Why Are You Still Using Shortest Path?

- Path Selection Strategy Utilizing High-functional Nodes -

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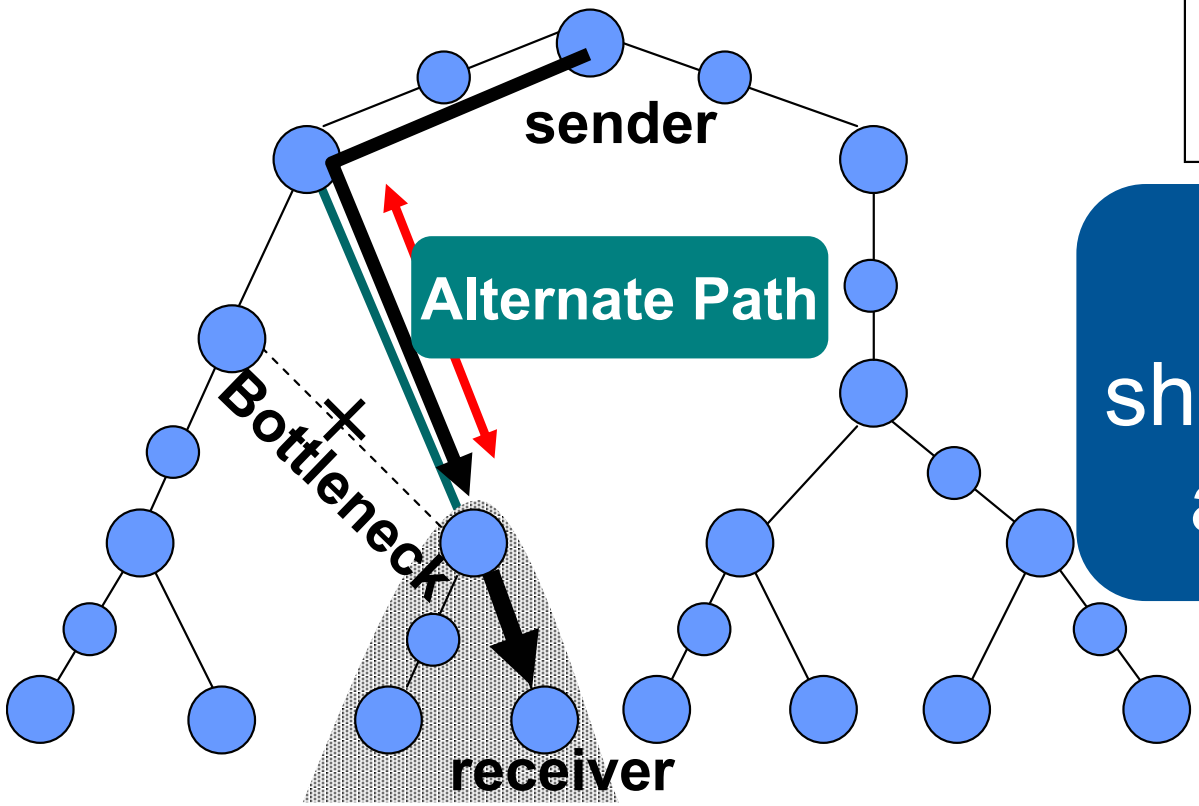
Introduction

