Karlsruhe Institute of Technology

Advanced Quality-of-Service Signaling for IP Multicast

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Motivation

- Upcoming Distributed Interactive Multimedia Environments
  - Tele-presence environments
  - Multiplayer online gaming
  - 3D tele-immersion environments

- Many different receivers for the same data flow
- High-definition displays with very high resolution
  - Many different sources (cameras) → interactive scenarios, real-time bounds

Group communication applications

High resource and real-time activity demand

Goal …

- Transportation of high bandwidth data streams via IP multicast
- QoS resource reservations for IP multicast necessary

IP multicast
for data dissemination

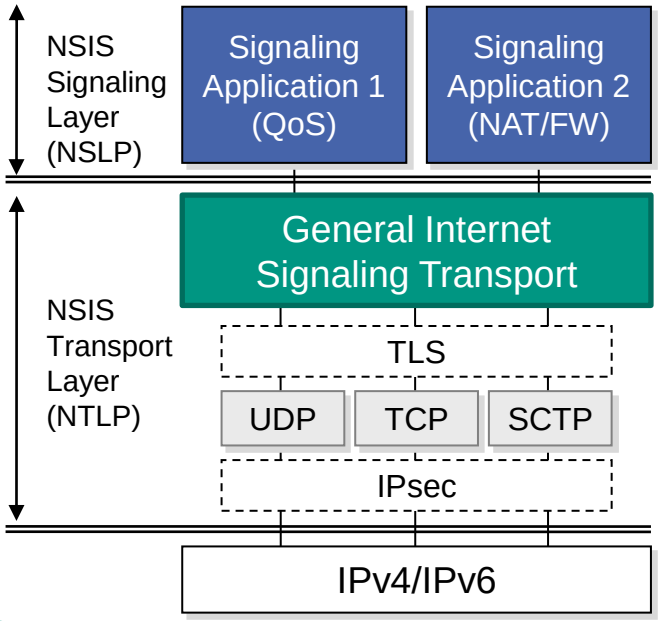
QoS Signaling
for resource reservations

→ Advanced QoS signaling for IP multicast needed

- RSVP provides multicast-capable QoS signaling protocol
  - But no mobility support, only receiver-initiated reservations, …
- Next Steps in Signaling (NSIS) protocols built as successor of RSVP
  - But designed to support IP unicast only …

