Session 4: Cutting edge cloud technologies: 5G, Cloud and IoT

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The European Commission, in a recent communication (April 19th), has identified 5G and Internet of Things (IoT) amongst the ICT standardization priorities for the Digital Single Market (DSM). This session will discuss the emergence of the mobile edge computing paradigm to reduce the latency for processing near the source large quantities of data and the need of the emerging 5G technology to satisfy the requirements of different verticals. Mobile Edge Clouds have the potential to provide an enormous amount of resources, but it raises several research challenges related to the resilience, security, data portability and usage due to the presence of multiple trusted domains, as well as energy consumption of battery powered devices. Large and centralized clouds have been deployed and have shown how this paradigm can greatly improve performance and flexibility while reducing costs. However, there are many issues requiring solutions that are user and context aware, dynamic, and with the capability to handle heterogeneous demands and systems. This is a challenge triggered by the Internet of Things (IoT) scenario, which strongly requires cloud-based solutions that can be dynamically located and managed, on demand and with self-organization capabilities to serve the purposes of different verticals.
APPLICATION A (SMARTCITY)
Cloud, Fog, Edge

➢ Reduce Data Communication and Data Processing Demands

➢ Data Storage and Data Processing Outside the Cloud
  ➢ Network
  ➢ Devices

➢ Proposals/Solutions
  ➢ Cisco
  ➢ MEC - The European Telecommunications Standards Institute ETSI launched an industry specification for Mobile Edge Computing (MEC) in Sept 2014
  ➢ A team at Carnegie Mellon University (CMU) has developed Cloudlets
  ➢ Microsoft Research (Victor Bahl): micro datacenter in AZURE
  ➢ Etc.
Some Fog Computing Related Concepts

- Mobile Cloud Computing (MCC): data storage and data processing happen outside mobile device.

- Mobile Edge-Computing (MEC): cloud server running at the edge of a mobile network and performing specific tasks that could not be accomplished with traditional network infrastructure.

- FC >> MCC + MEC
OpenFog

OpenFog Brings Together Innovation and Technologies

[Diagram showing various companies such as Intel, Microsoft, Cisco, ARM, TOSHIBA, PRISMTECH, FOGHORN, PRINCETON UNIVERSITY, and others connected through lines indicating cloud and services.]
Question 1

5G and fog computing are meant to impact the vertical industries and contribute to provide new or enhanced services. Do you think that the European and Brazilian economy and technology infrastructure is ready to integrate such solutions? What are the main barriers to be addressed by 2020 and opportunities?

Yes, the economic challenges can be addressed in European and Brazilian market. It means that operators are deploying technologies oriented to evolution 4.5G and 5G paths. Mainly the key infrastructure barriers are related to backhaul side, it means that we should have last mile fiber solution to carry the baseband protocols to radio units with low latency and delays between the edge and antennas.
Question 2

Pushing computation and storage to the edge addresses potential infrastructure and connectivity limitations of cloud-only IoT architectures. Trust, service and application orchestration, resilience, and analytics still remain important challenges. In your opinion, what should be the role of the industry in driving academia to investigate new innovative solutions to address these challenges?

It is clear that the main role is to work in a Cloud environment. The integration between the IoT system architecture should be ready for Big Data Analytics and simple to integrate with third party systems. It means that orchestration part should be capable to enable network level by easily integrated and managed by client system (third party).
The EU sees 5G as the main driver for the Digitalization of industry and society. In your opinion, what are the main security challenges? Since the 5G standardization are looking for a system capable to slice network in different services oriented to different customer’s needs, the self-service part that open the structure to outdoor world it is a key part of the system that can provide security challenges. Keep the system protected can be not only through operators’ door but also through customer door, since customer will be able to adjust the network as requested.

The interoperability between 3G, 4G and 5G will be also a challenge, it means that from terminal side we also have open door to be addressed and solved.
Question 4

How do you think 5G will change security and trust relationships?

In 5G we have in place the cloud structure as new IT technologies, SDN/NFV those solution will require different security changes. Privacy will be a concern since we will have different kinds of end services, such as, smarthome, health care, smart transportation, etc.
Question 5

Standardization helps towards interoperable solutions. How is Brazil cooperating with Europe on 5G and how is contributing to standardization through 5G America?
Question 6

The standardization landscape is very fragmented with many SDOs and standards proposed in cloud and even more in IoT. What should be role of policy makers and industry to avoid a potential fragmented market hindering interoperability?

At this moment industry is working to build different alliances to speed up the 5G standardization, this also include research and development phase and tests.

For standardization is health to have a single and unified SDO to enable the standards and discussion on 5G.

