Supporting Multi-dimensional Naming for NDN Applications

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Introduction

Apply NDN to IoT applications

Data naming

Internet data
1. Natural units or granularitites
2. one-dimensional hierarchical naming
3. LPM lookup operations

Gap problem of data naming

IoT data
1. Intrinsic spatial-temporal nature
2. User requests with multi-dimensional attributes

VANET
WSN
DTN
MANET
...

IoT applications
Introduction

Goal: design efficient name translation and optimization solution to fill the gap

- support multi-dimensional user requests in IoT applications
- keep the original LPM operations unchanged

Gap analysis between user requests and one-dimensional names

<table>
<thead>
<tr>
<th>User requests</th>
<th>Interest names and lookup results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>Space</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>A</td>
<td>sectionA, roadA</td>
</tr>
<tr>
<td>B</td>
<td>roadA</td>
</tr>
<tr>
<td>C</td>
<td>sectionA, roadA</td>
</tr>
<tr>
<td>D</td>
<td>roadA</td>
</tr>
</tbody>
</table>

In-network content

Goal: design efficient name translation and optimization solution to fill the gap

- support multi-dimensional user requests in IoT applications
- keep the original LPM operations unchanged
Middleware design

Translate multi-dimensional and flexible user requests into original NDN Interests with one-dimensional naming
Raw data naming

- one-dimensional naming consisting of multi-dimensional components based on hierarchical and discretized names for the raw application data
- support flexible granularity, name aggregation and longest prefix matching

Example of middleware design in vehicle communications

/middleware/space/.../time/.../type/...

<table>
<thead>
<tr>
<th>Component &amp; Format</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>space /roadID/mile_index</td>
<td>( roadID: ) a unique identifier for each road ( mile_index: 0, 1, 2, ..., i, ...; ) ( i ) denotes the section ( (i, i + 1) ) mile</td>
</tr>
<tr>
<td>time /date/minute_index</td>
<td>( date: /year/month/day ) ( minute_index: 0, 1, 2, ..., j, ...; 287; ) ( j ) denotes the duration ( (5j, 5(j + 1)) ) minutes.</td>
</tr>
<tr>
<td>type /speed/avg</td>
<td>average speed of vehicles</td>
</tr>
<tr>
<td>type /speed/max</td>
<td>maximum speed of vehicles</td>
</tr>
<tr>
<td>type /speed/min</td>
<td>minimum speed of vehicles</td>
</tr>
<tr>
<td>type /traffic</td>
<td>number of vehicles passing by</td>
</tr>
</tbody>
</table>
Request expression from the APP layer

- No explicit requirements on the order about different dimensions
- The asterisk wildcard is allowed.

```
/userRequest/space/roadID/{pointA, pointB}
/time/{/yearA/monthA/dateA/tsA, /yearB/monthB/dateB/tsB}
/type/...
```

e.g. ”/space/broadway/{2.5,5.7}” denotes a road section from 2.5 mile to 5.7 mile of Broadway Blvd

/space/broadway/*
Data discovery

- There may exist various aggregated names which are different from the raw names.
- It is better to request the contents with aggregated names rather than the raw names if the contents with aggregated names exist in the network.
- To obtain the network status about what kinds of contents are available within the network.
  - Called metadata stored at local metadata base (MDB)
Interest name translation

- Basic translation
  - the APP inquiry with flexible and continuous multi-dimensional attributes will be semantically translated into the raw names with fixed and discretized granularity.

- Name optimization
  - a shorter name is preferred in the Interest packet if it can be satisfied by the network.
  - sending Interests with aggregated names rather than the raw names will help reduce the burden of NDN content routers and improve the network efficiency greatly.
1) **Compatibility Consideration**
   - It is built on standard NDN layer and has no any modifications on original NDN packet format and protocol operations.
   - Not all the nodes are required to implement the middleware.

2) **Complexity Analysis**
   - processing capacity about database lookup;
   - metadata base memory and metadata discovery protocol overhead
     - The ChronoSync-like scheme in small-scale network.
     - More scalable metadata discovery protocol to control the dissemination scope of the details about content availability.

3) **Testbed Validation Approaches**
   - Short-term: the middleware module works independently.
   - Long-term: a more generalized middleware integrated into the NFD. And a new API needs to be designed to provide Interest translation service to the APP layer.
Scheme comparison:

- Name Optimization (NO): the proposed middleware architecture with full functions.
- Raw Names (RN): the proposed middleware architecture with basic translation function only.
- Arbitrary Aggregation (AA): the proposed middleware architecture without data discovery function.
Results of handover latency

Metric: number of Interests sent by the content consumers.

Aggregation degree: the percentage of the raw names already being aggregated.
Results of connection setup time

**Metric:** average content retrieval time for each user request.

Aggregation degree: the percentage of the raw names already being aggregated.
Thank You!