Networld 2020 vision for the future

Rui Luis Aguiar
Networld 2020 Steering Board Chair
Instituto de Telecomunicações /Universidade de Aveiro

ruilaa@ua.pt

- IT Sites

Aveiro | Coimbra| Lisboa

Not for profit association of:

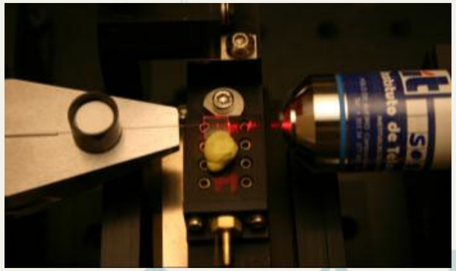
Universidade de Aveiro
Universidade de Coimbra
Universidade de Lisboa
Altice Labs
Nokia
Universidade de Porto
Universidade da Beira Interior
Instituto Ciências e Tecnologias Empresariais

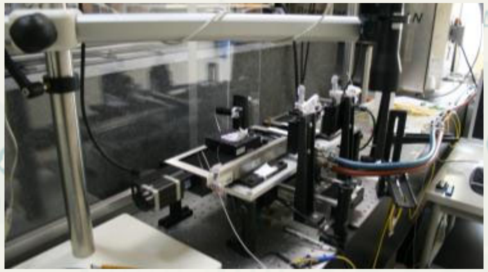
Main partnerships

- Instituto Politécnico de Leiria (IPL-STG)
- Instituto Politécnico de Coimbra (ISEC)
- Instituto Politécnico de Lisboa (ISEL)
- Instituto Politécnico de Setúbal (EST)
- Instituto Politécnico de Tomar (ESTT)
- Universidade do Algarve (UAlg)
- Universidade de Évora (UEv)
- Universidade da Madeira (UMad)

Instituto de Telecomunicações - Aveiro

PhD researchers	~80
PhD students	~94





- Optical communications
- Radio communications
- Networking, mobile networks, future internet
- Electronic design for telecommunications

ATNOG – Advanced Telecommunications and Networking group

- 11 PhD, ~50 members

- **IEEE Distinguished Lecturer – Communications**
- Engaged in 5G development from its early discussions

- Multiple lines of work
  - Research
  - Industry cooperation
  - Standardization
- High practical component
  - Testbeds, implementations, tools...
- Open Source contributions

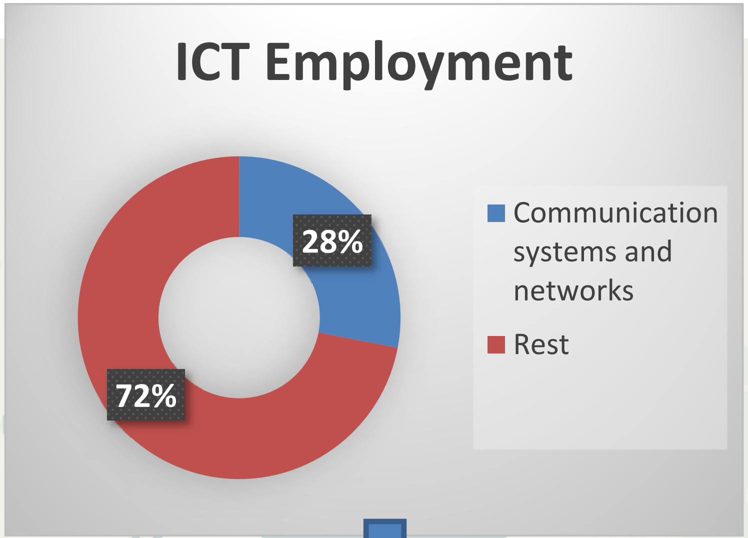
    https://github.com/ATNoG

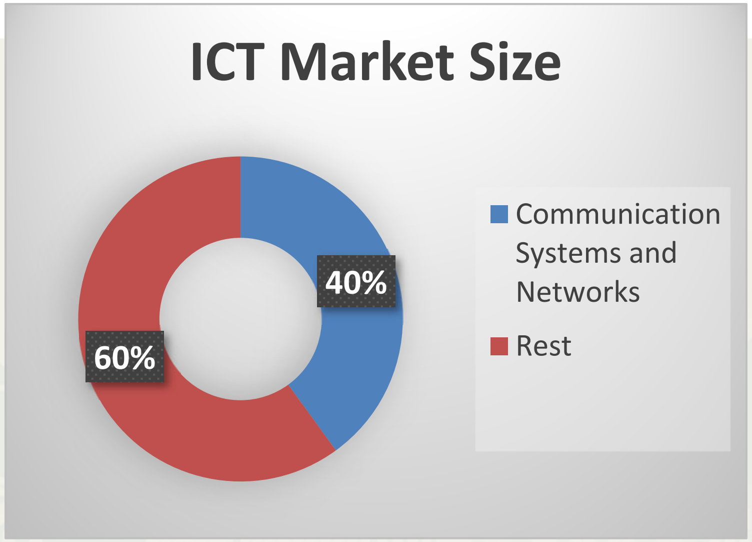
    Test infrastructures

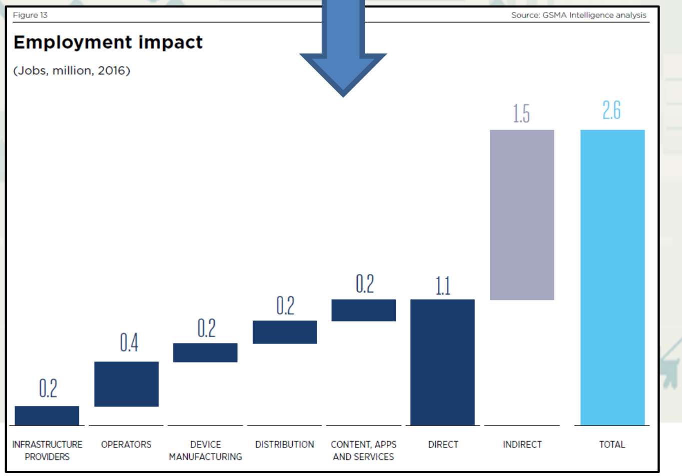
Outline

- Who is Networld2020
- What is our process
- What is our (current) view
- Steps ahead

Strong Economic Contributor







Employment impact of the mobile industry

Verticals Benefits	Automotive (€ mn)	Healthcare (€ mn)	Transport (€ mn)	Utilities (€ mn)	Total (€ mn)
Strategic	13,800	1,100	5,100	775	**19,770**
Consumer	13,900	207	-	3,000	**17,110**
Third Party	13,700	72	-	-	**13,770**
Total	**42,200**	**5,530**	**8,300**	**6,470**	**62,500**

Totals may not correspond due to rounding

Source: *Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe* A study prepared for the European Commission DG Communications Networks

Source: EU Commission: Digital Agenda Scoreboard – The EU Sector and its R&D Performance 2017