- 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

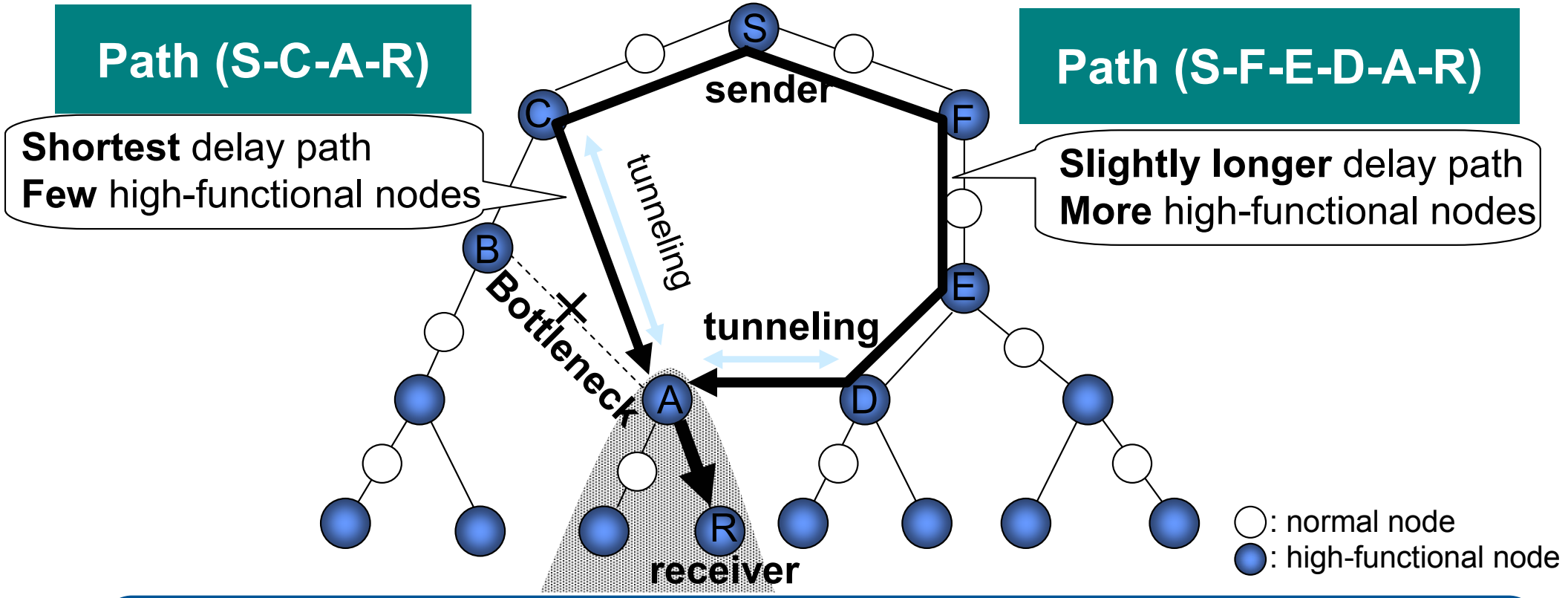


Recover and maintain QoS of end receiver

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

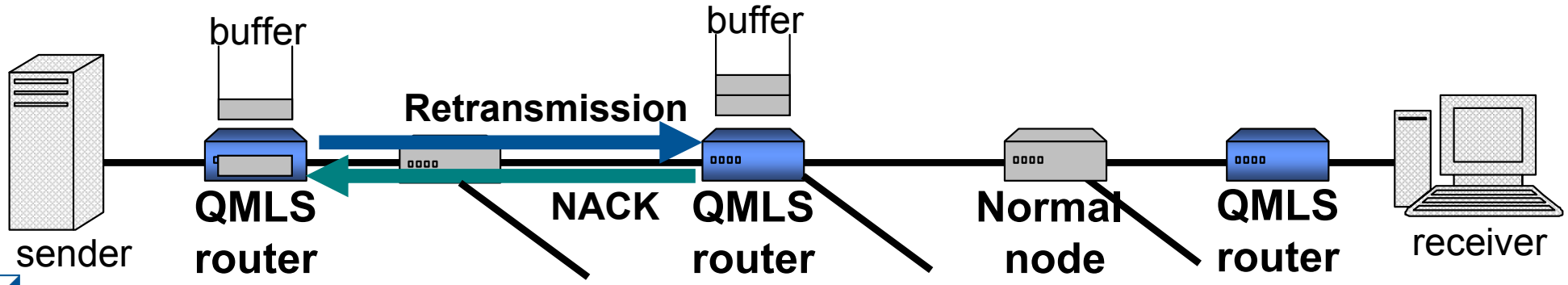
QMLS Router as High-functional Node

- 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

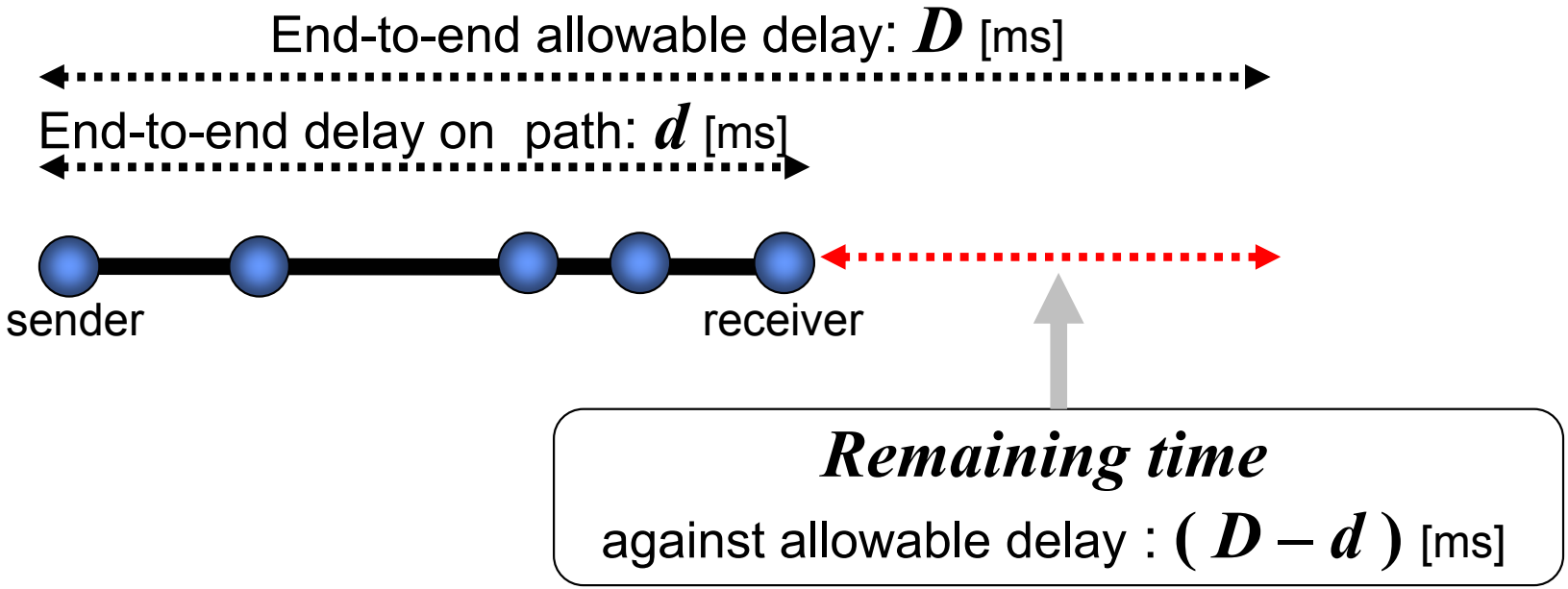
