Network Softwarization Stays to Become A Reality

Aki Nakao
Professor, Department Chair of GSII
The University of Tokyo
Executive Senior Fellow, Keidanren
Chairman, 5GMF Network Architecture Committee
2018/12/11
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UTokyo has been a member of ETSI and 3GPP
EU-Japan Jointly Funded Project on 5th Generation Mobile Network (PIs: Akihiro Nakao@Utokyo and Tarik Taleb @Aalto University)

A network slice for every service!

EUJ-01-2016 - 5G – Next Generation Communication Networks

**Our Partners**

- Aalto University
- The University of Tokyo
- Universal Device Gateway
- NEC Networks & System Integration Corporation
- KDDI Research
- EURECOM
- Waseda University
- Hitachi
- Fraunhofer
- MANDAT
- FOKUS

**Funding Size**

- **EU Total cost:** EUR 2.2M
- **JP Total cost:** 225 M JPY

**Duration:** 3 years (2016-2019)

5G!Pagoda is funded by the European Commission’s H2020 program under grant agreement n° 723172.

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Some Numbers ...

- **26** Scientific Publications

- **52** standards contributions to SDOs
  (e.g., 5 to ITU-T SG13, 1 to ITU-T SG20, 3 to IETF, **43** to 3GPP)

- **11** Keynotes, **3** Expert Panels, and **1** Tutorial

- **3** core demos and many others of supporting technologies

- **Organization of major Events**
  - IoT Week 2018, FUSECO FORUM 2017, Helsinki5GWeek 2017
Open Implementation and Standardization

Open Source Implementation is a great step toward standardization
What is Softwarized RAN for?

- Edge Computing Consolidation
- Data Analytics
- Slicing for eMBB/URLLC Applications
Our 5G Field Trials for eMBB/URLLC
From Autonomous Driving to Coordinated Driving

INTEL says the Passenger Economy represents a 7-trillion-USD global opportunity in 2050.

According to the report of NHTSA in 2015, about 94% of traffic accidents had been caused by drivers (human errors)

Coordinate Driving:

Can we get rid of traffic signals?
Autonomous Intersection Management (AIM)

Location / Speed Of Vehicles (URLLC)

Intersection Manager (IM)

Low Latency Feedback Is necessary

Request
Confirm
Reject
Request

Ultra Reliable Low Latency and Edge Computing are Mandatory

http://www.cs.utexas.edu/~aim/

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Coordinated Driving via MEC

- URLLC (Ultra Reliable and Low Latency Communication) Applications
- MEC: Multi-Access/Mobile Edge Computing
- Harnessing edge servers
- Ultra low end-to-end delay
- Insufficient computational resources

Kengo Sasaki and Naoya Suzuki and Satoshi Makido and Akihiro Nakao
Vehicle Control System Coordinated between Cloud and Mobile Edge Computing, *IEEE SICE* (2016)

Kengo Sasaki and Naoya Suzuki and Satoshi Makido and Akihiro Nakao,
“Layered Vehicle Control System Coordinated between Multiple Edge Servers,”
3rd IEEE Conference on Network Softwarization (IEEE NetSoft) 2017
NTT Docomo x UTokyo Collaboration on Cooperative Driving

Experimental Settings  5G Equipment (4.5GHz)

Cars at Intersection  Collision Avoidance (Before)  Collision Avoidance (After)
NTT Docomo x Utkyko Collaboration on Cooperative Driving

- Press Released on Nov. 28\textsuperscript{th}, 2018
- NTT Docomo Open House Dec. 6\textsuperscript{th} and 7\textsuperscript{th}, 2018
NTT Docomo Open House
Dec, 6th and 7th
If e2e delay is larger than 150ms, more than 40% of the entire trajectory is course out.
4K/8K Realtime Drone Surveillance using 5G Cellular

Japan's First Real Time 4K Video Transmission using 5G Drone
June 2018
4K RealTime Video Transmission
Stitching 4K Video Feeds From 6 Fisheye-lens Cameras
Cycling Shimanami 2018
Cycling Shimanami 2018
備後フィッシュフェス

第3回 備後フィッシュフェス

2018.11.3（土）
10:00〜15:00

ふくやま美術館前広場
福山市西町二丁目4番3号

グルメブース

三原市 & 漁協

児島市 & 漁協

備後フィッシュフェス

主催：備後の地魚応援団

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5G Mobile Key Performance Indicators (KPI)

- **High Energy Saving**

- **Latency (ms) (RAN R.T. delay)**

- **Mobility (km/h)**

- **Capacity (bps/km²)**

- **Number of Connected Users**

- **Ultra Reliable and Low Latency Communication (URLLC)**
Real-Time Object Recognition via Deep Neural Network
Small form factor GPU for DNN in Drones