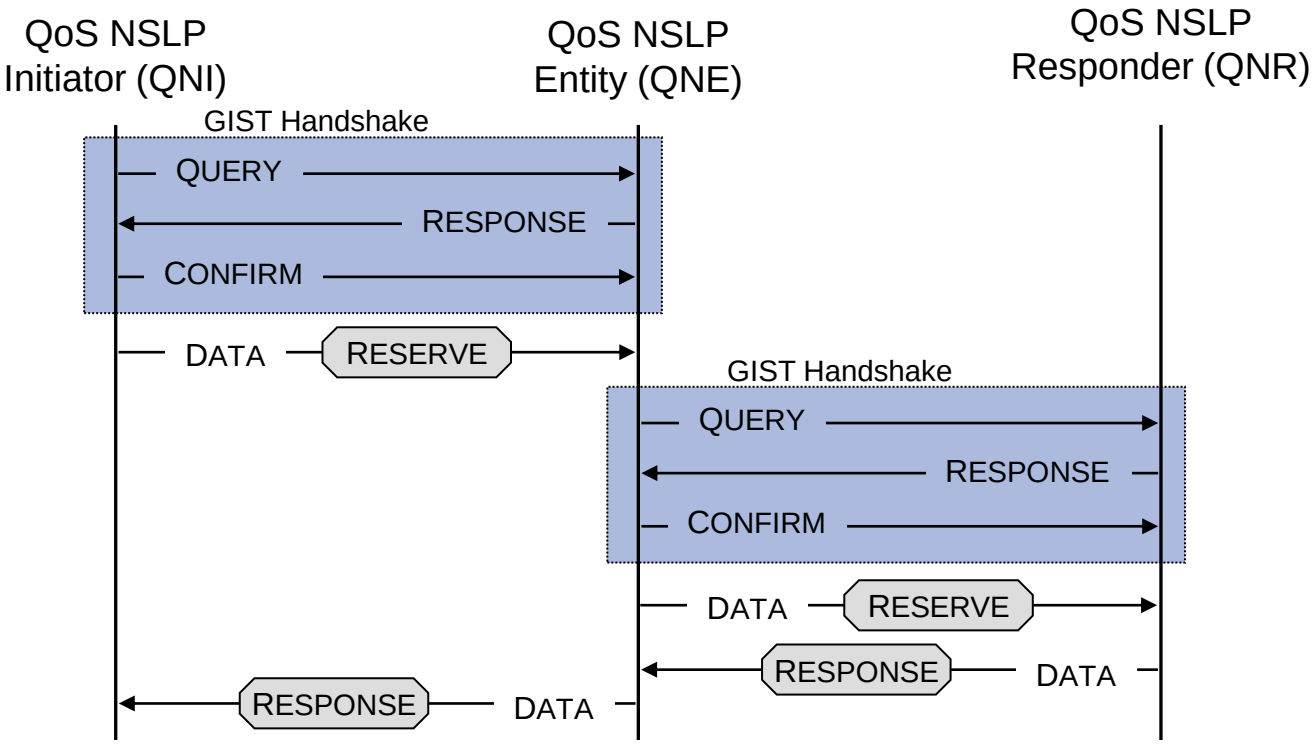
Next Steps in Signaling Protocol Suite

- IP-based signaling framework
  - Two-layered approach
- Quality-of-Service NSLP
  - Sender- and receiver-initiated reservations
  - Mobility support
  - Independent of specific QoS model
    - QoS NSLP QSPEC Template
- General Internet Signaling Transport Protocol (GIST)
  - Routing and transport of signaling messages
  - Path-coupled signaling
  - Signaling node discovery
  - Message transport (unreliable, reliable, secure)
- Recently standardized by the IETF
- Lots of running code available http://nsis-ka.org/



NSIS Protocol Interaction

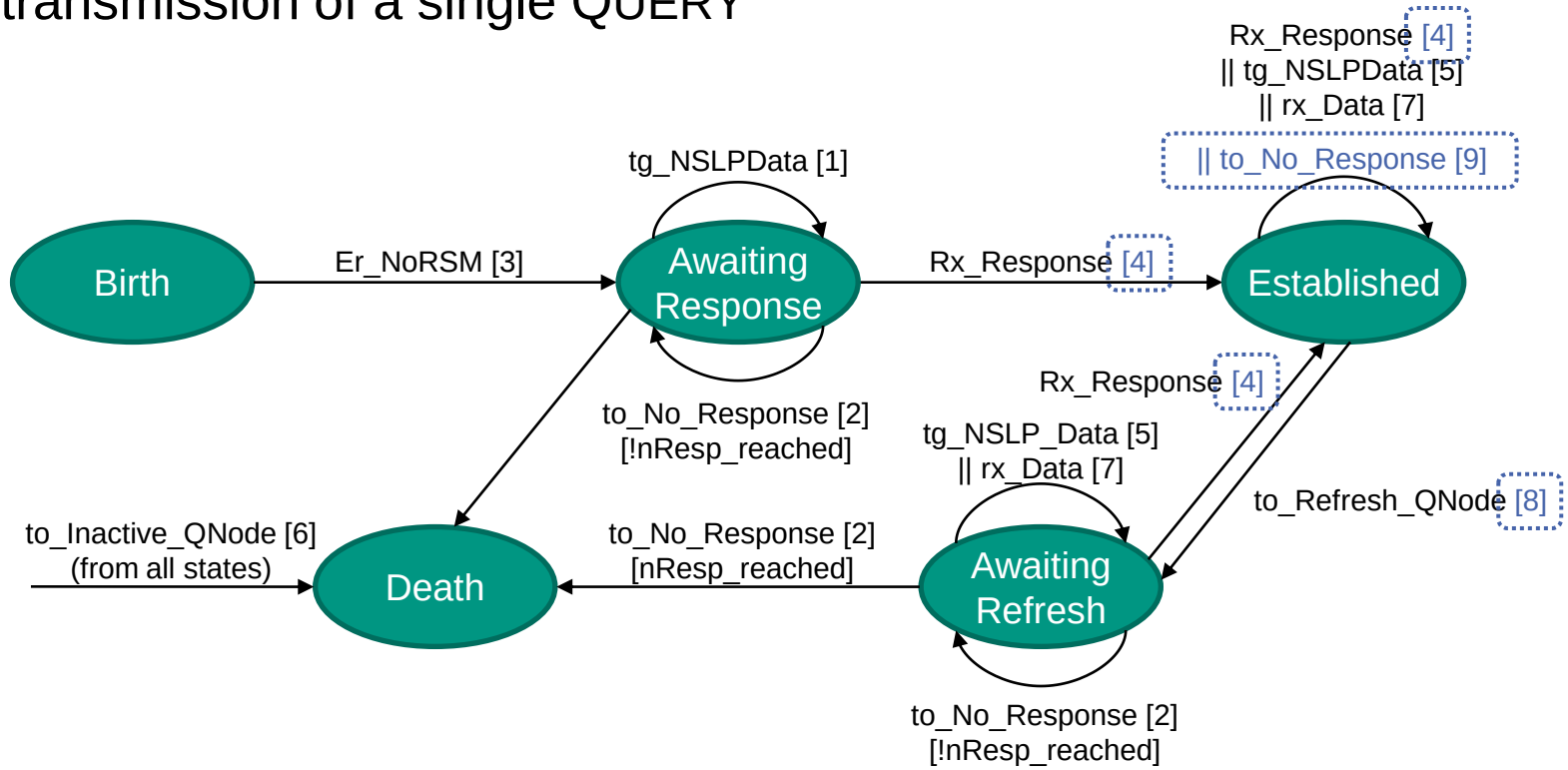
- Example of a sender-initiated reservation (Unicast)



