QoS support in IPv6 environments

Location, country

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Contributions

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Presentation Outline

- The need for QoS
- QoS Terminology & Metrics
- QoS Architectures
- IPv6 header & QoS
- Configuration Examples
- Performance Tests in IPv6 environments
- Conclusions

The need for QoS (1/2)

- QoS developments in IP networks is inspired by new types of applications:
  - VoIP, VoIP trunks
    - *Low bit rate variability, strict delay requirements, jitter sensitive*
  - Audio/video streaming
    - *Low/medium bit rate variability, elastic delay and jitter requirements*
  - Networked virtual environments, interactive gaming
    - *Medium bit rate variability, delay intolerant, jitter sensitive, error intolerant*
  - Mission critical, control traffic (signalling), tele-immersion
    - *Delay requirements, error sensitive*

The need for QoS (2/2)

- QoS developments in IP networks is inspired by new types of applications:
  - Videoconferencing, high quality video distribution
    - *High bit rate variability, strict delay requirements, jitter sensitive*
  - Interactive-transactional applications, e.g. e-commerce
    - *Delay requirements, error sensitive*
  - Elastic IP applications
    - *Delay, jitter and error tolerant*
  - GRIDs & Collaborative Environments
    - *Long lived connections, bulk data transfers, delay and error tolerant*

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Terminology

- **Quality-of-Service (QoS):** A set of service requirements to be met by the network while transporting a flow.
- **Class of Service (CoS):** The definition of the semantics and parameters of a specific type of QoS.
- **Service Level Agreement (SLA):** A negotiated agreement between a customer and a service provider on levels of service characteristics and the associated set of metrics. The content of the SLA varies depending on the service offering and includes the attributes required for the negotiated agreement.

QoS Metrics

- Bandwidth
  - Affected by the slowest link capacity, congestion mechanisms, device forwarding capabilities, queue scheduling, etc.
- Delay
  - Consisting of queuing, transmission, propagation, and switching delays.
- Inter-packet Delay Variation - *Jitter*
  - Caused by traffic multiplexing, variations in queue lengths, queue scheduling, etc.
- Packet loss
  - Caused by buffer exhaustion, congestion control mechanisms, etc.

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QoS Architectures

- Best Effort Internet
- Integrated Services
- Differentiated Services

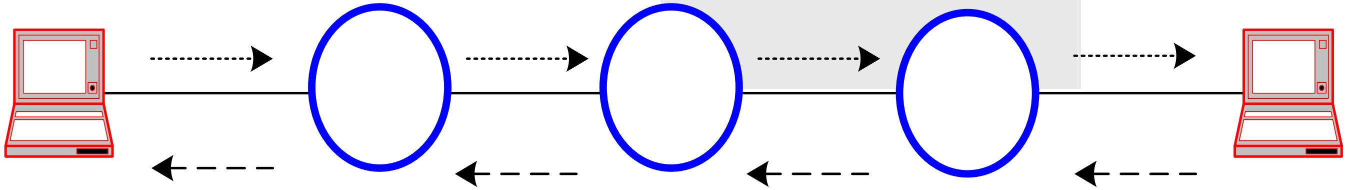
Best Effort Internet

- All packets are treated equally.
- Does not provide any performance guarantees to traffic.
  - Unpredicted bandwidth, delay, jitter

Service guarantees may be provided via over-provisioning!

Integrated Services (IntServ)

- Performance guarantees to traffic and resource reservations are provided on per-flow basis.
- Explicit admission control via signalling: RSVP
  - RSVP Path messages specify resource requirements of the applications.
  - RSVP Resv messages specify the reserved resources



IntServ Services

- Guaranteed Service
  - Provides guarantees for bandwidth (i.e. negligible packet loss) and delay but not for jitter.
  - Emulates a virtual circuit.
  - Suitable for non-elastic applications
- Controlled-load Service
  - Provides a “*better-than-best-effort*” service, similar to services provides in a lightly-loaded network.
  - Does not provide any strict guarantees on bandwidth, delay or jitter.
  - Suitable for elastic applications

IntServ Scaling Issues

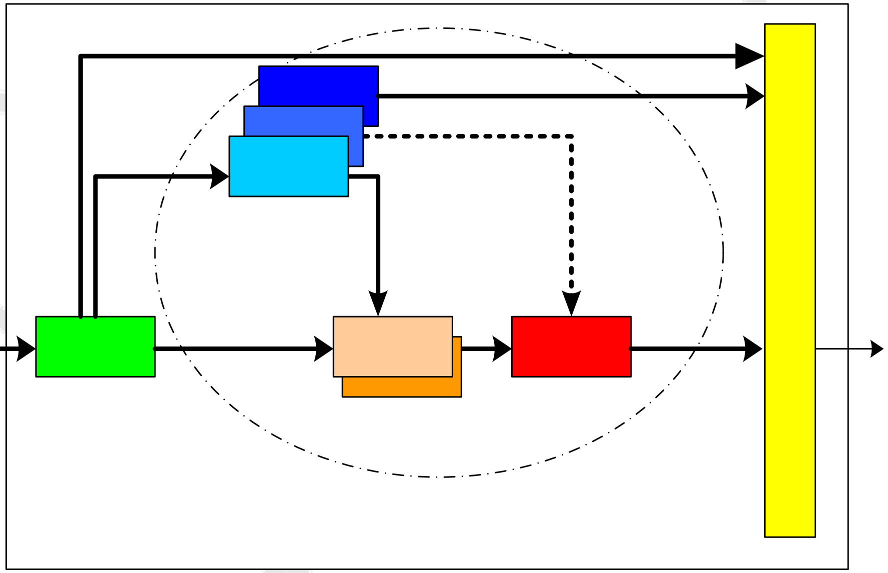
- Each routers maintains per-flow state information.
  - Data structures are created and maintained for each active flow.
- Each incoming packet is classified, policed (token bucket) and forwarded based on the flow state information.
  - Processing power is proportional of the concurrent active flows.
- Signalling overheads
  - RSVP refresh messages

