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An Adaptive Multipath Routing Algorithm for Maximizing Flow Throughputs

March 6, 2012

Yusuke Shinohara, Yasunobu Chiba and Hideyuki Shimonishi
System Platforms Research Laboratories
NEC Corporation

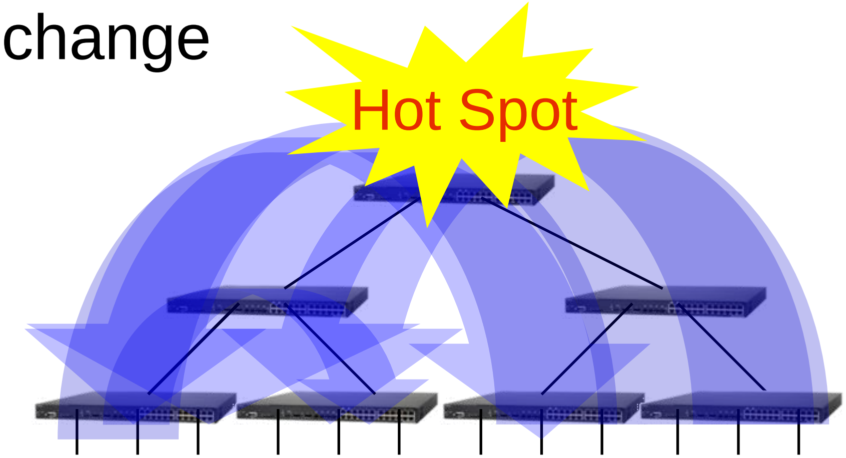
Outline

- Background
  - Original multipath routing algorithm
  - Problem statement
- Our proposal
- Evaluation results
- Conclusion and future work

Background

Changes in traffic pattern in data center

- Server to server “horizontal traffic”
- Daily and hourly demand change



Solution:

Mesh network + multipath load-balance

Back ground –cont'd

- Difficulty in load balance by ECMP
  - Uses equal cost path ONLY
    - Resolve paths by using packet header and hash function
  - Unawareness of link utilization
- Poor scalability of K-Shortest Path
  - Need huge path computation cost: O(n3 x N)
    - Depend on # of path candidates

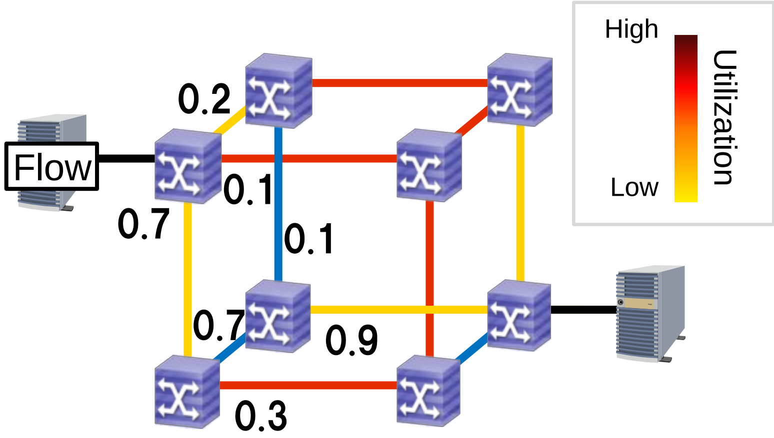
- Key issue:

Lightweight and efficient multipath selection considering link utilization

Multinomial Logit Based (MLB) routing (1/2)

Multinomial Logit Based Routing

- Based on logit model using random utility theory
- Random path selection based on the path cost of all considerable path
  - E2E path selection based on logit model
  - Enhance hop-by-hop path selection by using equivalent Markov model
- Periodical transition probability computation($O(n^3/3)$)



Multinomial Logit Based (MLB) routing (2/2)

- Transition probability $p(j \mid i)$ from node i to node j for destination d

$$p(i \mid j) = \exp\left[-\gamma \cdot c_{ij}\right] \cdot \frac{W_{jd}}{W_{id}}$$

γ : parameter of Gumbel distribution
c_{ij} : link cost between i and j
e_{ij} : link between i and j

$$\mathbf{W} = \left[\mathbf{I} - \mathbf{A}\right]^{-1}$$

$$a_{ij} = \begin{cases} \exp[-\gamma \cdot c_{ij}] & \text{(If link } e_{ij} \text{ exist)} \\ 0 & \text{(Other)} \end{cases}$$

