InfoWare 2019 Panel

Paving 5G+ Networking: Supporting Technologies and Solutions

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Chief Scientist and VP of Network Technologies, Futurewei

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June 30-July 4, 2019

Futurewei Technologies, Inc
5G: Requirements and Use Cases

- eMBB: Gigabytes in a second, 3D video, UHD screens
  - Smart home / building: Work and play in the cloud
  - Voice: Augmented reality
  - Smart city: Industry automation, Mission critical
  - uRLLC: Self driving car

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## 5G: Some KPIs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>End-to-end latency (note 3)</th>
<th>Jitter</th>
<th>Survival time</th>
<th>Communication service availability (note 4)</th>
<th>Reliability (note 4)</th>
<th>User experience data rate</th>
<th>Payload size (note 5)</th>
<th>Traffic density (note 6)</th>
<th>Connection density (note 7)</th>
<th>Service area dimension (note 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete automation – motion control (note 1)</td>
<td>1 ms</td>
<td>1 µs</td>
<td>0 ms</td>
<td>99,9999%</td>
<td>99,9999%</td>
<td>1 Mbps up to 10 Mbps</td>
<td>Small</td>
<td>1 Tbps/km²</td>
<td>100 000/km²</td>
<td>100 x 100 x 30 m</td>
</tr>
<tr>
<td>Discrete automation</td>
<td>10 ms</td>
<td>100 µs</td>
<td>0 ms</td>
<td>99,99%</td>
<td>99,99%</td>
<td>10 Mbps</td>
<td>Small to big</td>
<td>1 Tbps/km²</td>
<td>100 000/km²</td>
<td>1000 x 1000 x 30 m</td>
</tr>
<tr>
<td>Process automation – remote control</td>
<td>50 ms</td>
<td>20 ms</td>
<td>100 ms</td>
<td>99,9999%</td>
<td>99,9999%</td>
<td>1 Mbps up to 100 Mbps</td>
<td>Small to big</td>
<td>100 Gbps/km²</td>
<td>1 000/km²</td>
<td>300 x 300 x 50 m</td>
</tr>
<tr>
<td>Process automation – monitoring</td>
<td>50 ms</td>
<td>20 ms</td>
<td>100 ms</td>
<td>99,9%</td>
<td>99,9%</td>
<td>1 Mbps</td>
<td>Small</td>
<td>10 Gbps/km²</td>
<td>10 000/km²</td>
<td>300 x 300 x 50</td>
</tr>
<tr>
<td>Electricity distribution – medium voltage</td>
<td>25 ms</td>
<td>25 ms</td>
<td>25 ms</td>
<td>99,9%</td>
<td>99,9%</td>
<td>10 Mbps</td>
<td>Small to big</td>
<td>10 Gbps/km²</td>
<td>1 000/km²</td>
<td>100 km along power line</td>
</tr>
<tr>
<td>Electricity distribution – high voltage (note 2)</td>
<td>5 ms</td>
<td>1 ms</td>
<td>10 ms</td>
<td>99,9999%</td>
<td>99,9999%</td>
<td>10 Mbps</td>
<td>Small</td>
<td>100 Gbps/km²</td>
<td>1 000/km² (note 9)</td>
<td>200 km along power line</td>
</tr>
<tr>
<td>Intelligent transport systems – infrastructure backhaul</td>
<td>10 ms</td>
<td>20 ms</td>
<td>100 ms</td>
<td>99,9999%</td>
<td>99,9999%</td>
<td>10 Mbps</td>
<td>Small to big</td>
<td>10 Gbps/km²</td>
<td>1 000/km²</td>
<td>2 km along a road</td>
</tr>
<tr>
<td>Tactile interaction (note 1)</td>
<td>0,5 ms</td>
<td>TBC</td>
<td>TBC</td>
<td>[99,999%]</td>
<td>[99,999%]</td>
<td>[Low]</td>
<td>[Small]</td>
<td>[Low]</td>
<td>[Low]</td>
<td>TBC</td>
</tr>
<tr>
<td>Remote control</td>
<td>5 ms</td>
<td>TBC</td>
<td>TBC</td>
<td>[99,999%]</td>
<td>[99,999%]</td>
<td>[From low to 10 Mbps]</td>
<td>[Small to big]</td>
<td>[Low]</td>
<td>[Low]</td>
<td>TBC</td>
</tr>
</tbody>
</table>
Real Latency on the Internet