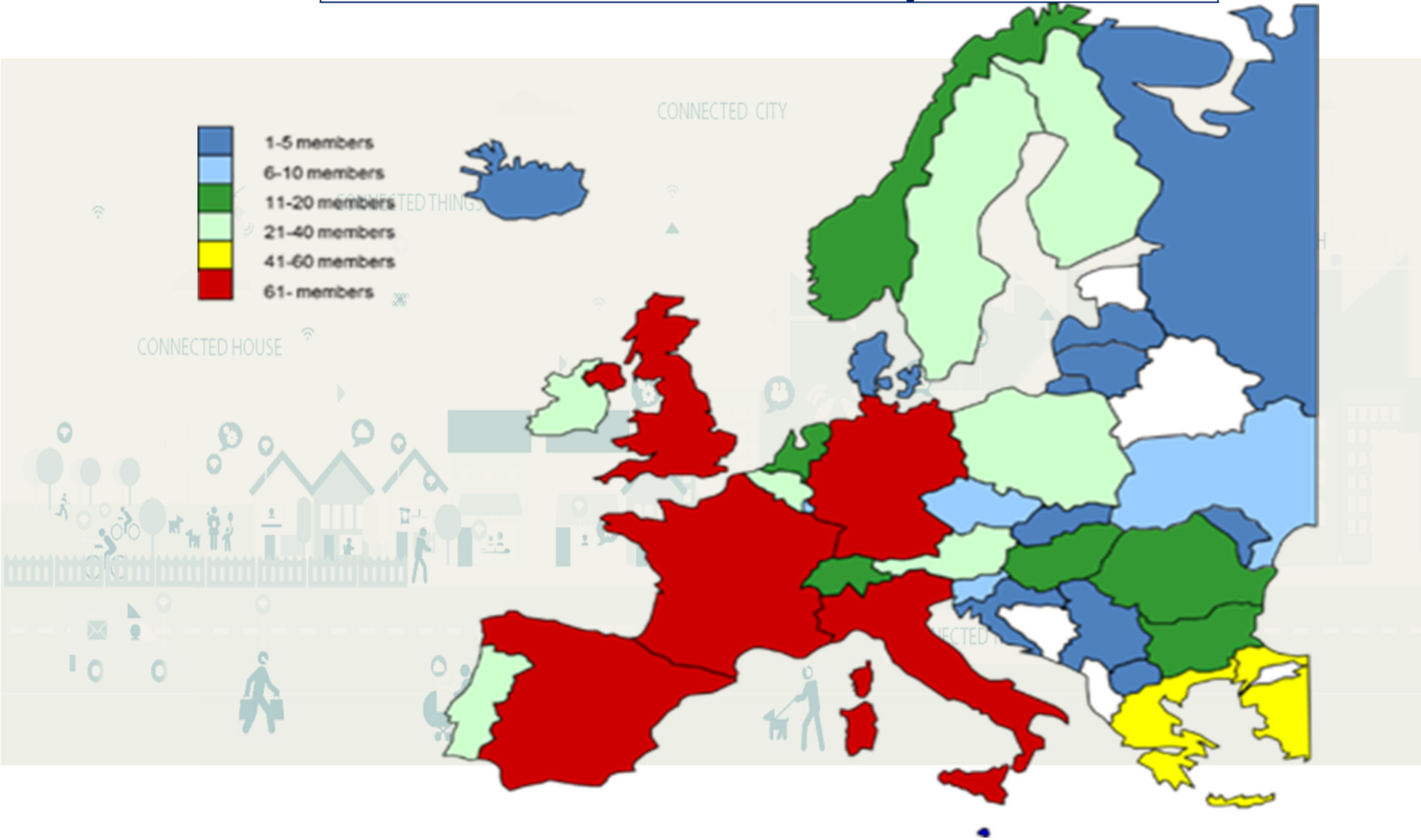
Networld2020 history

- Evolution of previous initiatives from Europe.
- Founded ~2014 to facilitate the lauching of a counterpart to EC in the communications domain
- Current format settled from 2016, when formally separated from 5G-IA

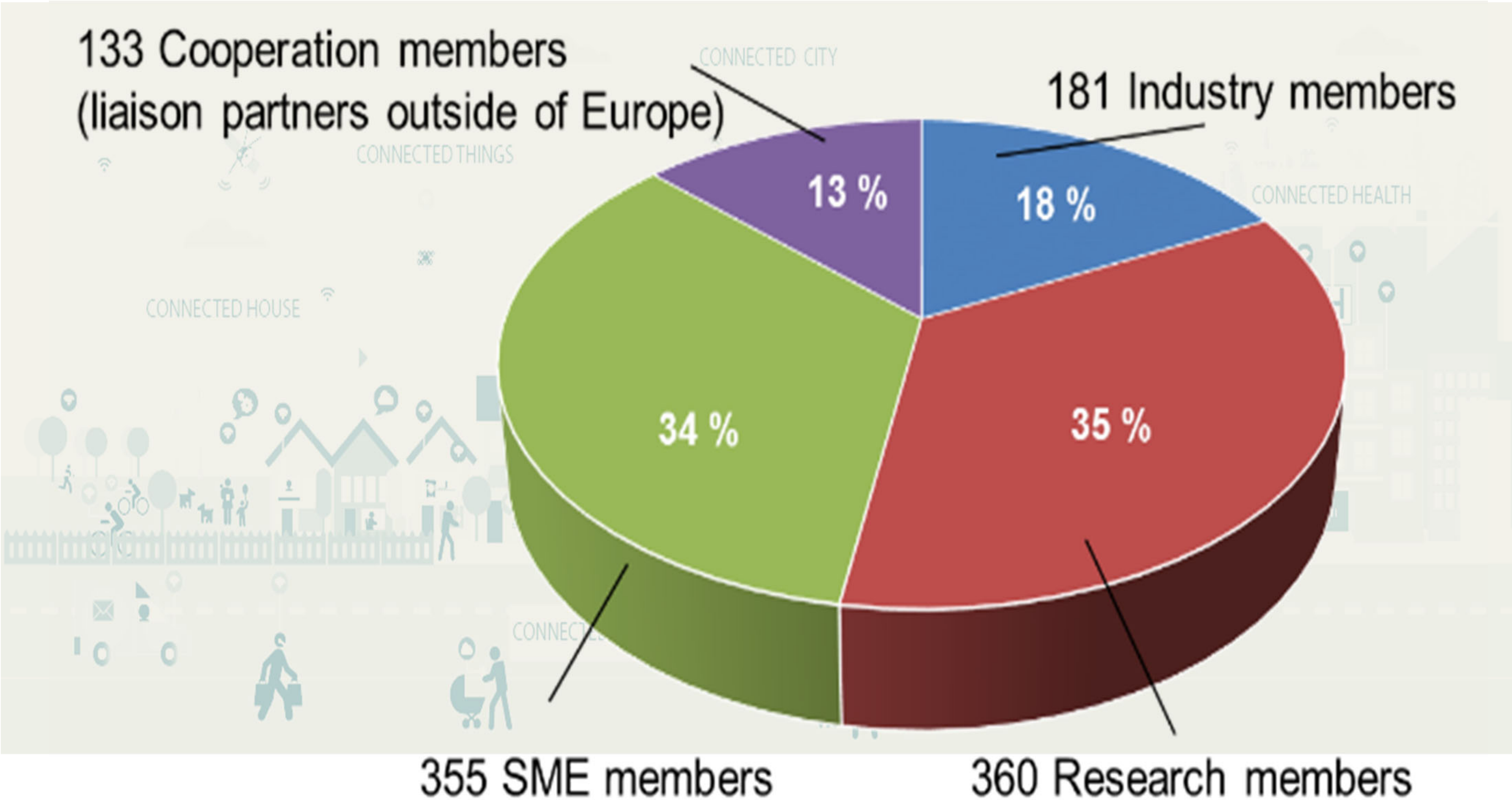
What is Networld 2020

- ETP (European Technology Platform)
- For communications networks and services.
- Volunteer organization, no funding
- Open to everyone
  - simple rules for acceptance membership (1000+ members)
  - No fees
  - Most general actions on web
  - Meetings (focused) organized few times per year
  - Industry/SMEs/Academia
- Managed by a Steering Board

Membership


1-5 members
6-10 members
11-20 members
21-40 members
41-60 members
61- members
CONNECTED CITY
CONNECTED THINGS
CONNECTED HOUSE

Membership


133 Cooperation members
(liaison partners outside of Europe)
181 Industry members
CONNECTED CITY
CONNECTED THINGS
CONNECTED HEALTH
CONNECTED HOUSE
13 %
18 %
34 %
35 %
355 SME members
360 Research members

Objectives

- To develop position papers on technological, research-oriented and societal issues
- To seek discussion of issues with decision makers in the political and public domain as well as in the industry and research community to bridge the gap between R&D and the expectations from the European society.
- To regularly develop an updated Strategic Research and Innovation Agenda (SRIA) for Europe in the communication networks
- To strengthen Europe’s leadership in networking technology and services so that it best serves Europe’s citizens and the European economy.
- To support the 5G PPP initiative

Outline

- Who is Networld2020
- **What is our process**
- What is our (current) view
- Steps ahead

Strategic Research and Innovation Agenda

- Updated ~2-3 years
- Used by EC community to frame future research funding
  - Influencing industry
  - Influencing governments' agenda
- Process triggered by the Steering Board
- Early draft build with resource to an Expert group
- Open consultation to the whole community

https://www.networld2020.eu/wp-content/uploads/2018/11/networld2020-5gia-sria-version-2.0.pdf

Last Trigger:

Visions for future Communications Summit

https://futurecomresearch.eu/

Speakers: Adam Wolisz, Artur Hecker Andrea Goldsmith, Gonzalo Camarillo, Edward Knightly, Henning Schulzrinne, Ian Akyildiz, Joerg Widmer, Lajos Hanzo, etc…

Outline

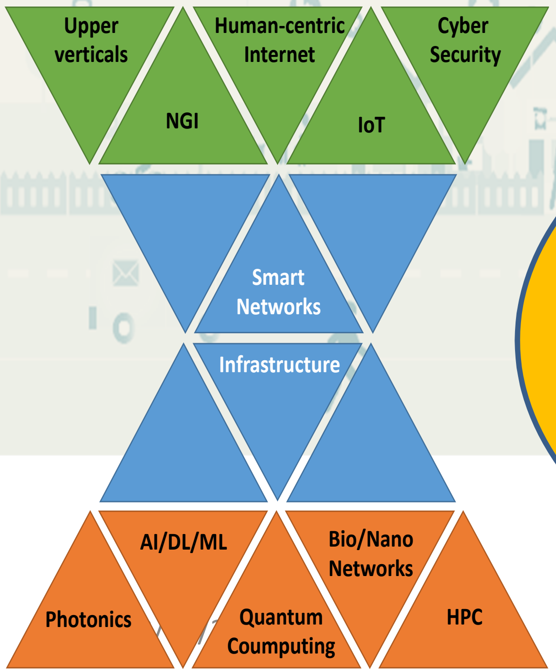
- Who is Networld2020
- What is our process
- What is our (current) view
- Steps ahead