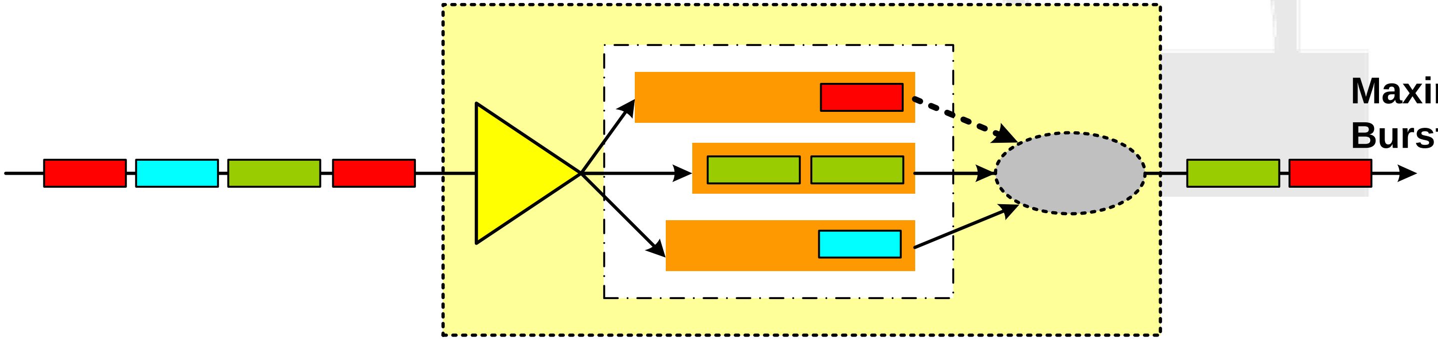
Differentiated Services (DiffServ)

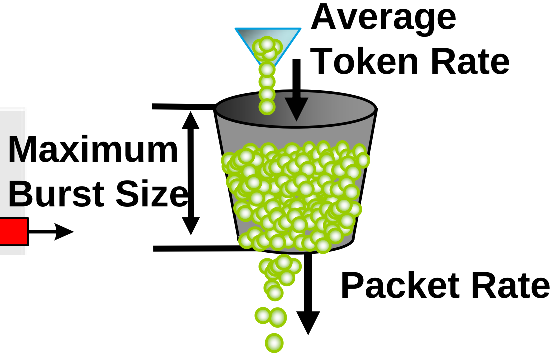
- Performance guarantees are provided to traffic aggregates rather than to flows.
  - Traffic classification is based on the Differentiated Service Codepoint (DSCP) field in the IP header.
  - Different Per-Hop Behaviours (PHB) are defined for each traffic class.
- DiffServ functionality is pushed at the domain boundaries.
  - Classification, policing, marking, etc are performed by edge routers.
- Core routers forward traffic based only on DSCP values

Basic QoS Mechanisms in DiffServ

- Classification
- Metering / Colouring
- Policing
- Shaping
- Queue management
- Queue scheduling







DiffServ Per-Hop Behaviours

- Expedite Forwarding PHB (EF-PHB)
  - Provide guaranteed bandwidth (a.k.a. negligible loss), low delay and jitter.
  - Strict admission control: Non-conformant traffic is dropped or shaped.
  - EF traffic should not be influenced by the other traffic classes.
- Assured Forwarding PHB (AF-PHB)
  - Four classes are defined that provide different forwarding guarantees. Within each class, there are three drop precedence.
  - Non-conformant traffic is remarked.

Service examples in DiffServ

- Premium IP
  - Based on *Expedited Forwarding PHB (EF-PHB).*
  - Gives absolute priority over any other class and provides low delay/jitter plus negligible packet loss guarantees.
  - Flavors: *PIP Virtual Wire (source & destination aware), PIP VoIP (destination unaware).*
- Less than Best Effort (LBE)
  - Exploits network resources without (negative) impact other traffic classes
  - Suited for specific scavenger applications
  - Uses low priority queue – 1% of capacity guaranteed

DiffServ Limitations & Challenges

- Although performance guarantees are provided on traffic aggregates, individual flows may experience low grade services.
- DiffServ lacks any signalling protocol for resource allocation (admission control) and QoS mechanisms control.
- Inter-domain QoS service provisioning can be difficult as no standardized class of service mapping exist between peer providers.

