Evaluation of MPLS P2MP Distribution Tree Algorithms

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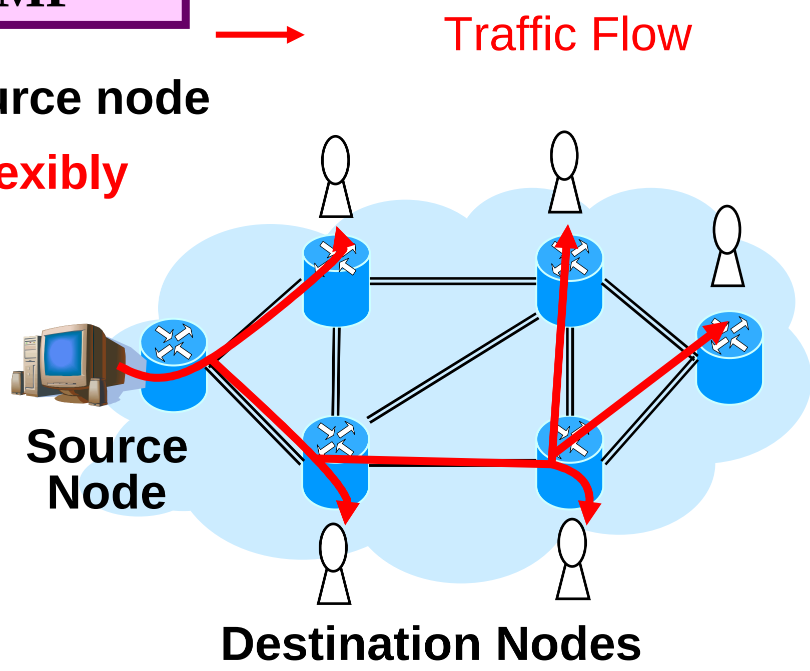
B a c k g r o u n d

Traffic engineering in multiprotocol label switching point to multipoint ［MPLS P2MP］can improve network economy and quality of service.

Traffic Engineering in MPLS P2MP

MPLS P2MP： A multicast tree from a source node to destination nodes can be chosen flexibly using traffic engineering.

IP multicast： A multicast tree is set according to the multicast protocol.



Objectives

In MPLS P2MP, we can improve multicast routing algorithms using traffic engineering.

Requirements for multicast routing algorithms:

- Unpredictably generated destination nodes
- Reduced delay in transmitting video data
- Reduced network cost

We compare routing algorithms considering delay time and economy and show the merit of our proposed one.

Conventional algorithms:

- Shortest Path Tree (SPT)
- Minimum cost paths heuristic (MPH)[Steiner Heuristic Tree]

Proposed algorithm:

- Constrained MPH (CMPH)[Steiner Heuristic Tree with Hop Constraint]

Steiner Tree Algorithm (MPH)

□: Add a locally optimal path to the previous tree.

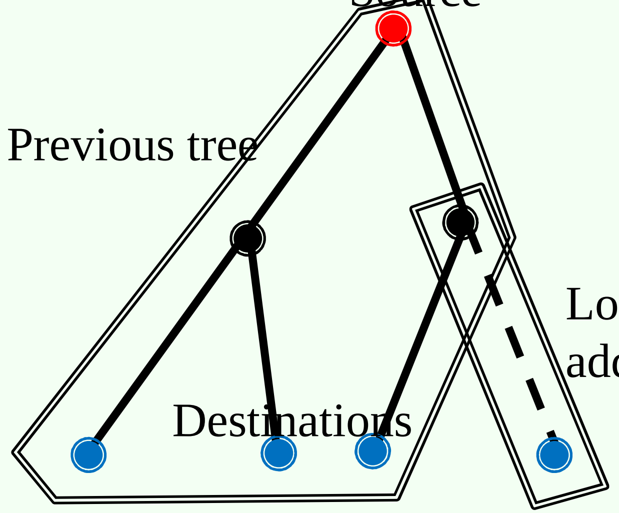
□-1: Compute distances between any two nodes.

□-2: Search for a minimal path to a destination using □-1.

□-3: Add the path obtained by □-2 to the previous tree.

□: Repeat □ until all destinations are connected.

Minimum Cost Paths Heuristic (MPH)



-The distances between any two nodes in a network are computed using the Dijkstra method.

-MPH can meet the demand of unpredictably generated destination nodes.

Steiner Tree Algorithm (CMPH)

□ Add a locally optimal path to the previous tree under the hop constraint.