- Link cost : Link utilization, delay or loss rate…
- Computations
  - Matrix **W** : $O(n^3/3)$ (periodical)
  - Transition probability $p(j \mid i)$: a multiplication and division (at transition)

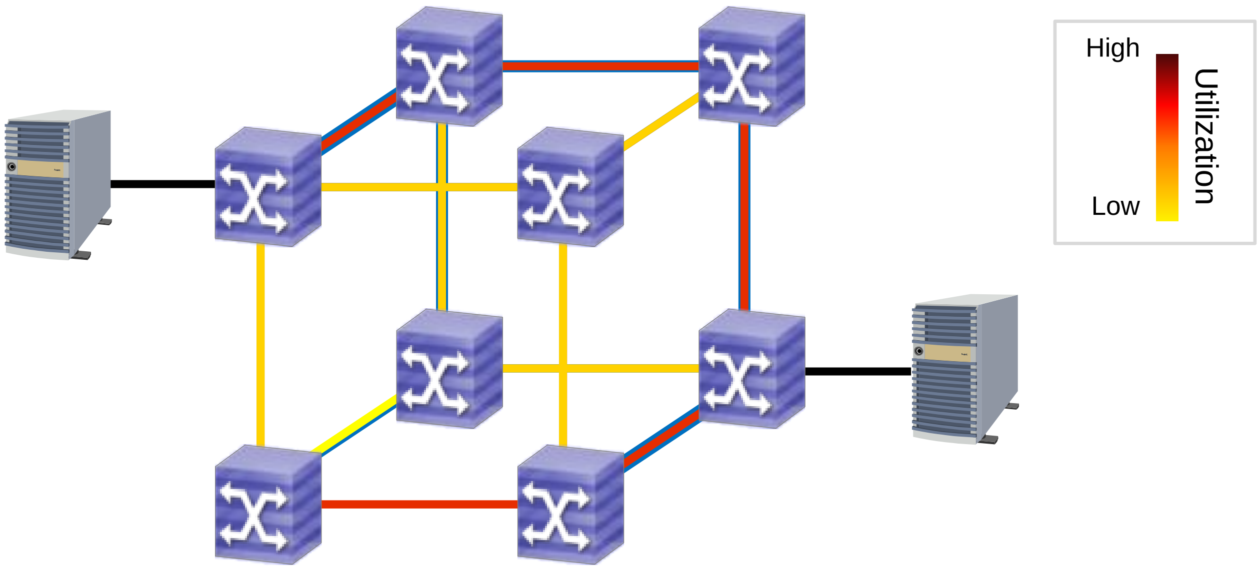
Problem statement

- Difficulty to determine path diffusion parameter in MLB routing
  - Best value changes dynamically
    - The best value depends on topology and traffic pattern
  - Its performance depends on the parameter γ
    - Large γ : Tends to select shortest paths and may cause congestion
    - Small γ : Tends to select various paths and may select unnecessarily detour paths path

Dynamic parameter tuning leads to lightweight and effective the multipath routing algorithm.

Overview of the proposed method

- Periodically update the path diffusion parameter
- Search optimum value to minimize the total path cost
  - Path cost : the sum of link utilization that traffic would experience
  - Compute traffic distribution with γ and link utilization
  - Estimate future link utilization with traffic distribution and traffic matrix
  - Estimate future path cost with traffic distribution and future link utilization

