Beyond 5G
At the core of the digital transformation

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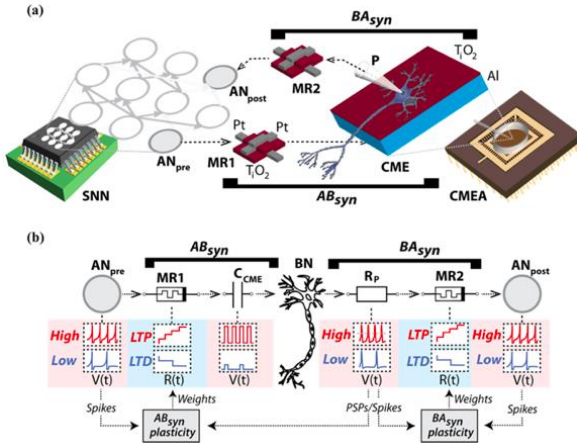
Neuromorphic computing

- 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



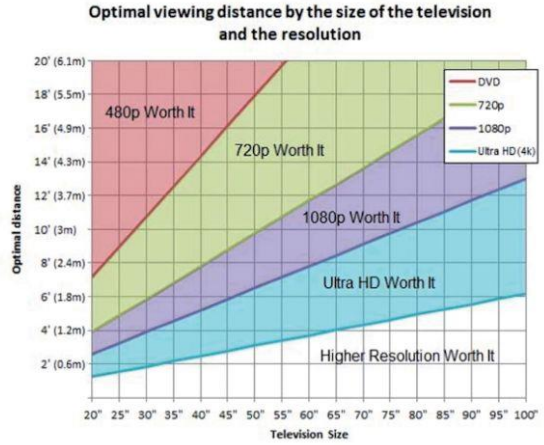
Scientists Linked Artificial and Biological Neurons in a Network—and Amazingly, It Worked

Agenda

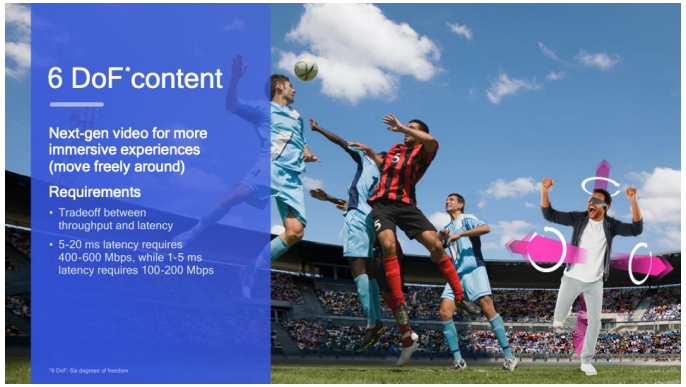
- Use cases for 2030 (or before)
- Overview of Requirements for 6G
- MEC – From functionality towards a new paradigm
  - The fusion of Connectivity AND computing capacities
- Related Research Directions
- And then?

Requirements and Use cases

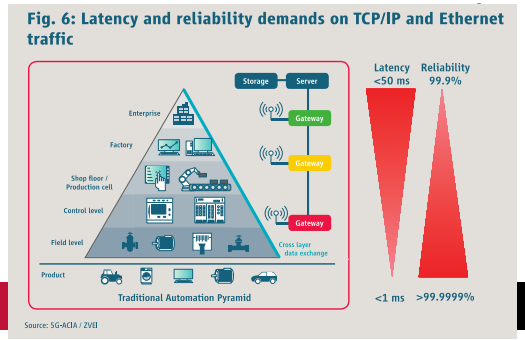
- **Higher capacity (higher antennas density, higher bandwidth, higher efficiency, new architectures)**
  - **4K/8K video streaming**
    - Per flow 100Mbps and more, 8K AND up to 120 frames/s
    - Sports zooming actions



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

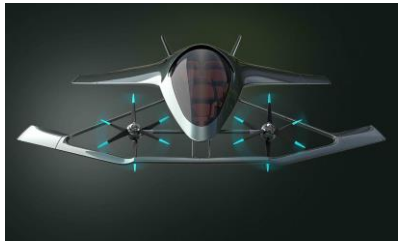


  - **Emerging industrial use cases**
    - Industry 4.0: On demand blueprints transmission for the 3D based plants, Motion control, controller-to-controller, Automatic guided vehicles
    - Smart Cities: Local road traffic analyses, V2R, Backhaul network of the city…
    - Distant collaborative design



