QoS Management for NNEW: Requirements, Challenges, and Solutions

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QoS: Quality of Service
NNEW: NextGen Network Enabled Weather
Talk Outline

✓ NextGen and NNEW background
  • QoS requirements and definition
  • Challenges and solutions
  • Alignment of QoS vision with FTI and SWIM
  • Conclusions
NextGen Weather Mission

- Poor weather has caused or contributed to [1]
  - 70% of all aviation delays
  - 87% of all aviation accidents
  - $1.2 billion of fiscal losses

- Reducing adverse impact of weather on the NAS is one of the important objectives of the NextGen Weather Mission

Secretary of the Air Force, Michael Wynne, emphasizes the Defense Department’s continued commitment to NextGen. [1]
NNEW’s Role in NextGen Mission

- Disseminates common and consistent weather information

- Provides standardized and composable services for data access and dynamic-data discovery

- Uses shared services in the SWIM layer, which in turn relies on the physical FTI network infrastructure
NNEW Architectural Components

- **NNEW Producers**
  - Sensors
  - Satellites
  - Model Generators
  - Multi-Agency (FAA/NWS)
- **NNEW Consumers**
  - NAS users
  - Airlines
  - Scientists
  - ...
- **NNEW Services**
  - Web Feature Service (WFS) – non-gridded data
  - Web Coverage Service (WCS) – gridded data
  - Registry-repository – dynamic data discovery
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Requirements for QoS

• Different NNEW applications have different needs for
  – Timeliness and Jitter
  – Data rate
  – Data loss

• Different data-types have varying ranges of size, and rate of production or consumption

• Without QoS management, applications may cause “Tragedy of the Commons”

Several QoS use-cases are listed in NextGen-Net-Enabled Weather Use Cases-V3-2
QoS Definition

“Delivering the Right Information at the Right Time to the Right People in the Right Form”

What does this definition really mean?
QoS Illustration in Everyday Life

- Interactive gaming requires low latency for real-time ‘feel’
- Link to Internet can become bottleneck
- Prioritization of network traffic needed to avoid game ‘jitter’

- Many home routers support QoS features
- Separates on-line gaming (real-time) traffic from routine traffic
- Packet prioritization by MAC address or Ethernet Ports
- QoS feature is localized to home router – QoS info not used by ISPs (yet)
QoS in NNEW

- In the context of NNEW QoS implies:
  - Satisfying varying bounds on timeliness, data rates, jitter, and data loss
  - Supporting these requirements in an end-to-end and cohesive manner to provide a common-weather picture to the NAS
  - Fulfilling the requirements in a secure, load-balanced, and fault-tolerant manner
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Challenges in Providing QoS to NNEW

1. Several potential bottlenecks in the end-to-end pathway
   - Any-one bottleneck can adversely impact the entire system

2. Inability to accurately predict resource requirements due to:
   - Shift in messaging paradigm
     Point-to-point to publish-subscribe
   - Dynamic data-access patterns
     Varying size and rate requirements of users
     Varying number of messages per user
     Varying number of users of the same or differing priorities

3. Economics of over-provisioning
   - Either pay for over-provisioning for (50% over) the peak traffic resulting in underutilization of resources
   - Or suffer adverse quality
Challenge 1: Potential QoS Bottlenecks Across the Different Layers

Application Layer - Contention for
- Middleware
- OS (CPU/memory/file IO)
- HW interfaces

Middleware Layer - Contention for
- Messaging Queues
- OS (CPU/memory/file IO)
- HW interfaces
- Other Services, such as Persistence, Transaction, & Security

Network Layer - Contention for
- Switch and Router Queues
- Bandwidth to FTI core
- Bandwidth Cost and Latency of the core network
- Other Services, e.g., Persistence, Transaction, & Security

- Middleware
- OS (CPU/memory/file IO)
- HW interfaces

Switch

Router

FTI Network Backbone

Service #1

Service #N

Middleware

OS

HW Interface

HW Interface
Suggested Solutions for Addressing Potential Bottlenecks

### Application Layer
- Classify and Prioritize users based on the data requested and importance of user to the NAS
- Direct users to Servers* based on their priority

### Middleware Layer
- Segregate MOMs based on User Priority, and resource intensiveness of data-types

### Network Layer
- Configure Switch and Router for QoS
- Segregate traffic using VPNs and MPLS TE
- Optimize BW usage by converging Weather Service BW usage