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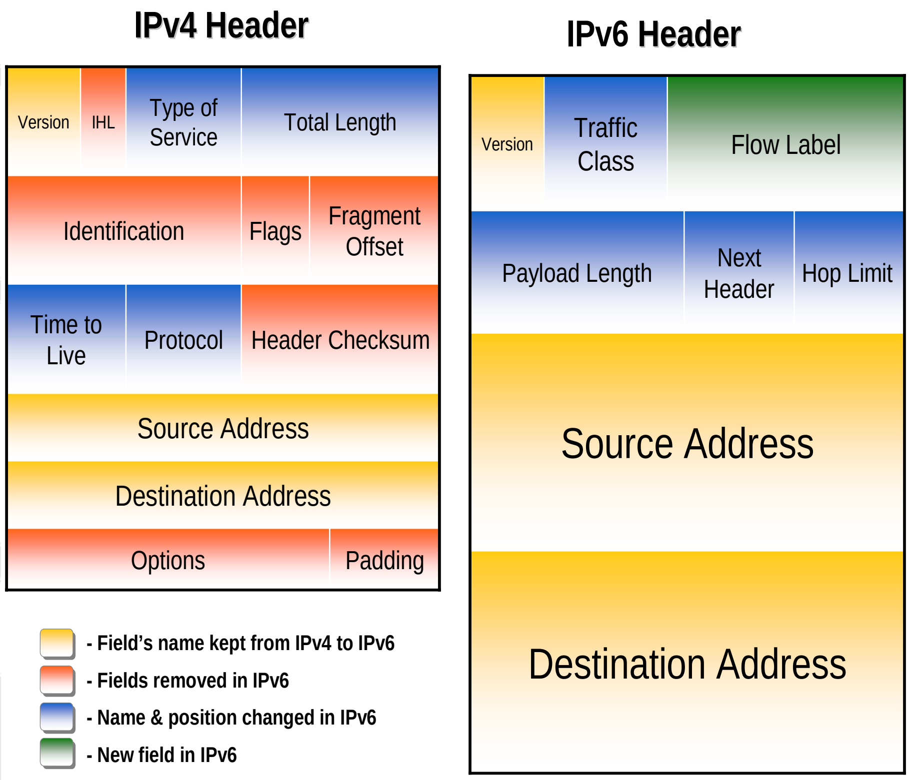
IPv6 & IPv4 Header Comparison

- The IPv6 header is redesigned.
  - Minimize header overhead and reduce the header process for the majority of the packets.
  - Less essential and optional fields are moved to extension headers



IPv6 and IPv4 headers are not *interoperable.*

QoS fields in IPv6 Header

- Traffic Class
  - An *8-bit* field used to distinguish packets from *different classes or priorities*.
  - Provides the *same* functionality as the ***type of service*** field in the IPv4 header.
- Flow label
  - A *20-bit* field defining the packets of the flow.
  - Selected by the source and never modified in the network.
  - Fragmentation or encryption is not anymore problem, as in IPv4.

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Configuration steps in MQC

- Define Class Map
  - Separate traffic into classes based on access lists (ACLs), DSCP/ToS, MPLS EXP, protocol, etc. or combinations of those criteria

    `class-map [match-any | match-all]` *`class-name`*

- Define Policy Map (Service Policy)
  - Associate a class map with one or more QoS policies, e.g. bandwidth allocation, queue management, (re)-marking

    `policy-map` *`policy-map-name`*

Configuration steps in MQC

- Apply a Service Policy to an interface
  - Associate a policy map to an physical or logical interface at input or output.

    service-policy {input | output} *policy-map-name*

Configuration examples

```
class-map match-any
  ip_premium_out
  match ip dscp 46
  match ip dscp 47
  match ip dscp 40
  match mpls experimental 5

class-map match-any lbe_out
  match ip dscp 8
  match mpls experimental 1
```

IP Premium classification *class-map*

LBE classification *class-map*

Configuration examples

```
policy-map QoS_out
  class ip_premium_out
      priority
  class lbe_out
      bandwidth percent 1
  class class-default
      exit
  exit

interface POS 0/1
  service policy output QoS_out
```