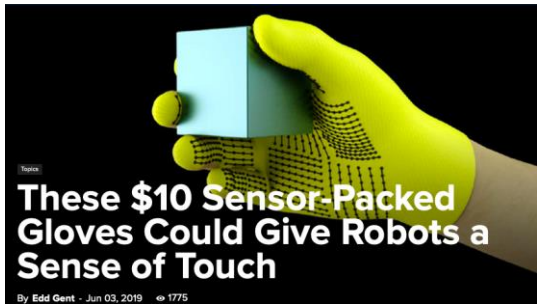
Requirements and Use cases

- **Lower latency**
  - **Autonomous vehicles (e.g. UAM/VTOL)**
  - **Control of drones**



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

- **Sensitive/Tactile Internet**



- **Telemedicine, e.g. remote surgery**
- **Remote robotics**

- **interactive distributed games**
- **Monitoring and control of industrial plants and critical infrastructures (grid, pipelines…)**

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

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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

Capability	Target in 5G [1][2]	Target in 5G LTE	Enhancement factor
Spectrum	<52.6 GHz	<1000 GHz	x 20
Bandwidth	<1 GHz	< 10 GHz	x 10
Peak Data Rate	(DL/UL) >20/10 Gbps	(DL/UL) >1000/500 Gbps	x 50
User Data Rate	(DL/UL) >100/50 Mbps	(DL/UL) >2000/1000 Mbps	x 20
Spectral Efficiency	(DL/UL) >30/15 bps/Hz	(DL/UL) >100/50 bps/Hz	x 3
Traffic Capacity	20 Mbps/sqm	1000 Mbps/cum	x 50
Density	>1 device/sqm	>10 device/cum	x 10
Reliability	>99.999%	>99.99999%	x 10
U-Plane Latency	<1 ms	<0.1 ms	10
C-Plane Latency	<10 ms	<1 ms	10
Power (Terminal)	<100's mWatts	<1 mWatt	100
Positioning accuracy	<30 cm	<1 cm	30
Mobility	<500 Km/h	<1000 Km/h	x 2

Eu Empower August 2019

- **High speed: xGbps per user**
- **Related High capacity**
- **Low Latency: 0,5ms**
- **Massive/Dense:**
  - **hundreds of billions of connected devices**
  - **2/sqm and x/cubicm**
- **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.**

