Distributed Cloud: A Modern Computing Paradigm Towards 5G Networks

Moacyr Martucci Junior
Agenda

- Introduction to 5G
- Distributed Cloud Computing on 5G
- Computing and Network Evolution Trends Towards 5G
- Conclusion

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What is 5G?

- **5G (IMT 2020) = 5th Generation of Mobile Networks**
  - Not only another G is Connectivity Revolution to IOT Deployment;
  - Merge Telecommunications + Cloud Computing + Big Data;

- **Challenges:**
  - Compatible with Legacy Networks;
  - Ubiquitous;
  - Low Energy Consumption;
  - Low Latency;
  - High Broadband.

Source: [2]

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## G’s Background

<table>
<thead>
<tr>
<th>Feature</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>800 MHz</td>
<td>900 MHz</td>
<td>2,100 MHz</td>
<td>2,600 MHz</td>
<td>3–90 GHz</td>
</tr>
<tr>
<td>Speed Technology</td>
<td>2 Kbps</td>
<td>64 Kbps</td>
<td>2 Mbps</td>
<td>1 Gbps</td>
<td>Higher than 1 Gbps</td>
</tr>
<tr>
<td></td>
<td>Analogue cellular</td>
<td>Digital cellular</td>
<td>Code division multiple access, Universal Mobile Telecommunications System</td>
<td>Long-Term Evolution Advanced, Wi-Fi</td>
<td>Multi-radio access technology, Wi-Fi, Wi-Gig</td>
</tr>
<tr>
<td>Services</td>
<td>Voice</td>
<td>Digital voice, SMS, packet (General Packet Radio Service), low-rate data</td>
<td>Higher quality audio and video calls, mobile broadband</td>
<td>High data rate, wearable devices</td>
<td>Very high data rate to fulfill extreme user demands, device-to-device, machine-to-machine, Internet of Things</td>
</tr>
<tr>
<td>Multiplexing</td>
<td>Frequency division multiple access</td>
<td>Time division multiple access</td>
<td>Code division multiple access</td>
<td>Orthogonal frequency-division multiple access</td>
<td>Orthogonal frequency-division multiplexing, filter bank multicarrier, nonorthogonal multiple access</td>
</tr>
<tr>
<td>Handover</td>
<td>No</td>
<td>Horizontal</td>
<td>Horizontal</td>
<td>Horizontal/vertical</td>
<td>Horizontal/vertical</td>
</tr>
<tr>
<td>Switching Core network</td>
<td>Circuit Public switched telephone network</td>
<td>Circuit/packet Public switched telephone network</td>
<td>Packet</td>
<td>All packet</td>
<td>All packet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Internet</td>
<td>Internet</td>
</tr>
</tbody>
</table>

Source: Adapted from [6]
Enhancement of key capabilities from IMT-Advanced to IMT-2020

<table>
<thead>
<tr>
<th>Metric</th>
<th>IMT-Advanced</th>
<th>IMT-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Data Rate (Gbit/s)</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>User Experience Data Rate (Mbit/s)</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>Spectrum Efficiency</td>
<td>3x</td>
<td>1x</td>
</tr>
<tr>
<td>Mobility (Km/h)</td>
<td>500</td>
<td>500x</td>
</tr>
<tr>
<td>Latency (ms)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Connection Density (device/km²)</td>
<td>100x</td>
<td>10</td>
</tr>
<tr>
<td>Area Traffic Capacity (Mbit/s/m²)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Network Energy Efficiency</td>
<td>100x</td>
<td>10</td>
</tr>
<tr>
<td>Network Energy Efficiency</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
The importance of key capabilities in different usage scenarios

- **Enhanced Mobile Broadband**
- **Massive Machine Type Communications**
- **Ultra-reliable and Low Latency Communications**

Source: ITU-R REC-M.2083-0
5G Usage Scenarios

Gigabytes in a second

Smart Home/Building

Voice

Smart City

Enhanced Mobile Broadband

3D video, UHD screens

Work and play in the cloud

Augmented reality

Industry automation

Self Driving Car

Mission critical application e.g. e-health

Future IMT

Massive Machine Type Communications

Ultra-reliable and Low Latency Communications

Source: [3]
Main Enabler Technologies - Physical Layer

New Radio Access technologies

Millimeter Waves

- 4G
- 5G Extension to higher frequencies

1GHz  6GHz  10GHz  30GHz  100GHz

Massive MIMO

- Linear
- Rectangular
- Cylindrical
- Distributed

4G

8 ≤

5G ≥64

Massive MIMO + 3D BeamForming

3D beamforming

2D antenna arrays

Horizontal

Vertical
5G Architecture

- Services/applications
- Function requirements 
  Ex: latency, availability
- Creation/operation/control 
  of multiple communications
- Implements commands provided by the upper layer
- Provides E2E services & distributed cloud platform

Diagram showing various 5G services and layers, including Business Service Layer, Business Function Layer, Orchestrator, Network Function Layer, and Infrastructure Layer.
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What is coming soon ...