Usually, 3GPPP is a key group to lead the 4G standards and can keep or adjust to provide the guidance in 5G.
Aditissional Slides
1. 5G Vision and Architectures

- Key Drivers, Requirements, Technologies
  - Driving factors for cellular network evolution 3G → 4G → 5G
    - Device, Data, and Data transfer rates
    - continuous growth in wireless user devices, data usage
    - desired: better quality of experience (QoE)
    - ~ 50 billion connected devices will utilize the cellular network services until 2025 → high increase in data traffic
  - Current State-of-the-art solutions are not sufficient!
  - Three views for 5G:
    - user-centric (uninterrupted connectivity and comm. services, smooth consumer experience)
    - service-provider-centric (connected intelligent transportation systems, road-side service units, sensors, and mission critical monitoring/tracking services)
    - network-operator-centric (scalable, energy-efficient, low-cost, uniformly-monitored, programmable, and secure communication infrastructure)
  - Consequence: three main 5G features
    - Ubiquitous connectivity: devices connected ubiquitously; uninterrupted user experience
    - Zero latency (~ few ms): for life-critical systems, real-time applications, services with zero delay tolerance.
    - High-speed Gigabit connection
1. 5G Vision and Architectures

- Key Drivers, Requirements, Technologies

- 5G disruptive capabilities
  - x 10 improvement in performance: capacity, latency, mobility, accuracy of terminal location, reliability and availability.
  - simultaneous connection of many devices + improvement of the terminal battery capacity life
  - lower energy consumption w.r.t. that today 4G networks; energy harvesting
  - Better spectral efficiency
  - help citizens to manage their personal data, tune their exposure over the Internet and protect their privacy
  - reduce service creation time and facilitate integration of various players delivering parts of a service
  - built on more efficient hardware
  - flexible and interworking in heterogeneous environments

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1. 5G Vision and Architectures

Key Drivers, Requirements, Technologies (cont’d)

- **5G - evolution of mobile broadband networks + new unique network and service capabilities:**
  - It will ensure *user experience continuity* in various situations
    - high mobility (e.g. in trains)
    - very dense or sparsely populated areas
    - regions covered by heterogeneous technologies
- **5G - key enabler for the Internet of Things, M2M**

- **Mission critical services:**
  - high reliability, global coverage and/or very low latency (currently they are handled by specific networks), public safety

- **It will integrate: networking + computing + storage resources into one programmable and unified infrastructure**
  - optimized and more dynamic usage of all distributed resources
  - convergence of fixed, mobile and unicast/mcast/broadcast services.
  - support multi tenancy models, enabling players collaboration
  - leveraging on the characteristic of current cloud computing
1. 5G Vision and Architectures

- **Key Drivers, Requirements, Technologies (cont’d)**

- **5G Key technological characteristics**
  - Heterogeneous set of integrated air interfaces
  - Cellular and satellite solutions
  - Simultaneous use of different Radio Access Technologies (RAT)
    - Seamless handover between heterogeneous RANs
  - Ultra-dense networks with numerous small cells
    - Need new interference mitigation, backhauling and installation techniques.

- **Driven by SW**
  - unified OS in a number of PoPs, especially at the edge of the network

- To achieve the required performance, scalability and agility it will rely on
  - Software Defined Networking (SDN)
  - Network Functions Virtualization (NFV)
  - Mobile Edge Computing (MEC)
  - Fog Computing (FC)

- **Ease and optimize network management** operations, through
  - cognitive features
  - advanced automation of operation through proper algorithms
  - Data Analytics and Big Data techniques -> monitor the users’ QoE
1. 5G Vision and Architectures

- **5G Generic Architecture**
  - multi-tier arch.: small-cells, mobile small-cells, and D2D- and CRN-based comm.


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## 1. 5G Vision and Architectures

### 5G: Why SDN, NFV, Cloud technologies in 5G?

<table>
<thead>
<tr>
<th>5G Challenge/Problem</th>
<th>Architecture and technology</th>
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<tbody>
<tr>
<td></td>
<td>SDN</td>
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<tr>
<td>High capacity</td>
<td>X</td>
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<tr>
<td>Scalability and flexibility</td>
<td>X</td>
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<tr>
<td>User centricity</td>
<td></td>
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<tr>
<td>Programmability</td>
<td>X</td>
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<td>Self-healing infrastructures</td>
<td>X</td>
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<tr>
<td>Heterogeneity of RATs</td>
<td>X</td>
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<tr>
<td>Interference mitigation</td>
<td></td>
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<td>Low latency</td>
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<td>Energy saving</td>
<td></td>
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<tr>
<td>Flexible management</td>
<td>X</td>
</tr>
<tr>
<td>Wide range of supported services</td>
<td>X</td>
</tr>
</tbody>
</table>
3. Cloud Computing Architectures in 5G

- Cellular systems evolution towards 5G (cont’d)
  - CRAN Cloud Radio Access Networks- solution proposed for 5G
  - CRAN (interest from academia and industry)
    - large number of low-cost Remote Radio Heads (RRHs), randomly deployed and connected to the base band unit (BBU) pool through the fronthaul links
  - **Advantages:**
    - RRHs closer to the users → higher system capacity, lower power consumption
    - the baseband processing centralized at the BBU pool → cooperative processing techniques to mitigate interferences
    - exploiting the resource pooling and statistical multiplexing gain → efficiency in both energy and cost
  - **Drawbacks:**
    - the fronthaul constraints have great impact on worsening perf. of CRAN, and the scale size of RRHs
    - accessing the same BBU pool is limited and could not be too large due to the implementation complexity

- Note: many architectures are proposed by different mobile operators, manufactory, researching institutes → an unified CRAN for 5G is still not straightforward

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C-RAN or Cloud-RAN

It applies recent Data Centre Network technology to allow a low cost, high reliability, low latency and high bandwidth interconnect network in the BBU pool. It utilises open platforms and real-time virtualisation technology rooted in cloud computing to achieve dynamic shared resource allocation and support of multi-vendor, multi-technology environments.