Jetson TX2

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU</td>
<td>NVIDIA Pascal™, 256 CUDA cores</td>
</tr>
<tr>
<td>CPU</td>
<td>HMP Dual Denver 2/2 MB L2 + Quad ARM® A57/2 M3 L2</td>
</tr>
<tr>
<td>Video</td>
<td>4K x 2K 60 Hz Encode (HEVC)</td>
</tr>
<tr>
<td></td>
<td>4K x 2K 60 Hz Decode (12-Bit Support)</td>
</tr>
<tr>
<td>Memory</td>
<td>8 GB 128 bit LPDDR4</td>
</tr>
<tr>
<td></td>
<td>59.7 GB/s</td>
</tr>
<tr>
<td>Display</td>
<td>2x DSL, 2x DP 1.2 / HDMI 2.0 / eDP 1.4</td>
</tr>
<tr>
<td>CSI</td>
<td>Up to 6 Cameras (2 Lane)</td>
</tr>
<tr>
<td></td>
<td>CSI2 DP-HY 1.2 (2.5 Gbps/Lane)</td>
</tr>
<tr>
<td>PCIe</td>
<td>Gen 2 1x4 + 1x1 OR 2x1 + 1x2</td>
</tr>
<tr>
<td>Data Storage</td>
<td>32 GB eMMC, SDIO, SATA</td>
</tr>
<tr>
<td>Other</td>
<td>CAN, UART, SPI, I2C, I2S, GPIOs</td>
</tr>
</tbody>
</table>
Real-Time Object Recognition via Deep Neural Network
Real-Time Object Recognition via Deep Neural Network from Drones
Real-Time Object Recognition via Deep Neural Network from Drones
The Same Recognition Model Applied to a YouTube Drone Video

https://www.youtube.com/watch?v=cxyPUpmeXwjjw&list=PLUcnRyRXHsDhqzXSi-3yoo1KifVcv-bq
YoloV2 with darknet pretrained weights

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The Recognition Model Trained With Stanford Pedestrian Data
RAN Slicing Comes Into Play!
5G Mobile Key Performance Indicators (KPI)

- **High Energy Saving**
- **Enhanced Mobile Broadband (eMBB)**
- **Latency (ms) (RAN R.T. delay)**
- **Mobility (km/h)**
- **Capacity (bps/km²)**
- **High Number of Connected Users**

- **Typical User Throughput (bps)**
- **Number of Connected Users**

- **Ultra Reliable and Low Latency Communication (URLLC)**
Implication: Network Slicing for URLLC and eMBB

Object Recognition by DNN
3D Mapping Information

URLLC Slice
Cloud

Edge
5G
Network Slicing

eMBB Slice

Application based Traffic Classification
(RAN Slicing, Machine Learning)

4K 360 degree Video Streaming

The University of Tokyo
Graduate School of Interdisciplinary Information Studies

Graduate School of Interdisciplinary Information Studies
RAN Slicing using OAI
Application Specific RAN Slicing extending FlexRAN

- Each RAN slice has its own RBs and MAC schedulers
- Assign UE to RAN slice at a granularity of UE
Experimental Results

Two App slices: **SpeedTest** and Default

**SpeedTest** Slice is with different percentage of RBs

<table>
<thead>
<tr>
<th>RBs</th>
<th>DL (Mbps)</th>
<th>UL (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2.11</td>
<td>0.94</td>
</tr>
<tr>
<td>6</td>
<td>4.22</td>
<td>1.84</td>
</tr>
<tr>
<td>9</td>
<td>6.38</td>
<td>2.70</td>
</tr>
<tr>
<td>12</td>
<td>8.30</td>
<td>4.36</td>
</tr>
<tr>
<td>15</td>
<td>10.7</td>
<td>5.72</td>
</tr>
<tr>
<td>18</td>
<td>12.8</td>
<td>7.72</td>
</tr>
</tbody>
</table>
Throughput Evaluation

Throughput of *SpeedTest* app

The throughput of both UL and DL is proportional to the number of assigned RBs.
Experimental Results

Two App slices: SpeedTest and Default

SpeedTest Slice is with different percentage of RBs

12RBs (25%)
DL: 8.44Mbps
UL: 4.80Mbps

24RBs (50%)
DL: 17.1Mbps
UL: 10.8Mbps

36RBs (75%)
DL: 24.9Mbps
UL: 15.4Mbps

50RBs (100%)
DL: 33.8Mbps
UL: 19.1Mbps

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Throughput Evaluation

Throughput of *SpeedTest* app

![Graph showing throughput evaluation](graph.png)

Throughput (Mbps)

# Proportion of RBs of *SpeedTest* slice
Experiments (2)

- App Cloner: SpeedTest, SpeedTesu
- SpeedTesu is a clone of SpeedTest, where everything is the same expect appname
Experiments (2)

- With App-specific UE Slicing, different Applications can get different RAN resources even they are on the same UE.
Conclusion

Softwarization stays to become a reality

Complex data processing and flexible network operation will be enabled in programmable softwarized infrastructure

Two Implications:

• Commercial Use Cases Initiated in Rural Areas
  e.g. Local Governments, Agriculture/Fishery IoT

• Academia is now empowered with CRAZY ideas
  e.g. RAN Slicing, Context Slicing, etc.