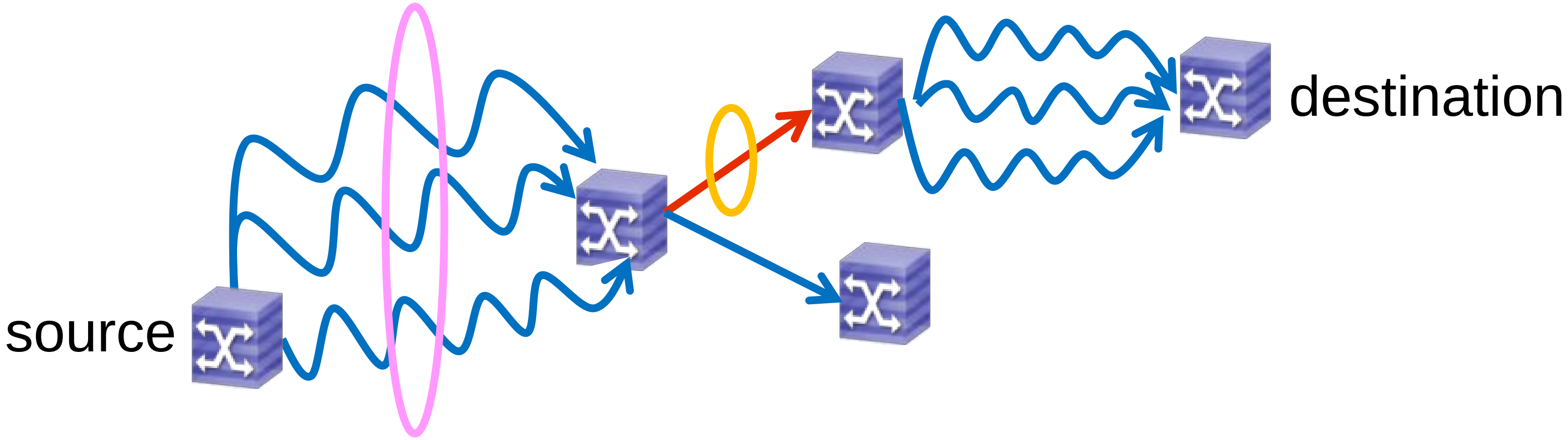


Parameter tuning with estimation (1/3)

- p_{odij} : Probability that the link e_{ij} is used by a flow from source o to destination d

$$p_{odij} = \frac{W_{oi} \cdot W_{id}}{W_{od}} \cdot p(j \mid i)$$

$$= W_{oi} \cdot \exp[-\gamma \cdot c_{ij}] \cdot W_{jd} / W_{od}$$



Parameter tuning with estimation (2/3)

- l_{ij} : Traffic amount on link e_{ij}

$$l_{ij} = \sum_{o}\sum_{d}\left(p_{odij} \cdot T_{od}\right)$$

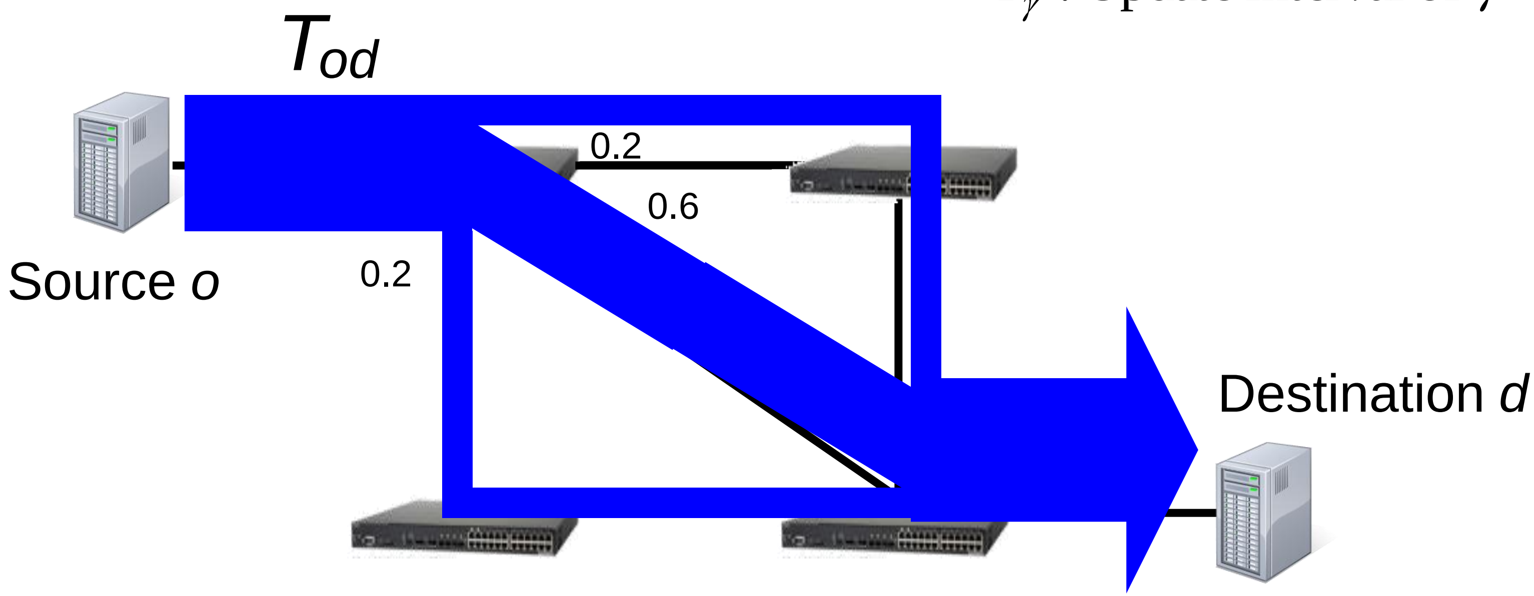
T_{od} : Traffic matrix from o to d

- c'_{ij} : Estimated future Link utilization at the next update

$$c'_{ij} = c_{ij} + l_{ij} / (bw_{ij} \cdot I_{\gamma})$$

bw_{ij} : Bandwidth of link e_{ij}

I_{γ} : Update interval of γ



Parameter tuning with estimation (3/3)

