Why Are You Still Using Shortest Path?

- Path Selection Strategy Utilizing High-functional Nodes -

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Introduction

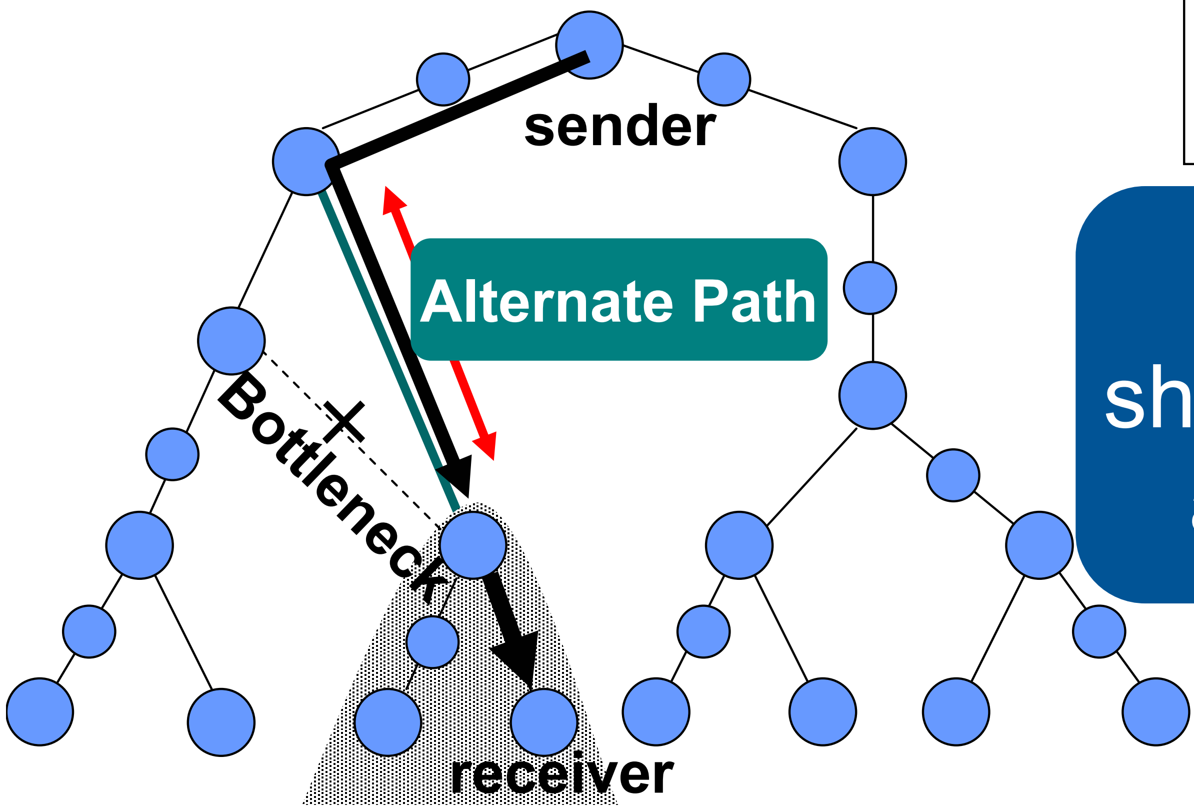
- Live streaming media
  - Delay-sensitive, Allowable delay
- Path selection for live streaming
  - Unicast -Shortest Path
  - Multicast
    - Shortest Path Tree (SPT)
    - Minimum Spanning Tree (MST)
  - **Multicast Tree Reconfiguration**
    - Shortest Path as alternative path

Is Shortest path selection really efficient?

What's Multicast Tree Reconfiguration?

- Avoid bottleneck link
- Set alternative path
- Reconfigure part of multicast tree