Dramatic Increase in Complexity

8.5 Billion Mobile Subscribers & 29 Billion Connected Devices by 2022
50% Enterprise Data will be Processed Outside Centralized DC or Cloud by 2022

Source: Adapted from [2]

Source Ericsson

Source Gartner
Mobile Edge Computing Drivers

Increased Bandwidth
Reduced Latency
Catalyst of Edge Computing

1. Latency
2. Bandwidth
3. Autonomy
4. Privacy

IOT, Video Surveillance, AI/Machine Learning, Public Safety, Content Delivery Network, Virtualized Network Functions

Source: Adapted from [2]
Distributed Cloud Computing Simplifies the Explosion of Edge Sites in 5G

Adaptive Cloud Fabric

Increases Agility & Speed to Service
Decreases Opex via Radical Simplification
Low Cost/Small Footprint

Source: Adapted from [2]

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Distributed Cloud Computing Concept

Edge Computing
- Low Latency, BW Costs, Autonomy, Privacy

Cloud Service Model
- Elasticity, Consumption Model, Ease of Use, Agility

A Decentralized Architecture with Multiple Edges: Bringing the Best of Both Worlds by Complementing Centralized Cloud

Source: Adapted from [2]
Networking Requirements for DCC

- Manage multiple sites as one logical unit;
- View of full state of network;
- Comprehensive network slicing;
- Rich services per slice;
- Rich telemetry, easy to troubleshoot per slice;
- Agnostic to compute virtualization layer;
- Reduced cost and footprint;
- No single point of failure;
- Secure.

Source: [2]
DCC Benefits

- Decrease latency;
- Improve service performance;
- Enable new services;
- Regulatory/compliance;
- Leverage new architectures that are more cost effective;
- Lower operational costs.
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Impact of Network Slicing

- Requires multi-tenancy at the management, control and data plane level;
- Each slice must be managed independently:
  - Automation: Third party automation tools;
  - Orchestration: Third party orchestration;
  - Visibility: Only tenant or application has visibility and access.

Slice 1: AR for Remote Field Techs: Ultra Low Latency, High Bandwidth
Slice 2: Factory Automation: Low Latency, Autonomous & Secure
Slice 3: Standard Corporate Traffic: Higher Latency OK, Secure

Source: Adapted from [2]
Research Context

**SDN**
- Service orchestration
- Flexible and scalable network
- Decreases network resource usage

**Distributed Cloud Computing**
- Decentralized processing capabilities
- Faster processing response
- Less bandwidth consumption

**Open Framework**
- IoT Connectivity
- Enable application for vertical sectors
DCC Requires Next Gen Data Center Fabric

Traditional Approach

- Closed & vertically integrated
- Vendor lock in
- Fabric but box-by-box config
- Expensive
- Slow feature velocity

Controller-based SDN Fabric

- White box economics, disaggregated
- State kept in central SDN controller
- Controller license +3 servers/N switches = $$
- OOB channel/port Single point of failure
- Latency challenge- geo distribution, re-convergence times
- Only greenfield due to closed protocols

Controllerless SDN Fabric

- White box economics, disaggregated
- Full state distributed to all switches
- N switches as 1 logical switch
- Simple to program
- Low latency for easy geo distribution
- No single point of failure
- Easy Brownfield Insertion

Source: Adapted from [2]
Adaptive Cloud Fabric For The Edge

Distributed SDN Fabric
• Federates all switches;
• Peer-to-peer fabric – no single point of failure;
• Stretches seamlessly across geographies;
• Adapts to any core/wan or topology;

Rich Services and Deep Slicing
• Unified data plane - VXLAN with full HW switch-offload;
• Any hypervisor, container or bare metal server;
• Deep network slicing across management, control, data planes;
• Distributed services – L3VPNs, L2VPN (p-to-p and p-to-mp);
• DC Gateways - 100+ tenant vRouters (HW offload) /1000+ VRFs;

Comprehensive Automation and Analytics
• Network topology abstraction simplifies provisioning, visibility and monitoring of policies, end-points & traffic across fabric;
• Fabric-wide TCP flow telemetry without probes or packet brokers;
• Huge flow database + Insight Analytics.
Every switch can control the fabric via API

Fabric control runs in-band without single point of failure

Standard protocols allow interoperability with 3rd party spine

Distributed control plane for rapid failover and re-convergence

Open, interoperable

Seamlessly extends across locations

1. Simple and cost effective to deploy
2. Adapts to any topology w/o geo limitations
3. Fully distributed and redundant for mission critical applications

Source: Adapted from [2]
DCC – 5G Operator (NFVi)

Network Function Virtualization Infrastructure (NFVi)

NFVi + 20 VNFS

Orchestration & Control

Adaptive Cloud Fabric

3rd party compute & storage
Virtualized, Containerized, Bare Metal

Today

Service Provider

Centralized Data Center

Regional DC

Central Office Head End

Base Station

Source: Adapted from [2]
The driver is digital transformation – required to be competitive;

AI & Machine Learning enable new applications;

The explosion of the Industrial IOT;

Improved customer and employee experience;

Enterprises must determine approach for edge computing:
  - Edge aggregators: e.g. MobiledgeX, Edge Gravity;
  - Public cloud/IaaS: e.g. Amazon Greengrass, Packet;
  - Managed Service Provider: telco-owned or independent;

Also other verticals – Education, Government, Health, Agrobusiness, etc.
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Distributed Cloud is emerging for both ISP and Enterprise;
Networking challenge is significant – explosion of edge sites;
Open networking can lower costs and speed innovation;
SDN fabric approach can radically simplify operations;
Controllerless SDN starts successful approaches in multi-site scenarios;
Now extending to distributed cloud.
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Any Questions, Suggestions
Thank you very much

Computing Towards 5G!

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