→ **GIST** and **QoS NSLP** must be adapted to be multicast-aware

Multicast Extensions for GIST

- QUERY messages are sent to the multicast destination address
- Replication of QUERY messages on multicast-aware GIST nodes
- Allow for the reception of multiple RESPONSE messages upon the transmission of a single QUERY



Multicast Extensions for GIST II

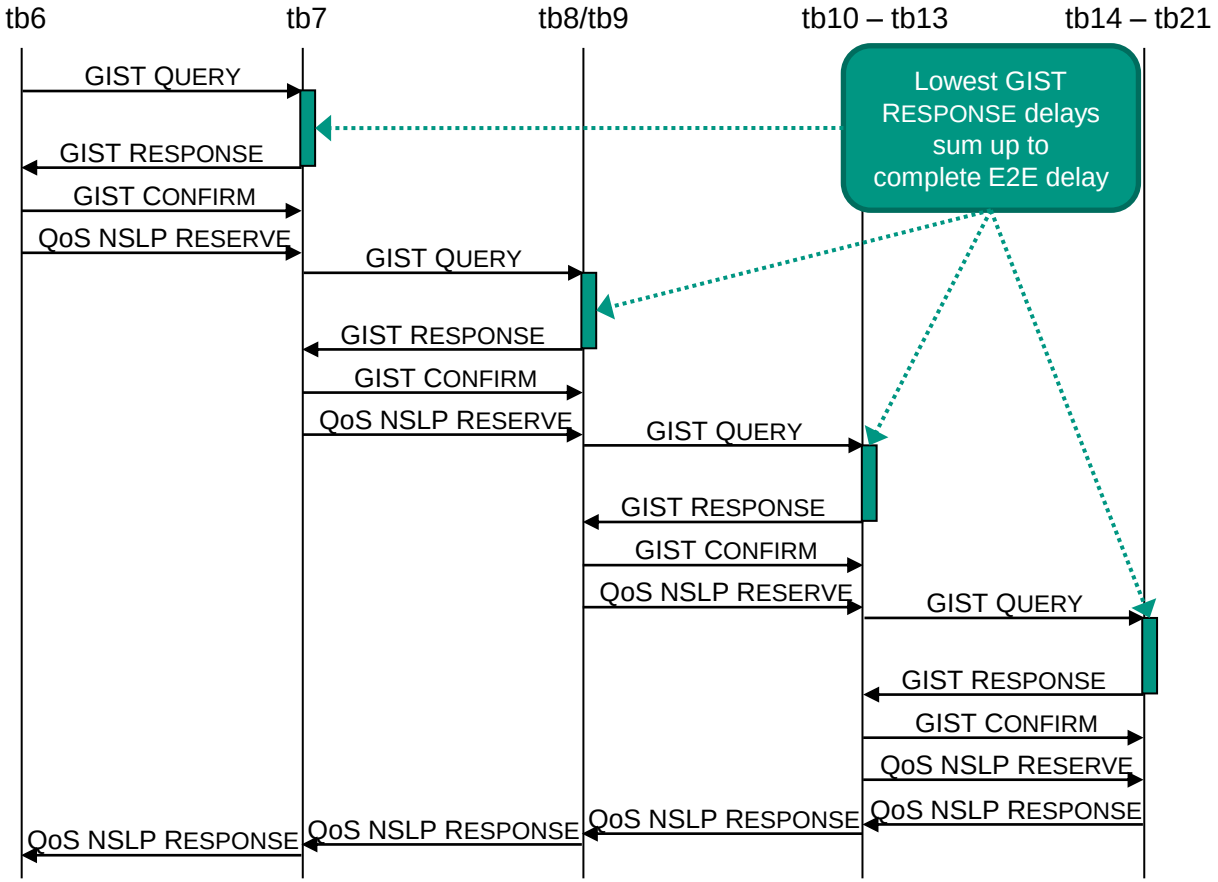
- Manage signaling routing state for a set of peers
  - Periodic GIST probing
    - Detect route changes
    - Handle group membership dynamics (joining/leaving peers)
  - Calculate number of opportunities per multicast peer to respond to GIST QUERY

- Maintain state for each single peer and a possibly corresponding messaging association
  - Dedicated messaging association per adjacent GIST peer
  - DATA messages must be directly addressed towards GIST peer → unicast signaling transport

