Fog Computing for 5G/IoT Developments

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Cloud Alone Can’t Support IoT, 5G, AI, ...

- Big Data at Things and Edges
- Delay Requirements
- Devices That Require Local Support
- Network Connectivity
- Network Bandwidth

Cloud-Edge-Thing
Service/App Interoperability

Horizontal
Service/App Interoperability

IT-OT-CT
Convergence

Courtesy of Tao Zhang
Industries Race Toward the Users

Moving Content to the Edge

Courtesy of Tao Zhang
Industries Race Toward the Users

CDN, Web Caching

Edge Computing

- Computing to Enterprise Edges
- Computing to Mobile Edges
- Computing to Wired Telecom Edges

Siloed Solutions
Isolated Edge Systems/Apps
Massive Confusion

Courtesy of Tao Zhang
Industries Race Toward the Users

CDN, Web Caching

Edge Computing

Cloud - Local Nodes

Proprietary or Open Architectures?

 Courtesy of Tao Zhang
The Era of Fog Computing Arrives

Horizontal architecture for distributing functions closer to users along the cloud-to-thing continuum

Courtesy of Tao Zhang
Small Company vs. Big Company

Small Company

Managing Director

- Chairman
- Operations (Projects)
- Technical (Quality, R&D)
- Personnel
- Finance

Big Company

Board of Directors

Managing Director

Company Secretary

- Director Finance
- Director Administration
- Director Planning
- Director Forestry Management
- Director Projects
- Director Engineering

- Director Audit & Assurance
- Financial Controller
- Investment Manager
- Monitoring & Evaluation Manager
- Manager Project Implementation
- IT/Prepaid System Engineer
- Manager Distribution
- Commercial Manager

- Finance Manager
- Accounts Officer
- Investment Manager
- Monitoring & Evaluation Manager
- Manager Project Implementation

- Human Resource Manager
- Logistics Manager
- Corporate Affairs Manager
- Pole Plant Manager
- Agro Forestry Manager
- Project Engineers
- Concession Area Managers
- Technical Manager

- Human Resource Officer
- Procurement Officer
- Stores Officer
- Transport Officer
- Support Staff

- Support Staff
- Support Staff
- Support Staff
- Support Staff
- Support Staff
People-centric network vs. IoT-oriented network

4 billion connected people

Gartner forecasts that 8.4 billion connected things in 2017, and 20.4 billion by 2020.
Fog Computing is the Future

Internet of Things
Seeking to connect more things and provide more services/applications

Fog Enables Computing anywhere along the Cloud-to-Thing Continuum
Cloud, Fog, Edge and Things

Cloud

Channel
Communication Network

Edge

Things
vertical Industries

Transmission

Cloud

Fog

Edge

Smart transportation
Vehicle network
Cellular networks

Intelligent manufacturing
Smart airport

SHIFT Shanghai Institute of Fog Computing Technology
Fog and Edge: a closer look

Fog is a superset of Edge Computing

 Courtesy of Mung Chiang
Use Case:
5G/IoT Applications
5G Technical Requirements

- Can **one** 5G network satisfy **all** diversified requirements?
- How to make 5G networks super flexible and adaptive?
TIP, February 22, 2016

- The Telecom Infra Project (TIP) is an engineering-focused initiative driven by operators, infrastructure providers, system integrators and other technology companies that aim to reimagine the traditional approach to building and deploying telecom network infrastructure.
- Focus areas: access, backhaul, and core and management.
- Open and collaboration!

<table>
<thead>
<tr>
<th>Members (growing)</th>
<th>AMN</th>
<th>ACACIA</th>
<th>IP access</th>
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<tbody>
<tr>
<td>ADVA</td>
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<td>Coriant</td>
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<td>Equinix</td>
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<td>Harman</td>
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<td>HCL</td>
<td>SK Telecom</td>
<td>iDirect</td>
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<td>Starsolutions</td>
<td>Sysmocom</td>
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<tr>
<td>Intel</td>
<td>Indosat</td>
<td>Telefonica</td>
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</tbody>
</table>
Google: target at 5G networks

- Google is partnering with leading mobile network operators globally to build a platform for operators to run their network services.
- Google will bring their expertise in SDN, NFV and Cloud to the carrier ecosystem, thus accelerate the transition to 5G and enable new features such as the application of machine learning.
- The platform will provide plenty of APIs which will enable new operational models and help operators bring new features.
- The platform is based on commodity hardware instead of dedicated hardware provided by telecom manufacturers.
Google Edge Nodes
Intel’s 5G Strategy