□-1 Compute distances between any two nodes under the hop constraint.

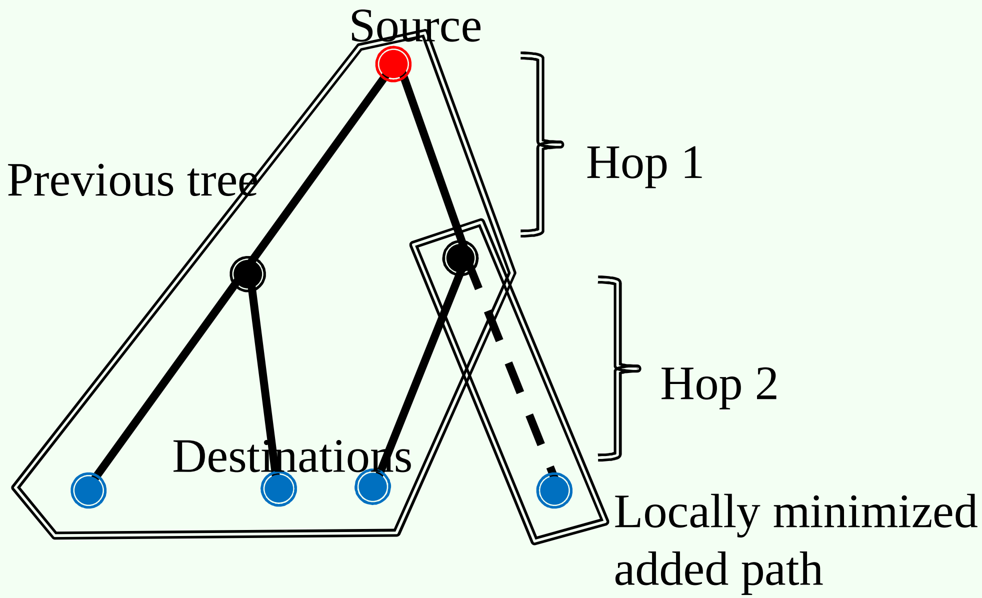
□-2 Search for a minimal path to a destination using □-1 under the hop constraint.

□-3 Add the path obtained by □-2 to the previous tree.

□ Repeat □ until all destinations are connected.

Constrained MPH (CMPH)

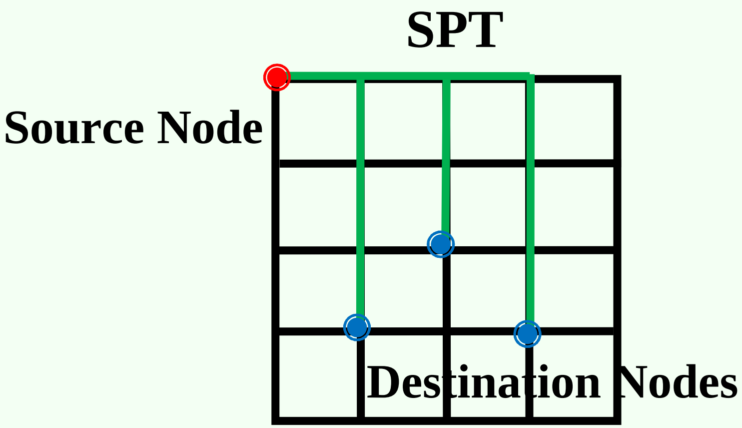
Hop 1 + Hop 2 < Hop constraint

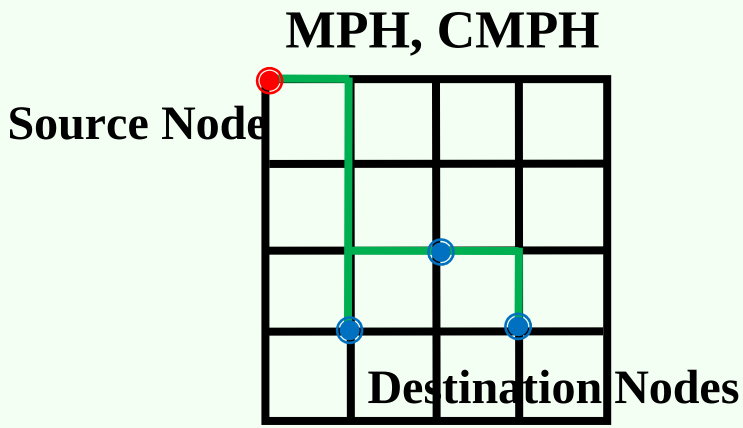


-The distances between any two nodes under the hop count in a network are computed using the matrix multiplication method.