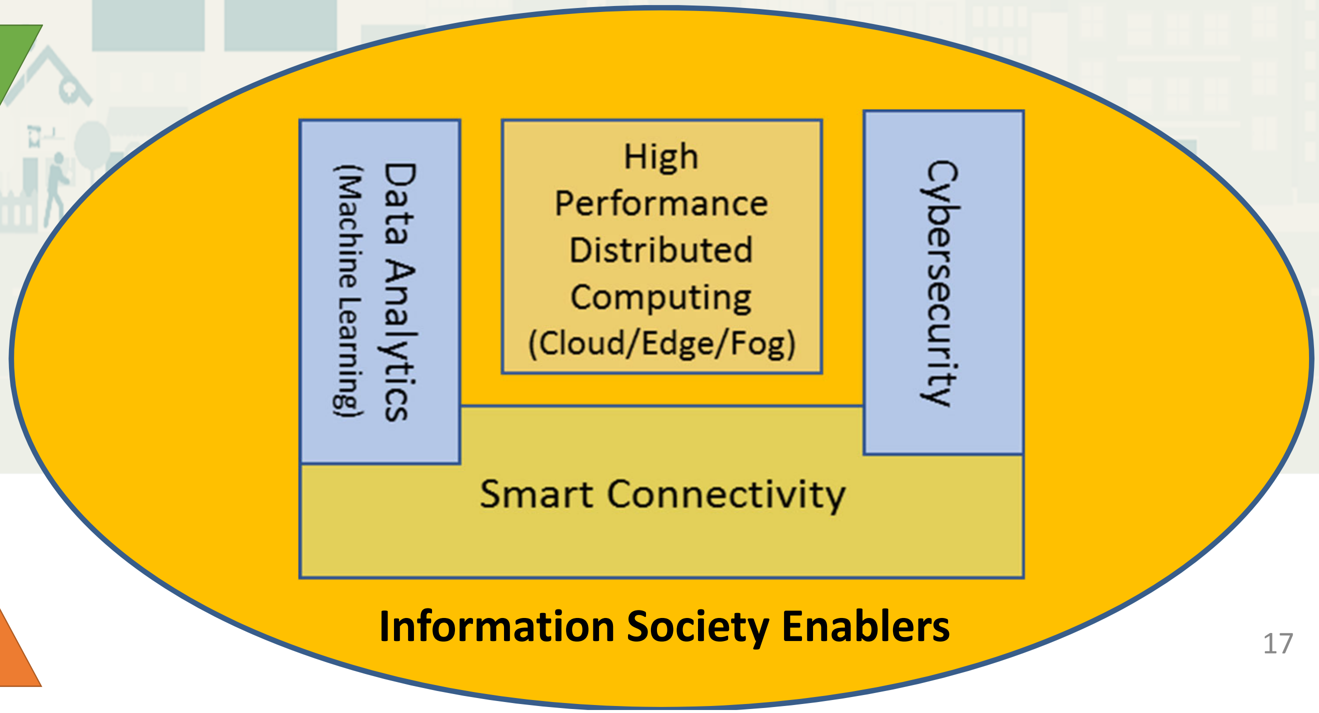
Key Societal Needs

- Safety for all:
  - Personalised and perpetual protection
- Connectivity for all:
  - Massive amounts of things and systems need to be connected in a scalable and cost-efficient way.
- Service for all:
  - Global reach and optimised local service delivery capabilities
  - Cognitive operations making use of Artificial Intelligence and Machine Learning mechanisms
- Performance for all
  - Seemingly infinite network capacity
  - Imperceptible latencies

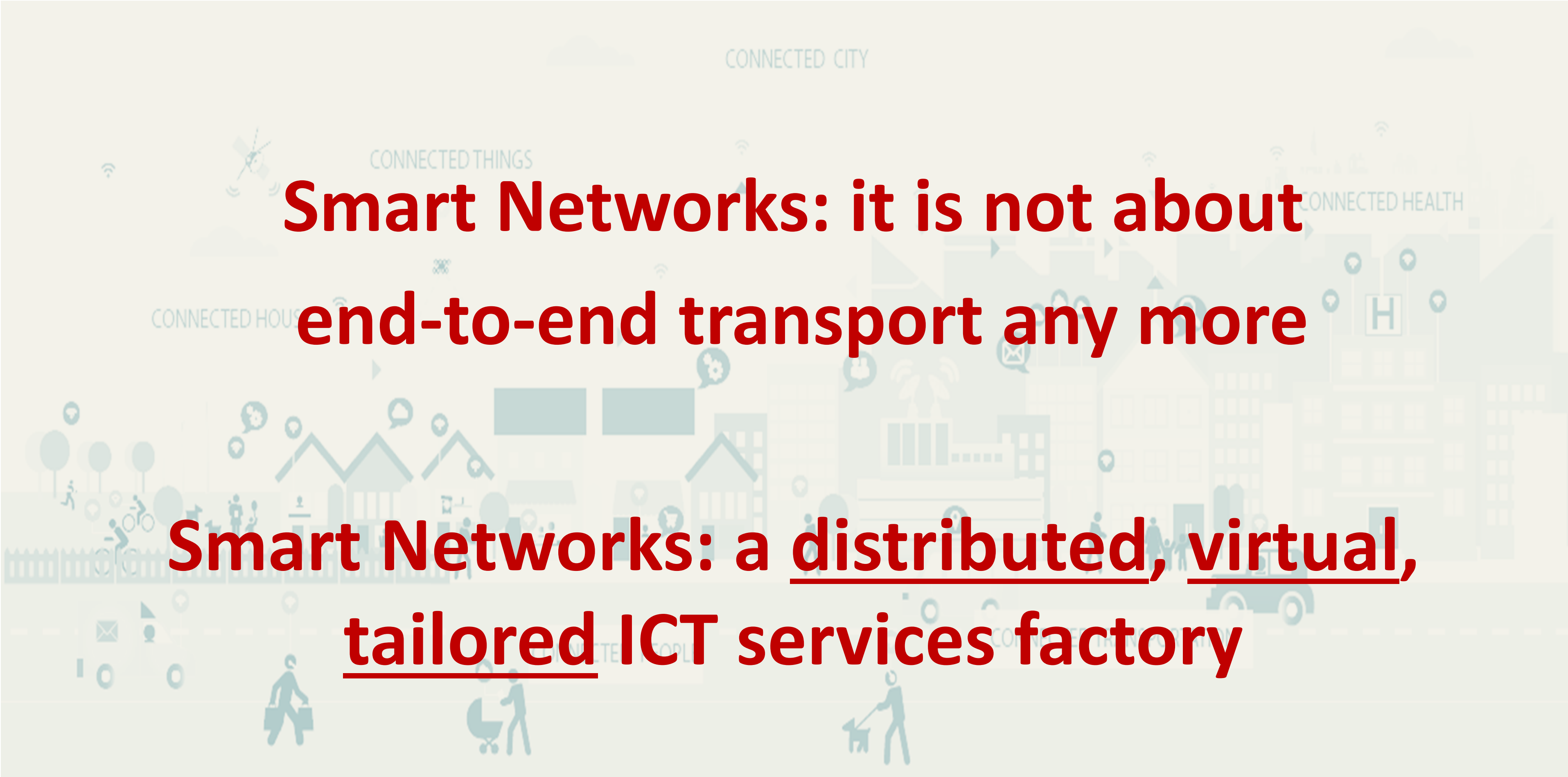
Smart Networks Vision

The Smart Networks concept provides the **necessary infrastructure** and builds on scientific advances in the areas of physical and logical sciences as well as key enabling technologies to provide a coherent framework supporting the future networks designs. It is a combination of Smart Connectivity, Data Analytics (AI and ML), high performance distributed computing and Cybersecurity