QoS policy definition *policy-map*

Apply *service policy* to an interface

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IPv6 QoS Performance Tests

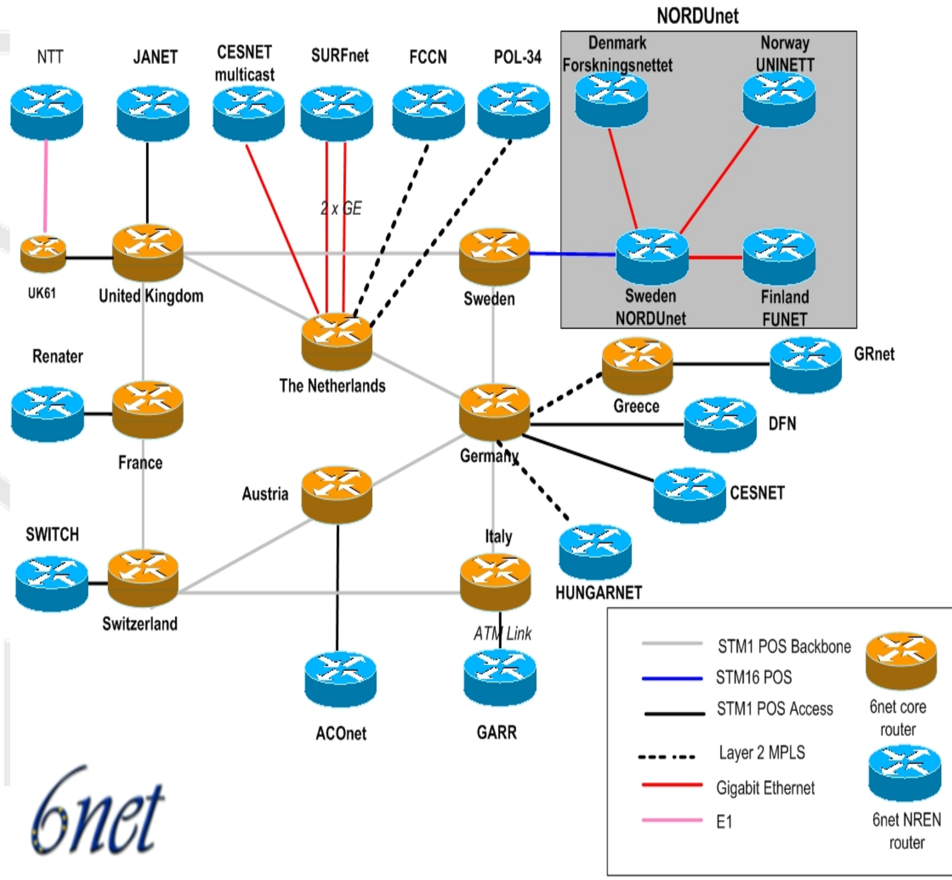
- Objectives
  - Perform diverse set of tests on hardware- and software-based routers
  - Validate the performance of basic QoS mechanisms with IPv6 traffic and identify missing functionality
- Test environment
  - IPv6-only 6NET research network
  - Dual stack GRNET production network

Services in 6NET & GRNET

- Premium IP (PIP)
- Best Effort (BE)
- Less than Best Effort (LBE)

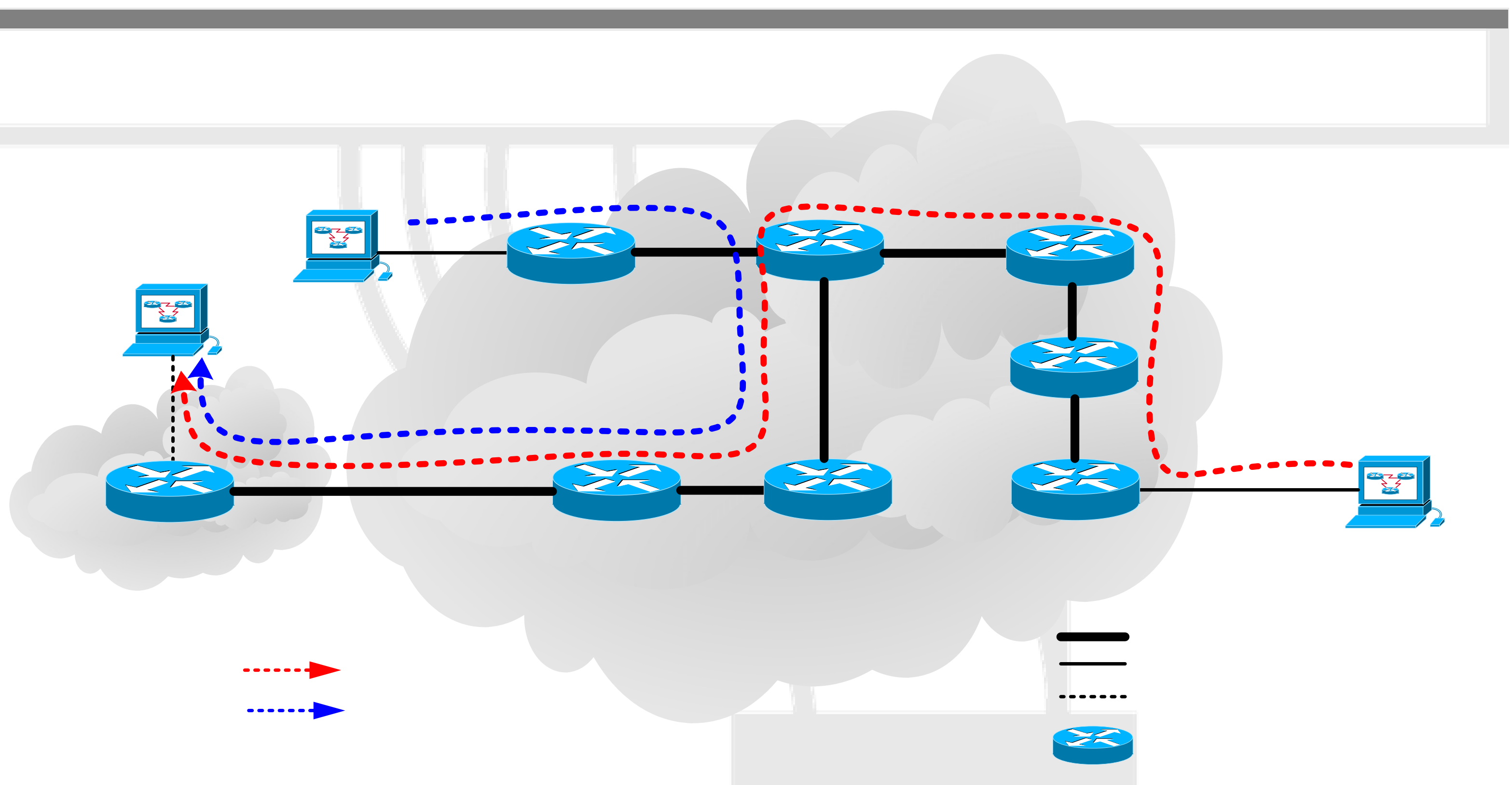
6NET Network

- Gain experience of IPv6 deployment. Extensively test a variety of new IPv6 services and applications.
- Technical specifications
  - IPv6 only network!
  - PoPs in sixteen European countries.
  - STM-1 core links, up to 1Gbps access links.
  - Cisco GSR12400 series routers in the core and 7200 series routers in the access.