- Maintain state about which signaling data packet was sent to which peer

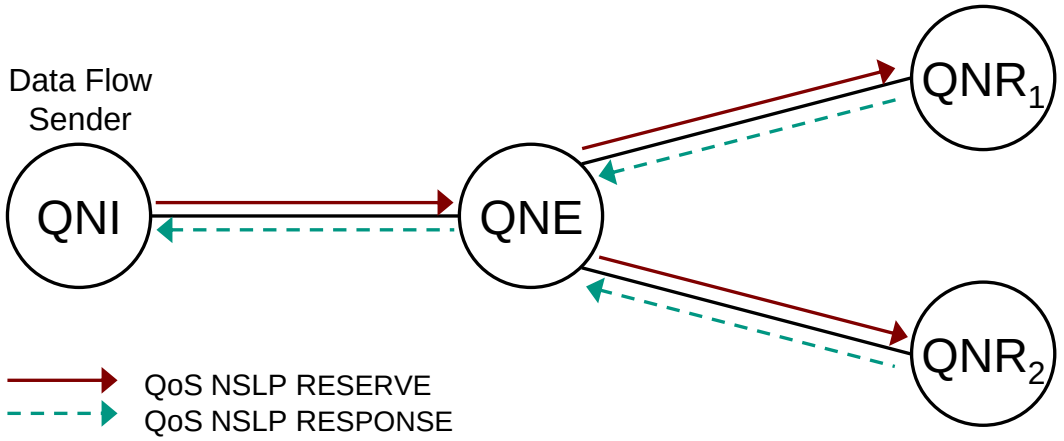
Multicast Extensions for GIST III

- Avoid Querying Node from being flooded by RESPONSE messages
  - $MaxMulticastResponseDelay = rand(0, \alpha \cdot T_1)$ T_1 initial timeout

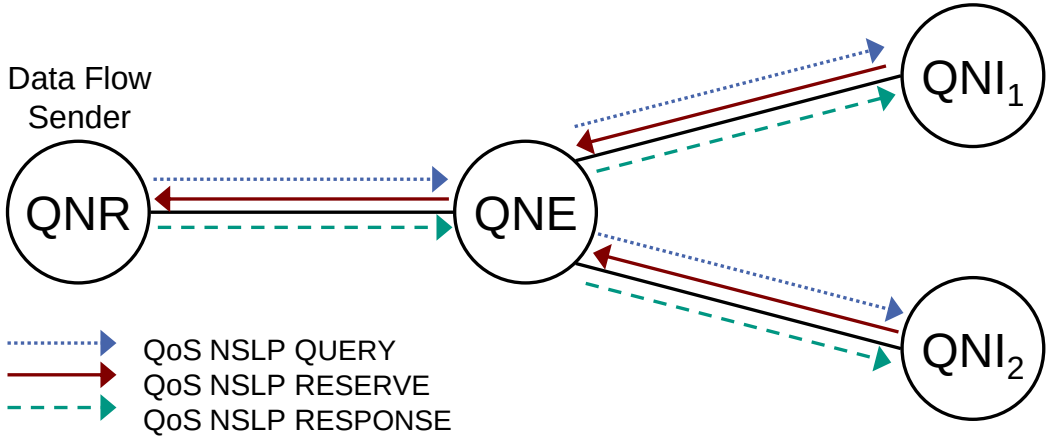


IP Multicast for QoS NSLP

- Sender-initiated reservation



- Receiver-initiated reservation



Multicast Extensions for QoS NSLP

- Identification of the last signaling hop
  - Multicast address cannot be used to identify last signaling hop (leaf node)
  - Look up multicast routing table or use configuration option

- Rerouting in case of multicast
  - Unicast: new signaling neighbor (SII handle) indicates re-routing
    - May tear down reservation on old branch
  - Multicast: may correspond to a recently joined peer
    - Maintain list of all SII-handles that were reported by GIST