- $\overline{C}_{od}$: Estimated future average path cost from source *o* to destination *d*

$$\overline{C}_{od} = \sum_i \sum_j p_{odij} \cdot c'_{ij}$$

- Select γ that has the lowest average cost

$$\gamma_n : \text{current value of } \gamma$$

$$\gamma_u : \gamma_n \cdot (1 + x)$$

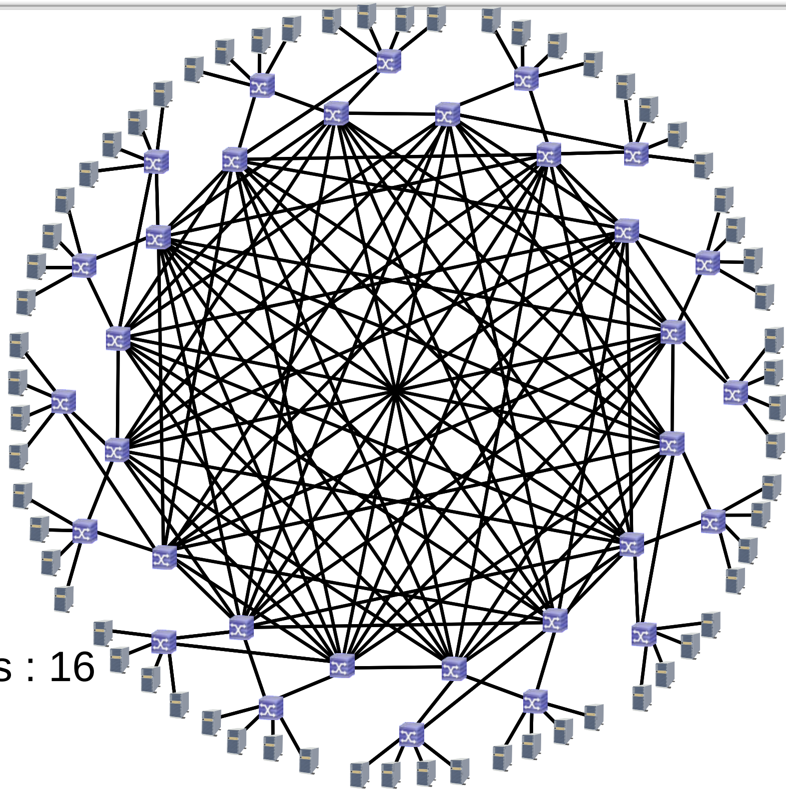
$$\gamma_l : \gamma_n \cdot (1 - x)$$

Experimental Evaluation (1/2)

Experimental evaluation on OpenFlow network

- OpenFlow Controller
  - We developed our method on our OpenFlow controller
  - Our OpenFlow controller notify topology to our method
  - Our method create flow entry after resolving path
- Edge switches
  - Open vSwitch
- Core switches
  - Our prototype OpenFlow switch (48 x GbE + 2 x 10GbE)
- Servers
  - Virtual Machine (KVM)

