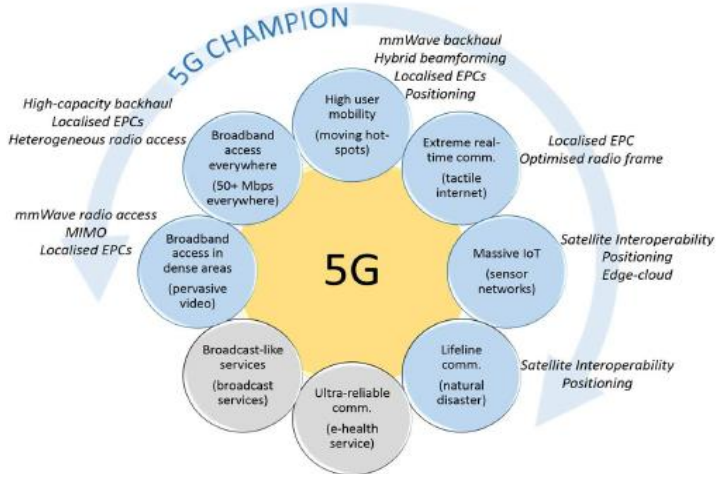
Europe

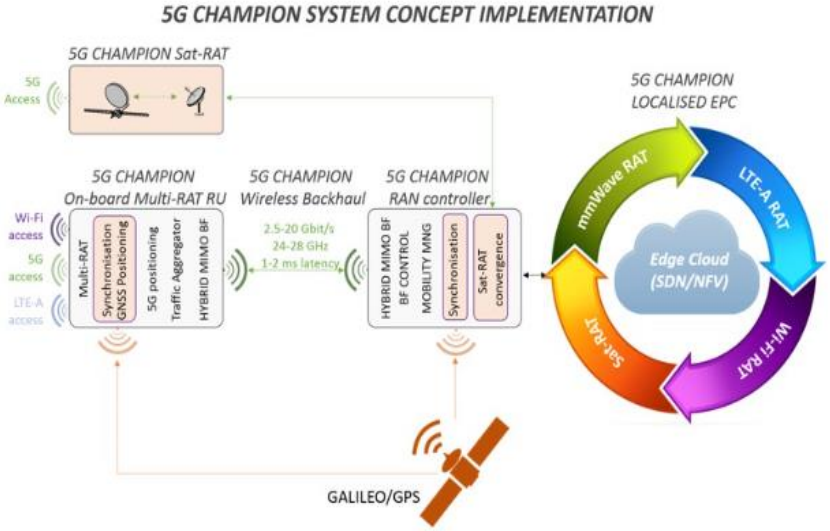
1. CEA-Leti (Coordinator), France
2. Nokia, Finland
3. Intel, Germany
4. Thales Alenia Space, France
5. University of Oulu, Finland
6. Fraunhofer HHI, Germany
7. Telespazio, France
8. iMinds, Belgium

Rep. of Korea

1. ETRI (Coordinator)
2. Seoul Metropolitant Rapid Transit
3. South Korea Telecom
4. HFR
5. Clever Logic
6. Seoul National University
7. Dankook University
8. Hanyang University
9. Korea Telecom
10. Eluon
11. InSoft
12. Mobigen
13. Gwangju Institute of Science and Technology

5GCHAMPION





- *Main technology enablers:*
  - mmWave Backhauling,
  - mmWave transceivers with reconfigurable antennas,
  - Localised evolved packet core supported by distributed or centralized mobile edge clouds with caching,
  - Media streaming functionalities,
  - Satellite radio access,
  - Satellite-terrestrial positioning.

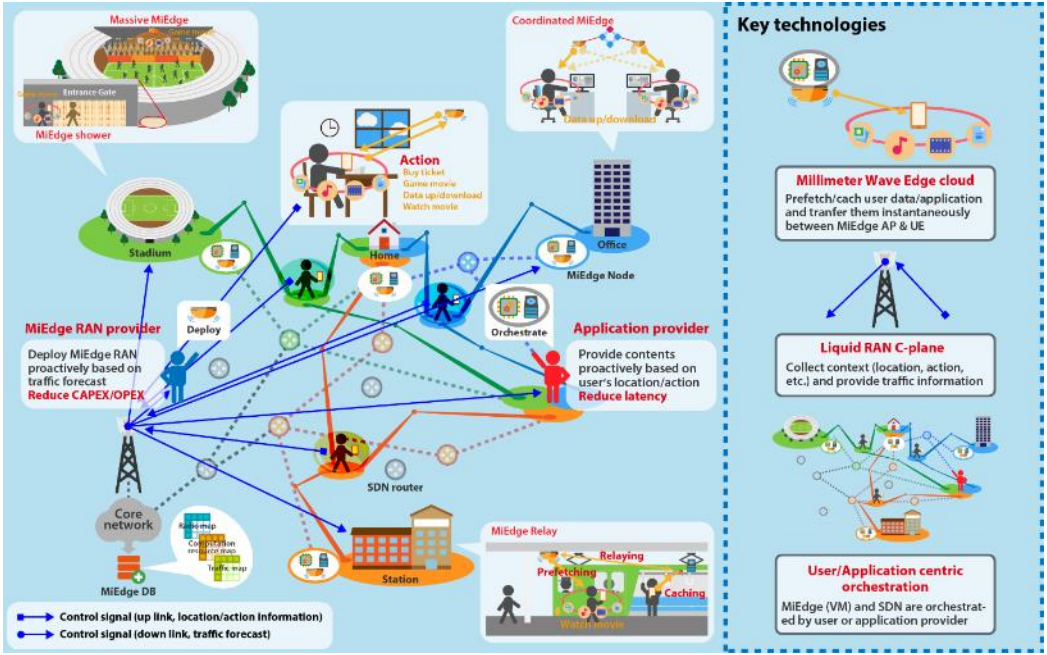
5G-MiEdge (5g-miedge.eu)