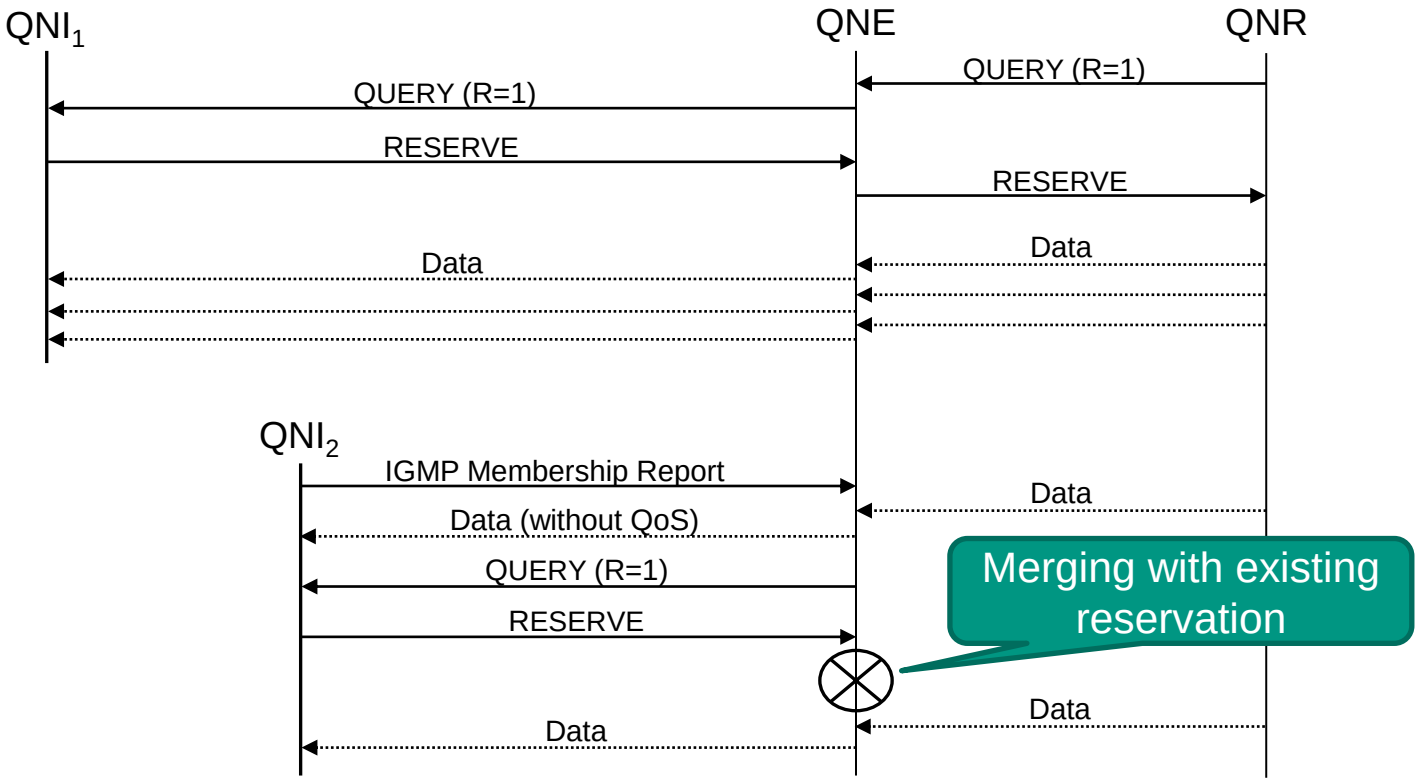
Multicast Extensions for QoS NSLP II

- Initial QUERY or RESERVE message for new neighbors
  - Refreshing Queries and refreshing Reserves may detect new multicast peers
    - Leads to delay for new neighbors
  - Emit QUERY/RESERVE as soon as SII-handle is reported
    - With full QSPEC and PACKET_CLASSIFIER objects
  - QUERY/RESERVE should then be forwarded for entire new branch

- Limit forwarding of signaling messages
  - Forward only initial RESPONSE (sender-initiated reservations) or RESERVE (receiver-initiated reservations) messages in upstream direction
    - Except if more resources must be allocated
  - Forward signaling messages in downstream direction only if of interest for entire multicast group
  - Becomes a bit more complicated for QNEs