http://www.6net.org

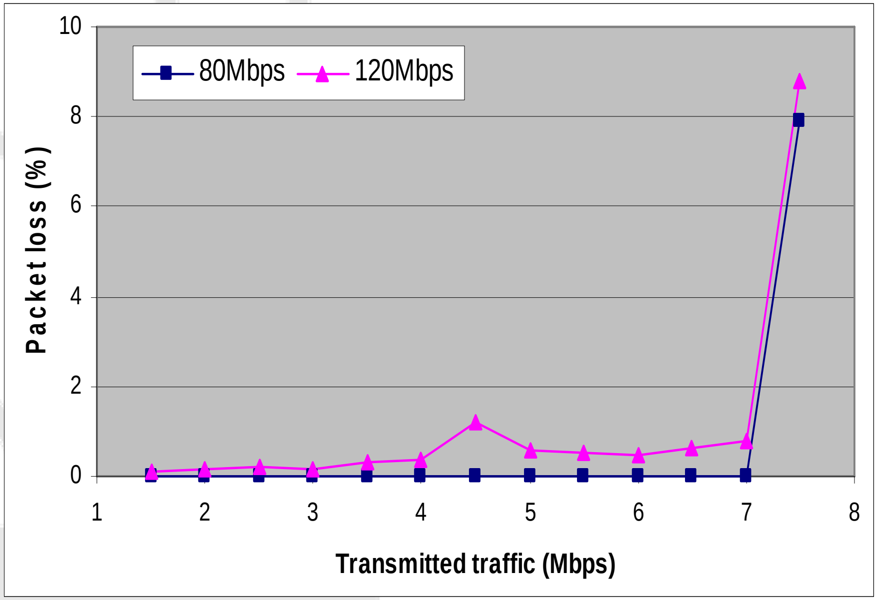
6NET test network



- Software-based traffic generators – *iperf*, *mgen* tools
- "Qualitative" tests - Validate that PIP traffic experience better services than other traffic

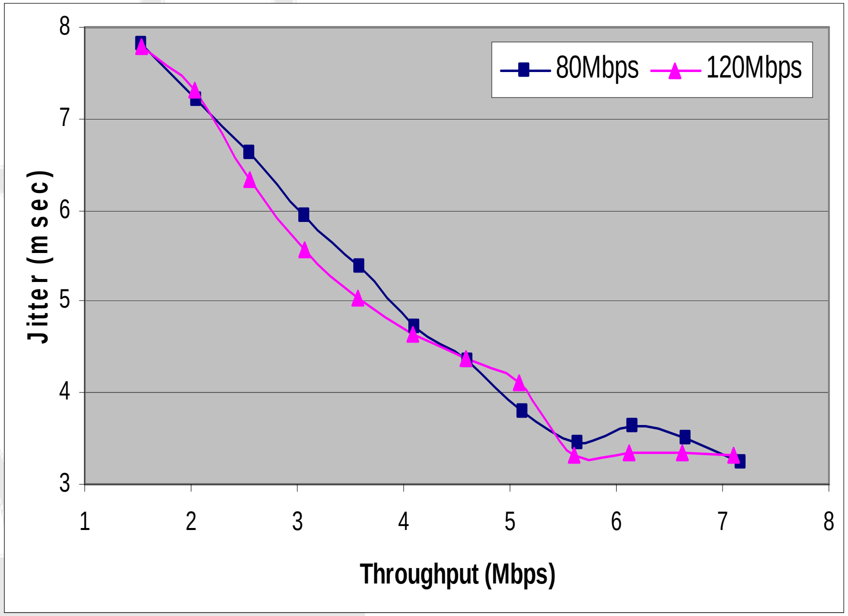
Packet loss for PIP traffic (UDP)

- Use mixture of PIP and BE traffic.
  - Gradually increase PIP traffic (UDP).
  - Create different levels of congestion with 80Mbps and 120Mbps background BE traffic.
  - Activate policing at 5% of the core links (STM-1).
- Results
  - Almost zero packet loss in both congestion scenarios.
  - Classification separates traffic into different queues
  - Priority queues protect Premium IP traffic.
  - Policing drops exceeding Premium IP traffic.