-CMPH maintains an acceptable delay time on destination nodes, but some nodes might not be connected under the hop constraint.

Three Conventional Multicast Trees





	SPT	MPH	CMPH
Mechanism	Connecting a source with destinations using shortest paths	Connecting a source with destinations such that total link length is minimized heuristically	Performing MPH under hop constraint
Economical effect	Not considering sharing links	Considering sharing links	Considering sharing links
Small hop count	Without hop constraint	Without hop constraint	With hop constraint
Computation	Fast	Slower than SPT	Slower than MPH

Simulation Outline

Purpose:
Evaluation of SPT, MPH, CMPH from the aspects of economy and hop count.

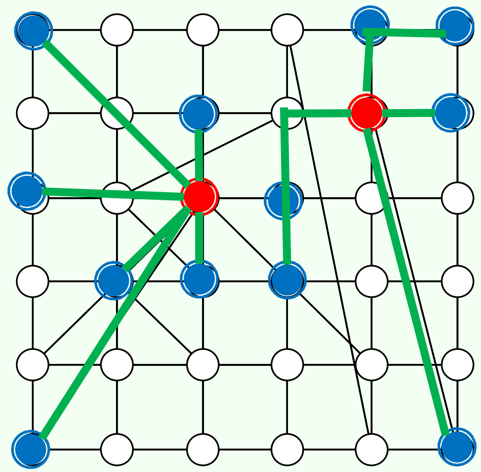
Evaluation scales	(1) Average hop count from a source to destinations (2) Ratio of destination nodes that satisfy the hop constraint (3) Tree cost modified by the ratio of connected and unconnected destinations
Network patterns	2 cases
Hop constraint	5, 8, 15
Tree numbers	6, 9, 12, 16, 20
Number of destination nodes in a tree	6
Routing algorithms	SPT, MPH, CMPH
Number of computations	100

Transmission Network Model

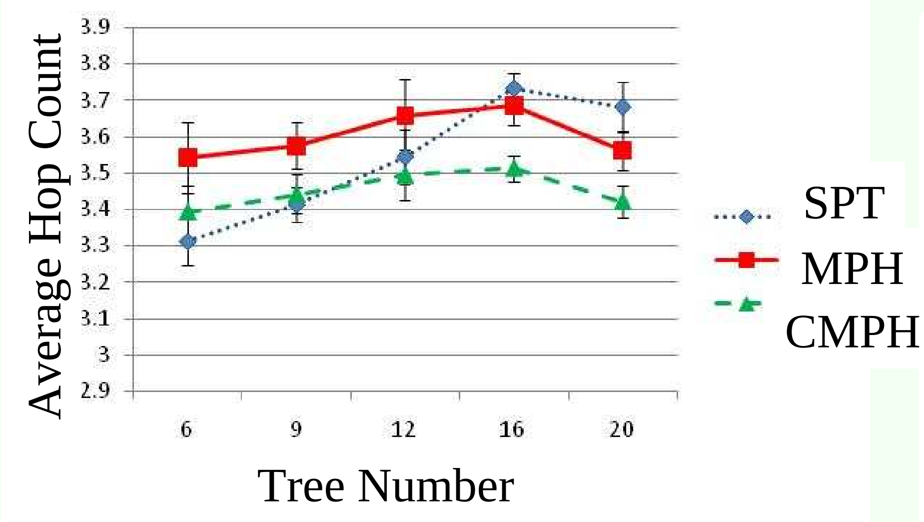
▪Following transmission network model was used in simulations.

Network topology	6×6 lattice + 10 short cut links
Link length	Lattice: 5 Short cut links: diagonal distances
Link capacity	2
Means to compute distances between two nodes	SPT: Dijkstra method MPH: Dijkstra method CMPH: matrix multiplication method
Means to generate multiple trees	Alternately adding paths across each of the trees.