Maintain application QoS reducing end-to-end total loss

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



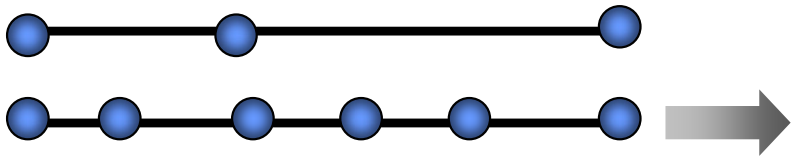
Path Selection Strategy (1/2)

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*

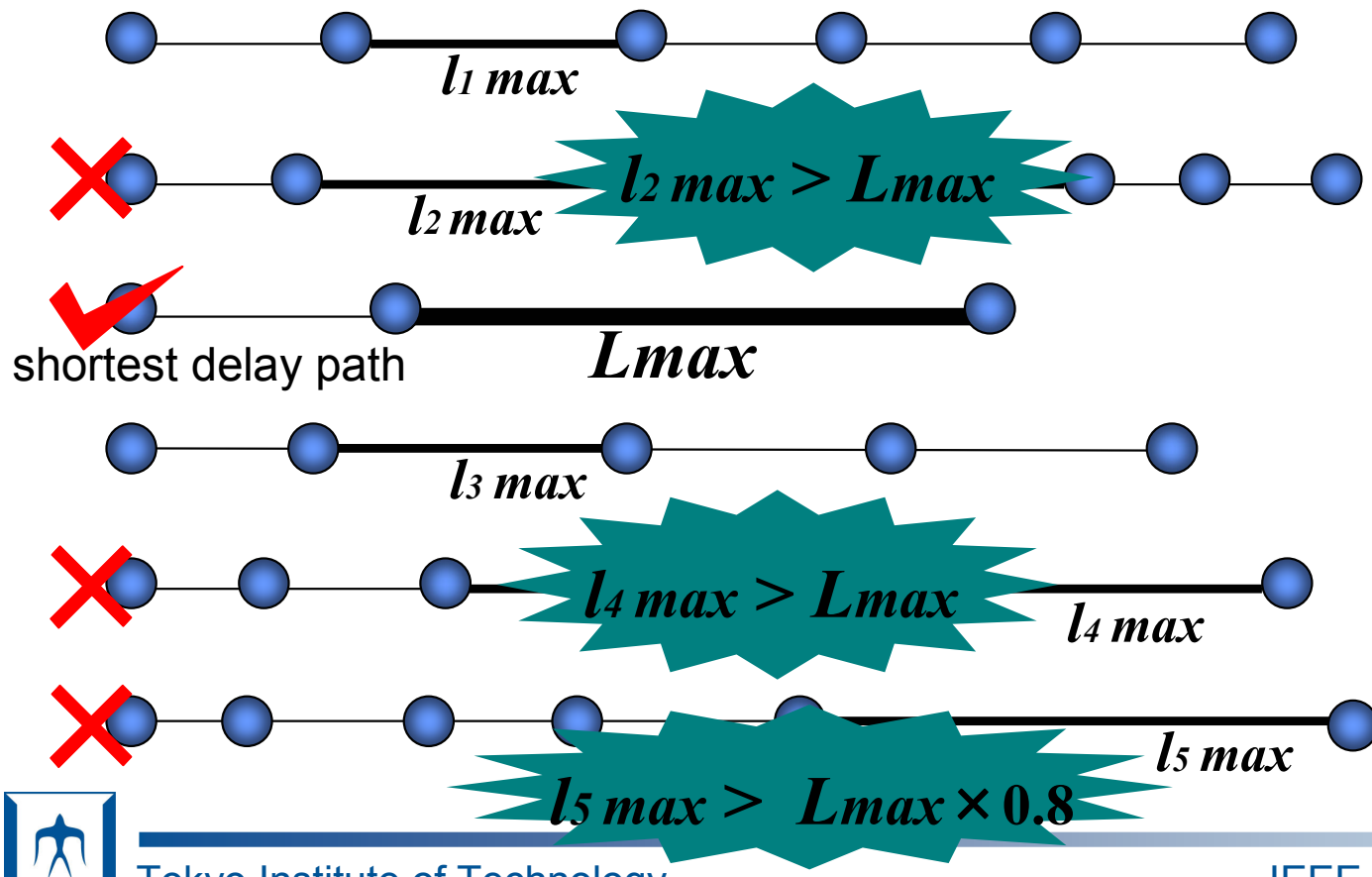
- Path Selection considering strategy 4, in addition to PSDR
- Eliminate any candidate paths with extremely long delay link first