https://enterprise.verizon.com/terms/latency/

<table>
<thead>
<tr>
<th>Verizon Enterprise Latency Statistics (ms)</th>
<th>2019</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>April</td>
</tr>
<tr>
<td>Trans Atlantic (90.000)</td>
<td>69.986</td>
<td>69.950</td>
</tr>
<tr>
<td>North America (45.000)</td>
<td>31.352</td>
<td>31.531</td>
</tr>
<tr>
<td>Asia Pacific (125.000)</td>
<td>85.806</td>
<td>85.201</td>
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<tr>
<td>Latin America (140.000)</td>
<td>90.968</td>
<td>88.450</td>
</tr>
<tr>
<td>EMEA to Asia Pacific (250.000)</td>
<td>144.462</td>
<td>119.350</td>
</tr>
</tbody>
</table>
Eugene Borcoci, Ph.D.
Professor of University Politehnica Bucharest, Romania

- Network Architecture
- SDN/NFV
- 4G/5G networking and slicing
- Fog/edge computing
- Vehicular communications
- 5 books, 4 textbooks, over 170 papers
Dirceu Cavendish, Kyushu Institute of Technology, USA/Japan

- Packet networks
- Network security
- Broadcast and wireless systems
- Distributed Computing and/or Web Services
Wireless communication systems and networking
- 4G/5G resource allocation
- Connected & autonomous vehicles
- QoE/QoS
- Video streaming and quality assessment
Position Statements
DEBATE
Are there any technical gaps between 5G requirements and the current technologies?
Can the 5G KPIs be achieved by the current technologies?
How successful or useful is network slicing?
Can SDN/NFV help achieve 5G KPIs?
How about Trust, Security and Privacy in 5G?
How successful or useful are these technologies?

- Network slicing
- MIMO
- NR
- Any others?
What new technologies and solutions do we have yet to develop?
InfoWare 2019
Panel on Future Networking

**Topic:** 5G+Networking: Supporting technologies and solutions

**Multi-domain and multi-tenant aspects in 5G slicing**

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Multi-domain and multi-tenant aspects in 5G slicing

- The 5G (fifth generation): new generation of mobile networks offering a large range of services to satisfy various customer demands

- Different from 4G concept: “one-fit-all”, 5G supports
  - dedicated, separated - logical slices – on top of a shared infrastructure
  - customization for various business demands with different requirements

- Driving forces for 5G: IoT, smart cities, industry, governance, IoV/automotive, safety/emergency, entertainment, environment, etc. → multiple types of “verticals” and tenants

- Standardization/fora organizations and projects are involved
  - NGNM, 3GPP, 5GPPP, ETSI, ITU-T, GSMA, BBF, ONF, IETF, IEEE, many int’l and European projects

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Multi-domain and multi-tenant aspects in 5G slicing

- **5G Network slicing** – multi-tenant, multi-domain, E2E, multi-provider/operator context → many open research issues and challenges, especially in management and control (MC) subsystems

- The overall system architecture and then the design depend on the model defined to solve the above aspects

- **Examples - 5G slicing M&C aspects**
  - Service/data model & mapping on slices - for *multiple tenants*
  - Customized slice design and preparation, stitching / composition in a *single domain* and *cross-domain*
  - Network slice life cycle management, monitoring and updating

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Multi-domain and multi-tenant aspects in 5G slicing

- **Tenant** – several variants of definitions- related to the 5G business models
- **Business model (actors)- variant 1 of definition**
  - **Infrastructure Provider (InP)** – owns and manages a PHY network and its resources
    - The resources, (WANs and/or data centers (DCs) are
      - virtualized
      - and then offered through APIs to a single or multiple tenants

- **Slice Tenant (ST)** – leases virtual resources from one or more InPs in the form of a virtual network, where the tenant can realize, manage, and provide network services to its users
  - *Note: in this model the ST creates the slices and the associated services*