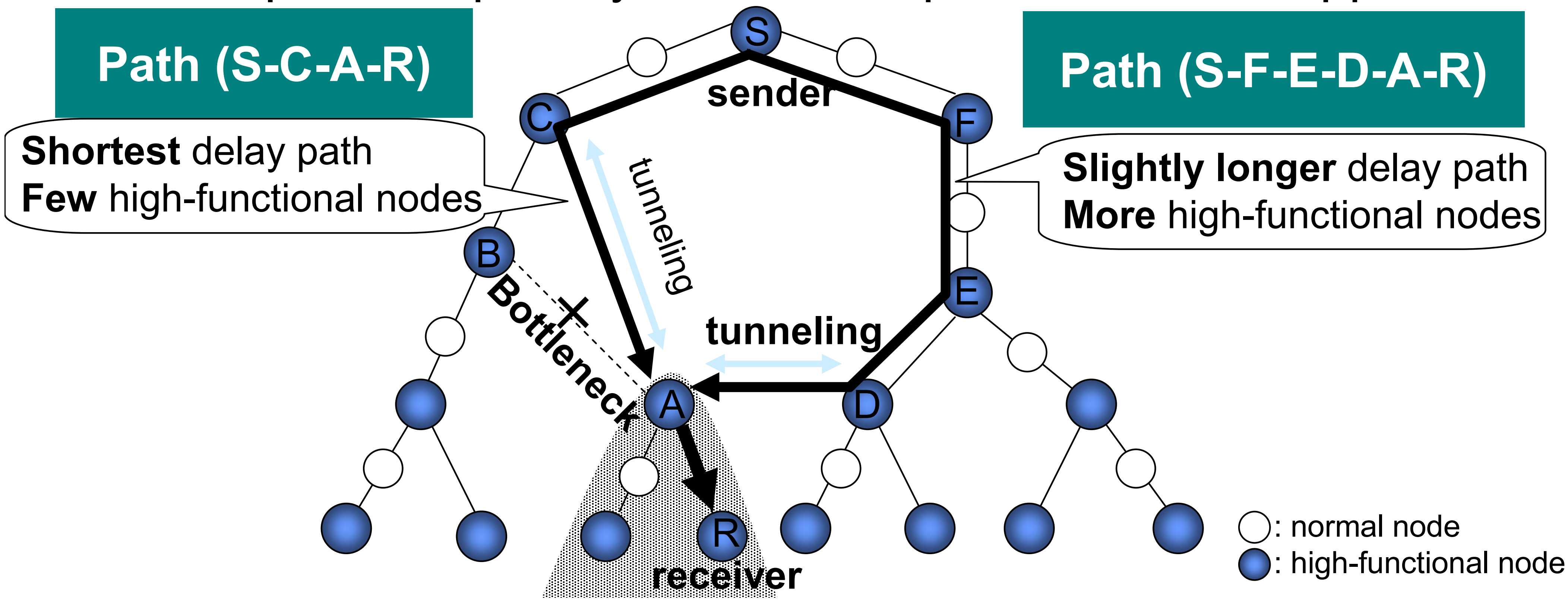
Recover and maintain QoS of end receiver



Generally,
shortest path is selected
as an alternate path

Problem on Networks with High-functional Nodes

- High-functional node
  - Special capability to maintain performance of application



Which Path Is Better
to maintain higher QoS against traffic variation?

Path Selection Utilizing High-functional Nodes

- On network with high-functional nodes
  - Application QoS varies depending on the number of high-functional nodes and their location on the path

Shortest path is not always most appropriate due to lack of high-functional nodes

It doesn't matter which path is taken as long as application QoS is sufficient

We should select a path that can **utilize high-functional nodes**

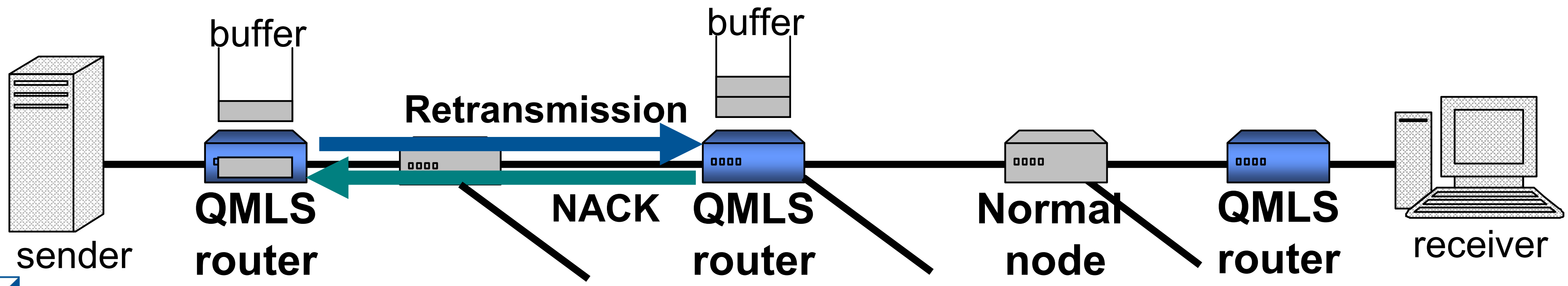
QMLS Router as High-functional Node

- QoS Multicast for Live Streaming (QMLS) Protocol
- QMLS router (relay node) partly placed on path
  - Loss detection, Retransmission