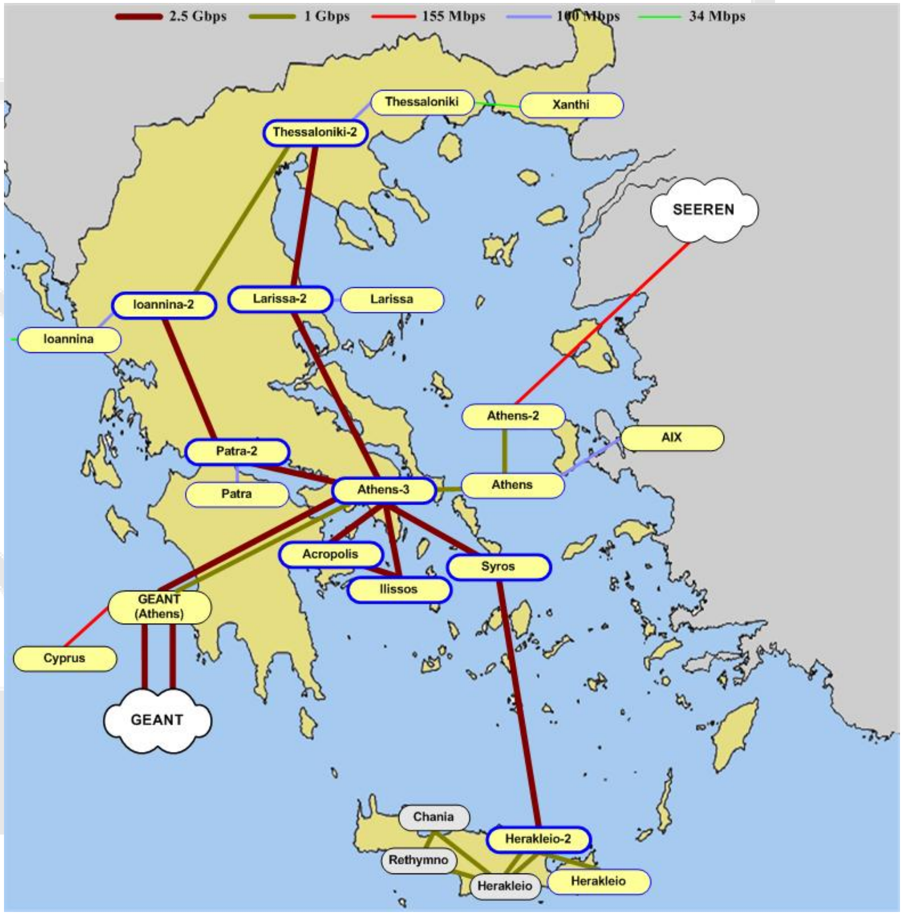
Jitter for PIP traffic (UDP)

- Use mixture of PIP and BE traffic.
  - Gradually increase PIP traffic (UDP).
  - Create different levels of congestion with 80Mbps and 120Mbps background BE traffic.
  - Activate policing at 5% of the core links (STM-1).
- Results
  - Jitter remains the same in both congestion scenarios. PIP traffic in priority queue is not affected from BE traffic.
  - Jitter is reduced as PIP rate is increased. A higher transmission rate leads to packets arriving closer together at the destination.