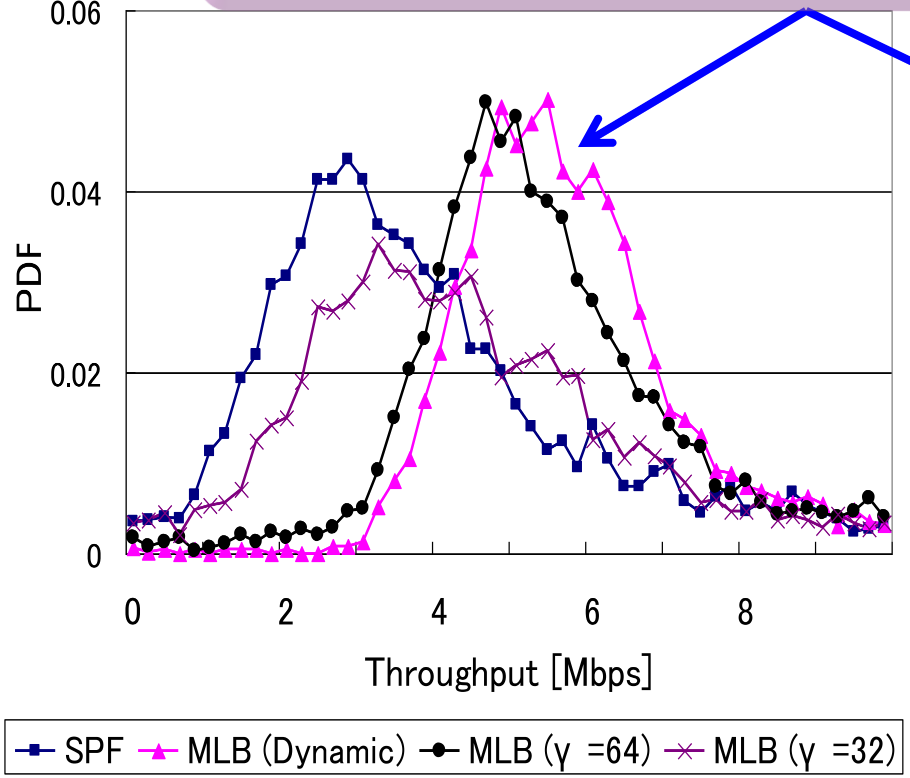
Experimental Evaluation (2/2)

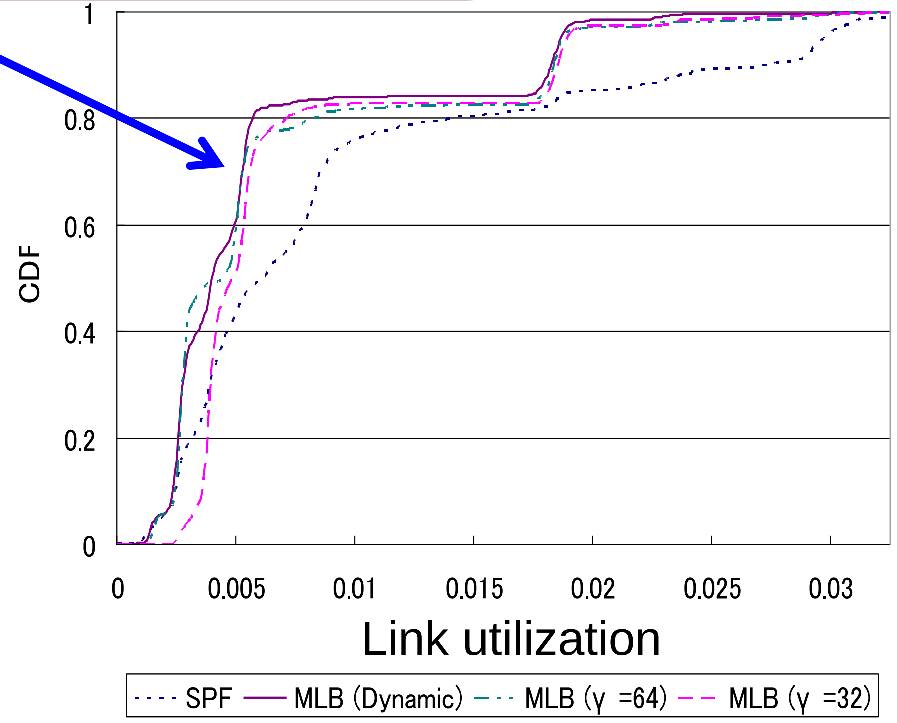


- Performance metric
  - Link utilization
  - Average throughput
  - The number of hops
  - Parameter γ
- Topology
  - Enhanced Hypercube
    - Core switch connects to switch whose hamming distances is one and two
    - Servers : 64, Edge switches:16, Core switches : 16
- Scenario
  - Each server has 8 sending thread
  - Each sending thread selects destination server randomly and sends for random time (1 – 10sec) using TCP
- Comparison method
  - Shortest Path First (SPF)
  - MLB Routing with static parameter (γ = 32, 64)

Result (1/2)