Reduce retransmission delay
Reduce end-to-end delay

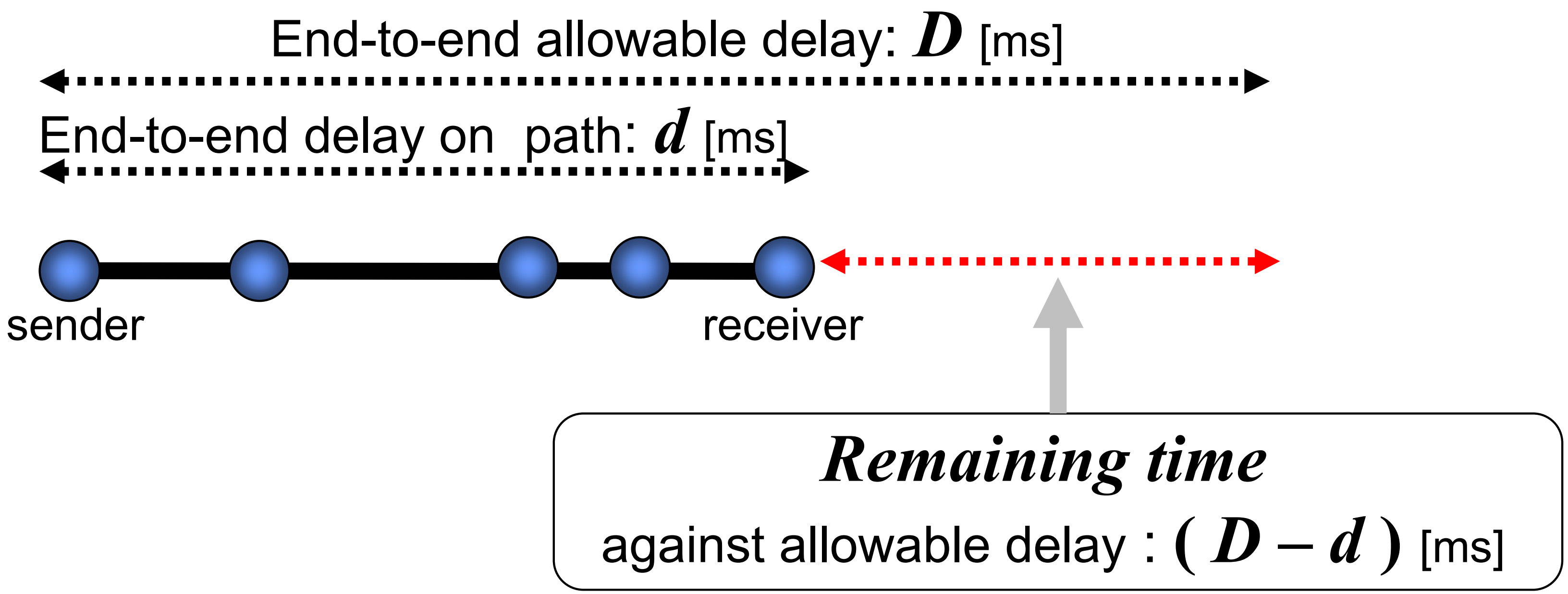
Maintain application QoS
reducing end-to-end total loss

Packets **lost on path**
+
Packet **exceeding allowable delay**



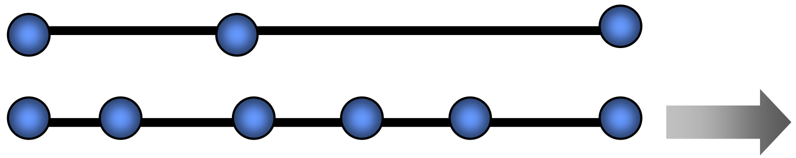
Path Selection Strategy (1/2)

1. Delay
   - As short as possible (comparable to shortest path)
2. Allowable delay
   - **Remaining time** against allowable delay -
   - As long as possible (for future retransmission delay)



Path Selection Strategy (2/2)

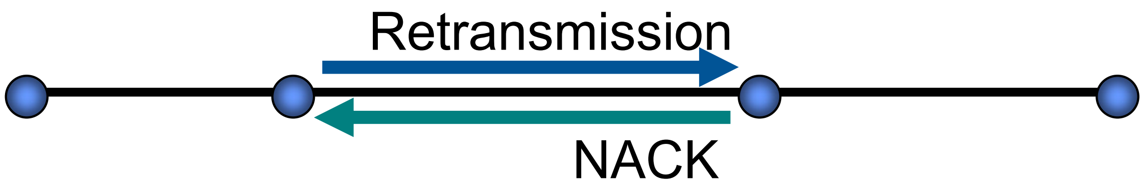
3. Number of relay nodes
   - As many as possible



Greater potential to maintain application QoS despite packet loss

4. Distance between two adjacent relay nodes
   - As short as possible

The shorter each distance is, the shorter retransmission delay becomes



Path Selection Method1 PSDR*

- Path Selection considering strategies 1, 2 and 3
- Each candidate path is evaluated using evaluation function

$$EV = r\,(D - d\,)$$

r : number of relay nodes on the path
d : delay on the path [ms]
D : end-to-end allowable delay [ms]

- Number of relay nodes r : Larger r is preferable (strategy 3)
- Delay on path d : Smaller d is preferable (strategy 1)
- Remaining time (D-d) : Larger (D-d) is preferable (strategy2)

