QoS Treatments in Information Centric Networks

using Disaggregated Name Component Approach

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Outline

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Motivation

- The need for defining a consumer driven QoS mechanism
- Design of a name-based QoS treatment specification
- Discuss the complementary nature between flow classification and QoS treatments
- Define the QoS treatment for ICN network
- Discuss QoS procedures at various ICN network elements

Consumer Driven QoS Mechanism

- A pull-based, consumer driven design directly influences the resource allocation in the network in terms of timing and rate of Interest traffic
- Awareness of the context of the application initiating the Interest to be used in deciding QoS treatment for individual data flows
- The flow classification is a prerequisite for QoS treatment and flow classification without treatment stops short of any action and benefits
- Once the QoS treatment is identified, various network elements to enforce it through their respective QoS aware procedures

Name-based QoS Treatment Marking

- A new 'type' of name segment leveraging its TLV based design to define a name segment whose purpose is to carry name-based metadata
- A name-based content metadata (QoS marker) would allow for an in-place processing of the interest request
  - Processing of name metadata while name segments are being processed
  - It is not required to read rest of the interest and data packet fields
- The name metadata segment is a non-routable segment (i.e. not a prefix or its part)
  - A similar scheme (HTTP path parameter) is widely accepted and used in HTTP based URLs
  - QoS marker is perhaps the first use case of name-based metadata and we need to explore other uses cases
- A name-based encoding of QoS marker makes it immutable
  - A capability of mutation of QoS marker and its use is for further study

Disaggregated Name Components

- The name is the characteristics of the content whereas QoS treatment is the characteristics of the network
  - An affinity between the two is implied without they affecting each other
  - QoS treatment is added to the content name as a non-routable name segment
- Direct encoding of QoS marker into the content name also makes it as a mandatory parameter of the packet (unlike optional hop-to-hop header)

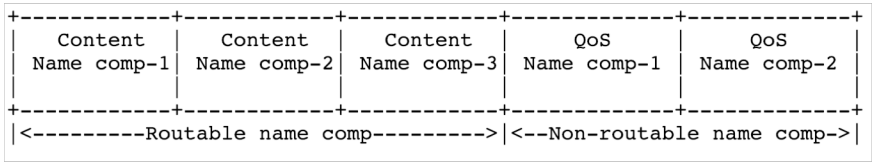

Figure: Reference model of name-based encoding of QoS marker

Network Procedures

- Consumer behavior
- Forwarder behavior
- Producer behavior

Consumer Procedure

- Consumer is aware of user's application and its QoS context
  - An application starting a simple video download compared to initiating a real-time video conferencing
  - Aware of user's service subscription and/or quality needs
- Consumer sends out the Interest into the network by adding QoS marker
  - Performs QoS marking by adding it as a name metadata into the content name

Forwarder Procedure

- An enhancement to PIT to preserve the QoS marker against the Interface
- The LPM is not affected as QoS marker is placed after the routable name
- Forwarder forwards the Interest based on the results of LPM
- Forwarder can use QoS marker in deciding the forwarding path returned by LPM
  - A QoS aware forwarding: a low delay (high b/w) over a high delay (low b/w) interface
  - Unlike PIT, there is no change in the FIB table; however, both (content name and QoS marker) are forwarded to upstream router
- The choice of forwarding path is essentially a problem of selection of the forwarding queue
  - The QoS aware forwarding then becomes the problem of selection of a specific queue(s)
- Based on the QoS marking in interest, there is a potential case of PIT scaling

Producer Procedure

- Producer is aware of disaggregation between routable name and its QoS marker and looks up the content using routable name component
- If content is found in an intermediate router node's content cache, it follows the same producer behavior as described above
- Since QoS marker is encoded into the content name, it is returned in the Data packet as is
  - This behavior is by design and producer does not have any explicit action

QoS-Aware Forwarder Design

- PIT Enhancement
- PIT Scaling and Optimization
- Forwarder on Data Arrival
- QoS Marker Design
- Advantages and Summary

PIT Enhancement

- PIT to maintain the mapping of Interface + Content Name + QoS Marker

#	Interface Id	Content Name	QoS Marker
1	face-1	/youtube/med/vid-1	/qos-level-1
2	face-2	/youtube/med/vid-1	/qos-level-2
3	face-1	/youtube/med/vid-1	/qos-level-3