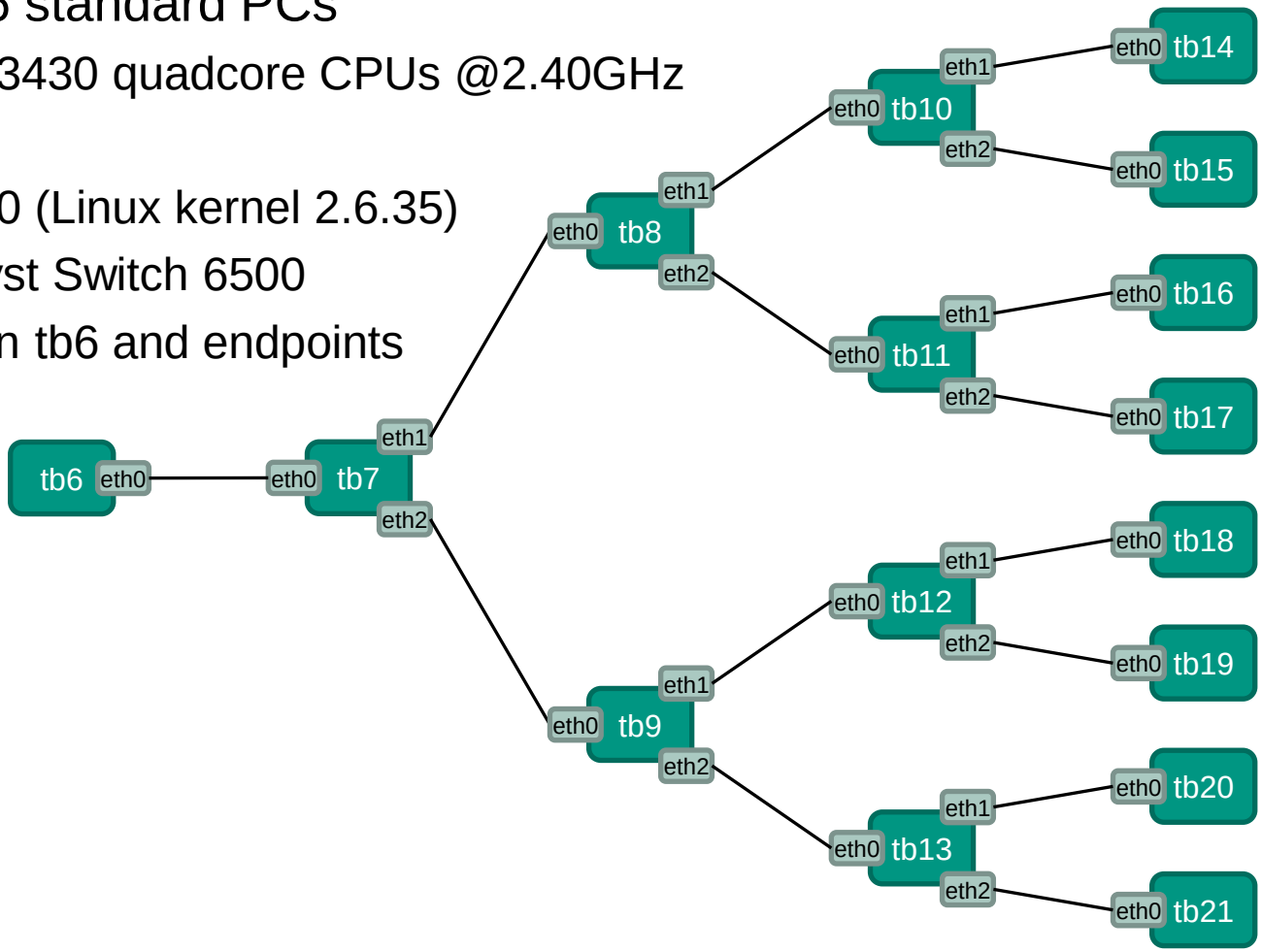
Multicast Extensions for QoS NSLP III

- Merging of reservations belonging to different branches
  - QNE must keep track of all Reservation Sequence Numbers
  - QNE must maintain individual RESERVE validity timers



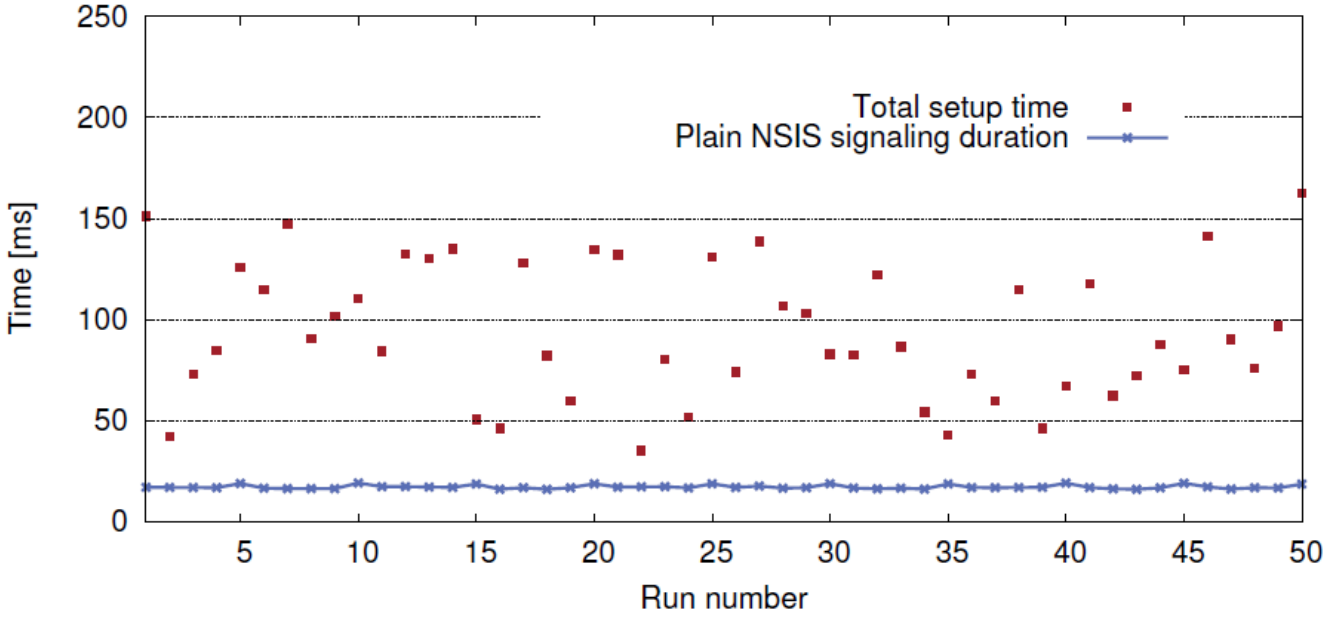
Evaluation Topology

- Testbed with 16 standard PCs
  - Intel Xeon X3430 quadcore CPUs @2.40GHz
  - 4 GB RAM
  - Ubuntu 10.10 (Linux kernel 2.6.35)
  - Cisco Catalyst Switch 6500
  - RTT between tb6 and endpoints ~2.5 ms