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*

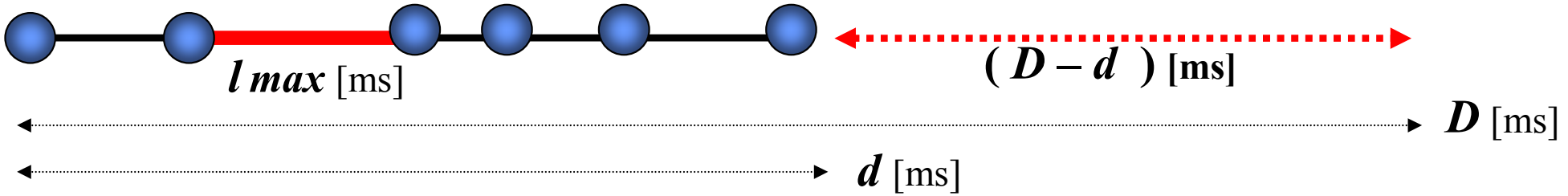
- Path Selection considering strategy 4, in addition to PSDR
- Eliminate any unsuitable path with extremely long delay link first
  - consider relationship between retransmission on ***lmax*** and ***remaining time***

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

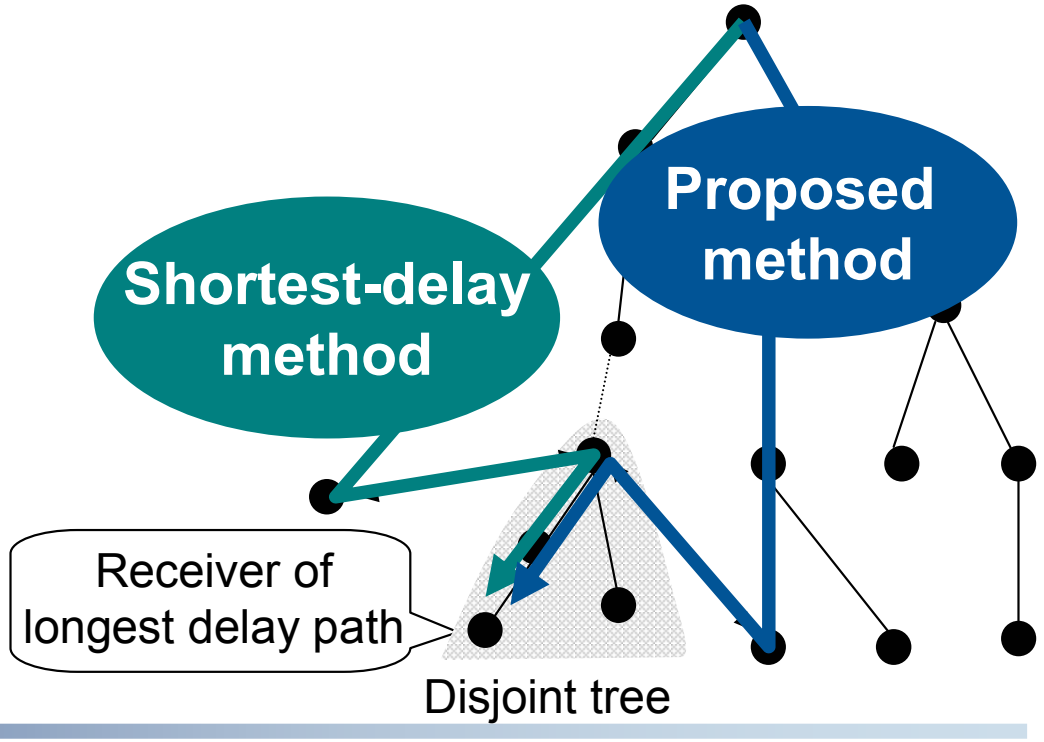
Proposed three path selection methods

		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-

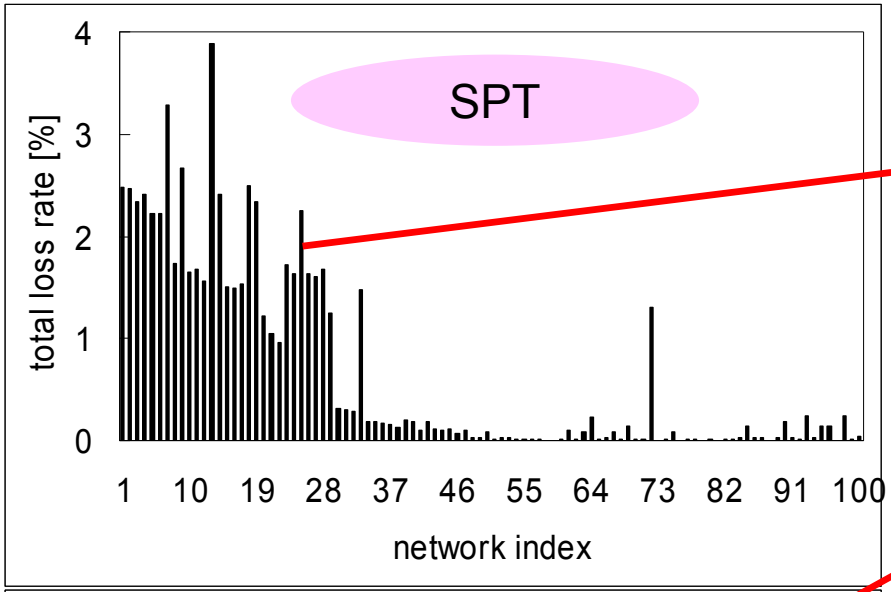