China Mobile Research Institute: C-RAN
Korea: CCC (Cloud Computing Center)
5. Fog Computing in 5G

- Fog/Edge (FC) computing characteristics [*]:
  - Fog computing nodes (FCN) are typically located away from the main cloud data centres, at the edge.
  - **Cloud computing on fog nodes** enables *low and predictable latency*
  - FCNs
    - are *wide-spread* and geographically available *in large numbers*
    - provide applications with *awareness of device geographical location* and device context.
    - *can cope with mobility of devices*
      - i.e. if a device moves far away from the current servicing FCN, the fog node can redirect the application on the mobile device to associate with a new application instance on a fog node that is now closer to the device.
    - *offer special services that may only be required in the IoT context* (e.g. translation between IP to non-IP transport)

- Fog application code runs on FCNs as part of a distributed cloud application


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5. Fog Computing in 5G

- **FC provides**
  - light-weight cloud-like facility close of mobile users
  - users with a direct short-fat connection versus long-thin mobile cloud connection
  - customized and engaged location-aware services

- **FC is still new and there is lack of a standardized definition**

- **Comparison between Fog/Edge (FC) and Conventional Cloud Computing [†]**:

<table>
<thead>
<tr>
<th></th>
<th>Fog Computing</th>
<th>Cloud Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target User</strong></td>
<td>Mobile users</td>
<td>General Internet users,</td>
</tr>
<tr>
<td><strong>Service Type</strong></td>
<td>Limited localized information services related to specific deployment locations</td>
<td>Global information collected from worldwide</td>
</tr>
<tr>
<td><strong>Hardware</strong></td>
<td>Limited storage, compute power and wireless interface</td>
<td>Ample and scalable storage space and compute power</td>
</tr>
<tr>
<td><strong>Distance to Users</strong></td>
<td>In the physical proximity and communicate through single-hop wireless connection</td>
<td>Faraway from users and communicate through IP networks</td>
</tr>
<tr>
<td><strong>Working Environment</strong></td>
<td>Outdoor (streets, parklands, etc.) or indoor (restaurants, shopping malls, etc.)</td>
<td>Warehouse-size building with air conditioning systems</td>
</tr>
<tr>
<td><strong>Deployment</strong></td>
<td>Centralized or distributed in regional areas by local business (local telecommunication vendor, shopping mall retailer, etc.)</td>
<td>Centralized and maintained by Amazon, Google, etc.</td>
</tr>
</tbody>
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6. Mobile Edge Computing

Why MEC?

- MEC provides IT and cloud-computing capabilities within the RAN in close proximity to mobile subscribers.
- MEC accelerates content, services and applications so increasing responsiveness from the edge.

- Main standardization actors: ETSI, 3GPP, ITU-T

- RAN edge offers a service environment with ultra-low latency and high-bandwidth as well as direct access to real-time radio network information.
  - (subscriber location, cell load, etc.) useful for applications and services to offer context-related services.

- Operators can open the radio network edge to third-party partners.

- Proximity, context, agility and speed can create value and opportunities for mobile operators, service and content providers, Over the Top (OTT) players and Independent Software Vendors (ISVs)

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6. Mobile Edge Computing

- **MEC Use Cases examples (content-oriented) (cont’d)**
  - **Video Analytics**
    - distributed video analytics solution: efficient and scalable mobile solution for LTE
    - The video mgmt. application transcodes and stores captured video streams from cameras, received on the LTE uplink
    - The video analytics application processes the video data to detect and notify specific configurable events e.g. object movement, lost child, abandoned luggage, etc.
    - The application sends low bandwidth video metadata to the central operations and management server for database searches. Applications: safety, public security to smart cities

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Same source as in previous slide

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6. Mobile Edge Computing

- **MEC Use Cases examples**
- **Internet of Things (IoT)**
  - IoT generates additional messaging on telecoms networks, and requires gateways to aggregate the messages and ensure security and low latency.
  - Real-time capability is required and a grouping of sensors and devices is needed for efficient service.
  - IoT devices are often low in terms of processor and memory capacity, so need to aggregate various IoT messages connected through the mobile network close to the devices.
  - This also provides an analytics processing capability and a low latency response time.

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_Yun Chao Hu et al., "Mobile Edge Computing A key technology towards 5G" ETSI White Paper No. 11_  
_Sheet 5, September 2015, ISBN No. 979-10-92620-08-5_  
_DataSys 2016 Conference May 22, 2016 Valencia, Spain_