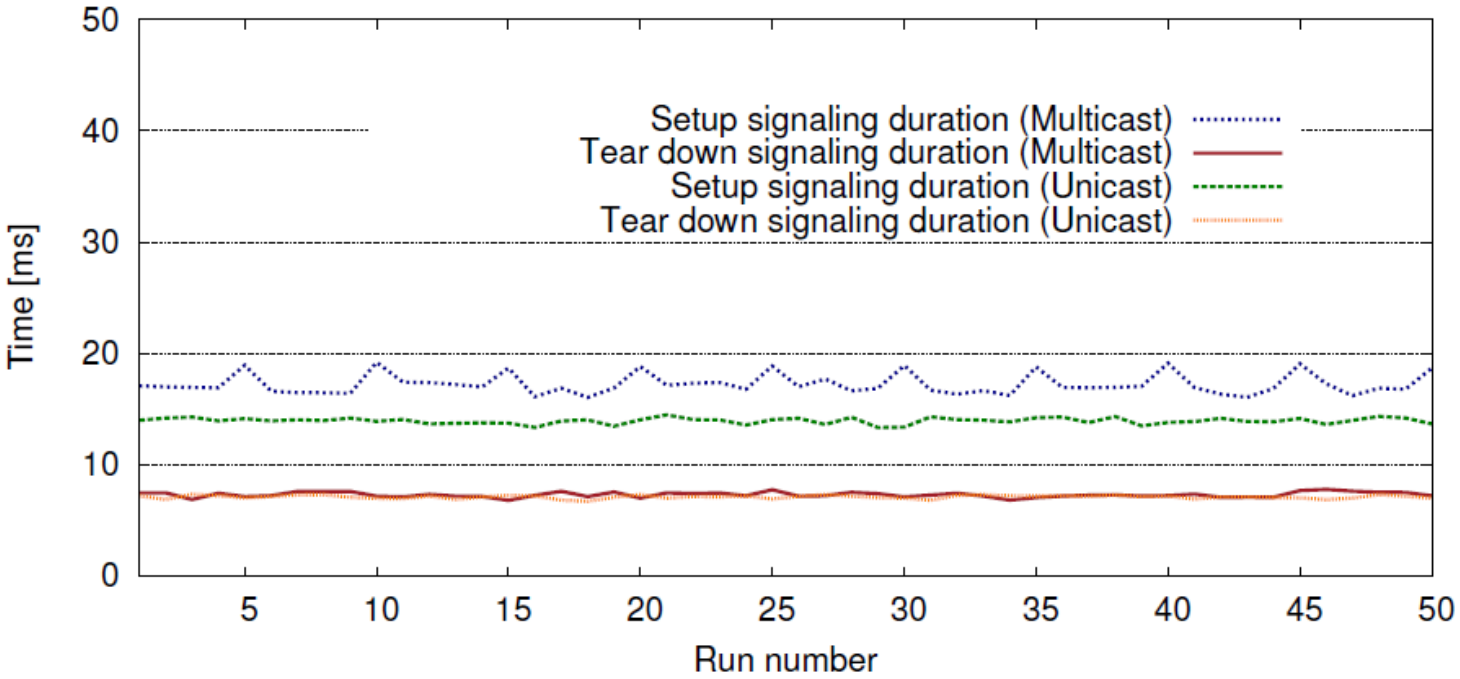
Evaluation of Signaling Performance I

- Total setup time – duration between originating GIST QUERY on tb6 until first QoS NSLP RESPONSE is received
- Plain NSIS signaling duration – total setup time minus accumulated artificial GIST response delays
- Sender-initiated reservations
  - 17.5 ms on average [16.87, 18.11] ms