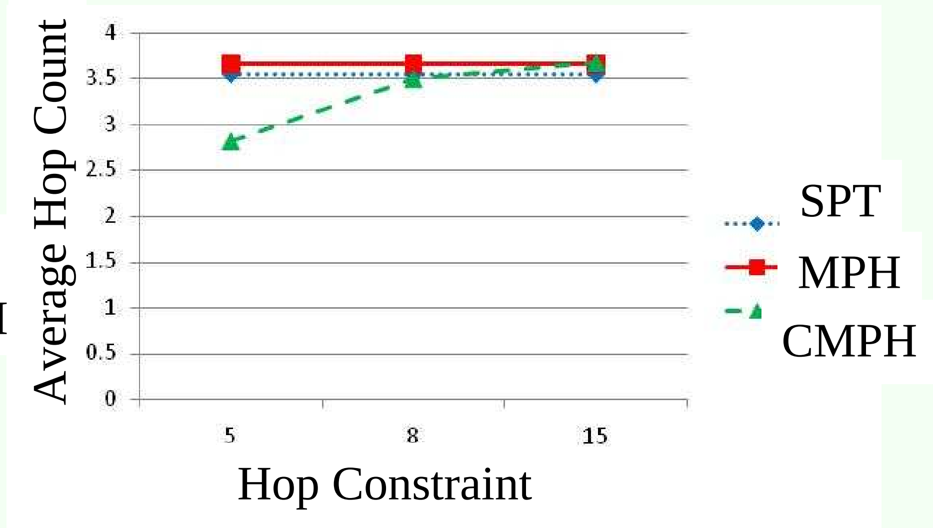
Transmission network example



Simulation Result (Average Hop Count)



Hop Constraint: 8

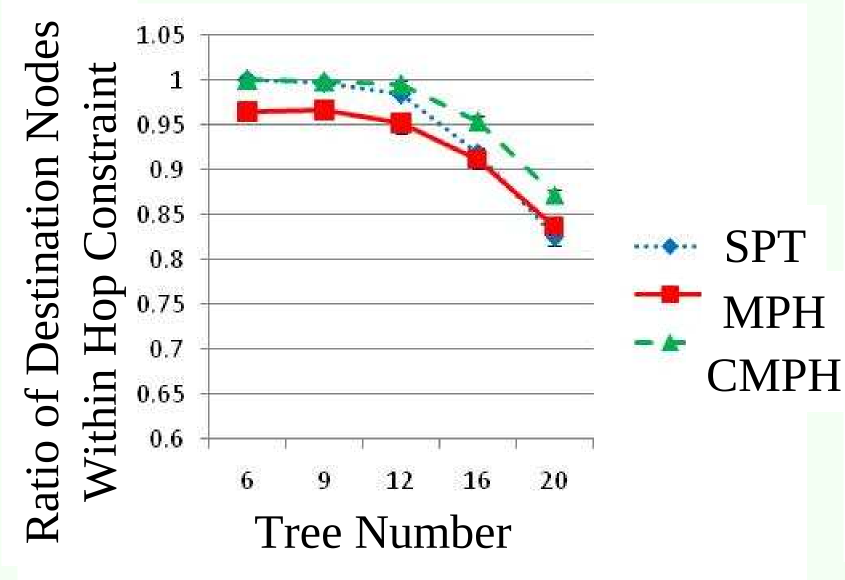


Tree Number: 12

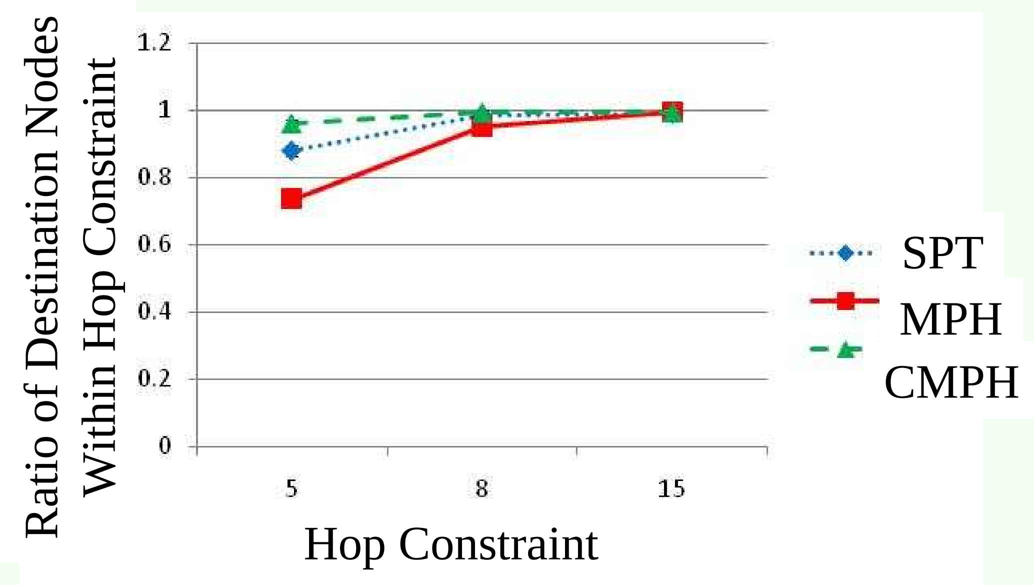
Average hop count:

