Beyond 5G
At the core of the digital transformation

Daniel Kofman
Prof. at Telecom ParisTech
Directeur at LINCS

Telecom Paris – 13 Mars 2020
Neuromorphic computing

- Beyond Moore’s law...
- Memristive synapses connect brain and silicon spiking neurons
  - Nature, February 25, 2020
  - The scientific research
- Hybrid artificial-biological neural network that communicated using biological principles, but over the internet.
  - Singularity University, March 2020
  - The scientific dissemination
Agenda

- Use cases for 2030 (or before)
- Overview of Requirements for 6G
- MEC – From functionality towards a new paradigm
  - The fusion of Connectivity AND computing capacities
- Related Research Directions
- And then?
Requirements and Use cases

- Higher capacity (higher antennas density, higher bandwidth, higher efficiency, new architectures)
  - 4K/8K video streaming
    - Per flow 100Mbps and more, 8K AND up to 120 frames/s
    - Sports zooming actions

- Virtual, Augmented and Mixed Reality
  - From a gadget towards new paradigms for content consumption and for advanced industrial processes
  - Volumetric videos (holograms)

- Emerging industrial use cases
  - Industry 4.0: On demand blueprints transmission for the 3D based plants, Motion control, controller-to-controller, Automatic guided vehicles
  - Smart Cities: Local road traffic analyses, V2R, Backhaul network of the city...
  - Distant collaborative design
Requirements and Use cases

- **Lower latency**
  - Autonomous vehicles (e.g. UAM/VTOL)
  - Control of drones
  - Sensitive/Tactile Internet
  - Telemedicine, e.g. remote surgery
  - Remote robotics
  - Interactive distributed games
  - Monitoring and control of industrial plants and critical infrastructures (grid, pipelines...)

ASKA eVTOL – autonomous AI based
https://www.askafly.com
General trends

Applications viewpoint

- **From Mobile Internet of Everything towards Mobile Intelligence of Everything**
  - Fully distributed (e.g. edge and fog computing) resources, functionalities, data, intelligence, capabilities, actuation...
  - Vertical Federated Learning
- **Adapted to specific requirements of the various activity sectors (verticals)**
  - E.g. Extended reality and Sensitive/Tactile Internet, Unmanned Aerial Vehicles, Swarm Systems,
    - The future of medicine, the future of transportation and logistics (5GAA), industries of the future (5GACIA)...
- **Convergence: using the same system for communications, sensing, radar, etc.**
  - Network embedded image processing, AI, etc. for images analysis and recognition
  - Enabling high sensing density
  - Wireless power transfer
Agenda

- Use cases for 2030 (or before)
- Overview of Requirements for 6G
- MEC – From functionality towards a new paradigm
  - The fusion of Connectivity AND computing capacities
- Related Research Directions
- And then?
Requirements and Use cases

- Explosion in the number of connected devices, diversity in connectivity paradigms (e.g. Low Power WAN)
  - Towards growing and efficient IoT
- Support of Mission critical infrastructures, services and applications
  - Seven “9” and more
- Network as a Service (NaaS)
  - Dynamic creation of virtual networks with specific capabilities and capacity
    - Slicing, virtualization, orchestration
  - Small Cell as a service - SCaaS.
  - Networking and Edge computing fusion
    - Multi-access Edge Computing (former Mobile Edge Computing)
  - A network that supports communications but also - and maybe one day, mainly - sense, memorize and compute (think?)
    - 2+ Tiers
  - Local Breakout to Internet and other services
Requirements and Use cases

- Precise, cost effective and energy effective geolocation
  - Indoor Traceability

- Business Models: Networking and networking costs embedding in services and applications
  - Reading your favorite newspaper abroad with no additional charges

- Security and safety
  - Higher dependency on the ICT infrastructures
  - Much larger opportunities for attackers

- For short: Totally Transparent Network
  - From users point of view
Requirements, Technology Viewpoint

- Intelligent usage of “all” the radiofrequency spectrum (till THz)
  - Autonomous, Intelligent and Collaborative wireless technologies (DARPA)
- Fully modular, dynamically reconfigurable, secure, safe, ...
  - Virtualization, orchestration, O-RAN, collaborative economy,
- Edge side-link based networking
- 5G NR based Access, Fronthaul, Midhaul and Backhaul
- Non terrestrial networks adaptability (HAP, LEOs, MEOs)
- Deterministic behaviors
- Indoor and outdoor location accuracy
- Time Synchronicity (1 µs)
- Spectral efficiency
- Energy efficiency
- Low cost
Some quantitative figures

- High speed: xGbps per user
- Related High capacity
- Low Latency: 0.5ms
- Massive/Dense:
  - hundreds of billions of connected devices
  - 2/sqm and x/cubic cm
- 5G PPP (June 2019)
  - Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
  - Saving up to 90% of energy per service provided.
  - Reducing the average service creation time cycle from 90 hours to 90 minutes.
  - Creating a secure, reliable and dependable Internet with a « zero perceived » downtime for services provision.
  - Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.
Agenda