Vision for Smart Networks

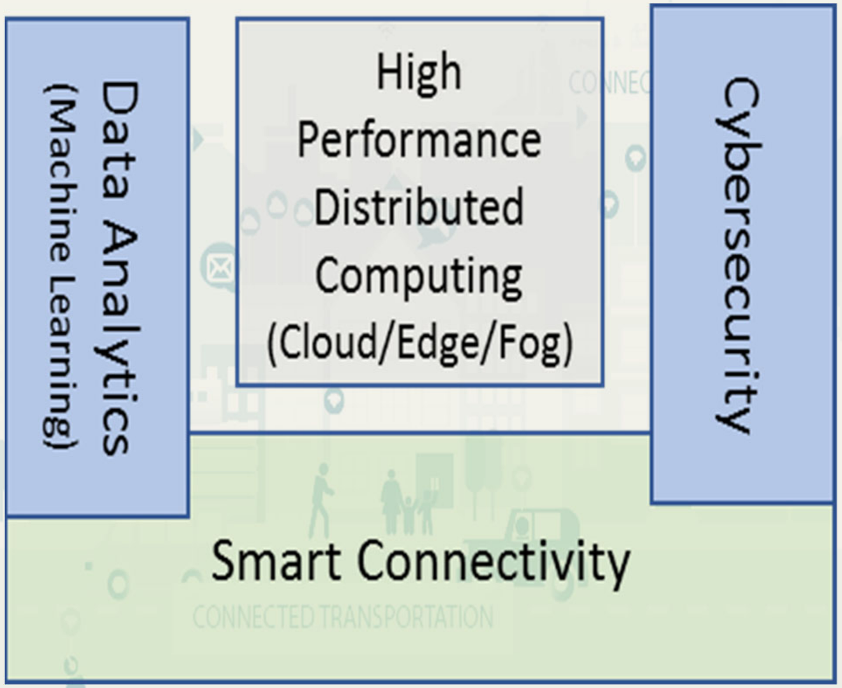


Smart Networks: it is not about end-to-end transport any more

Smart Networks: a distributed, virtual, tailored ICT services factory

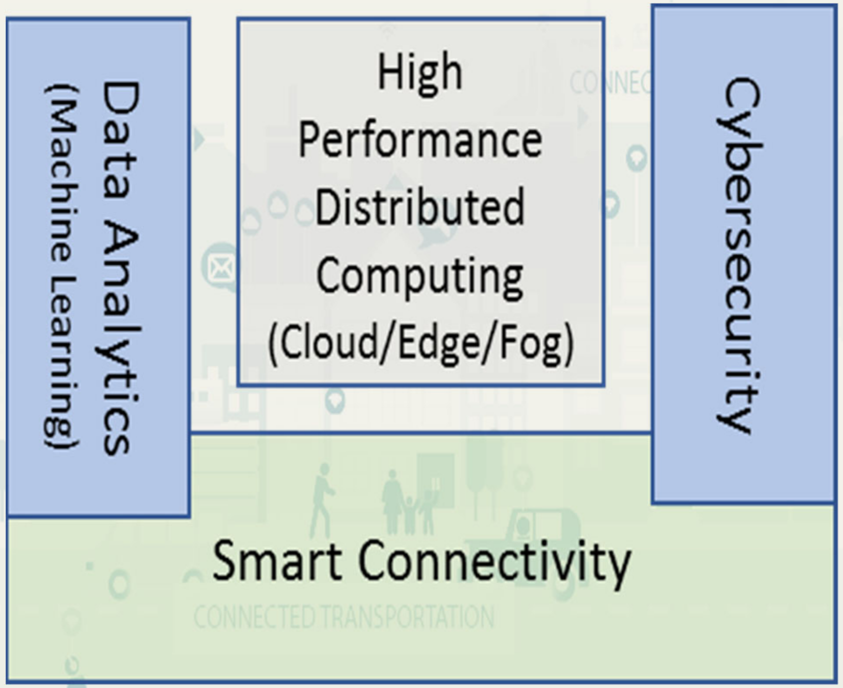
Network Architecture and Control

- **Smart Networks:**
- Integrated C3: Computing, Communication and Control
- Single, unifying, control framework
- Instantiation and execution of any control architecture(s)
- Isolated control and data domains for each tenant
- Multitenancy and federation of resources and slices
- Low delay, low energy highly efficient radios
- Higher capacity and more flexible optical systems
- Ubiquitous Satellite communications



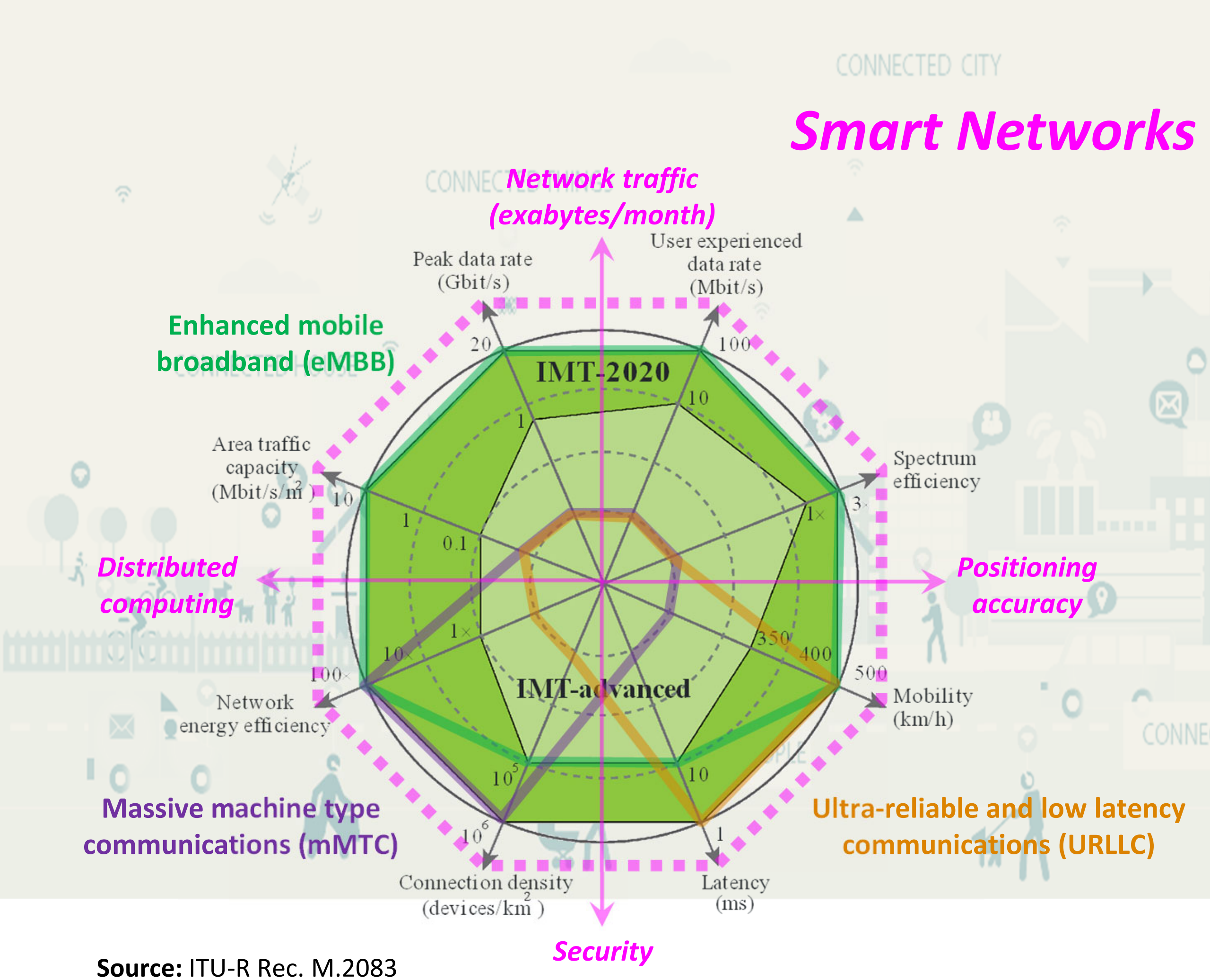
Network Architecture and Control

- **Smart Networks:**
- Integrated C3: Computing, Communication and Control
- Single, unifying, control framework
- Instantiation and execution of any control architecture(s)
- Isolated control and data domains for each tenant
- Multitenancy and federation of resources and slices
- Low delay, low energy highly efficient radios



Smart Networks: fundamental cornerstone for the production of all services

Smart Networks: Vision and Use Cases for ~2027



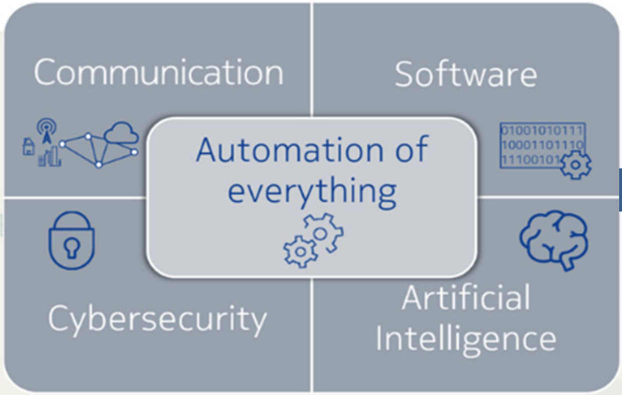
Target use cases

- Tbps throughput
- sub-ms latency
- Gbps availability
- Extreme reliability
- mMTC everywhere
- Extreme energy efficiency
- Very high security
- Very high mobility
- cm-level localization
- ...