- Name: Millimeter-wave Edge Cloud as an Enabler for 5G Ecosystem

- Funding scheme: FP8, Europe-Japan co-funding, 2016.06 – 2019.05

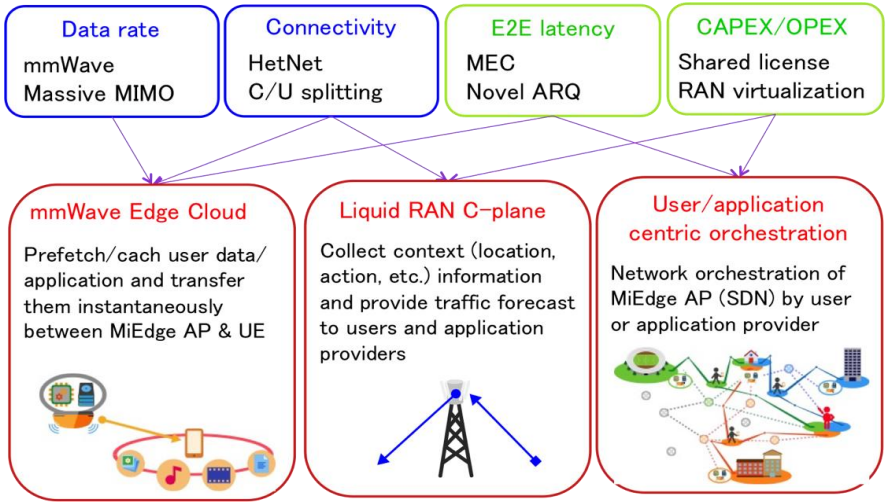
- *Key Target:*
  - 5G proof-of-concept in conjunction with the 2020 Japanese Summer Olympics.

- *Key technology enablers:*
  - mmWave Access & Backhaul,
  - User/Application Centric Orchestration,
  - Liquid RAN Control-plane:
    - novel ultra-lean and inter-operable control signaling over 3GPP LTE to provide liquid ubiquitous coverage in 5G networks, based on acquisition of context information and forecasting of traffic requirements.

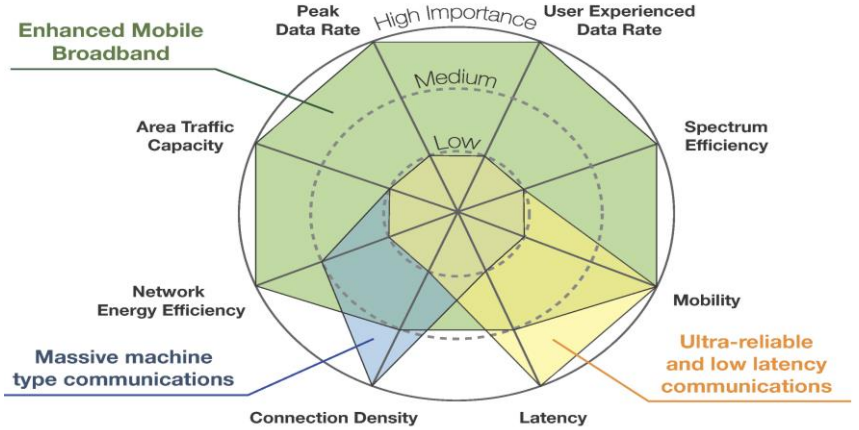


5G-MiEdge

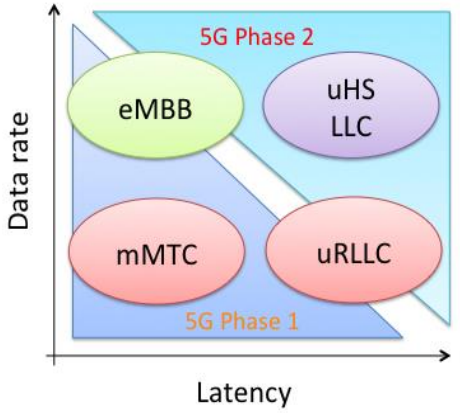
- Main research directions:
  - Focus on the ultra High-Speed and Low Latency Communications (uHSLLC) use cases and related technology enablers
  - Synergize between mmWave and MEC technologies



Technology enablers for uHSLLC and related KPIs



5G KPI defied in IMT-2020

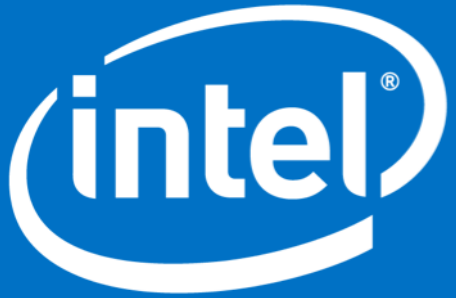


Q&A

➢Questions?

Disclaimers
5G-MiEdge: The research leading to these results are jointly funded by the European Commission (EC) H2020 and the Ministry of Internal affairs and Communications (MIC) in Japan under grant agreements N° 723171 5G MiEdge in EC and 0159-{0149, 0150, 0151} in MIC.

5GCHAMPION: The research leading to these results was supported by the Institute for Information & communications Technology Promotion (IITP) grant, funded by the Korea government (MSIP) (No.B0115-16-0001, 5GCHAMPION), and received funding from European Union H2020 5GPPP under grant n. 723247.



Intel Communication and Devices Group