- Proposed vs. shortest path tree (SPT) reconfiguration
- 100 random network topologies with 60 nodes
  - Assume a link with max delay as a bottleneck -> Reconfigure
  - Evaluate receiver of reconfigured path in disjoint tree
- Simulation conditions
  - Packet drop rate at each node is varied randomly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

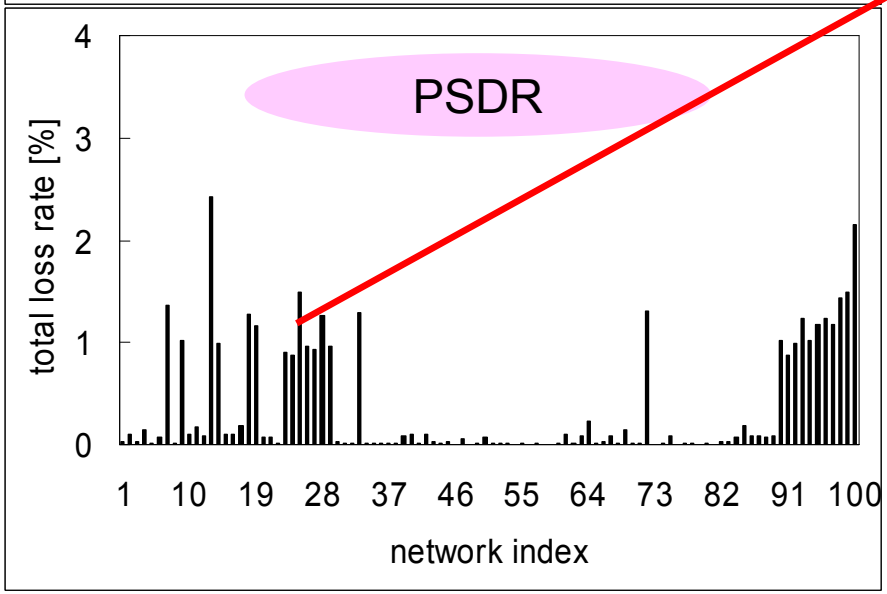
CBR rate	500 kbps
Packet size	200 byte
Allowable delay (D)	100 ms
Link bandwidth	10 Mbps
Delay on the link	1 - 30 ms
Random loss rate at node	0 - 0.1

