Intelligent IoE Fog Networking technologies based on ICN

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Agenda

1. Introduction
2. Related Work
3. Requirement & Principles
4. Proposed Intelligent Framework
5. Prototype & Applying case
6. Summary
1. Introduction (1/3)

• **Service aspects**
  
  – AI service appeared as the core of the 4th industrial revolution
  
  – Attempts to enter AI service for each service domain

  • AI technology for image recognition, speech recognition, Go, etc. is superior to human

  • AI technology shows good performance even in creative field such as art, music, literature
1. Introduction (2/3)

- **Network aspects**
  - **Massive devices, Mobile oriented, Massive traffic**
  - **Constrained device size, Real-time & Reliable comm.**
1. Introduction (3/3)

• **Service + Network aspects**
  – Attempt to apply AI in network domain
  – Try with two perspectives
    • Supporting AI domain services well
      – Fog / Edge computing for data and computing of AI
      – Name based ICN for processing large data at network level
    • Using AI technique itself to improve network performance
      – AI-based network intelligence
      – Intelligent network management, configuration, control, etc
2. Related work – Fog/Edge Computing (1/3)

• Why Fog/Edge Computing?

Cloud-computing at the network edge.

- Proximity
- Ultra-low latency
- High bandwidth
- Real-time access to access network and context information
- Location awareness

<Ref. ETSI MEC Overview>
2. Related work – Fog/Edge Computing (2/3)

• **Benefit of Edge/Fog Computing**
  
  – Quality of Experience
  
  – Contextualized services
  
  – Efficient utilization of the Radio and the Network resources
  
  – Innovative applications and services towards mobile subscribers, enterprises and vertical segments
2. Related work – Fog/Edge Computing (3/3)

- **Edge/Fog computing vs. cloud computing**

  - **Cloud Data center**
    - Exist in Core
    - Multiple high-end servers
    - Processing and storing an enormous amount of data

  - **Edge/Fog computing layer**
    - Exist in the edge network
    - Comprise of devices
    - Process, compute, temporarily store data
    - Responsible for sending data to Cloud

  - **Smart Things**
    - Exist in proprietary network
    - Sense or generate data
    - Transmit the data to its nearest layer

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2. Related work – ICN (1/3)

• **Why ICN (Information-Centric Networking)?**
  – The estimated video traffic will reach 79% of the Internet traffic by 2018
  – Content distribution is the primary task for today’s Internet
  – Traditional paradigm of communication network is end-to-end, i.e. host-centric
  – End-to-end has many drawbacks when dealing with large scale content distribution, efficiency, security and privacy
  – Paradigm shifts from host-centric to content-centric
    • Content consumer only cares what it is instead of where it is from

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2. Related work – ICN (2/3)

- **Characteristic of ICN (Information-Centric Networking)**
  - ICN is a clean-slate redesign of the current Internet infrastructure
  - Communication object (CO) is accessed by name
    - CO includes a content, a device, and a service
  - ICN enables in-network caching
    - so that content is distributed in a scalable, cost-efficient and secure manner
  - Reasonable solution for low-latency & massive IoT

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2. Related work – ICN (3/3)

- **Benefit of ICN (Information-Centric Networking)**

  \[<As Is>\]
  \[
  \text{Server bottleneck with concentrated on contents in current IP environment}
  \]

  \[<To Be>\]
  \[
  \text{Transfer Content without Server bottleneck in ICN environment}
  \]
3. Requirements & Principles (1/2)

• General Requirements
3. Requirements & Principles (2/2)

• **Design Principles**

- ICN based communication for Inter-networking
- Applied Fog concept to Edge network as domain network
- Information centric reliability support (Information security and privacy)
- Domain specific networking structure
- Name and Information centric Mobility Support
- IP core network consideration
- Global Testbed

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3.1 Considerations for IoE

• **When the IoT data generated is**
  – Delay-sensitive
  – High-volume
  – Trust-sensitive
  – (Intermittently) Disconnected