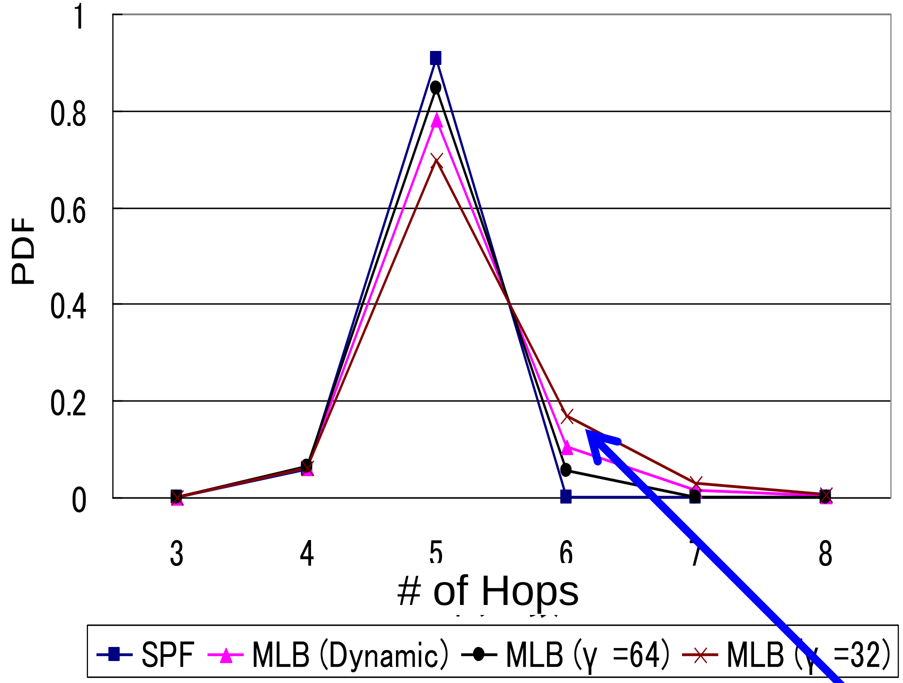
Our method achieves the best performance by load balancing

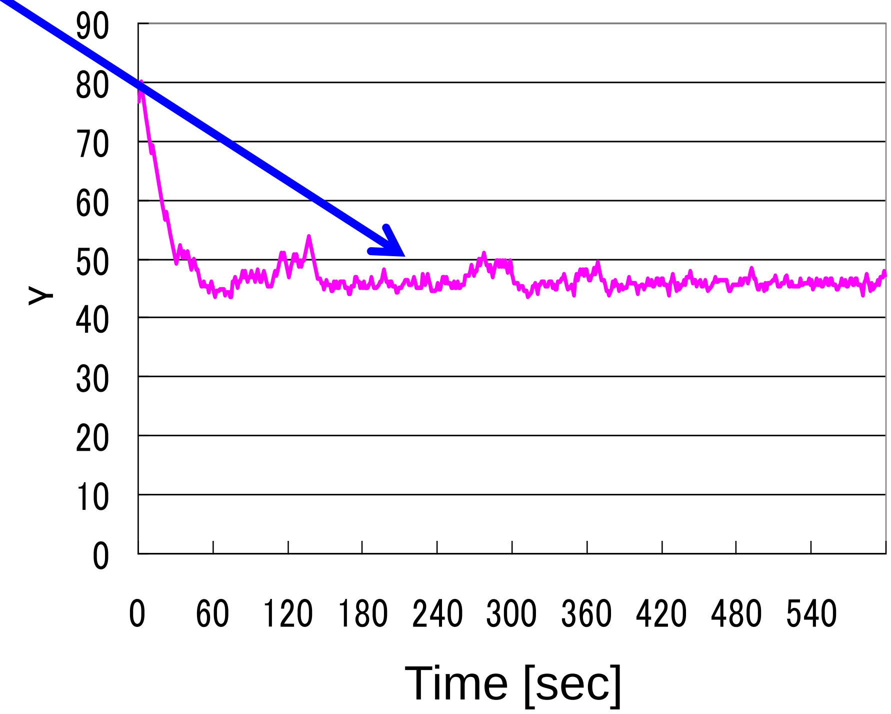




Result (2/2)

Our method tunes the parameter
to appropriate value





MLB with static parameter increases
the number of hops by selecting redundant paths

Conclusions and Future works

Conclusions

- Needs for mesh network and dynamic routing
- Existing schemes and problem statement
  - MLB routing has difficulty to setup parameter
- Proposal method
  - Dynamic parameter tuning for MLB routing
- Experimental evaluation
  - Our method enhance routing performance by tuning parameter

Future works

- Comparison with other routing algorithms
- Reduction of overhead

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