- Select path which has max value for EV for reconfiguration

* Path Selection considering Delay and Relay nodes

Path Selection Method2 PSDR-DP*

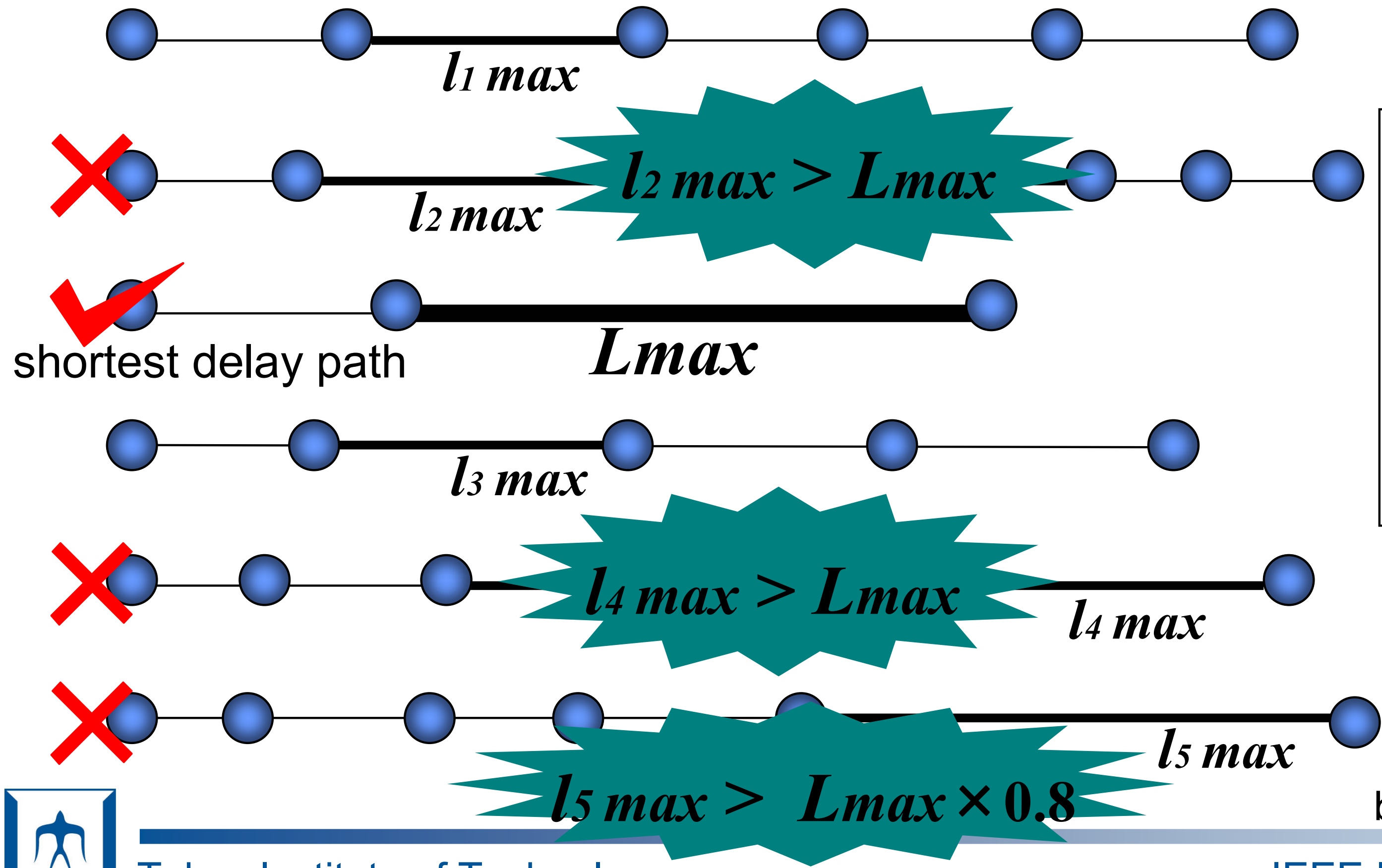
- Path Selection considering strategy 4, in addition to PSDR
- Eliminate any candidate paths with extremely long delay link first

Path Elimination Inequality

$$l_k\ max < Lmax \times \alpha$$

Evaluation function for PSDR

$$EV = r\,(D - d)$$



α : Parameter for adjusting the number of eliminated candidates ($0 \leqq \alpha \leqq 1.0$)

Lmax : max delay link on shortest path

l max : max delay link on each candidate path

*PSDR with a limited Distance between relay nodes using Parameters

Path Selection Method3 PSDR-RP*

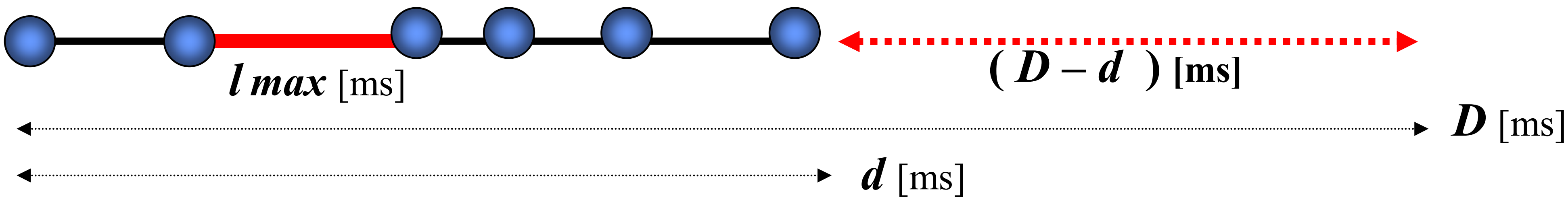
- Path Selection considering strategy 4, in addition to PSDR
- Eliminate any unsuitable path with extremely long delay link first
  - consider relationship between retransmission on ***lmax*** and ***remaining time***

Path Elimination Inequality

$$l_k\, max < (D - d) \times \beta$$

Evaluation Function for PSDR

$$EV = r\,(D - d)$$



β : Parameter for adjusting the number of eliminated candidates $(0 \leqq \beta \leqq 1.0)$

