An Architecture of a Network Controller for QoS Management in Home Networks with Lots of IoT Devices and Services

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IoT Services in Home

- So many use cases are proposed
  - Energy monitoring and management
  - Home Security
  - Remote control of home appliances based on users’ lifestyle
  - Health management

- Our focus: Cloud-based IoT services
Too Much Traffic by Many Services

Potential Congestion
Caused by
- Too much traffic by devices and services
- Temporal quality degradation of Wi-Fi, Internet connection, etc
Handling Congestion

- Once congestion happens,
  - Data may not be delivered to destinations timely
  - Quality of Life (QoL) of the users is degraded
    Users cannot enjoy services that they need to use

- QoS has been applied to prioritize certain types of traffic
  - Latency, bandwidth, etc
    - Implemented by IntServ, DiffServ, SDN, etc
  - QoS in IoT can be thought as broader than network term, such as data accuracy, timeliness, etc [Li 2014]

- Applying QoS to IoT traffic in home could improve QoL
Problem to apply QoS to IoT Traffic in Home

- Which and how traffic should be prioritized?

- It depends on
  - Devices – What kind of data each device sends/receives?
  - Services – Which data is more important to provide service?
  - Users – How do users think importance of each service?

- No one has enough knowledge to decide
  - Usually no skilled administrator manages the home network
  - Details on devices and services are hidden from users

We cannot apply QoS to IoT traffic in home, because we cannot know which traffic should be prioritized
Contribution

- Propose an architecture of the controller for applying QoS to IoT traffic in a home network without skilled administrator
  - Key is to design interfaces for IoT devices, service providers, and users *separately*
  - Controller decides which traffic is important

- Simple prototype implementation based on architecture
- An example use case scenario
Related Work

- IoT Platforms for data exchange have standard ways to describe devices on the platforms
  - FIWARE – Define devices through device registration
  - W3C Web of Things (WoT) – Thing Description

- Both are based on Entity – Attribute – Value model
- We reuse the model as much as possible, and make minor modifications for network control

- Implementation of QoS has been extensively studied for last 10+ years
  - Traffic Engineering, Traffic Shaping/Policing, Scheduling, etc.
  - We use existing mechanisms for applying QoS to traffic. Our focus is how QoS parameters should be configured.
Environment Assumption: Where and How Controller Works

Controller: Configure networking devices to deploy QoS based on device/service/user/network status.
(Optional) Feedback to devices and services.

Input to Controller

No one knows the overall situation, but each party knows partial information that is related to

<table>
<thead>
<tr>
<th>Know</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IoT Devices (Device Vendors)</strong></td>
<td></td>
</tr>
<tr>
<td>Device Details (Traffic volume, Choices of data types)</td>
<td>How data is used Importance of data</td>
</tr>
<tr>
<td><strong>Services (Service Providers)</strong></td>
<td></td>
</tr>
<tr>
<td>Importance of data for providing the service</td>
<td>Importance of services for the life of users</td>
</tr>
<tr>
<td><strong>Users</strong></td>
<td></td>
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<tr>
<td>Importance of each service</td>
<td>Implementation details on services and devices</td>
</tr>
</tbody>
</table>

Controller provides different interfaces for each party to receive the partial information
Proposed Controller Architecture

API for Devices
Data types that each device can send/receive

API for Services
Importance of data from service’s view

API for Users
Importance of services from user’s view

Controller

Overall Priority Estimation
(Device, Data Name, Src/Dest, Overall Priority)

QoS Implementation

Admission Control, Bandwidth Control, Scheduling, etc

Networking Devices

Feedback

Devices / Services

2019/1/13
Things to Consider When Designing API

- IoT data exchange platforms, like FIWARE
  - Data is transferred via the platforms
  - Destination visible at the home gateway is the platform

- Cloud-integrated Devices:
  - Device interacts with cloud services when it accepts a request

Coflow [Chowdhury 2012] in IoT
API Design at a Glance

- **API for Devices**
  - Properties and Commands that a device provides
  - Destination (if autonomously sending data to others, e.g. FIWARE)
  - IoT Coflow (properties/commands, destination)

- **API for Services**
  - (User, Device, Property, Service Endpoint (URL, IP address, etc), Priority to provide service)
  - Service Endpoint can be keywords, e.g. FIWARE
    - Controller internally translates to pre-configured URL

- **API for Users**
  - (Service, Priority of Services for their life)
  - Devices owned by Users, and Device Endpoint (IP address, etc)
Prototype Implementation

- All types of priorities in three levels (tentative)
- Overall Priority Estimation:
  - Prioritize traffic to provide service that are important for users
- Currently limited to admission control
An Example Use Case Scenario

Controller

Home

Cloud Services

Companion Robot
- Retrieve text of speech from robot
- Send text to speech to robot based on the text of speech and facial expression (Picture)

Home Monitoring
- Retrieve pictures from multiple cameras, and find suspicious activities
- Picture (by B) is less important than Picture (by A and C) because area covered by B overlaps with A and C

Text of Speech
Text to Speech
Picture

Picture (by A)
Picture (by B)
Picture (by C)
An Example Use Case Scenario

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We want to use robot

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Text to Speech
Picture

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We are going out, so prioritize home monitoring

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Insufficient Bandwidth to deliver pictures from three cameras

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Concluding Remarks and Future Work

- Traffic should be controlled in home network where many IoT devices and services are deployed
- Problematic because no one knows which traffic is important
- Our controller architecture try to solve the problem by:
  - Receive partial information from parties involved
  - Automatically estimates the overall priority of each traffic

Future work
- More sophisticated estimation algorithm
- Verification of appropriateness by real applications
  - API, priority, etc
- More solid prototype implementation for deployment