• Provide a full suite of products for covering almost every part of the new networks that will all seamlessly interact

• 5G networks will have to be designed to be more flexible, relying on software that can be reprogramming to handle different tasks running on more generic hardware, instead of being built on more customized hardware dedicated to specific tasks

• Links between different parts of the 5G network all made by Intel will be able to interact more efficiently and quickly, while Intel software gives users a smooth experience
Intel 5G Modem (Codenamed GoldRidge)
5G Stand-alone and Dual-connectivity

- World’s first global 5G modem with ultra-high throughput operation and low latency
- Operation in both sub-6 GHz and mm-Wave bands with compact chip kit
- Pairs with the world’s first 5G sub-6 GHz and 28 GHz RFICs
- Supports key 5G NR technology features, including low latency frame structure, advanced channel coding, massive MIMO and beamforming
- Pairs with LTE modems such as Intel’s XMM™ 7360 LTE modem for 4G/5G dual connectivity
Qualcomm: maintain its Modem and RFFE leadership in 5G era

• Qualcomm’s 5G vision: a unifying connectivity fabric, including enhanced mobile broadband, Mission-critical services, Massive Internet of Things

• Qualcomm has a strong background of wireless communication technology and mobile chipset design base on ARM architecture

• Qualcomm is driving 4G and 5G in parallel to their fullest potential, pushing LTE towards 5G with its end-to-end system approach

• Qualcomm announces X16 and X50 modems for Gigabit LTE and 5G Connectivity
5G Vision: GPP-based Platform

- Software defined mobile network and resource/network function virtualization could meet different diversified 5G use cases and business models, i.e. eMBB, mMTC and uMTC.
Motivation: Flexible and Adaptive

- To decouple software and hardware designs
- To realize flexible deployment of network functions

Current: Dedicated Hardware Platform
Future: GPP-based Platform
Dedicated accelerations with FPGA and DSP

Virtualization of baseband resources

Source: Alcatel-Lucent Shanghai Bell
Facebook OpenCellular: an Open Source Wireless Access Platform

- **Radio**: Radio with integrated front-end, which is based on SDR/SoC and supports network-in-a-box or access point.
- **GBC**: General Baseband Computing
- **Function**: SMS messages, voice calls, basic data connectivity using 2G implementation.

Source: Facebook
it is a just mini PC

Intel NUC 5i7RYH
Core i7-5557U
3.1 GHz-3.4 GHz
Dual-core
4 MB cache
Price: < 600 USD

Futuremark PCMark 7
Overall PCMark Score
Intel NUC5i7RYH - Core i7-5557U
Higher Scores = Better Performance

<table>
<thead>
<tr>
<th>Processor</th>
<th>Score</th>
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<tbody>
<tr>
<td>Intel Core i5-4670K</td>
<td>6401</td>
</tr>
<tr>
<td>Intel NUC NUC5i7RYH (i7-5557U)</td>
<td>5515</td>
</tr>
<tr>
<td>Intel Core i5-3470</td>
<td>5379</td>
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<tr>
<td>Intel NUC5i5RYK (i5-5250U - Samsung SSD)</td>
<td>5268</td>
</tr>
<tr>
<td>Intel NUC5i5RYK (i5-5250U - Intel SSD)</td>
<td>5139</td>
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<tr>
<td>AMD A10-6800K</td>
<td>4585</td>
</tr>
<tr>
<td>Intel NUC DC3217BY (i3-3217U)</td>
<td>3483</td>
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</tbody>
</table>

Source: Internet
You think it is a just mini PC

Intel NUC 5i7RYH
Core i7-5557U
3.1 GHz-3.4 GHz
Dual-core
4 MB cache
Price: < 600 USD

- eNodeB
- EPC

Radio Access Network (RAN)
Core Network (EPC)

Source: Internet

External Network

SGW
PGW
MME
PCRF

SHIFT
Shanghai Institute of Fog Computing Technology
Software Defined Mobile Network

- Based on OAI open-source LTE platform
- Real-time software defined LTE network (including RAN and EPC) on a multi-core GPP-based platform
- FDD and TDD modes
- Support multiple commercial LTE mobile terminals for each eNB
- Support video streaming and web browsing traffic
Delay of baseband signal processing

- TD-LTE uplink and downlink on a GPP-based platform;
- Multi-core parallel computing achieves real-time requirements.

