Personalizing the Home Network Experience using Cloud-Based SDN

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Overview

- This paper is about service management

- Empowering home network user to;
  - Self-customize the network experience
  - Service personalization
  - e.g. father’s laptop prioritized over kid’s iPad

- Using SDN-enabled architecture
  - Abstract the network, Simplify and
  - Exposed via automated interface
Motivation: Home Network

- Complexity
- Array of connected devices (e.g. tablets, smart phone, TV, game console, wearable devices and gadgets)
- Diverse requirements of different devices/applications
- Limited resources at access network
- Concern of activity online (e.g. Kids)
Challenges

- Indeed users want control!
  - But typically are unskilled
  - “Automated self-provisioning” is a key point

- Some featured home gateways allow customization
  - Requires user sophistication
  - Static and non-uniform solutions
  - Not address the bottleneck link coming into home

- ISP is best positioned, but:
  - Managed services require manual configuration
  - Traffic discrimination may raise “net neutrality” issue
  - Invisible into home network (NAT)
Use-cases

- **Enhanced QoE for:**
  - Streaming video (e.g. YouTube)
    - Large share of downstream Internet traffic
    - Suffering of variable bandwidth available
      - Start-up delay and rebuffering
  - Video conferencing (e.g. Skype)
    - Becomes popular means of communication
    - Interactive communication; more sensitive
      - Loss, latency, and bitrate

- **Parental control for:**
  - Web content (e.g. social networking)
  - Need of dynamic and customized
    - Based on age of kids, values, priorities
    - E.g. restriction of web access while studying or social networking for elementary years
**System Architecture**

- **Front-end user agent**
  - Hosted on the cloud

- **Back-end SDN (switch, controller, ISP agent and APIs)**

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**Diagram: System Architecture**

- **Home Network**
  - Home Gateway

- **ISP Network**
  - Access Switch
  - Network Controller

- **Home agent**
  - (User Interface)

- **Internet**
  - APIs

- **User’s policy**
Operational Scenario

- Device specific, high-level demand (policy) is taken via UI
- Translated into low-level network semantics
- Communicated to network controller
- Applied into the switch

<table>
<thead>
<tr>
<th>id</th>
<th>owner</th>
<th>type</th>
<th>Slicing</th>
<th>BW %</th>
<th>Block Facebook</th>
<th>Sniff</th>
<th>Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dad</td>
<td>Laptop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Family</td>
<td>GoogleTV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>update1</td>
</tr>
<tr>
<td>3</td>
<td>Son</td>
<td>Laptop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>update2</td>
</tr>
<tr>
<td>4</td>
<td>Daughter</td>
<td>iPad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>update3</td>
</tr>
<tr>
<td>5</td>
<td>Mum</td>
<td>Desktop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>update4</td>
</tr>
</tbody>
</table>

add new device
APIs

- **Bandwidth assurance**
  - "Policy": "minBW"
  - "Device_ID": "MAC"
  - "rate": X (minimum rate of queue)
  - Creates/updates a queue on the switch and pushes the flow into the respective queue

- **Parental Control**
  - "Policy": "PC"
  - "Device_ID": "MAC"
  - "black-list": {IPaddr1, IPaddr2, .. }
  - creates static flow that drops all traffic originating from the pre-defined range of IP block destined to the related device
Prototype

- **Home Agent**: the web portal runs as a standard HTML web-site, and is served by an off-site web-server run by ISP

- **ISP Agent**: runs as a java program on an internal ISP server, communicating over HTTP with the Home agent
Experimental Evaluation

- **Test suite:**
  - Skype video call
  - Pytomo tool
    - open-source YouTube crawler and analyzer
  - MOS measurement for an HD video

- **Network condition:**
  - No b/g load
  - Light b/g load
  - Medium b/g load
  - Heavy b/g load (aggressive IDM)
  - Heavy b/g load with service assurance
Skype: technical metrics

<table>
<thead>
<tr>
<th>Condition</th>
<th>Bandwidth (Kbps)</th>
<th>Frame Rate (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No load</td>
<td>3 ms</td>
<td>10^3</td>
</tr>
<tr>
<td>Light load</td>
<td>86 ms</td>
<td>10^2</td>
</tr>
<tr>
<td>Medium load</td>
<td>686 ms</td>
<td>10^1</td>
</tr>
<tr>
<td>Heavy load</td>
<td>1331 ms</td>
<td>10^0</td>
</tr>
<tr>
<td>Heavy load + Slicing</td>
<td>2 ms</td>
<td>10^{-1}</td>
</tr>
</tbody>
</table>
Skype: visual perception

- No b/g load
- Heavy b/g load
- Heavy b/g load with service assurance
<table>
<thead>
<tr>
<th>Metric</th>
<th>No load</th>
<th>Heavy load</th>
<th>Heavy load + Slicing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average playback duration (s)</td>
<td>203.7</td>
<td>128.9</td>
<td>172.1</td>
</tr>
<tr>
<td>Average startup delay (ms)</td>
<td>4.6</td>
<td>511</td>
<td>0.646</td>
</tr>
<tr>
<td>Average buffering duration (s)</td>
<td>0</td>
<td>0.994</td>
<td>0</td>
</tr>
<tr>
<td>Average initial bitrate (kbps)</td>
<td>4955</td>
<td>1149</td>
<td>3924</td>
</tr>
<tr>
<td>Number of interruptions</td>
<td>0</td>
<td>11</td>
<td>0</td>
</tr>
</tbody>
</table>
The MOS value gradually drops while more loads are introduced to the network.

The last row shows how the user can benefit from managed service quality realizing similar performance as no load.

Indeed, this QoE improvement comes at the cost of slowing down the other unimportant downloads.
Parental Control:

- FaceBlock!
  - Used the publicly available block of IP addresses provided by Facebook to populate a blacklist
  - Enable/disable static flows instructing the switch to drop the associated flows
  - Once enabled, the blocking takes place immediately
Conclusions and Future Directions

- Access network remains a bottleneck
- User benefits from self-customisation and enhanced QoE
- ISP benefits from user satisfaction and monetization opportunity
- End-goal: make network dynamic so it can be exposed programmatically to outside entities

Future Work:
- Offering more features
- Dynamic negotiation via Apps interface
- Over legacy networks