Providing multi-layered and coherent QoS
## Suggested Solutions for Addressing Potential Bottlenecks

<table>
<thead>
<tr>
<th>QoS Issue</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU/Memory/Io contention on single physical node</td>
<td>• Additional cores, memory, I/O interfaces&lt;br&gt;• OS-Level basic process priorities&lt;br&gt;• OS/VM thread priorities&lt;br&gt;• OS-Level POSIX real-time priorities&lt;br&gt;• Memory locking (prevents process paging/swapping)&lt;br&gt;• Move to multiple nodes</td>
</tr>
<tr>
<td>Middleware messaging latency</td>
<td>• Use priority features supplied with middleware&lt;br&gt;• Enhance middleware's QoS features if needed&lt;br&gt;• Separate message broker instances for different traffic priority classes</td>
</tr>
<tr>
<td>OS Network I/O latency</td>
<td>• Tune OS network transport parameters (e.g. queue depth, TCP driver parameters)</td>
</tr>
<tr>
<td>Hardware interface latency</td>
<td>• Multiple hardware interfaces&lt;br&gt;• Not likely to be a bottleneck since hardware queues tend to already be limited in size.</td>
</tr>
<tr>
<td>Switch and router latency</td>
<td>• Employ QoS features of enterprise class switches&lt;br&gt;• Multiple LANS/multiple switches</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>• Blend edge router QoS capabilities with core FTI QoS capabilities to minimize bandwidth need&lt;br&gt;• Overprovision</td>
</tr>
<tr>
<td>Core network latency</td>
<td>• Configure edge switches/routers to provide all possible 'hints' to core network w/respect to efficient routing of prioritized packets.</td>
</tr>
</tbody>
</table>
Challenges 2 and 3, and testing

Lincoln Test bed

- Designed a small testbed emulating the FTI environment
- Designing a testbed-application to
  - Approximate resource requirements (challenge 2) and minimize over-provisioning costs (challenge 3)
  - Test potential bottlenecks (challenge 1)
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Alignment with SWIM’s Vision

- Using SWIM-recommended software for application and middleware QoS management
  - Apache Camel/Fuse Mediation Router
  - Apache ActiveMQ/Fuse Message Broker
  - Apache ServiceMix/Fuse ESB
  - Apache CXF/Fuse ServiceFramework

- Sponsored student project with Tufts University to support Diffserv bits in Apache ActiveMQ
- Patch submitted for incorporation into future release
Alignment of Network QoS with FTI

- Collaborating and cooperating with FTI’s network management team

- Selecting priorities at the application and middleware layer that aligns with the FTI proposed priorities at the routers and switch layers

Picture communicated to us by Dr. Edwin J. Zakrzewski, ITT Corporation, Supporting FAA Telecommunications Services Group. This is a “Harris Draft Concept”.
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Conclusions

- Providing multi-layered QoS provisioning approach that
  - Coherently addresses QoS issues across all the layers
  - And, it is cost-effective

- QoS management entails
  - Classifying and prioritizing users using policies consistent across all the layers
  - Redirecting users to appropriate WCS/WFS based on their QoS needs (Application-layer)
  - Using multiple brokers as well as queues, selecting the broker’s optimizing parameters, and investigating DDS and marking of ActiveMQ packets (Middleware-layer)
  - Configuring routers and switches – traffic conditioning and scheduling (Network-layer)

- Our suggested solutions align with the QoS vision of the SWIM and FTI programs
Questions, Comments, or Suggestions
Network-layer QoS (In the testbed Routers)

Critical Priority
High Priority
Medium Priority
Best Effort Priority

Policing meters the flow and drops or marks packets in excess of specified data rate.
Queueing policies incorporate congestion avoidance strategies for TCP. (Weighted Random Early Drop, WRED)

Traffic Conditioning
Classifier

Traffic Conditioning
Router ingress

Classified Packets

Classification commonly based on IP Addr, protocol, TCP/UDP Ports

Unclassified Packets

Policing

Shaping similar to policing, but adds queues to support data rate smoothing

Output Queuing with Congestion Avoidance

Scheduler

Strict Priority

CBWFQ

Shaper

Scheduler

Output interface Hw queue depth typically ~2-4 pkts. Not a significant source of delay

Queuing/Scheduling

Router egress

Router egress

Scheduling policies determine how the packets are dispatched out of the routers. Example include Strict Priority or Class Based Weighted Fair Queuing (CBWFQ)