D : end-end Allowable delay

d : end-end delay of candidate path

l max : max delay link of candidate path

*PSDR with limitations on the Retransmission delay using Parameters

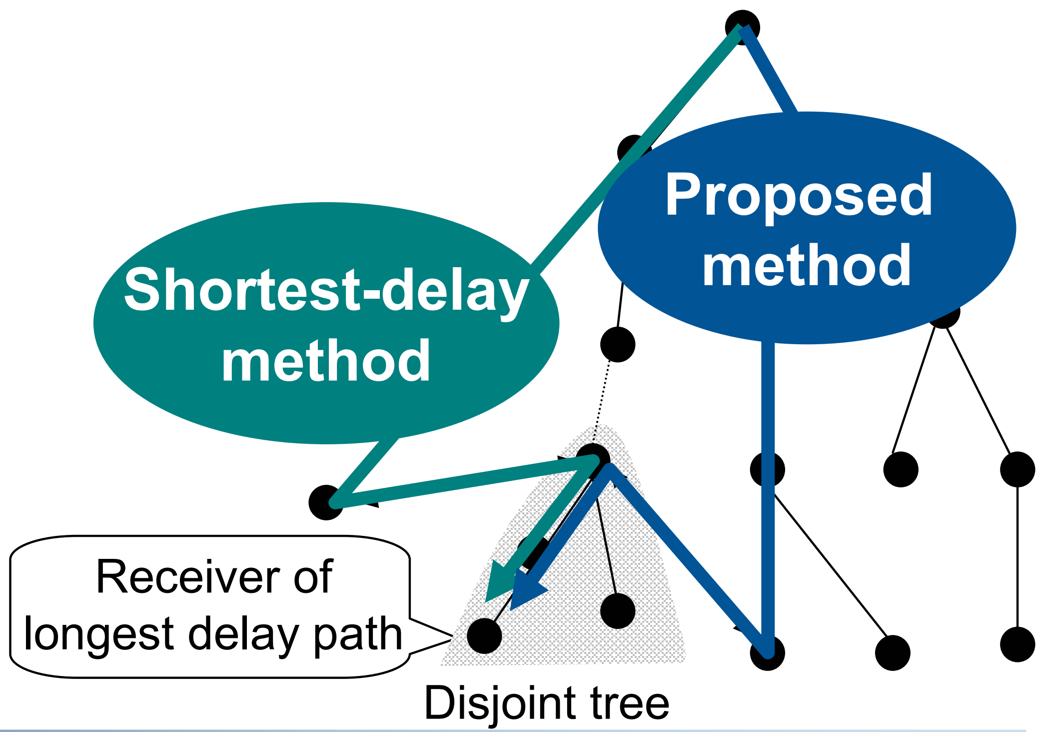
Proposed three path selection methods

		PSDR	PSDR-DP	PSDR-RP
Path elimination inequality		n/a	$lmax < \alpha\, Lmax$	$lmax < \beta\,(D - d)$
Path selection function		$EV = r\,(D - d)$	$EV = r\,(D - d)$ (applied to remaining candidates)	$EV = r\,(D - d)$ (applied to remaining candidates)
Path selection strategy	delay	✓	✓	✓
	Allowable delay	✓	✓	✓
	No. of relay nodes	✓	✓	✓
	Location of Relay nodes	-	✓	✓