- **CMPH < MPH**
- **SPT has a wide range when tree number changes.**
- **Gap between CMPH and MPH reduces when hop constraint loosens.**

Simulation Result (Ratio of Destination Nodes that satisfy the Hop Constraint)



Hop Constraint: 8



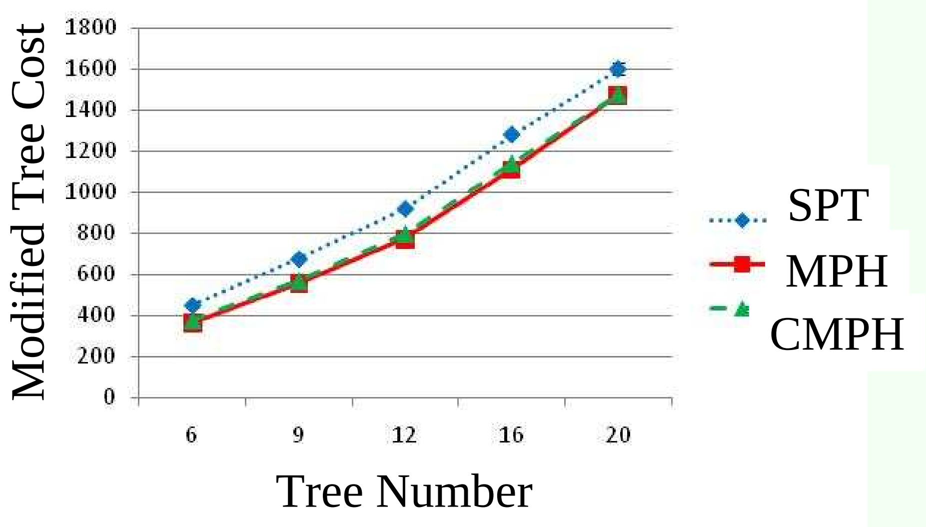
Tree Number: 12

Ratio of destination nodes that satisfy the hop constraint:

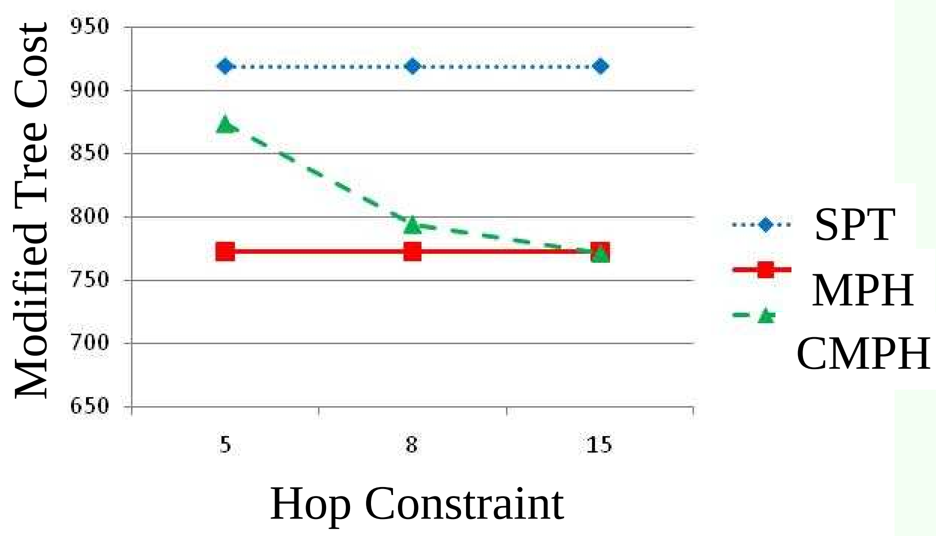
- **CMPH > SPT > MPH**
- **The gap between CMPH and MPH reduces when hop constraint loosens.**

- Even if we consider unconnected destination nodes, CMPH gives the highest QoS (ratio of destination nodes that satisfy the hop constraint) among the three.