- **End user (EU)**: consumes (part of) the services supplied by the tenant, *without providing them to other business actors*
Multi-domain and multi-tenant aspects in 5G slicing

- **Tenant? – (cont’d)**
  - **This example:** recursive model


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Multi-domain and multi-tenant aspects in 5G slicing

- **Tenant?**
- **Business model (actors)- variant 2 of definition**

- **Infrastructure Provider (InP)**— owner of the PHY infrastructure (network/cloud/data center) and lease them to operators
  - It can become an SLP if it leases the infrastructure in slicing fashion
- **Slice Provider (SLP)**— typically a telecom SP, owner (or tenant) of the infrastructures from which network slices can be created
  - *Note: in this model the Slice Provider is distinctly defined as slice-constructor*

- **Slice Tenant (ST)**— the user of specific network/cloud/data centre slice, in which customized services are hosted
  - STs can make requests – to SLPs- for creation of new slices by using a service model
  - *Note this ST may have one or more End Users*
Multi-domain and multi-tenant aspects in 5G slicing

- **Tenant ?**
- **Business model (actors)- distinct Slide provider- architecture**
Multi-domain and multi-tenant aspects in 5G slicing

- **Multi-domain-related aspects**
  - **E2E NSL overall objective:** to provide slices
    - E2E multiple-domain
    - logically isolated and independent
    - including: the *terminal, RAN resource, core network (CN), transport network (TN)*
    - with customized network M&C for different scenarios, service and vertical industry

- **Challenges (still - open research issues)**
  - Multi-domain orchestration architecture capable to construct multi-domain slices
    - by provisioning
    - on demand
  - while preserving different administrative domains independence and their own M&C policies

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- **Multi-domain-related aspects**
  - Architectural generic solution
    - Example: multi-domain NSL orchestrator + domain individual orchestrators

VNFM - Virtual Network Function Manager; VIM – Virtual Infrastructure Manager


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Multi-domain and multi-tenant aspects in 5G slicing

- **Multi-domain-related aspects**
  - **Architectural solutions**
    - **Example 1**: (see previous architecture-slide)
      - multi-domain NSL orchestrator
      - multi-domain Resource orchestrator
      - domain individual managers (VIM, WIM)
    
    - **Example 2:**
      - **Novel top architectural plane - Service Broker (SB)**
        - to handle slice requests from verticals, Mobile Virtual Network Operators (MVNO), and application providers
        - collects service capability information from admin. domains, creating a global service support repository
        - interacts with the Operating/Business Support System (OSS/BSS)
        - Involved in admission control and negotiation

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Multi-domain and multi-tenant aspects in 5G slicing

- Multi-domain-related aspects
  - Architectural solutions

  - Example 2 (cont’d)
    - Multi-domain Service Conductor (MSC) stratum - service management across federated domains
    - Cross-domain Slice Coordinator - defined for each E2E slice

  - Orchestration plane
    - Each domain will have a dedicated one, involving the NFV style architecture for the M&C

- Example 3
  - ……
Multi-domain and multi-tenant aspects in 5G slicing

- **Conclusions**

- **5G slicing - still open research areas**
  - Vertical extension of: multi-tenant capabilities
  - Horizontal extension; E2E multi-domain capabilities

- **Examples of projects on 5G slicing:**
  - 5G Essence, 5G-Picture, 5G City, 5G-Monarch, 5GTango, 5G-Xhaul, CogNet, Matilda, NOMA, NORMA, SESAME, SliceNet, Transformer, etc.

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Thank you!
Paving 5G+ Networking: Supporting Technologies and Solutions

5G Security Aspects

Dirceu Cavendish, Kyushu Institute of Technology, Japan
5G Networking

5G Salient Characteristics

- Flexible and efficient spectrum usage (including millimeter wave)
- Efficient data transport: control/emergency/low latency
- New use cases
  - Automotive: connected cars (cV2V, cV2I), ADAS
  - Healthcare: smart medical devices, remote healthcare
  - Smart homes/cities: surveillance, home automation
5G Security