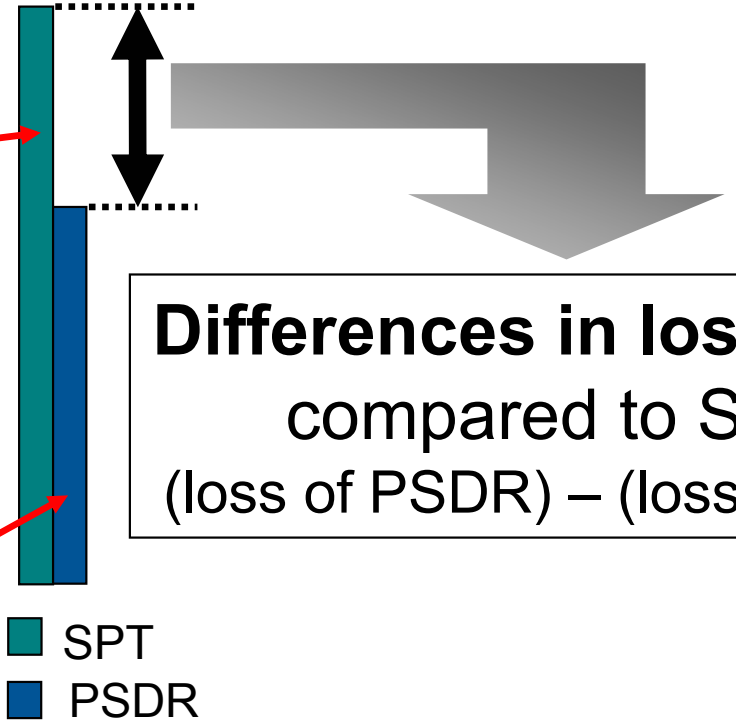


End-to-end total loss rate on receiver

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







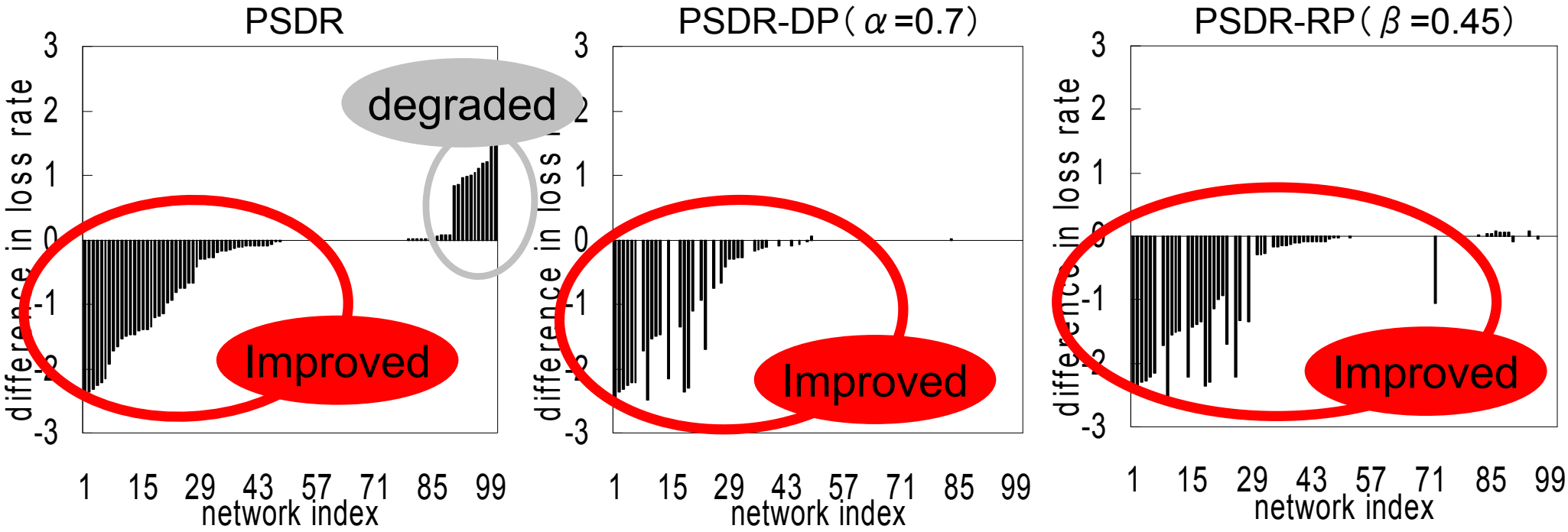
Differences in loss rates
compared to SPT
(loss of PSDR) – (loss of SPT)