Source: China Mobile
Delay of baseband signal processing

- **Our GPP-based platform:** IBM System x3400 M3 with 2.13GHz CPU, quad-core Intel Xeon E5606, 4G RAM, 256G HDD, Linux Debian 7 OS with the version 64 bits Ubuntu 14.04 DeskTop.
- **Turbo decoding** is the bottleneck for real-time processing.

<table>
<thead>
<tr>
<th>Function</th>
<th>Rate (Mbps)</th>
<th>Processing Time(µs)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2.152</td>
<td>8.76</td>
</tr>
<tr>
<td>De-scrambling</td>
<td>7.96</td>
<td>21.93</td>
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<tr>
<td>De-modulation</td>
<td>7.89</td>
<td>13.72</td>
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<tr>
<td>De-interleaving</td>
<td>6.27</td>
<td>30.19</td>
</tr>
<tr>
<td>Turbo decoding</td>
<td>113.44</td>
<td>465.01</td>
</tr>
</tbody>
</table>
Network Slicing for Various Use Cases

- **Open Source Software:** to build a collaborative community and ecosystem for innovations in EPC, eNB and terminals.
- **GPP-based Hardware:** to replace dedicated hardware (e.g. ASIC), thus enabling flexible and adaptive service creations and deployments for various use cases and business models.
Fog-enabled 5G Platform

- GPP-based platform to realize software defined EPC and eNB BBU
- CPRI between BBU and RRU
- FPGA/DSP Acceleration
Chapter 2: ShanghaiTech Fog Node

- Four Intel core
  i7-4700EQ CPU
- 16GB DDR3
- 240G SSD
- 2TB HDD
- USRP B210 RF Module

- F-RAN
- Auto-driving
- Robots
- Fog Application Support
- Linux OS, SDN-eNB, SND-EPC, node & service discovery, node management software Virtualization, software Container
- Inter i7 CPU, USPR, RF HW, FPGA, Sensor/Actuators/Cameras...
Chapter 2: ShanghaiTech Fog Node

- Highly aligning with OpenFog Reference Architecture
- Fog application support: management, storage, etc

Platform Hardware

Application Services

Node Management (IB) & Software Backplane

Application Support

F-RAN

Auto-driving

Robots

Fog Application Support

Linux OS, SDN-eNB, SND-EPC, node & service discovery, node management software Virtualization, software Container

Inter i7 CPU, USPR, RF HW, FPGA, Sensor/Actuators/Cameras...
OpenFog Testbed for 5G/IoT R&D

LTE + 5G hierarchical network architecture
- 6 macro-cell base stations
- 10~20 micro-cell base stations
- 100+ small base stations
- Trial of GPP-based BSs

802.11ac high speed WLAN
- 100~200 outdoor APs
- 1000~10000 indoor APs
- UDN, multi-carriers
- Trial of GPP-based APs

ShanghaiTech University
LTE+5G macro-cell BSs
802.11ac outdoor APs
Fog-enabled 5G Platform for Various Vertical Applications

- Business Platform
- Monitor Center
- Data Analysis
- Network Management
- Autonomous Car
- Video Surveillance
- Environment Monitoring
- Smart Grid
Join the OpenFog Consortium!

Thanks you!

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ShanghaiTech University

FOXCONN

ZTE

Nanyang Technological University

The Chinese University of Hong Kong

Institute for Information Industry

Industrial Technology Research Institute

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
GCR Web Site and WeChat Publicity ID

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4月24日，国际雾计算产学研联盟大中华区研讨会，上海科技大学
SHIFT @ ShanghaiTech University

- **SHIFT**: Shanghai Institute of Fog Computing Technology
- http://shift.shanghaitech.edu.cn
We are recruiting: Tenure-Track & Tenured Faculty Positions in Fog Computing

ShanghaiTech University invites highly qualified candidates to join our newly established Shanghai Institute of Fog Computing Technology (SHIFT), which is a joint lab between ShanghaiTech University and Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, to lead the following research areas in fog computing and networks.

- Fog computing architecture and theory
- Big data processing in fog computing
- Security in fog computing
- Low-power sensors for fog computing
- Fog computing for Internet-of-Things (IoT)
- Next-generation communication with fog computing
- Fog computing test-beds

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