Evaluations -simulation conditions-

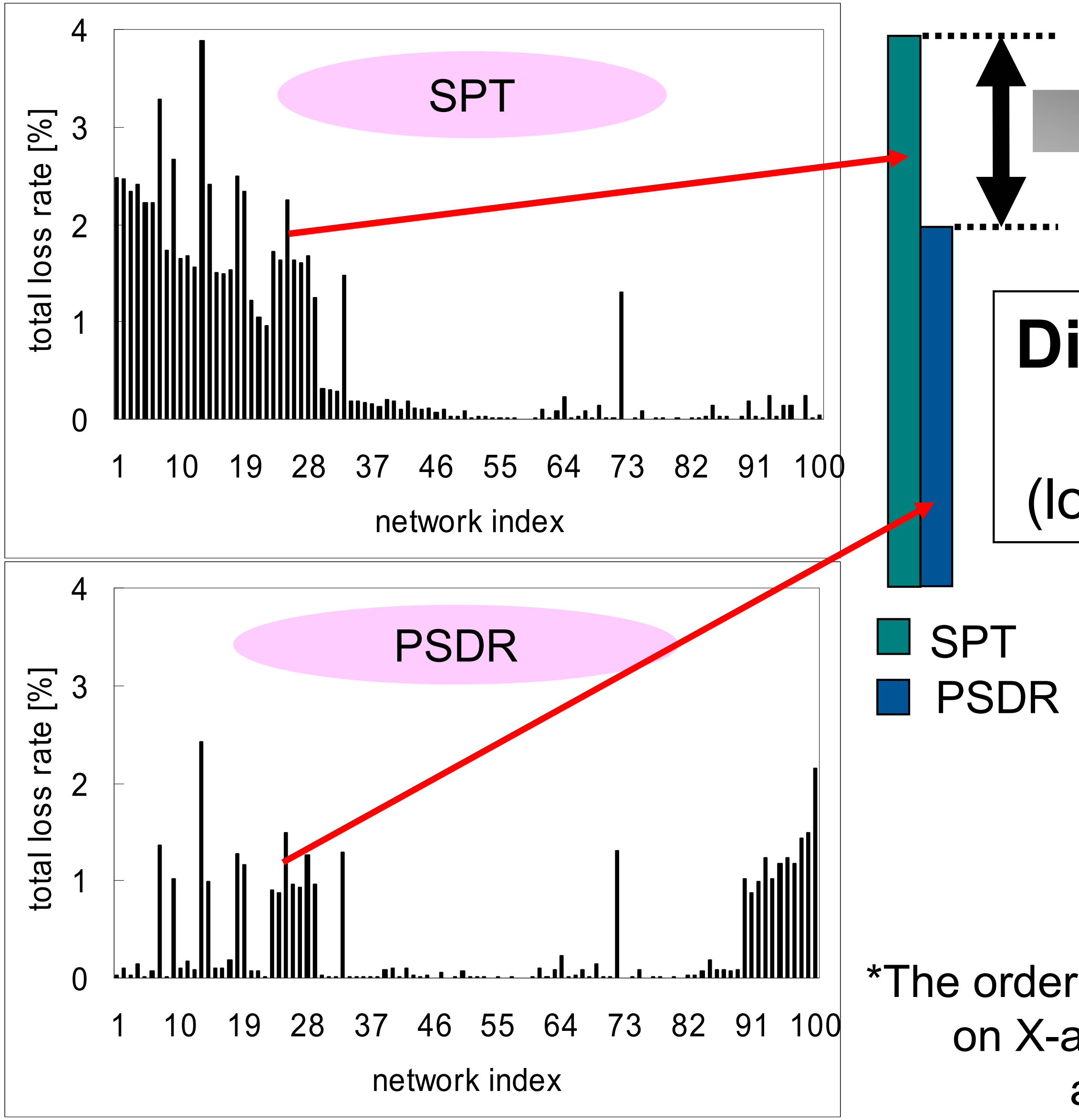
- Proposed vs. shortest path tree (SPT) reconfiguration
- 100 random network topologies with 60 nodes
  - Assume a link with max delay as a bottleneck -> Reconfigure
  - Evaluate receiver of reconfigured path in disjoint tree
- Simulation conditions
  - Packet drop rate at each node is varied randomly as traffic variation

CBR rate	500 kbps
Packet size	200 byte
Allowable delay (*D*)	100 ms
Link bandwidth	10 Mbps
Delay on the link	1 - 30 ms
Random loss rate at node	0 - 0.1



End-to-end total loss rate on receiver

- End-to-end loss rate using SPT and PSDR



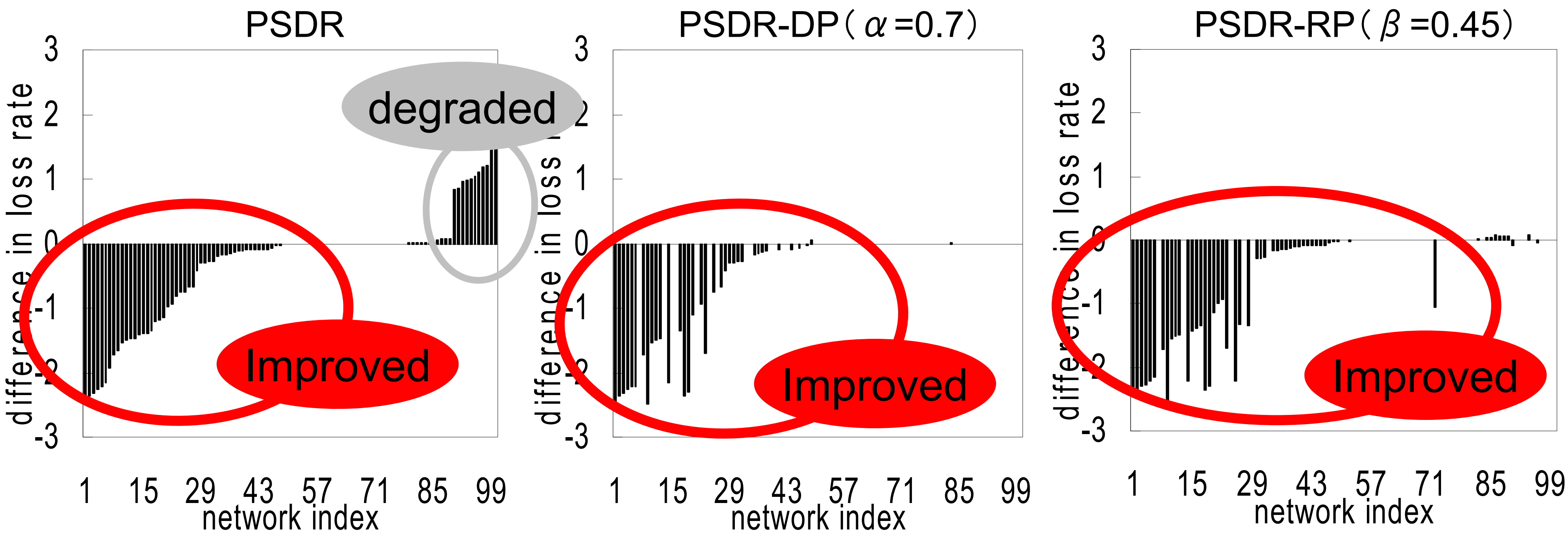
Differences in loss rates
compared to SPT
(loss of PSDR) – (loss of SPT)