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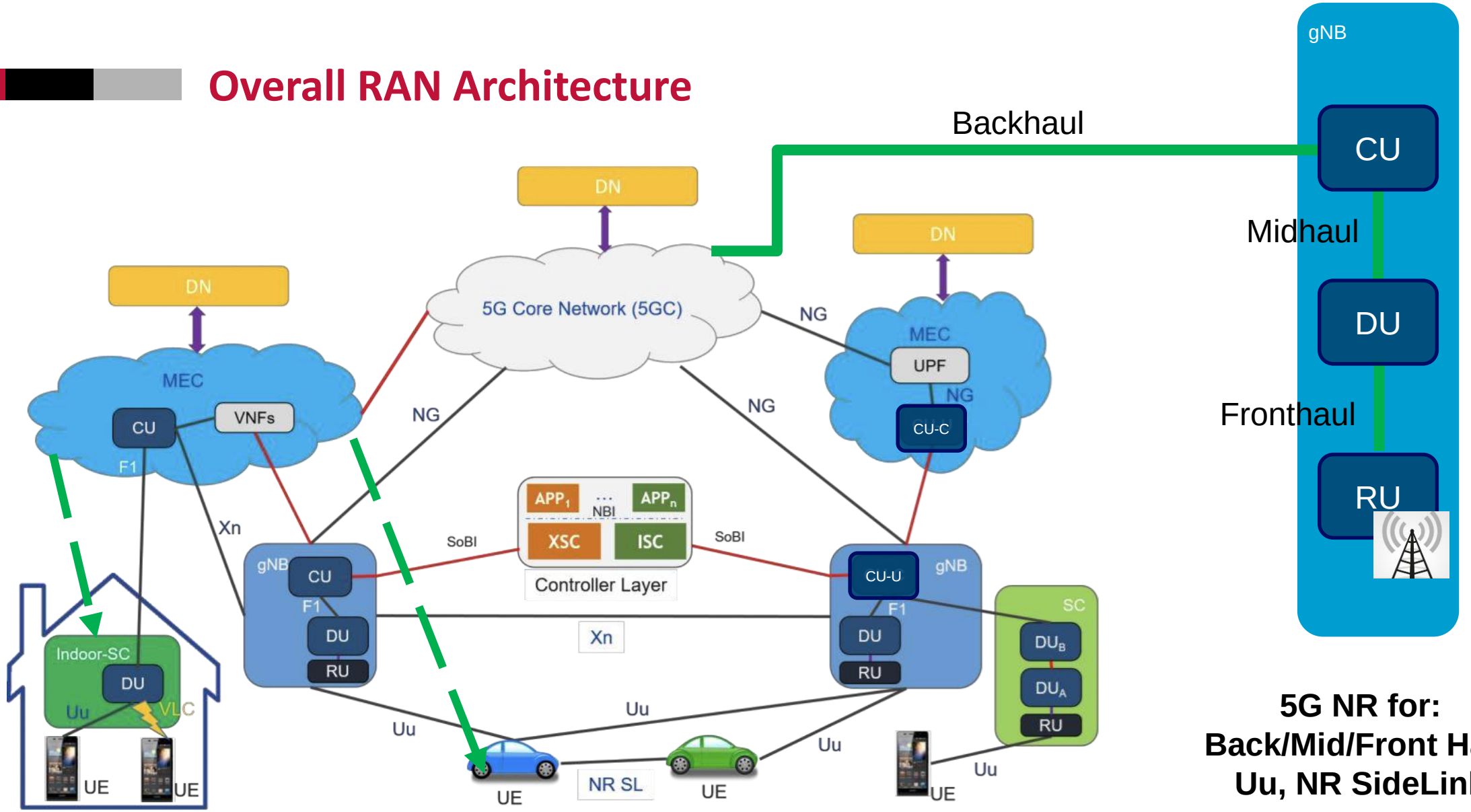
Overall RAN Architecture



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

1st image from 5GPP

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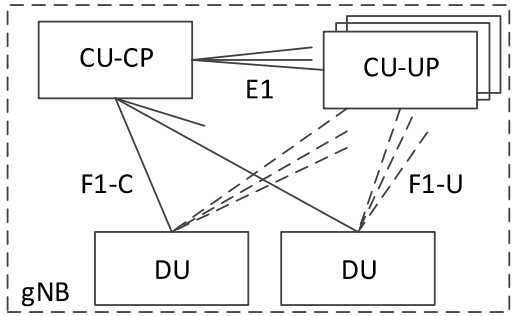