*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

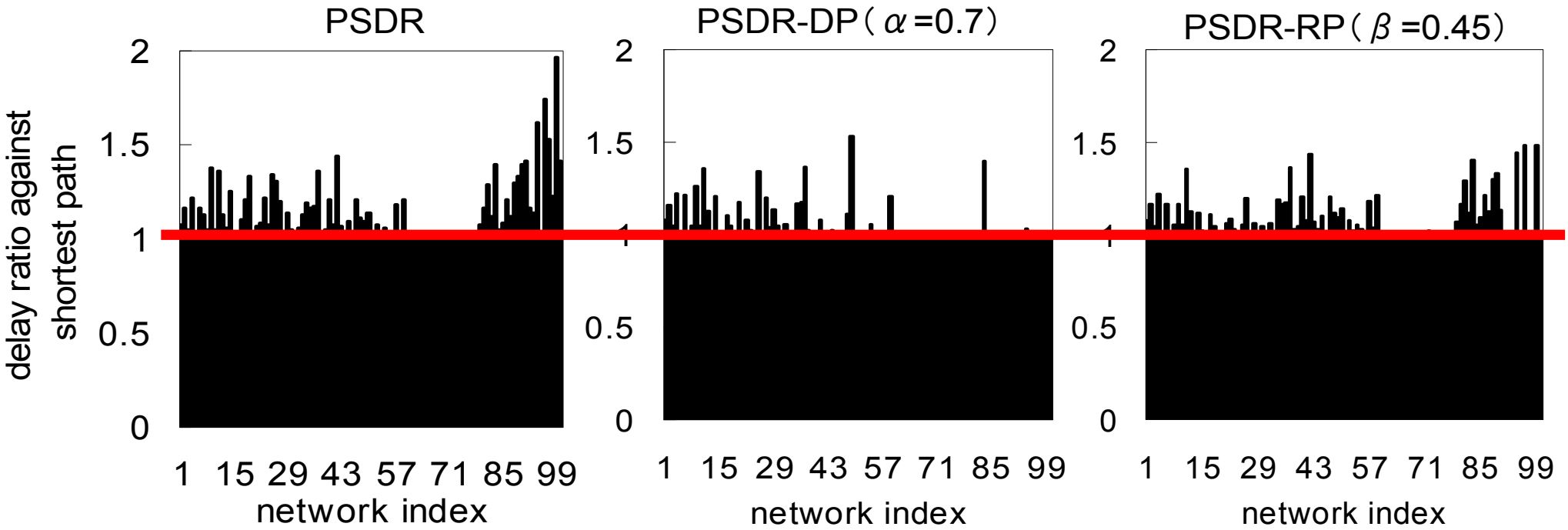
(loss rate for each **proposed method**) – (loss rate for **SPT**) on each topology



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**)