*The orders of network topologies
on X-axis in both graphs
are the same

Reduction in loss rate

- Differences in loss rate compared to SPT

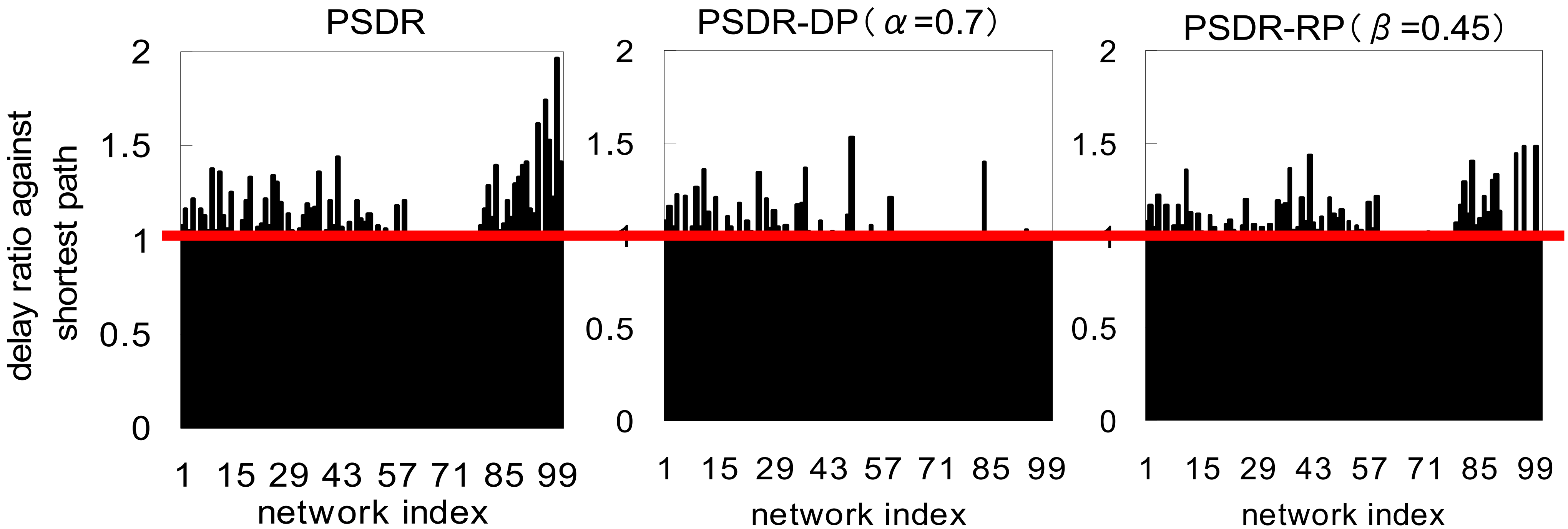
(loss rate for each **proposed method**) – (loss rate for **SPT**) on each topology



Proposed path selection can select paths that reduce end-to-end loss rate better than SPT

Strategy Satisfied -Delay on Path (strategies1, 2)

- Fraction of delay on selected path
  - (delay by **proposed method**) / (delay by **SPT**)