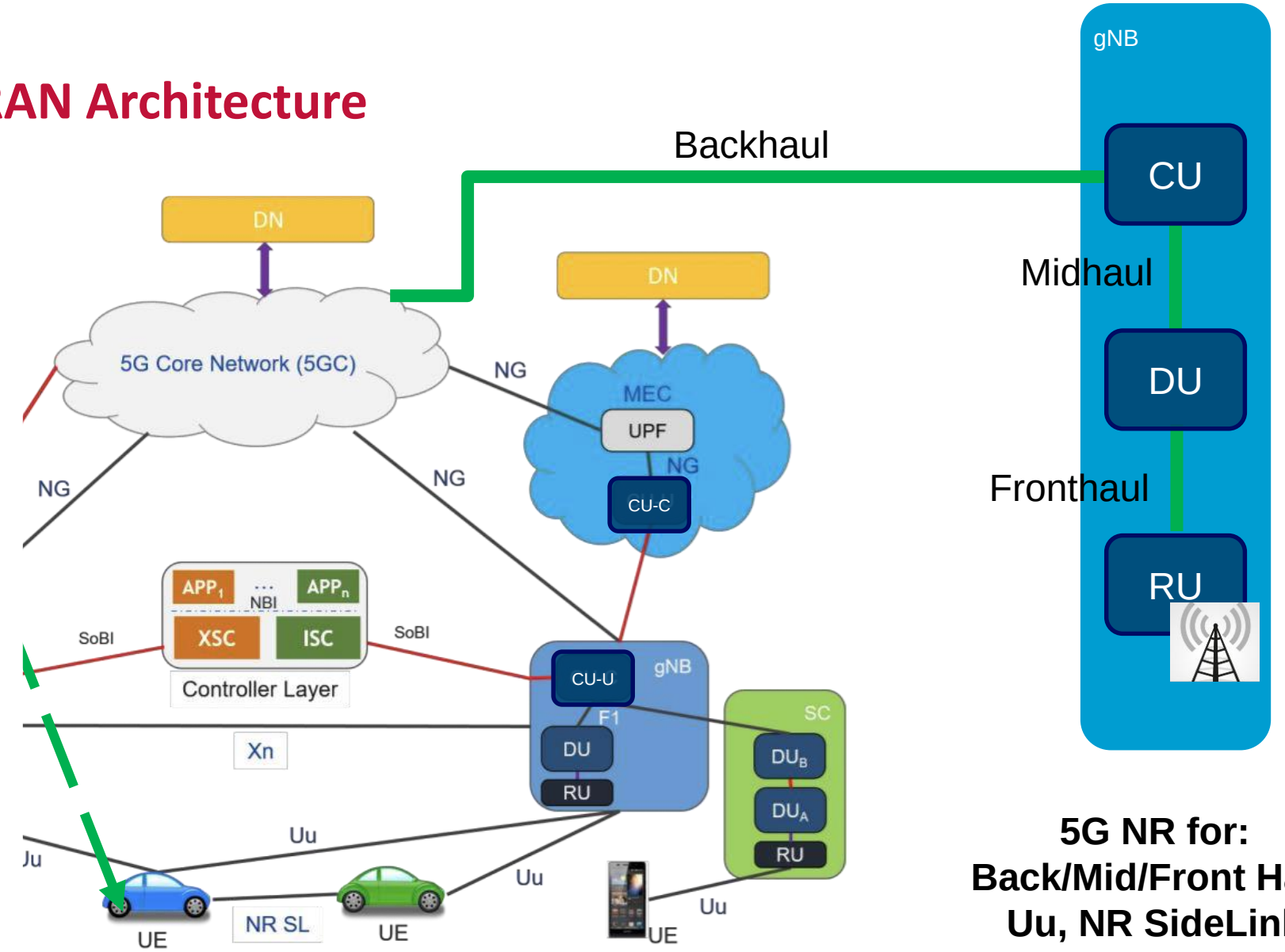

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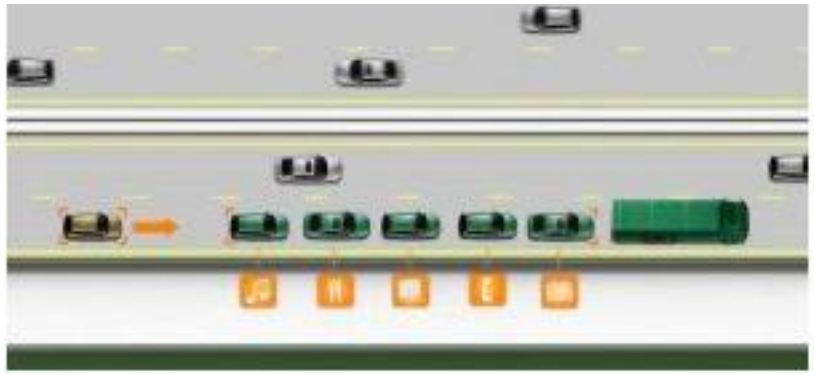
Research domains

- 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

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Towards Totally Transparent Networks and Systems

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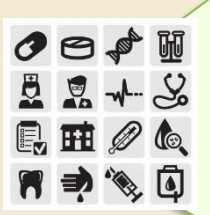
Energy

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 simultaneaous 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

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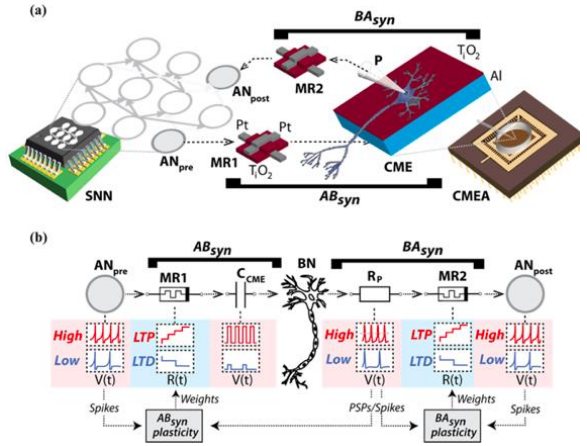

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Quantum computing

- 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**