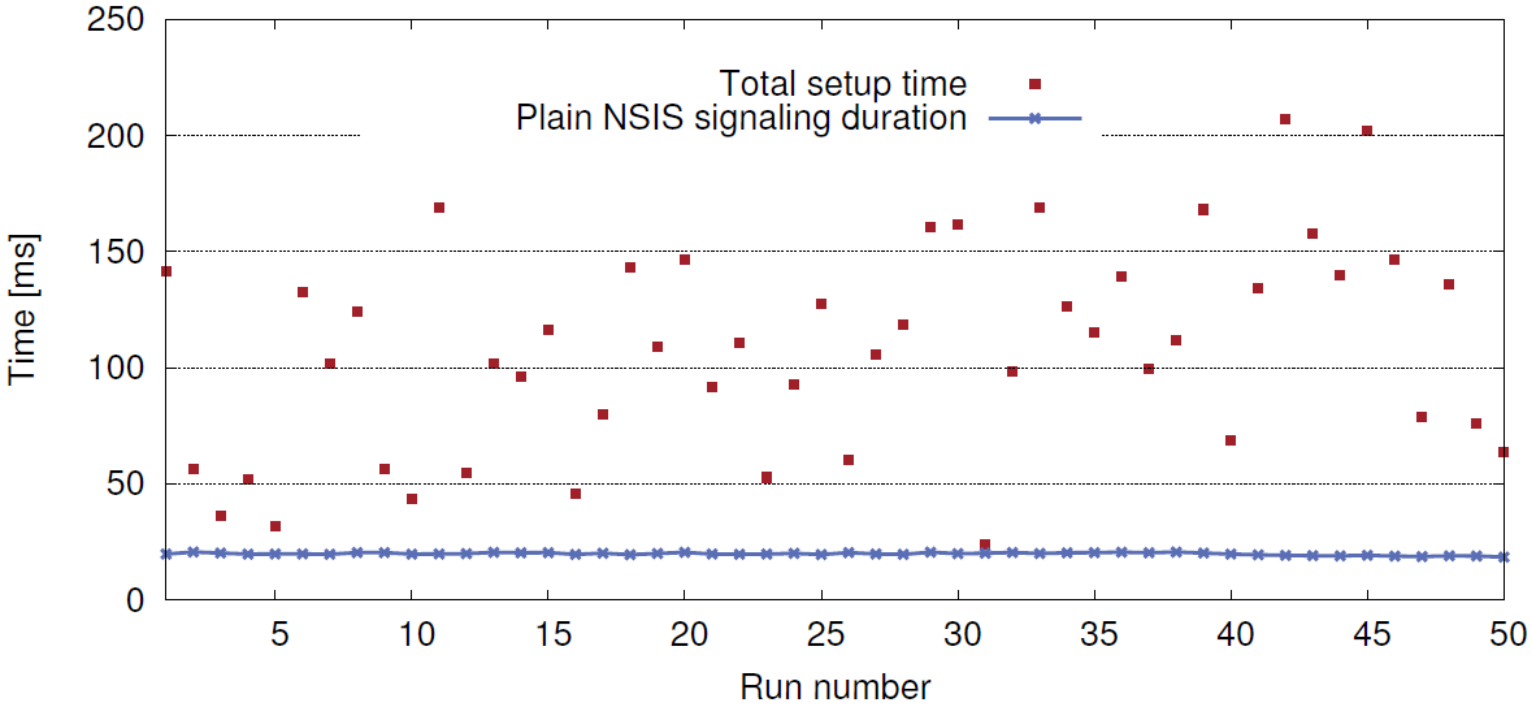
Evaluation of Signaling Performance II

- Sender-initiated reservations
  - Multicast plain signaling duration — 17.50 ms [16.87, 18.11] ms
  - Unicast plain signaling duration — 13.97 ms [13.90, 14.09] ms
  - Multicast tear down time — 7.31 ms [7.26, 7.36] ms
  - Unicast tear down time — 7.11 ms [7.09, 7.14] ms



Evaluation of Signaling Performance III

- Receiver-initiated reservation
  - Multicast plain signaling duration 20.5 ms [19.75, 21.29] ms



Discussion

- Scalable sender-initiated reservations?
  - Sender doesn’t need to be aware of every single receiver
    - Only of directly adjacent nodes
- Killer-reservation problems?
  - Merging is the responsibility of *Resource Management Function* (RMF)
    - May trigger new RESERVEs in upstream direction if necessary
- Are receiver-initiated reservations superior to sender-initiated reservations?
  - Each receiver may have specific QoS demand
  - Heterogeneous multicast requires useful adaptation replicating nodes
  - But sender must still decide for a specific codec

Conclusion

- Next Steps in Signaling protocols can be extended to support IP multicast
  - No new protocol data units necessary
  - Multicast adaptations do not affect unicast operation
- Offers new opportunities
  - Scalable sender-initiated reservations for IP multicast
  - NSIS allows for “reliable” messaging transport (hop-by-hop)
  - NSIS allows for use of enhanced security features
  - QoS model independence
  - Not limited to QoS signaling only
- Future work
  - Use NSIS multicast capabilities to deploy virtual networks
  - Study integration of mobile multicast users

Backup Slides

Multicast Extensions for GIST II

- Replication of signaling messages
- Manage signaling routing state for a set of peers
  - Handle group membership dynamics (joining/leaving peers)
  - Detect route changes through periodic GIST probing
  - Opportunities per multicast peer to respond to GIST QUERY

$$n = \left\lfloor \frac{T_2}{RoutingStateValidity + T_1} \right\rfloor$$

Initial Timeout $T_1 = 500\ \mathrm{ms}$
May be increased up to $T_2 = 64 * T_1$

- Maintain state for each single peer and a possibly corresponding messaging association
  - Dedicated messaging association per adjacent GIST peer
  - DATA messages must be directly addressed towards GIST peer → unicast signaling transport
- Maintain state about which signaling data packet was sent to which peer

Implementation and Evaluation

- Implementation based on existing open-source NSIS-ka suite
  - C++, Linux

- Extended routing table
  - New hash table for all multicast peers
    - Hash table key: each peer's Network Layer Information (NLI) entry
    - Missed responses
    - Re-use existing messaging association
    - Data messages of send queue
  - Further extensions
    - Boolean entry if querier used IP multicast address
    - Dedicated slot for NoResponse timer
    - Variable for the minimum of all routing state validity timers of all peers

Extended Routing Table

Routing key | Routing entry

MRI / Session-ID / NSLP-ID	is_responder	dmode	secure	state	multicast_peers
Routing key 1	…	…	…	…	
Routing key 2	…	…	…	…	
Routing key n	…	…	…	…	

multicast_peers:

NLI	missed_ responses	ma_reuse	transmitted_ count
NLI 1	…	…	…
NLI 2	…	…	…
NLI 3	…	…	…
…	…	…	…

NLI	missed_ responses	ma_reuse	transmitted_ count
NLI 1	…	…	…
NLI n	…	…	…
NLI m	…	…	…
…	…	…	…

NLI	missed_ responses	ma_reuse	transmitted_ count
NLI 1	…	…	…
NLI 2	…	…	…
NLI 3	…	…	…
…	…	…	…

Evaluation IV

- Signaling message overhead in the network