- Use cases for 2030 (or before)
- Overview of Requirements for 6G
- MEC – From functionality towards a new paradigm
  - The fusion of Connectivity AND computing capacities
- Related Research Directions
- And then?
Overall RAN Architecture

5G NR for:
Back/Mid/Front Haul
Uu, NR SideLink

1st image from 5GPP
Overall RAN Architecture

5G NR for:
Back/Mid/Front Haul
Uu, NR SideLink
Agenda

- Use cases for 2030 (or before)
- Overview of Requirements for 6G
- MEC – From functionality towards a new paradigm
  - The fusion of Connectivity AND computing capacities
- Related Research Directions
- And then?
Research domains

- Real time, **Application aware**, radio resources allocation
  - Example: buffering of video streaming for dealing with real-time constrained applications
- Optimizing new trade-offs
  - Example: BB vs latency for 6doF immersion (DoF = degrees of freedom)
- MEC: Optimal control of Application offloading capabilities
  - Based on app requirements, radio state, V-RAN/MEC topology
- MEC: Joint radio and computing resources allocation
  - AI based solutions – reconfiguring flows requirements, optimizing resources allocation
- Multi-Access Edge Computing slicing, Slicing at the Edge, SC as a Service
  - Optimal Dynamic Functionality placement
  - Dynamic management of shares resources between slices
- New mobility protocols: Device mobility, attached VMs location, functionality availability AND radio infrastructure.
  - Advance base stations collaboration
- Reliability: How to reach the six “9” in as SW based platform
  - New modelling and verification approaches
Research domains

- Automation of operation and maintenance
  - Management of shared resources between slices, role of AI
  - Dynamic topology adaptation: SC as a Service

- Mesh RAN Network: NR for Fronthaul, Midhaul, Backhaul plus

- Vehicular platooning, cooperative collision avoidance, remote driving, autonomous navigation, cooperative sensing (not only related with driving)...
  - Optimal architecture local, MEC and Central Cloud based

Drive Tests
Agenda

- Use cases for 2030 (or before)
- Overview of Requirements for 6G
- MEC – From functionality towards a new paradigm
  - The fusion of Connectivity AND computing capacities
- Related Research Directions
- And then?

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”

- Mark Weiser
Towards Totally Transparent Networks and Systems

- Energy
- Transportation
- Supply Chain
- Smart City
- Smart House/Building
- Health
Towards Totally Transparent Networks and Systems

Service Platforms

- Energy
- Supply Chain
- Transportation
- Smart City
- Smart House/Building
- Health
Some general concepts

- World digital twin enabler
- Federated Artificial Intelligence
- Wireless power transfer and Energy harvesting for autonomous short range communications
  - University of Essex, UESTC-China and ZTE: hybrid access points for simultaneous wireless information transfer and wireless energy transfer in smart cities.
- Integrating spatial telecommunications
  - Massive LEO and High Altitude Platforms
- O-RAN – Open and Fully interoperable RAN
Neuromorphic computing

- Beyond Moore’s law...
- Memristive synapses connect brain and silicon spiking neurons
  - Nature, February 25, 2020
  - The scientific research
- Hybrid artificial-biological neural network that communicated using biological principles, but over the internet.
  - Singularity University, March 2020
  - The scientific dissemination
Quantum computing

- Beyond Moore’s law...

- What if we could teach photons to behave like electrons?
  - A Stanford-led team has created a pseudo-magnetic force that can precisely control photons.
  - Use case example: Light-based chips that would deliver far greater computational power than electronic chips.
  - "What we've done is so novel that the possibilities are only just beginning to materialize," Avik Dutt

- Towards quantum personal computers?
  - Starting with Quantum based MECs?

- Free-space, mobile, light communication, with quantum cryptography protection?
What is your vision?
Glossary

- 5G AA – 5G Automotive Association
- 5G 5G-ACIA - 5G Alliance for Connected Industries and Automation
- cMTC: Critical Machine Type Communication
- eMBB: Enhanced Massive BroadBand
  - which transfers multi-gigabyte on demand
- eVTOL: electrical Vertical Take Off and Landing
- mMTC: Massive machine type communications
  - which connects many terminals and sensors
- NSSAI: Network Slice Selection Assistance Information
Glossary

- SDAP: Service Data Adaptation Protocol
- SPS: Semi-Persistent Scheduling
- Transmission media
  - Optical fibers
  - Free space optics (FSO)
  - High-frequency radio-waves including millimeter-wave (MMW) and THz-waves.
- URLLC: Ultra-reliable and low-latency communications
  - which enables rapid feedback for mission-critical applications such as autonomous driving.
- UAM: Urban Air Mobility
The Japanese government announced plans to put together a comprehensive strategy regarding future 6G wireless communication networks
  • January, 2020