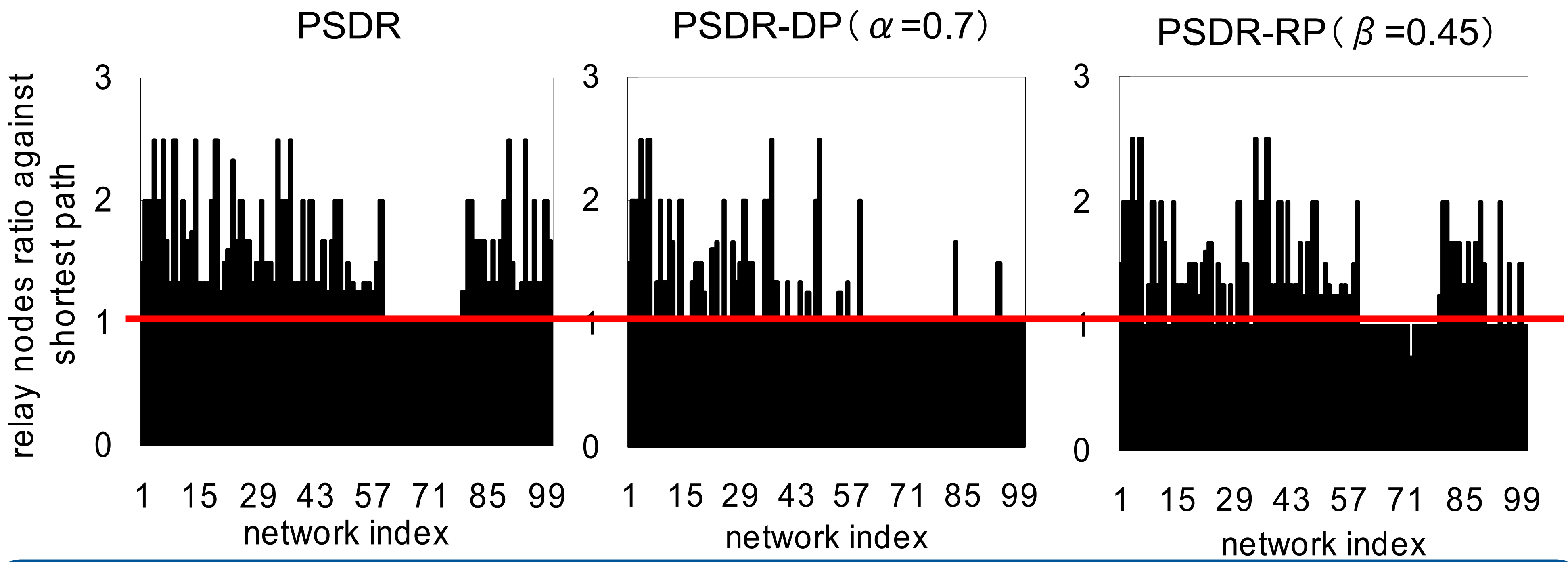


Proposed path selection can select paths with **slightly larger or comparable delay** to SPT

Small delay within allowable delay for live streaming media

Strategy Satisfied -No. of High-functional Nodes (strategy3)

- Fraction of no. of high-functional nodes on selected path
  - (no. of high-functional nodes of proposed) / (those of SPT)

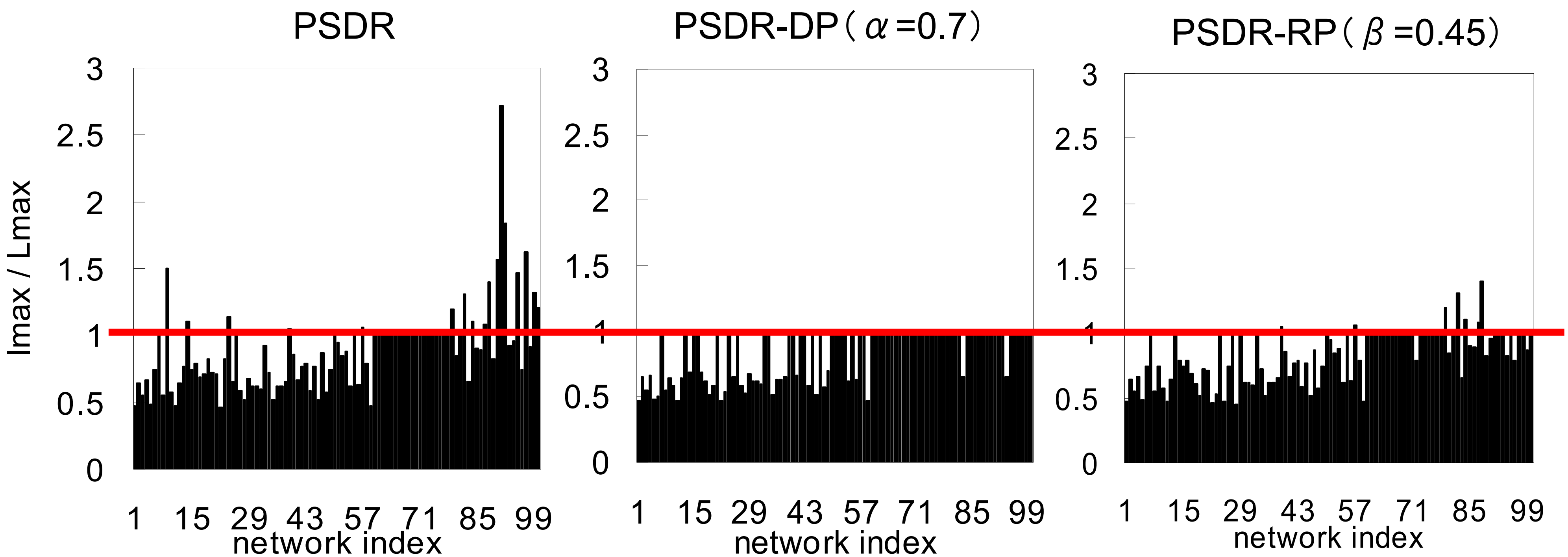


Proposed path selection can select paths with more high-functional nodes than SPT

Immediate loss detection and recovery to maintain application QoS

Strategy Satisfied -Distance between high-functional nodes

- Fraction of max distance on selected path
  - ***lmax / Lmax***



PSDR-DP and PSDR-RP can avoid paths with large distance between relay nodes

Reduce retransmission delay between each relay nodes

Conclusion

- Path selection strategy considering high-functional nodes
- Path selection method
(PSDR, PSDR-DP and PSDR-RP)
- Proposed path selections utilize high-functional nodes and maintain required application QoS better than shortest path method

Proposed path selection methods can reconfigure multicast tree so that it has tolerance to traffic variations

Future Works

- Apply our method to a model with both high-functional node and normal node
- Apply our methods to ALM (Application Level Multicast)
- Look into the complexity of proposed approach vs. shortest
- Discuss bottleneck link