• **Countless examples**
  – Both near term & further out

- Video Analytics
- Augmented Reality

- Data heavy
- Compute intensive
- **Response times <30ms**
- Small form factor
- Low power

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3.2 Considerations for Information

Edge Cloud for information

Physical sensors

Raw Data
- Sensing data
- Single unit data
- Time series data
- Common value

Information
- Pre-processing data
- Adding Extra value
- Simple data analysis

Centralized Cloud

Knowledge
- Processing Information
- Meaningful data
- Deep analysis
- Common knowledge

Service domains

Wisdom
- Applying Knowledge
- Dedicated knowledge for a specific service

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4. Proposed Intelligent Framework

self-learning Knowledge-converged Super Brain (KSB)

1. Collect data with status
2. Refine the collected data
3. Machine learning · knowledge extraction
4. By inferring · optimizing by fusion with domain expert knowledge
5. Provision of prediction, prevention and optimization intelligence

※ KSB : Knowledge-converged Super Brain
4.1 Proposed self-learning platform

All-around cross-domain knowledge convergence self-learning engine platform

- to refine and self-learn the multimodal data collected from the IoE network, extract the knowledge,
- to provide knowledge inference and optimized domain intelligence services by merging with domain knowledge

Cross-domain Data to Knowledge

Application Developer Interface
Workflow Orchestration
Data Ingestion & Analytics Pipeline

Device | Data Mart | Big data Analytics Engines

Domain-agnostic & Specific Libraries, knowledge accumulation

kwihooi@etri.re.kr (Concept)
4.2 Proposed Fog/Edge Platform

• A novel Domain networking architecture
  – ICN based communication
    • CICN based Implementation
    • IP and ICN interworking with CICN
  – Fog/Edge computing concept
    • Define of specific purpose nodes
      – Gateway node, networking, storing, computing, Information process,
  – Intelligence
    • Intelligent Information analysis
      – Applying ML

* CICN(Community ICN) : ICN open source made by CISCO(formerly Parc CCNx)
4.2.1 Basic ICN vs. Proposed Fog

- **Consumer**
  - Interest to "/etri/7th/temp"
  - Name Routing
  - Scale/Mobility management
  - Consumer

- **ICN Network**
  - Name Routing
  - Content Object "/etri/7th/temp/24°C"

- **Producer**
  - Interest to "/etri/7th/temp/24°C"

- **IP Network**
  - Content Object "/etri/7th/temp" as Name
  - Interest to "/etri/7th/temp" as Name

- **Intelligent IoE Fog Networking Platform**
  - Info. Sync.
  - Producer

- **Intelligent IoE Fog Networking Platform**
  - Producer


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4.2.2 Information Process

- IoE data preprocessing
  - Classification of IoE information types (application types)
    - Classification of Content Object by CNN and RNN
  - Applying cache strategies
    - E.g., mission critical information must be push to Cloud or consumer directly without cache

- Interest analysis
  - Develop filter rules
    - Name based filter
  - Applying cache strategies
    - Prefetching Information
    - Decision of Cache rules
5. Prototype & Applying case

- 1. Information prefetching: Considering Autonomous network control aspects
- 2. Mobile Crowd Sensing: Considering Intelligent Application service aspects
- 3. Smart Construction: Considering Both Autonomous network control & Intelligent Application service aspects
5.1 Applying case – Information prefetching (1/4)

• Purpose
  – Proposed Fog vs. basic CICN performance comparison
  – KPI: Information acquire time & packet loss ratio

• Testbed setup
5.1 Applying case – Information prefetching (2/4)

- Basic CICN architecture

- Proposed architecture (Information prefetching)
5.1 Applying case – Information prefetching (3/4)

- Result

CICN(Prefetching off)  Proposed Fog(Prefetching on)
5.1 Applying case – Information prefetching (4/4)