5G service slicing

- Slices
  - Smartphone service
  - Vehicle service
  - M2M services (e.g. healthcare)
- Cellular security protocols:
  - Authentication and Key Agreement (AKA)
  - Extensible Authentication Protocol (EAP)

Cloud computing - New cloud/virtualization technologies have become commonplace.
- Cloud security issues:
  - Users lack control and visibility of resources/data
  - Unauthorized cloud services risk assessment/monitoring (transparency)
  - CSP application programming interfaces (APIs) as attack “entrances”
  - Separation of multiple CSP tenants in shared cloud resources
  - Data replication on virtual redundant cloud network resources increases data leakage risk

How cloud security mechanisms interact with 5G networking elements
- End-to-end protocols:
  - IoT device seeking mutual authentication/secure communication with cloud infrastructure
- Cellular security protocols (AKA, EAP) interaction with cloud security
5G Vehicular Networks and Security

5G Vehicle communication
- Vehicle to Vehicle (V2V)
  - Milliseconds latency: “5G direct”
  - Reliable and continuous signal
- Vehicle to Infrastructure (V2I)
  - Efficient cloud services: CDN, edge computing

Threat types
- Vehicular sensing
  - GPS: spoofing
  - Radar: Small dangerous objects
  - Camera: object occlusion; object distraction; non-standard road demarcation
  - Proximity: position/range attacks
- Autonomous Driving Aided System
  - Image processing pattern recognition failures (e.g. stop sign miss)
  - Auto driving logic failure: unexpected scenario; software error

Mitigations
- Multiple sensor sources for consistency checks
- Multiple position camera sources and checks
- Secure/tiered 5G protocols/services
- Emergency procedures: collision avoidance procedures
- Self-learning: cloud crowdsourcing driving performance, near misses, and collision events
Healthcare and 5G security

5G enabled Healthcare
- Vital signs tracking wearables
- Secure remote consultation
- Remote assisted surgery
- 2D/3D scanning

Threats
- Vital signs tracking/monitoring
  - Location (GPS) spoofing
  - Authentication spoofing
  - Personal Health Information (PHI) leakage
- Secure Remote Consultation
  - PHI leakage
- Remote assisted surgery
  - Denial of Service attack
- Imaging Scanning
  - Image processing pattern recognition failures

Mitigations
- Multiple sensor sources with consistency checks
- Multifactor authentication
- Cloud/Network encryption
- Cloud/Network encryption
- Secure/tiered 5G services
- Secure Cloud AI services
Relevant security technologies

**Private Public Key Infrastructure (PKI):**
private certificates issued for limited authentication scopes

- Internal enterprise PKIs.
- Cloud based private PKI infrastructure/services: intermediate root/keys management (secluded Hardware Security Module)

**Identity based authentication:**
authentication based on prover claimed identity only

- Requires small hardware prover footprint (IoT devices)
- Convenient for verifier (public keys only)

**Physically Uncloneable Functions (PUFs):**
hardware authentication based on unique physical properties of each electronic device

- Unique circuit/chip unit identification (IoT scalable)
- On demand (authentication epoch) key generation
- Low power/processing
Approaches to 5G and B5G

Xiaohong Peng
Wireless Communications & Networks – 5G Research Group
Aston Institute of Photonic Technology
Aston University

Panel Session at IARIA Vehicular2019, 3rd July 2019
Technologies vs. Use Cases in 5G Networks

QoE-controlled network slicing

- CAV

- Education

- Healthcare

- Event

- Manufacturing

- eMBB

- mMTC

- uRLLC

- Fibre backhaul and fronthaul
Performance Trade-off in 5G Networks

Capacity vs. Coverage

High capacity over a small area

Lower capacity with wider coverage
High throughput is always accompanied by low fairness
Video Content delivery in 5G Networks

Slicing for video streaming

Fronthaul

Backhaul

Edge caching

Slicing for broadcast/multicast

UE-1 (playback)

UE-n (playback)

Server-1

Server-n
It’s a Quality Issue

QoS

QoE

QoL

Quality of Service

Quality of Experience

Quality of Life
Fundamental Trade-Off

Quality Requirement  Resource Cost

QoS → Network → QoE → End user

How to maintain a good march between QoS and QoE?
Thank You