Source: ITU-R Rec. M.2083 (modified)

Major Research Areas

Networld 2020 SRIA (100+pages!) has identified 8 strategic research lines:



Problem space similar to previous generations but emphasis and solutions will be different

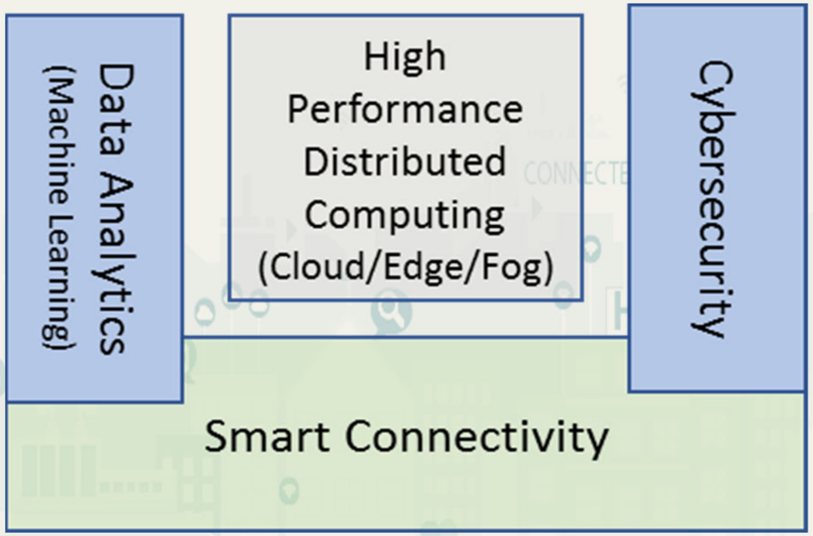
1. **Network architecture and control**
2. **Radio technology and signal processing**
3. **Optical networks**
4. **Edge computing and meta-data**
5. **Network and service security**
6. **Communication satellite technologies**
7. **Human centric and vertical services**
8. **Future and emerging technologies**

SRIA: https://www.networld2020.eu/wp-content/uploads/2018/11/networld2020-5gia-sria-version-2.0.pdf

1. Control of Smart Networks

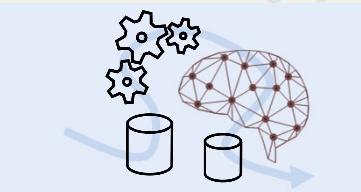
Smart Networks ::= networks based on

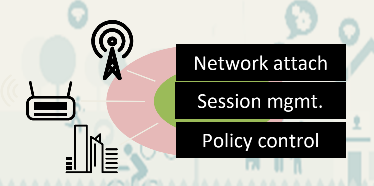
- a single, unifying control framework
  - instantiate and execute any control architectures
  - large use of technologies like AI/ML to implement data-driven closed control loops
  - From cognitive (at first) to intuitive (then) network behaviours
- spanning any resources a tenant is authorized to control, including
  - enterprise and telecom networks
  - virtual and physical
  - data centers and routers
  - satellites and terrestrial nodes, etc.

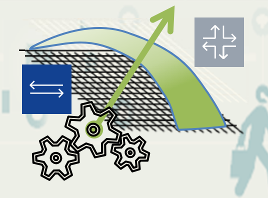


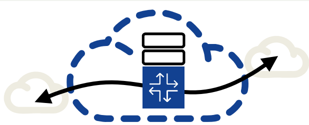
- Not limited to 5G in particular or to mobile networks more generally, but rather aims at machine-aided, end-to-end, fine-grained and native service deployment "over everything"
- Not limited to a single domain of any kind, but rather a per tenant view, where a tenant can pool together and use any resources available
  - Tenant = a physical network provider, any MVNO or a syndication of different stakeholders agreeing on common policies and needs (i.e. a vertical), or a single terminal, an application type or an application on a terminal
- Not limited to current technology enablers (e.g. SDN and NFV)

1. Features of SN Control









- **Cognitive and autonomic network service end-to-end orchestration**
  - using existing AI/ML algorithms as well as propose new, network-suitable, distributed AI/ML, to implement data-driven closed control loops that can enable cognitive and (later) intuitive network behaviour
  - based on network and non-network functions and datasets
- Dynamic pooling of local resources from diverse participating devices
- Offer programmable analytics to the application layer through open interfaces
- Support and instantiate more and more service intelligence at the edge, as well as across cores

1. SN Control: Technology areas

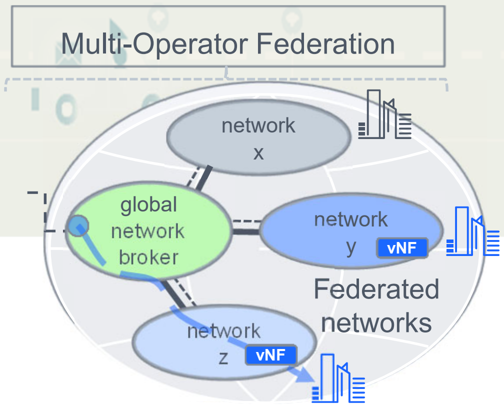
- Virtualised Network Control
  - Control of Various Virtualization Layers
    - VF performance areas
    - VF Continuity, Elasticity and Portability
    - VF Security
- Fully Integrated Fixed-Mobile Architecture
  - Common operational control for ultra-small access nodes and access-agnostic core
  - User-centric networking

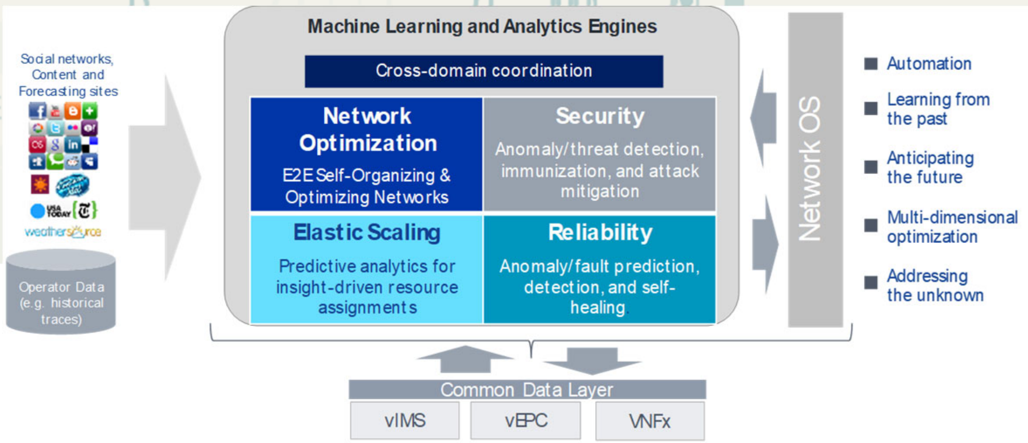
1. SN Control: Technology areas

- Slicing and Orchestrators
  - Elasticity of slices in support of dynamic business models with infrastructure providers
    - Orchestration and control to reach out to all infrastructure resources, seamlessly
  - From blueprints to execution on top of a shared, distributed infrastructure
    - distributed execution under contention (different capacities, variable loads from other executed slices)
  - Dependability
    - Across the various attributes of Availability, Confidentiality, Integrity, Performance, Reliability, Survivability, Safety, Maintainability

1. SN Control: Technology areas

- Evolution of NFV/SDN and AI/ML-based Network Control
  - No more network elements, but just VFs
  - Human-driven network management & control of Smart Networks will not be possible
  - Full automation is required to
    - Instantiate a complete end-to-end network (RAN, mobile core, transport network, as well as the Data Network)
    - Provisioning of Network Services across multiple operators and/or service providers when requested, requested via open interfaces
    - Fast lifecycle management (LCM) of the network automatically triggered based on vendor-independent FCAPS management
    - Plug & Play of new components into a live production network
  - Network-specific adaptations of existing AI/ML algorithms are needed
    - Gathering network-typical and network-characteristic datasets for training and validation of any such proposals
    - Current architectures, approaches and procedures to train and validate AI/ML algorithms are mostly focused on static pattern recognition (e.g. images, sounds, diagnostics of fixed analysis data…)
    - Evolve from mostly centralized AI/ML algorithms to distributed ones (challenges of scalability, consistency, consensus, convergence)
    - Improved security

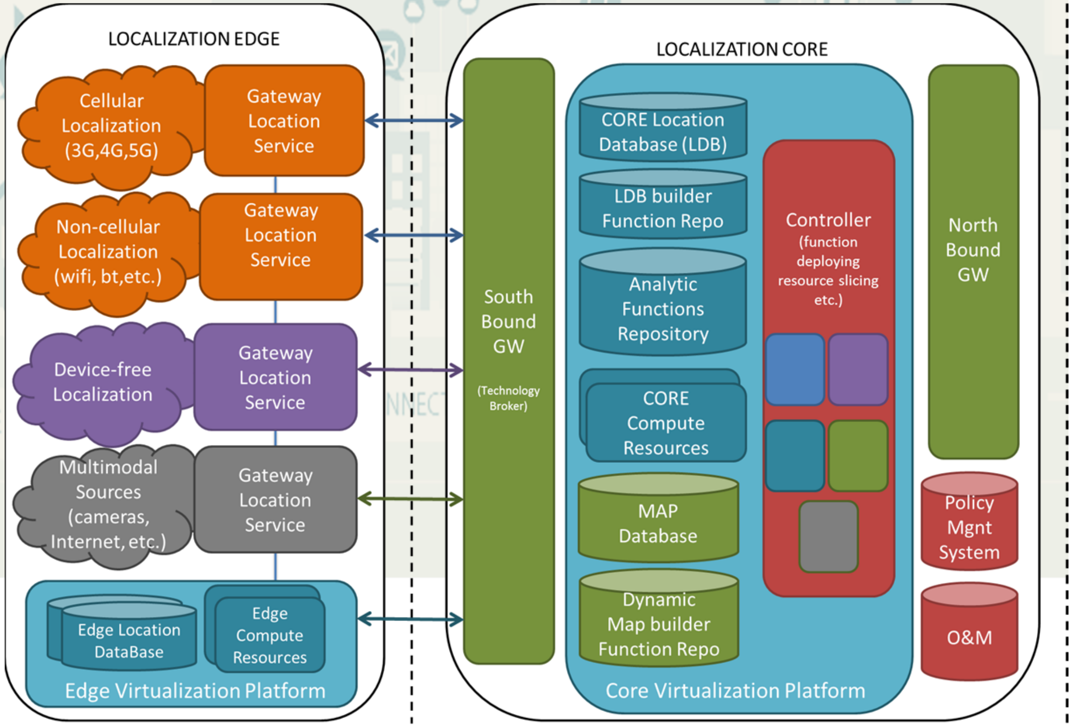




1. SN Control: Technology areas

- Network-Based Localisation
  - SN control will incorporate by design technologies and interfaces to enable location/context-based services and powerful business analytics
  - RTLS with features like
    - Terminal localisation with sub-meter accuracy
    - Device-free localisation
    - Spatiotemporal analytics
    - Multi-modal Analytics

