Internet of Programmable Things for In-Network Data Analytics

The University of Tokyo
Akihiro Nakao
Marriage between Softwarization and Data Analytics

• Flexible infrastructure for sensing/analyzing/learning traffic in data plane
  Data Plane Programmability
  In-Network Machine Learning

• Data analytics for complex actuation (automated agile operation) human may not achieve
In 2021, mobile traffic will amount to 48.3 EB per month.  

1EB = 10^{18}B

Global increase in mobile network traffic

Global increase in data center traffic

1ZB = 1000EB = 10^{21}B

The amount of data that has traversed the Internet since its creation
## Utilization of Mobile / IoT Data

<table>
<thead>
<tr>
<th>Data Type / Field</th>
<th>Project</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location Information</td>
<td>NTT Docomo</td>
<td>Provide population statistics from the anonymized location data of mobile phones</td>
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<td></td>
<td>“Mobile Spatial Statistics”</td>
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<tr>
<td>Automobile Probe</td>
<td>Toyota</td>
<td>Provide traffic information and statistics generated from telematics data for improving traffic congestion and public safety</td>
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<tr>
<td></td>
<td>“Telematics Service”</td>
<td></td>
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<tr>
<td>Automobile Probe</td>
<td>Sony Assurance Inc.</td>
<td>Analyze customers’ telematics record and provide cash back for safety driving</td>
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<tr>
<td></td>
<td>“Telematics Insurance”</td>
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<tr>
<td>Medical Information</td>
<td>NTT Docomo Health-Care</td>
<td>Provide services for improving health and life style by visualize and analyze activity data obtained from wearable smart wrist bands.</td>
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<td></td>
<td>”Moveband3”</td>
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<td></td>
<td>Omron Health-Care</td>
<td></td>
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<tr>
<td></td>
<td>“Wellness Link”</td>
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<tr>
<td>Financial Information</td>
<td>Hitachi</td>
<td>Enable personal asset management across multiple financial accounts</td>
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<td></td>
<td>Financial API Service</td>
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EU-Japan Jointly Funded Project on 5th Generation Mobile Network (PIs: Akihiro Nakao @ Utoyou and Tarik Taleb @ Aalto University)

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

**Our Partners**

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

**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.
Sustainable Development Goals (SDGs) as Common Vision

UTokyo Future Society Initiative


UTokyo FSI promotes SDG-oriented projects in a wide range of fields throughout the University, and showcases them as actions taken by the University as a whole.

In particular, in regards to collaboration with the industrial sector, the University utilizes the SDGs as a basic common vision for new business growth.

As of 2018/4/5, 170 SDGs projects have been registered
https://www.u-tokyo.ac.jp/adm/fsi/ja/projects.html

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“Softwarization Everywhere”
= E2E Programmability

- Softwarized Programmable UE/Sensors
- Softwarized Programmable IoT GateWay
- Softwarized Programmable eNB/EPC/MEC
- Softwarized Cloud Data Centers

Data Analytics Possibility
Data Analytics Possibility
Data Analytics Possibility
Data Analytics Heavily Conducted

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Sliceable Software Defined Data Planes

Applications

Control Plane

Data Plane

Network Applications

Control-Plane Elements

Programmable Data-Plane Elements

AI/ML
- Deep ML
- AI OAM

AI/ML
- ML Offload
- Autonomous OAM
- Annotation
- Sampling
- Characteristics Extraction

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In-Network Machine Learning for Application Identification
JHPCN Project JH170041-NWH @ NakaoLab
The Joint Usage/Research Center for Interdisciplinary Large-scale Information Infrastructures

[Diagram showing the flow of data from Phones With Agents to Traffic Classification, Feature Extraction, Classifier Update, and Deep Neural Machine Learning.]
Application Specific Traffic Breakdown

Chrome  Total  Facebook  Tethering  YouTube

![Graph showing traffic breakdown for Chrome, Total, Facebook, Tethering, and YouTube.](chart.png)

Days and times include: Tue 4PM, Tue 8PM, Wed 12AM, Wed 4AM, Wed 8AM, Wed 12P.

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Application-Specific Bandwidth Control (FLARE and P4)

Youtube (mediaserver): 3Mbps
Chrome 2Mbps
android.browser: 500kbps
Association between **Low-Level** Operation Data and **High-Level** Application Identification
Softwarized Base Station For Data Analytics

**Conventional Approach**

- **eNB**
  - RRC
  - PDCP
  - RLC
  - MAC
  - PHY

- **CPU**

- **DSP/FPGA**

**Our Approach**

- **eNB**
  - RRC
  - PDCP
  - RLC
  - MAC
  - PHY

- **EPC**
  - SP-GW
  - MME
  - HSS

- **MEC**
  - Service

**Challenges**

- Processing power for complex data handling
- Stable operation especially fluctuation in latency
- Sharing computational resources with network function virtualization

**Data Analytics Possibility**

- Offload complex processing to FPGA and DSP
- Softwarization of all digital signal processing

- Sharing H/W resources among eNB, EPC and MEC
OAI Field Experiment on Hongo Campus Collaboration with Fujitsu

Experimental License @1.7GHz


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LTE Softwarized Base Station

- Connect 10UEs
- DL Throughput: 15Mbps
- UL Throughput: 5Mbps
- Continuous Operation: Over 24+ hours
Preliminary Experimental Results

**5MHz**
- DL: 8.44Mbps
- UL: 7.99Mbps

**10MHz**
- DL: 14.91Mbps
- UL: 12.44Mbps

**20MHz**
- DL: 67.27Mbps
- UL: 13.88Mbps

- The experimental network is deployed on LTE-FDD Band3 (1.7GHz) to avoid interfering with other carriers (Docomo/au/softbank).
- Throughput was measured with SpeedTest Application running on a Fujitsu’s Arrows M04 Android phone.
Collecting Operation Data in Real Time

- Operation Data from Softwarized Base Station

Insert 40 hook points in software
Realtime monitoring of throughput and signal strength in KIBANA
GDPR

The EU General Data Protection Regulation (GDPR) is the most important change in data privacy regulation in 20 years - we're here to make sure you're prepared.

What constitutes personal data?
Any information related to a natural person or ‘Data Subject’, that can be used to directly or indirectly identify the person. It can be anything from a name, a photo, an email address, bank details, posts on social networking websites, medical information, or a computer IP address.

https://www.eugdpr.org/eugdpr.org.html

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50% of citizens share data by 2019: Gartner

Gartner predicts that by 2019, 50 percent of citizens in million-people cities will benefit from smart city programs by voluntarily sharing their personal data.

Predicts 2017: Government CIOs Are Caught Between Adversity and Opportunity
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Challenges

• Flexible (data plane) Infrastructure
  • Machine Learning Offload
  • Autonomous OAM
  • Annotation
  • Sampling
  • Characteristics Extraction

• In-Network Machine Learning

• Sensing / Inference without privacy violation
  • Operational Data
  • Traffic Data
  • Social Network Application Data

• Viable Use Cases