• Summary
  – Light traffic: transfer 100 interest per every 1 sec
  – Heavy traffic: transfer $10^7$ interest per every 100 usec

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<thead>
<tr>
<th></th>
<th>CICN</th>
<th>Proposed Fog</th>
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<tbody>
<tr>
<td></td>
<td>Light</td>
<td>Heavy</td>
</tr>
<tr>
<td></td>
<td>56 msec</td>
<td>786 msec</td>
</tr>
<tr>
<td></td>
<td>28 msec</td>
<td>30 msec</td>
</tr>
<tr>
<td>Info. Query time</td>
<td>0%</td>
<td>42%</td>
</tr>
<tr>
<td>Packet loss ratio</td>
<td>0%</td>
<td>0%</td>
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5.2 Applying case – Mobile crowd sensing (1/4)

- **Purpose**
  - Implementation of ICN based Mobile Crowd Sensing
  - characteristic: Mobile Fog & without IP

- **Testbed setup**

  - ETRI building #7, 3rd Floor Lab
    - Raspberry Pi 3 + DHT22
      - (Temperature, Humidity sensor)
      - CICN installed
    - BLE beacon
      - Beacon ID 1FD2BD

  - ETRI building #7, 1st Floor Lab
    - Raspberry Pi 3 + DHT22
      - (Temperature, Humidity sensor)
      - CICN installed
    - BLE beacon
      - Beacon ID 1FD2BD

- Clients

**Diagram:**

- ETRI building #7, 3rd Floor Lab
  - Raspberry Pi 3 + DHT22
    - BLE beacon
      - Beacon ID 1FD2BD
  - Mobile Fog
    - CICN installed
5.2 Applying case – Mobile crowd sensing (2/4)

• Basic MCS architecture
  – **Crowdsourcing** of sensor data from Mobile devices

• Proposed Mobile Fog based MCS architecture
  – Acquire data from Mobile Fog device
  – Only transfer Data analysis result to Central Cloud
    • small amount of volume
5.2 Applying case – Mobile crowd sensing (3/4)

- Result

- Mobile Fog

- 3rd Floor Lab Visit

- Movement

- 1st Floor Lab Visit

- 3rd Hum.

- 3rd Tem.

- 1st Hum.

- 1st Tem.

screen of client (3rd Floor)

screen of client (1st Floor)
## 5.2 Applying case – Mobile crowd sensing (4/4)

- **Summary**
  - New MCS based on proposed fog architecture
  - Service implementation **based on Ethernet connectivity using ICN** (without IP)
  - Data collection **based on local area** using BLE beacon

### Table: Mobile Crowd Sensing vs. Propose Fog based MCS

<table>
<thead>
<tr>
<th></th>
<th>Mobile Crowd Sensing</th>
<th>Propose Fog based MCS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Connectivity</strong></td>
<td>• IPv4/IPv6, TCP/UDP, HTTP/CoAP</td>
<td>• Ethernet, ICN App.</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td>• Cloud based data collection</td>
<td>• Fog node based data collection</td>
</tr>
</tbody>
</table>
5.3 Applying case – Smart construction

• Purpose
  – Implementation of monitoring service of construction
  – Characteristic: scalable media data transfer based on alarm
    * We plan to co-work with HECAS (Korean vendor)

• Testbed setup

Bundang-gu, Sungnam-si, Kyunggi-do, Korea
6. Summary

- **Data are transformed into wisdom through the IoE computing architecture including Intelligent Fog networking platform.**
  - We assume that huge amount of sensed data are generated from smart things, and these data may be formed as single unit data, time series data, or meaningless digits.
  - Firstly these data are **processed or analyzed at the Fog platform**, so that the result of analysis may be transmitted to Cloud.
  - After then accumulated **these pre-analyzed data as called information** are again processed to make **common knowledge**.
  - Finally, the common knowledge will be applied to **specific IoE service domains as the wisdom**.
Thank you.

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