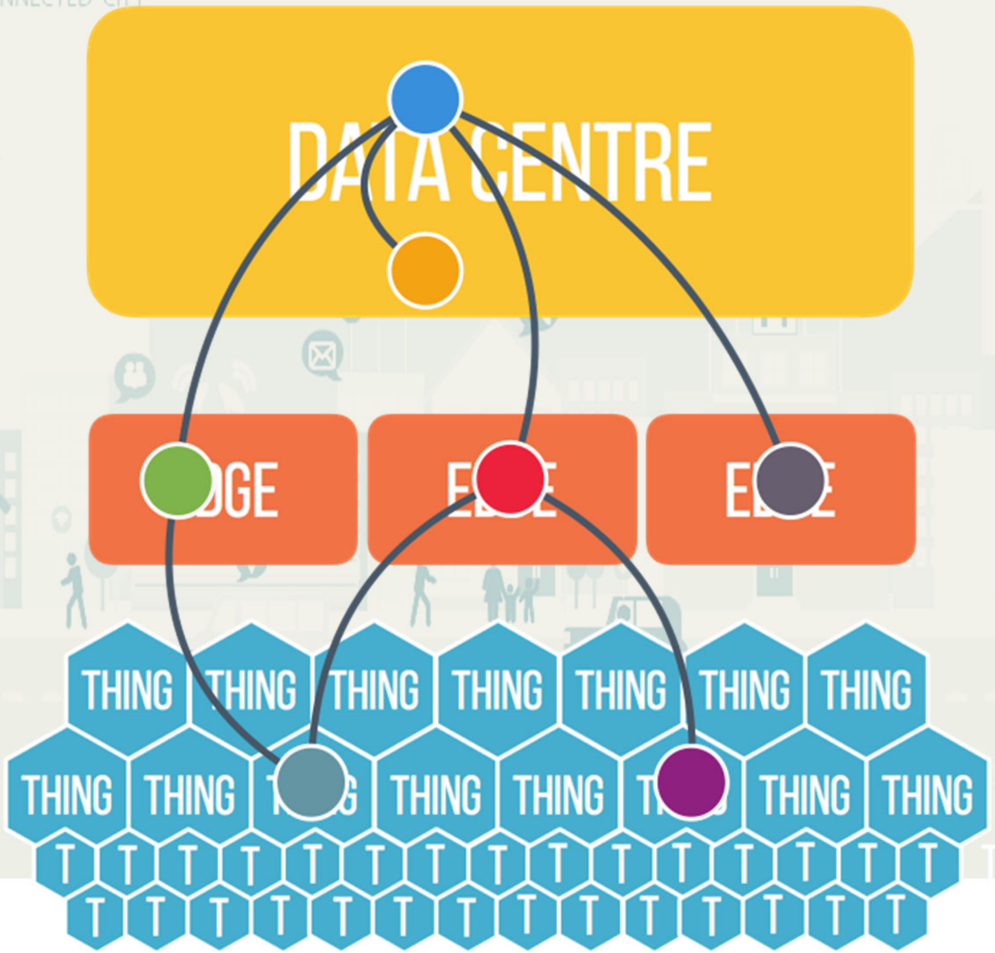
⇒ SN Control will have to manage network and non-network information



1,3 SN Control: Edge Computing and Meta-data

NETWORLD 2020

- Fog Computing: multi-tier approach (Cloud, Edge, Fog)
- Abstraction of an elastic compute, storage and communication fabric in a decentralised manner



2. Radio: Spectrum Refarming and Reutilization

Motivation

- Traditionally, dedicated spectrum allocated to each radio access technology (RAT)
- Spectrum reutilization between RATs (spectrum sharing) offers an efficient utilization of resources and great flexibility, e.g., for load-balancing.

Target & Challenge

- Efficiently re-utilize the existing spectrum resources, improve spectral efficiency, reliability, availability, ...
- Joint utilization of licensed and unlicensed spectra
- Spectrum usage supported by multi-RAT connectivity
- E.g. using cognitive radio based solutions. UE can choose the best RAT depending on link qualities.

eMBB	High Frequencies Super Data Layer Addressing specific use cases requiring extremely high data rates	Above 6 GHz 800 MHz assignments (contiguous)
eMBB, URLLC, mMTC (wide-area but no deep coverage)	Medium Frequencies Coverage & Capacity Layer Best compromise between capacity and coverage	2 – 6 GHz 100 MHz assignments (contiguous)
mMTC, eMBB, URLLC	Low Frequencies Coverage Layer Wide-area and deep indoor coverage	Below 2 GHz (up to 20 MHz paired / unpaired)

Source: Huawei

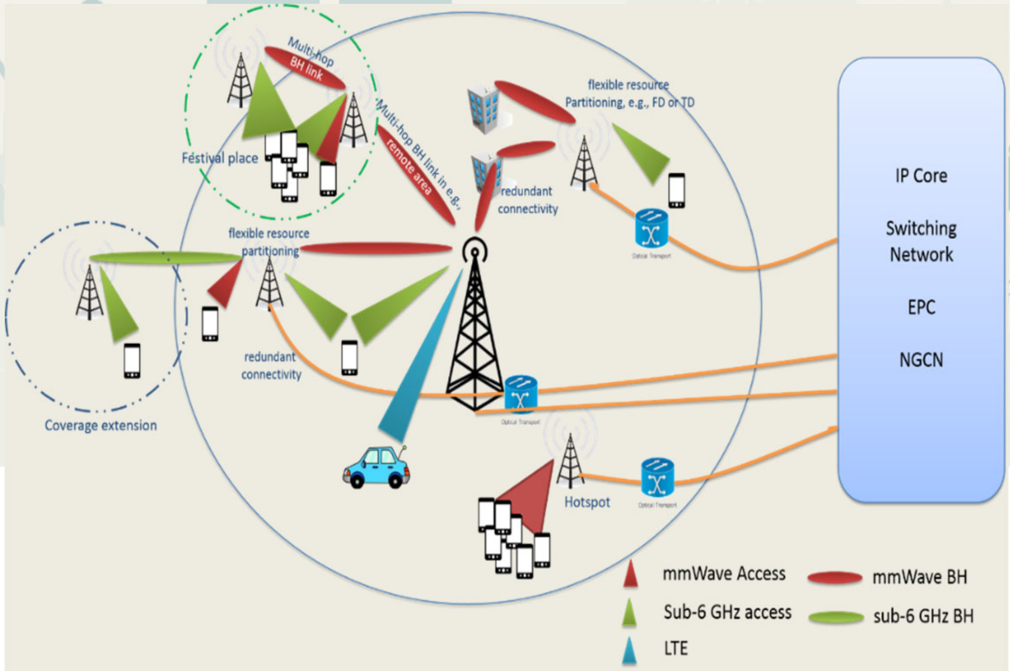
2. Radio: Millimeter Waves and Cellular Networks

Motivation

- ❑ mmWave below 50 GHz considered for 5G NR by 3GPP
- ❑ Diverse requirements on throughput, latency and reliability, pose new challenges, e.g. on backhaul links
  - Massive content with data rates up to 1000 Gbps
  - Massive control with 1 ms response time to enable mobile edge caching (MEC) and extreme reliability.

Target & Challenge

- ❑ Efficient TX and RX beamforming (BF) in terms of high data rate, low power consumption, minimized size.
- ❑ Modulation coding scheme implementation with low power, low cost, high throughput.
- ❑ Develop overall system with target < 1pJ/bit.
- ❑ E.g. using multi-stream approach (e.g. OAM),1-bit ADC, constant envelope modulation, etc.



Source: Fujitsu

2. Radio: Terahertz Communications

Motivation

- THz communication in the 0.1-10 THz band *) , between microwave and infrared bands.
- <1 m range possible at ~10 THz carrier.
- > tens m range possible at tens or hundreds GHz.
- While the total consecutive bandwidth of mmWave systems is less than 10 GHz, the one in THz communication is in in the order of multiple THz.

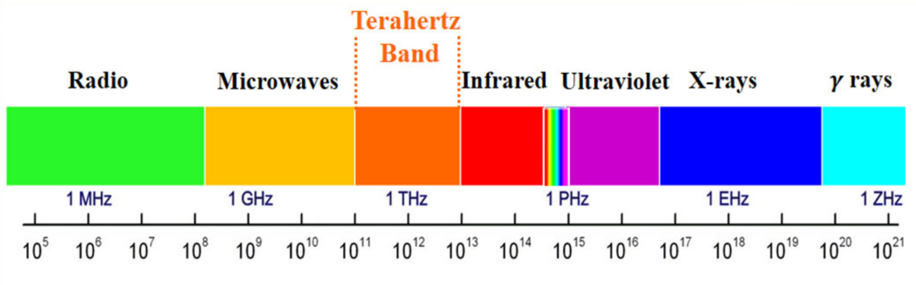


Image source: https://bwn.ece.gatech.edu/projects/teranets/index.html

*) I. F. Akyildiz, J. M. Jornet and C. Han, "Terahertz band: Next frontier for wireless communications," *Physical Communication (Elsevier) Journal*, vol. 12, pp. 16–32, 2014.