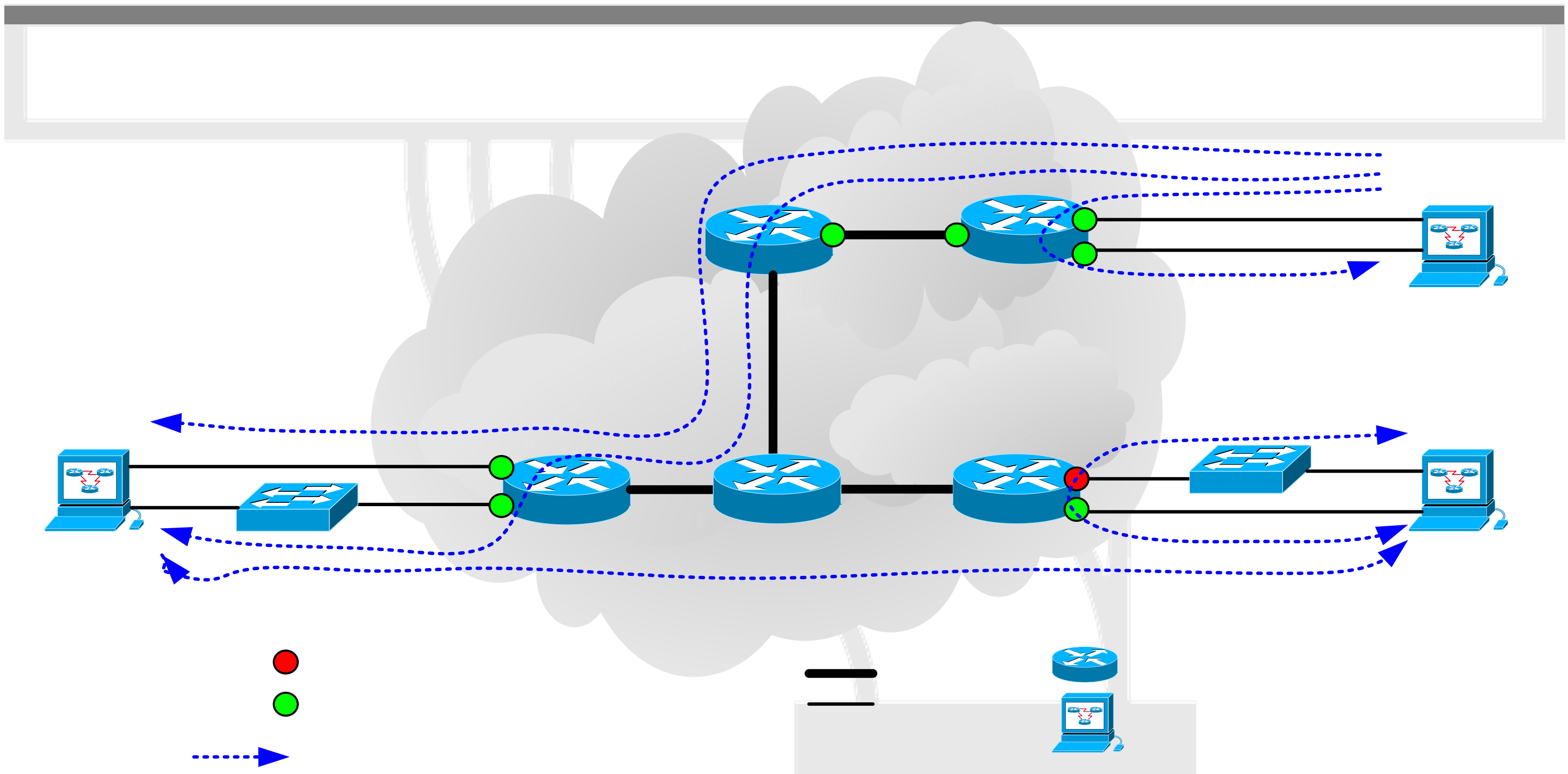


GRNET Network

- GRNET is the *Greek National Research and Education Network (NREN).*
- Technical specifications
  - Dual stack network!
  - 12 PoPs in major cities.
  - STM-16 core links, up to 1Gbps access links.
  - Cisco GSR12400 series with 4xGE (Eng3) and 10xGE (Eng4+) line cards.
  - 5Gbps connection to upstream provider (GÉANT).



GRNET2 Testbed



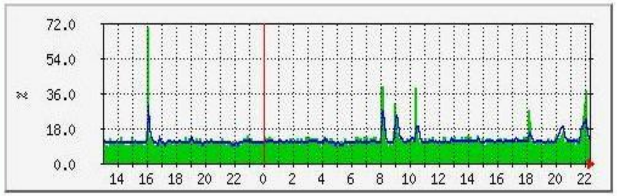
- Hardware-based traffic generators – Smartbit 600.
- Collect accurate time-related statistics.

CPU Impact

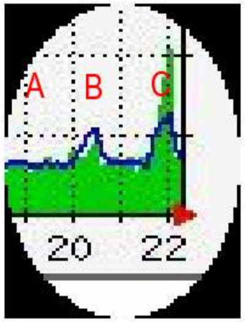
- Generate IP traffic at 2Gbps for a 30min period
  - Use IPv4, IPv6, and mixture of IPv4/6 traffic.
  - Use Eng3 and Eng4+ cards.
  - 500Mbps IPv4 production traffic – 12% average load.
- Results
  - No impact with IPv4 traffic.
  - 7% absolute increase with mixture of IPv4 & IPv6 traffic.
  - 11%(26%) absolute increase for 5min (1min) intervals for IPv6-only traffic. Routing problem impacted network connectivity.

The statistics were last updated **Wednesday, 1 June 2005 at 22:24** at which time **'ilissos-1.grnet.gr'** had been up for **14:18:53**.

`Daily' Graph (5 Minute Average)



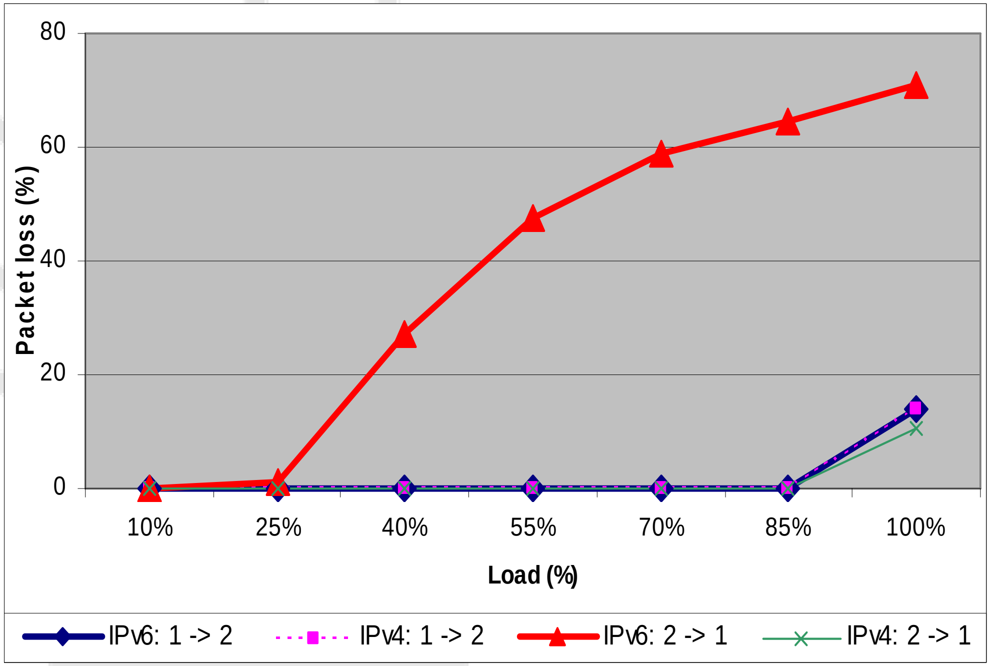
Max 70.0 % (70.0%) Average 12.0 % (12.0%) Current 11.0 % (11.0%)
Max 30.0 % (30.0%) Average 12.0 % (12.0%) Current 13.0 % (13.0%)