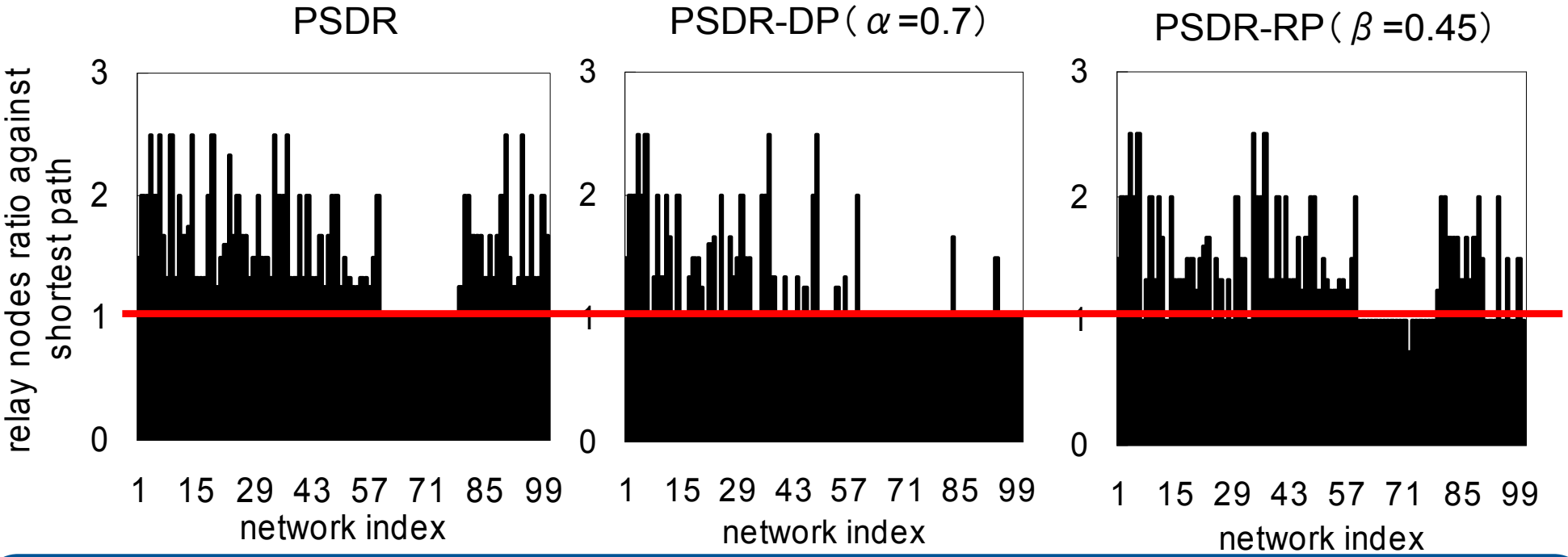


Proposed path selection can select paths with **slightly larger or comparable delay** to SPT

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)

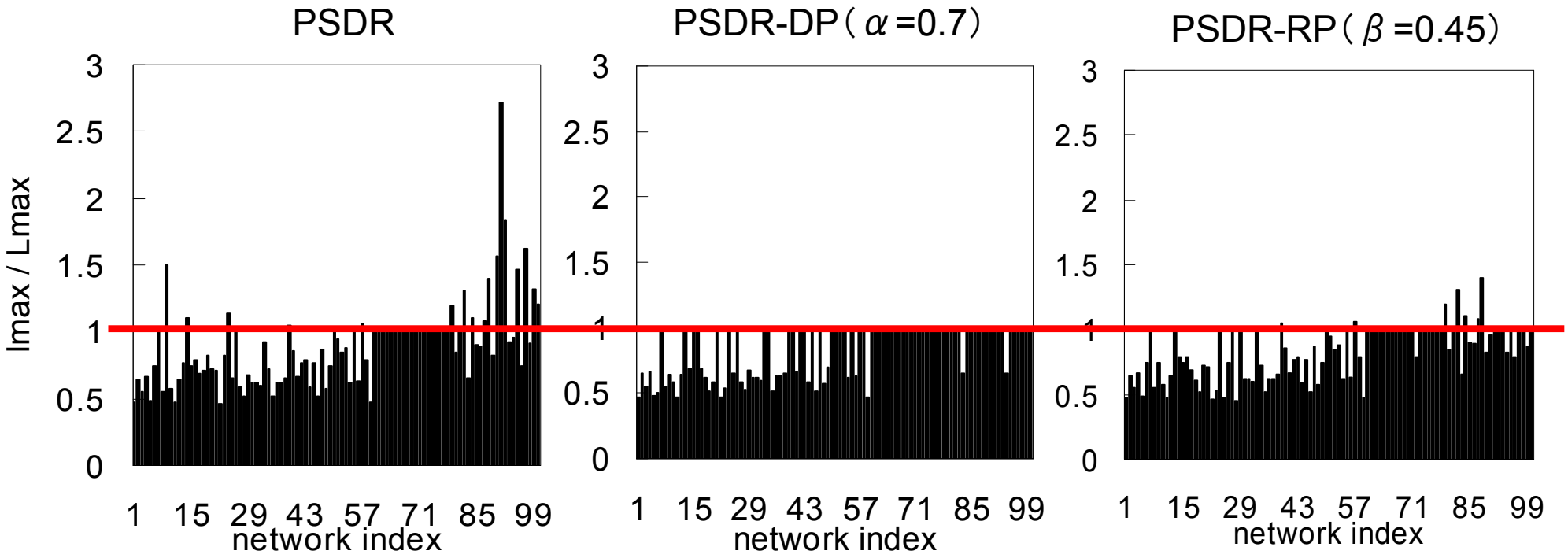


Proposed path selection can select paths with **more high-functional nodes** than SPT

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