Target & Challenge

- New channel models for THz band: spreading loss, molecular absorption loss, scattering loss, etc.
- New experimental platforms and testbeds that can operate at THz frequencies.
- Novel MAC protocols: The huge bandwidth may eliminate the need for contention-based schemes, packet size optimization, adaptive error control, etc.
- New congestion control at the transport layer to accommodate traffic in the order of Tbps.
- Modeling and mitigating non-linearities, phase noise, …
- New modulation types, e.g. femtosecond-long pulse-based modulation.
- ADCs/DACs for tens of Giga samples/sec
- Efficient realizations of MIMO antenna arrays, e.g.
  - Graphene, a carbon based nano-material, supports the propagation of Surface Plasmon Polariton (SSP) waves
  - 1024 antenna elements could be packed in an area smaller than $1mm^2$ if plasmonic material is used.
- Regulation and standardization of THz bands, …

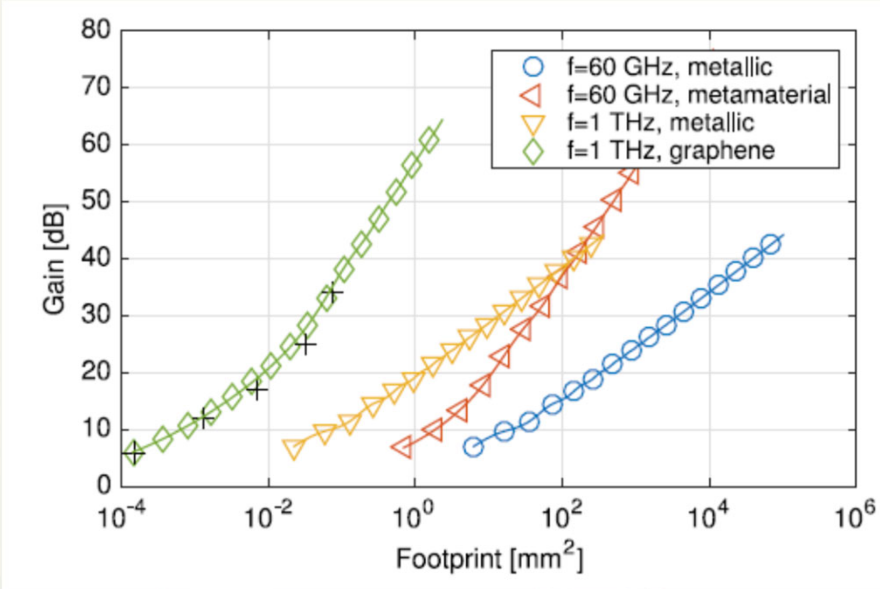
2. Radio: Ultra-Massive MIMO

Motivation

- Ultra-Massive MIMO (UM MIMO): Antenna arrays in the order of thousands of elements, e.g. to be employed in THz bands.
- Highly directional antenna elements to achieve very high array/BF gains and combat the very large path loss.
- Similar to traditional MIMO systems in lower frequencies, UM MIMO can also be used for spatial multiplexing.

Target & Challenge

- Construction of graphene-based antenna arrays
- Channel modeling of UM MIMO; modeling the mutual coupling among antenna elements.
- Feeding/control of each antenna element
- Real time estimation of 1000s of channel elements, feedback, … to enable UM MIMO operation
- Advanced space-time-frequency coding to exploit all diversities and achieve optimal performance, etc
- ...



Array gains of graphene-based antenna arrays

*) I. F. Akyildiz and J. M. Jornet, “Realizing ultra-massive MIMO communication in the (0.06-10) terahertz band,” *Nano Communication Networks (Elsevier) Journal*, vol. 8, pp. 46-54, March 2016.

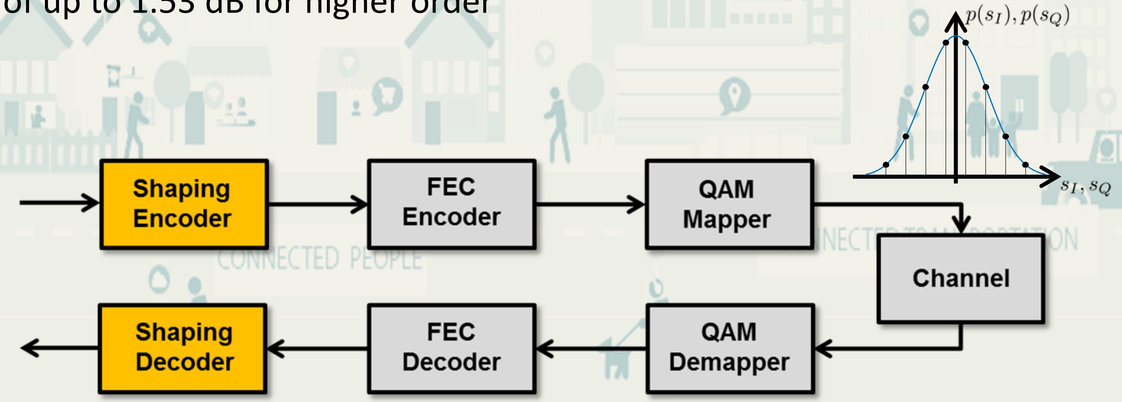
2. Radio: Enhanced Modulation and Coding

Motivation

- Channel decoder is often considered as the most complex part of the TRX chain.
- Future new use cases like Tbps throughput, extreme URLLC and low-energy consumption pose new requirements on designing coding and modulation schemes.
- Current mobile systems use BICM and generate uniformly distributed channel input symbols, resulting in a signal shaping loss of up to 1.53 dB for higher order modulations.

Target & Challenge

- Advanced channel coding and modulation schemes for Tbps throughput and extreme URLLC.
- Extreme low-power consumption channel coding and modulation schemes, esp. for extreme mMTC.
- Advanced coded modulation schemes which remove the signal shaping loss and approach the Shannon limit.



Example: Probabilistically shaped coded modulation (PSCM) for removing the signal loss.

2. Radio: Improved Positioning and Communication

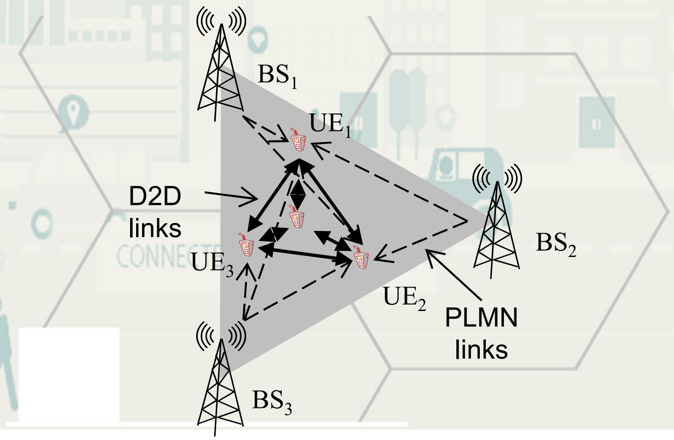
Motivation

- High accuracy positioning has been identified as a key enabler for many VI applications, e.g. autonomous driving for connected cars, local collaboration of unmanned aerial vehicles, etc.
- FCC set a requirement of ~50 m for localization in case of an emergency call (so-called E-911), which can be met by 3G and 4G *).
- For 5G system, the toughest requirement (as set in 3GPP TS 22.261 v16.2.0 – Service requirements for the 5G System (Rel-16)) is ~0.5 m for locating moving objects such as forklifts, or parts to be assembled by using both 3GPP and non-3GPP technologies.

*) W. Xu, M. Huang, C. Zhu and A. Dammann, "Maximum likelihood TOA and OTDOA estimation with first arriving path detection for 3GPP LTE system," *Transactions on Emerging Telecommunications Technologies (ETT)*, 27, pp. 339-356, 2016.

Target & Challenge

- For Smart Factory/I4.0, V2X vulnerable road user discovery, etc, an accuracy of 10 cm may be required.
- Future wireless systems will have higher bandwidth, more antennas, densed network and D2D links, which enables a radio positioning with cm-level accuracy.
- With combined/joint positioning and communication, improved spectral efficiency, energy efficiency, and reduced latency can be achieved.