- The table design and the state shown is only to explain and represent an idea
  - Optimization of this design and its performance is a matter of specific implementation
- QoS marker takes precedence for Interest aggregation for same content name
  - Two or more Interests (#1 and #2) with same content name, but with different QoS markers are received on two different interfaces
  - Two or more Interests (#1 and #3) with same content name, but with different QoS markers are received on the same interface
- A potential PIT scaling issue when implementing a QoS aware forwarding

PIT Scaling Issue
(and partial loss of Aggregation)

#	Interface Id	Content Name	QoS Marker
1	face-1	/youtube/med/vid-1	/qos-level-1
2	face-2	/youtube/med/vid-1	/qos-level-2
3	face-1	/youtube/med/vid-1	/qos-level-3

- With multiple Interests (for same content) with different QoS marking are received on the same Interface
  - Since QoS markers are different, forwarder forwards both the Interests upstream, creating two PIT entries as shown in the table
- The net result is that for given content, PIT aggregation has to be loosened up proportional to the number of unique QoS markers
  - The extent of losing the interest aggregation at PIT depends on the design of QoS markers
- The extent of loss of aggregation at PIT and impact on scale can be controlled by
  - Keeping the # of QoS markers limited
  - In real-time case, we may not hit this upper bound all the times
  - Using a hierarchical or partial order of QoS treatment (described on next slide)

Controlling the Loss of PIT Aggregation
(Hierarchical/partial order of QoS markers)

- **Forward** the second (duplicate) Interest only if receives **with a higher QoS marking** than the one already pending in PIT
  - **Replacing** existing PIT entry with higher QoS marking from the new Interest
  - **Updating** existing PIT entry irrespective of the interface the Interest is received on
  - Data to the downstream Interface goes either with its original QoS marking or with a higher QoS marking updated by second (duplicate) Interest
- **Do not forward** the second (duplicate) Interest **with a lower QoS marking** for which an Interest with higher QoS marking is already pending
  - In most likelihood, Data with higher QoS marking may return faster than the Data with lower QoS marking
  - As a result, a user with lower quality subscription may experience a better response time
    - This is a legit behavior, as ICN is fundamentally designed to optimize the network round-trip time

Forwarder Behavior on Data Arrival

- The arrival of Data packet to satisfy all PIT entries against the content name, in addition to the QoS markers in Data packet
- Two possibilities depending on the type of QoS marker aggregation in PIT
  - If aggregation is done with the highest QoS marker
    - Data arrival satisfy all the pending Interest irrespective of the received QoS marker
    - Data forwarded to all the Interests recorded in the PIT for given name
  - If aggregation is done with a hierarchical/ordered set of QoS markers
    - Data arrival to satisfy all the pending Interests with QoS marker <= the QoS marker in the Data packet
- The hierarchical/ordered set aggregation should be more flexible and perform the Data forwarding close to the original QoS marking

QoS Marker Design – Hierarchical or Flat?

- Selection of the marker scheme is an important part of this design
- Hierarchical or an ordered QoS marker design provides an opportunity to optimize the loss of Interest aggregation at PIT
  - Hierarchical scheme of QoS marking is relatively more complex to process
- Flat naming scheme design of QoS marker does not help optimize the loss of Interest aggregation at PIT
  - Flat naming scheme of QoS marker is simple and easy to integrate as single name segment
- Following factors govern the selection and type of QoS markers
  - The type of service user subscribes with the service provider
  - The type or class of service consumer is running (e.g. RFC4594)

Advantages

- A flexible scheme by virtue of disaggregation of routable name component and non-routable name component
- QoS markers potentially can be designed to achieve both flow classification as well as QoS based scheduling in the network
  - This is a second level design problem
- The independence of routable name component and the QoS marker, not to impact the (FIB) scaling
  - An opportunity to implement QoS-aware forwarding decisions

Summary & Future Work

- Disaggregation of routable content name and non-routable, mutable QoS markers provides better flexibility
- Independence between content name and QoS marking makes their evolution much easier and yet bounded to content name keeping with ICN principles
- A potential impact on PIT scaling and an optimization to deal with the problem
  - Number of pending Interests requests in PIT for same content to be normalized around the highest QoS marking (more detailed look required)
- Future work items (work-in-progress)
  - Evaluate the performance of name-based QoS marking scheme
  - Evaluate the impact on PIT aggregation and advantages of optimization
  - Design a naming scheme/standard for QoS marking
  - Explore if/how QoS marking scheme can also be used for flow classification
  - Explore the use cases of in-network mutation of the QoS marker


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