A: Tests with IPv4 traffic
B: Tests with mixture of IPv6 and IPv4 traffic
C: Tests with IPv6 traffic

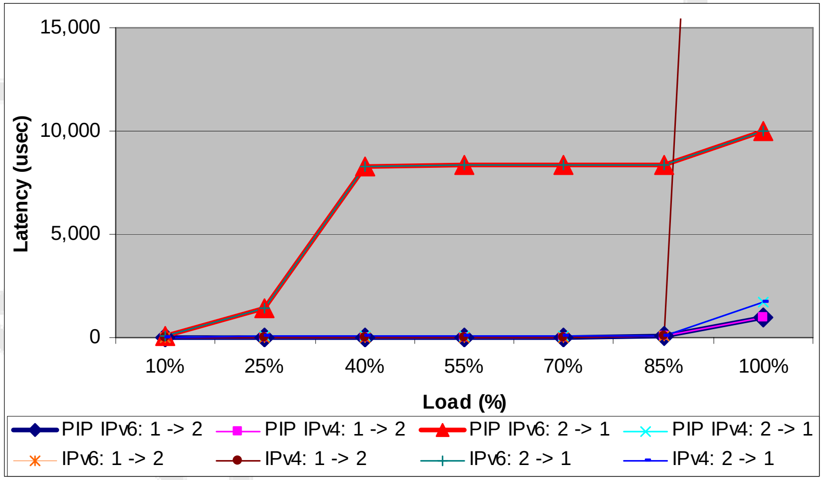
Packet loss for BE traffic in Eng3/Eng4+ cards

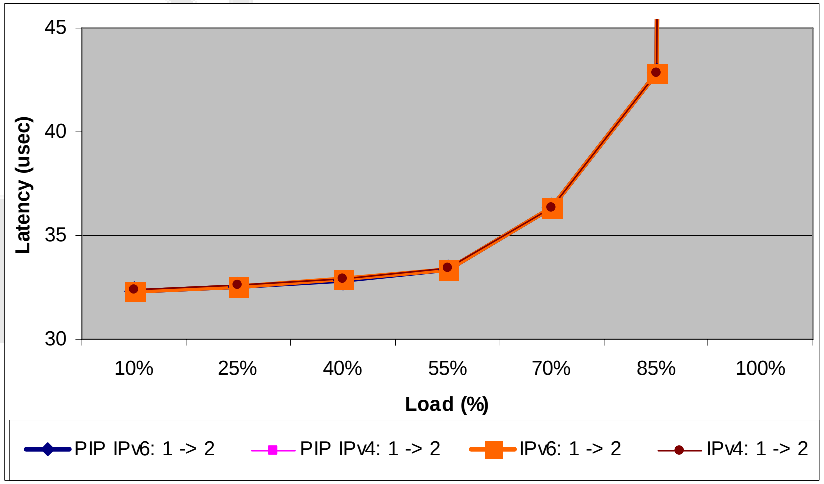
- Create bidirectional IPv6 and IPv4 flows.
  - Gradually increase traffic load.
  - Use Eng3 and Eng4+ cards.
- Results
  - Different IPv6 switching capabilities for Eng3 (hardware-based) and Eng4+ (software-based) GigEthernet cards.
  - IPv6 and IPv4 traffic experience the same packet loss in Eng3 card (direction 1->2).
  - IPv4 packet loss in Eng4+ card (direction 2->1)



Latency and packet loss for PIP traffic in Eng3/Eng4+ cards

- Create bidirectional IPv6 and IPv4 flows.
  - 2% of load is PIP traffic.
  - Increase load gradually.
- Results
  - Latency for PIP traffic in Eng3 card is very low provided zero packet loss (<85% load). When there is packet loss (100% load), PIP latency is increased but still remains thousand times smaller than (IPv4/6) BE latency. PIP traffic experiences no packet loss.
  - PIP IPv6 experiences higher packet loss and latency than PIP IPv4 in Eng4+ card. Probably, PIP IPv6 traffic is handled as BE.





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Conclusions

- The IPv6 protocol, in terms of QoS support, is **neither superior nor inferior** to IPv4 counterpart. However, the *flow label* field in the IPv6 header is expected to ease provision of services in the future.
- Routers under test allowed the definition of a **common QoS policy** for IPv6 and IPv4 traffic. This simplifies the delivery of QoS in production networks.
- New hardware / software does not do impose limitations in the support of IPv6 QoS
  - Achieved performance for IPv6/v4 traffic is identical.
- Old hardware / software may either lacks some pieces of functionality or provide lower level services to IPv6 compared to IPv4 traffic.
  - Testing is needed.

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Revision Questions!

- What are the difference related to QoS between the IPv6 and IPv4 headers? Is there any improvement in the IPv6 and why?
- Shall we expect different performance guarantees for IPv6 and IPv4 traffic? Under which conditions?
- Is there any functionality limitations or security consideration in the deployment QoS services in a production network?