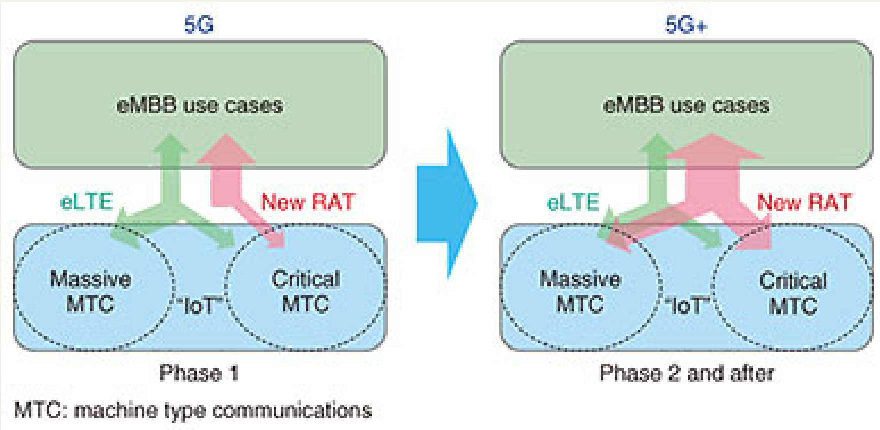


Example: Cooperative positioining can achieve high accuracy.

2. Radio: Random Access for Massive Connections

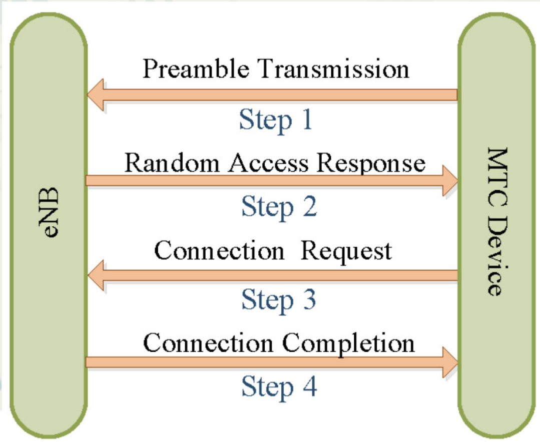
Motivation

- The future vision of IoT envisages a very large number of connected devices, generating and transmitting very sporadic data (mMTC).
- How to coordinate such a network without spending the whole network resource and node energy in protocol overhead?



Target & Challenge

- Develop
- Design such new random access codes for which the superposition of up to K distinct codewords can still be uniquely decoded. The ID of the transmitter can be found as part of the message, if necessary.
- Challenges include
  - Low complexity/energy protocols, low-cost devices
  - Massive number of devices with low overhead, and potentially with energy and latency constraints.



Source: NTT techn review

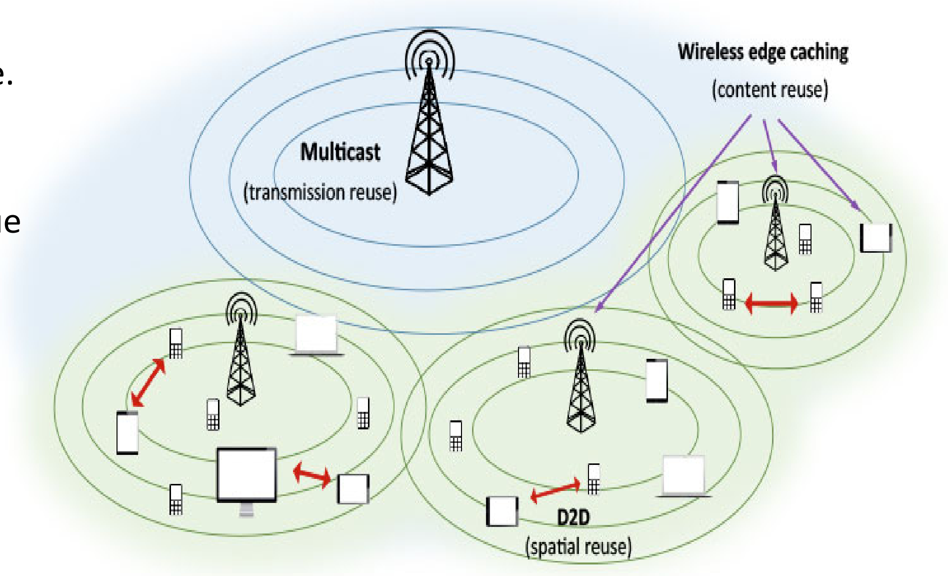
1,2. Radio and SN Control: Wireless Edge Caching

Motivation

- On-demand video streaming and Internet browsing
  - Asynchronous content reuse
  - Highly predictable demand distribution
  - Delay tolerant, variable quality
- The wired backhaul to small cells is weak or expensive.
- The wireless capacity of macro-cells is not sufficient.
- Wireless caching can increase spectral efficiency (due to efficient reuse of resources) and reduce latency (due to smaller distance between content and user).

Target & Challenge

- Caching is implemented in the core network, and needs to be considered for wireless.
- Challenges include
  - Coding (e.g., combining edge caching with modern multiuser MIMO physical layer schemes).
  - Protocol architectures (e.g., combining edge caching with schemes for video quality adaptation).
  - Machine learning based content popularity estimation and prediction, to efficiently update the cached content.



Source: NYU Wireless

3. Optical Networks

- Flexible Capacity Scaling: Coherent technologies and new wavelength bands
- New Switching Paradigms: FlexE, FlexOTN and Flexgrid, plus, SDN control
- Optical Wireless Integration: high capacity and control for RoF with signal QoS monitoring
- Optical Network Automation: common information model
- Optical Integration 2.0: Silicon Photonics & amplific.

5. Network and Service Security

- Security transformation
  - Networks’ evolution towards more dynamism and flexibility impacts security
  - Static security solutions do no longer apply
    - Change towards a “Software Defined Security”
  - Security challenges should be considered from the start
    - E.g., slice integrity and isolation across multi-owned infrastructure segments
  - Programmability on the radio side also leads to new range of potential attacks

6. Communication Satellite Technologies

- Satellite allows seamless extension of 5G+ services
  - Multimedia delivery
    - Classical broadcast to homes, Content delivery to the edge
  - Broadband Access
    - Fixed broadband, Mobile broadband, Backhaul
  - Machine Type Communication (M2M and IoT)
  - Reliable and Critical Communications
    - Disaster and Emergency Communication, Air Traffic Management, Governmental Communication (resilience, security, availability)
  - Connected Car
    - Traffic updates, Ecall, SOTA (Software update over the Air)
- Advances in ground and space segments
  - E.g., RRM, Content delivery optimisations, nano-systems, etc.
- Convergence with heterogeneous networks

7. Human Centric and Vertical Services

- Users will have a greater level of control
  - Going from software-centric to human-centric
    - E.g., be more transparent in interactions with digital services
- Evolution towards an ICT continuum platform
  - E.g., clouds, networks, IoT and data will enable multitudes of entities and devices to combine to form dynamic and intelligent collectives
  - Will intelligently learn from the network environment and historic data, and dynamically adapt to a changing situation
- Industries are experiencing a digital transformation
  - Business models are changing and opening new opportunities

7. Human Centric and Vertical Services

- Verticals will benefit from higher levels of abstraction
  - Fully automatic and network unaware mode
  - Network agnostic automation processes
    - E.g., usage of AI/ML techniques
  - Automation in the orchestration process
    - E.g., intent-oriented service definition over abstracted infrastructure, real-time telemetry of services and massive correlations, proactive adjustment of parameters to meet service intents
    - "Follow-me" actions to maintain QoE in composed SLAs
- Extreme automation and "zero-touch" service orchestration
  - Use of data-analytics, AI driven orchestration, cloud-native management applied to NFV orchestration

8. Future and Emerging Technologies

- Evolution of future networks, based on
  - better underlying technologies, drastically improving communication and computing performance,
  - new techniques for network softwarisation and related primitives and interfaces,
  - intelligent and autonomous algorithms,
  - data,
  - applications integrated with the network, performing in part also networking functionality

8. Future and Emerging Technologies

- Main future technologies
  - Physical stratum
    - Nano-things networking, e.g. using graphene antennas
    - Bio-nano things networking, e.g., allowing the engineering of biological embedded computing devices
    - Quantum networking
  - Algorithms and data
    - Impact of the use of AI/ML on the network
    - Impact of IoT on the network
    - Impact of Blockchain technologies on the network
    - Evolution of protocols: ultra-low latency, increased flexibility, privacy and security becoming more relevant, etc.

8. Future and Emerging Technologies

- Main future technologies (cont'd)
  - Applications
    - Application level networking: the network must evolve to support highly distributed content, stored, processed, and delivered from a pervasive fog computing infrastructure, with effective quality of experience management
    - Applications (components) in the network: deep integration of application and service functionality pervasively within the network
    - Applications Making Specific Demands to the Network: the traditional networking API (i.e., the Berkeley Sockets API) is too low-level, too limited, and does not expose the dynamic, changing, nature of the network, nor the high-level services and features needed to support modern applications

Outline

- Who is Networld2020
- What is our process
- What is our (current) view
- Steps ahead

Our plans for now

- Start a series of cross-disciplinar meetings in Europe, to understand the relation between other disciplines and communications
- To renew the "Visions" model, with a global event collecting inputs from diferent entities

we will welcome cooperation from other parties for this!

Conclusions

- Fortunately…
  - We will have a large number of áreas where to perform research
- Unfortunately
  - Some of the challenges above are tough

Lets' work all together towards designing the networks of the future!

NETworld 2020

Thank you for your attention!

(and we welcome visiting or permanent researchers.
Just contact ruilaa@ua.pt)

www.networld2020.eu