Simulation Result (Modified Tree Cost)



Hop Constraint: 8



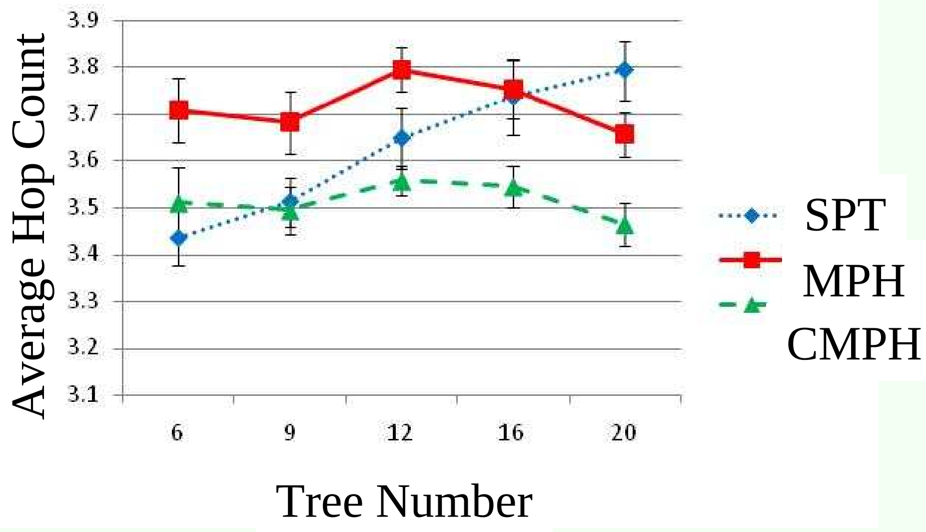
Tree Number: 12

Modified tree cost:

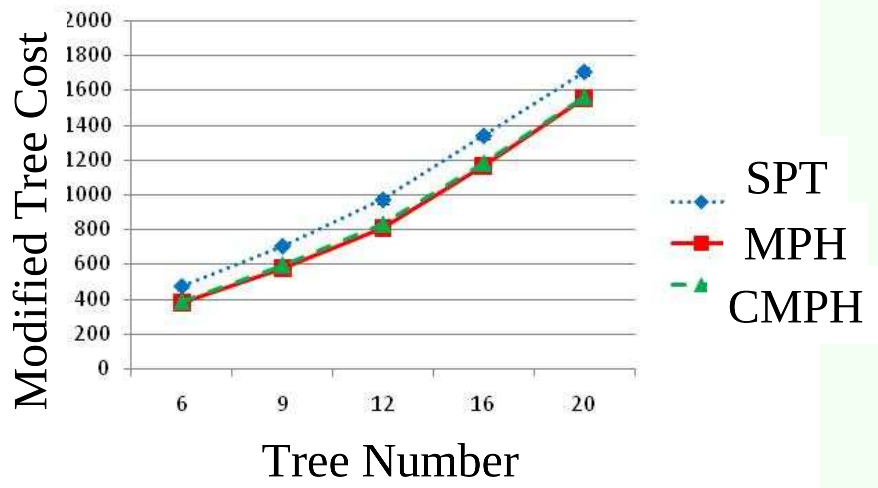
- **MPH < CMPH < SPT**
- **MPH ≈ CMPH when hop constraint was median or large.**

- If we want to reduce network cost and maintain high QoS, CMPH with the appropriate hop constraint is the best choice as shown in our simulation.
- How to decide the appropriate hop constraint in real networks is future study.

Simulation Result (Network altered)



Hop Constraint: 8



Hop Constraint: 8

We changed the network by reassigning the short cut links and made a similar simulation.

- **The properties of average hop count and modified tree cost are unchanged.**

Summary

- Dynamic Steiner heuristic algorithm with hop constraint such as CMPH attains low cost and high QoS at the same time.

- Addition of suitable hop constraint does not mean increase of network cost.

- Estimation on more realistic network is future study.

Thank you very much for your attention.

Computation Time

▪ **Average computing time per trial in this simulation:**
1 min 12 sec (2 GHz PC, EXCEL VBA)
- When tree number increases, computing time increases at an accelerated pace because of the re-computing of the distance.
- CMPH takes a longer time than MPH or SPT because of the difference of distance computation time.

▪**Computation of the distance between any two nodes:**
CMPH → matrix multiplication method (order: $O(|V|^4)$)
SPT, MPH → Dijkstra method (order: $O(|V|^3)$)
(V: node set)