HELSINKI UNIVERSITY OF TECHNOLOGY
Networking laboratory

Investigation on the fisheye state algorithm in context with QoS routing

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Overview of Routing Algorithms

- Distance Vector
- Link State
- Comparison of DV & LS

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Distance Vector Algorithm

- Distributed Bellman-Ford routing algorithm
  - Start Condition
  - Sending Step
  - Receiving Step

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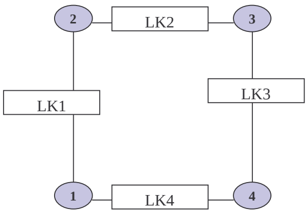
DV Algorithm



Start Condition:
Each node initializes the routing table with a vector or distance to all directly attached networks

NODE1'S Routing Table

Destination	Link	Cost
NODE1	Local Link	0
NODE2	LK1	1
NODE4	LK4	1

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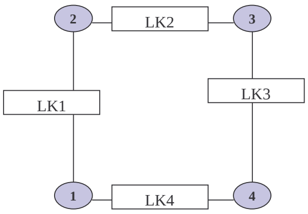
DV Algorithm



Sending Step:
Each node advertises its current routing table to all neighboring nodes.

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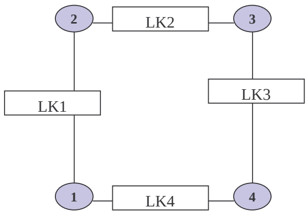
DV Algorithm



Receiving Step:

Each node advertises its current routing table to all neighboring nodes.

The node finds the neighbor that is closer to D than to any other neighbors.

The node updates its cost to D.

NODE1'S Routing Table

Destination	Link	Cost
NODE1	Local Link	0
NODE2	LK1	1
NODE3	LK1	2
NODE4	LK4	1

DV Algorithm---Receiving Step

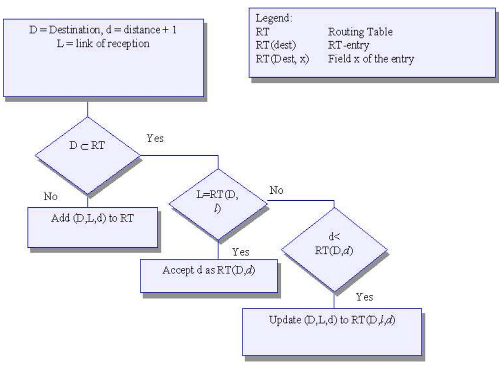


Figure 2 Processing of received distance vectors

BEGIN

When a node receives a message from the neighbor node:

The node checks whether the destination already exists in its routing table,

If yes, checks whether the link of reception is same as the existing one.

If yes, update the d = distance +1 to the routing table,

Otherwise, if [d = distance +1] < existing distance in the routing table,

Update the new distance d to the routing table

If not, accept the destination D as the new entry in the routing table with (D, L, d)

END

Link State Algorithm

- Each node maintains a copy of global topology table (GTT)
- Dijkstra's algorithm is used to find the shortest path to every other node
- The nodes do not exchange distances to destinations.
- Link State Advertisement (LSA) is flooded throughout the whole network

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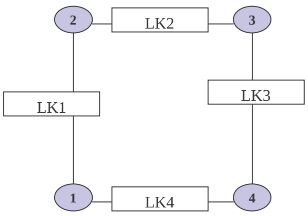
LS Algorithm



GTT Table

From	To	Link	Distance
N1	N2	1	1
N1	N4	4	1
N2	N1	1	1
N2	N3	2	1
N3	N2	2	1
N3	N4	3	1
N4	N3	3	1
N4	N1	4	1

Routing Table

Destination	Link	Cost
N1	Local Link	0
N2	1	1
N3	1	2
N4	4	1

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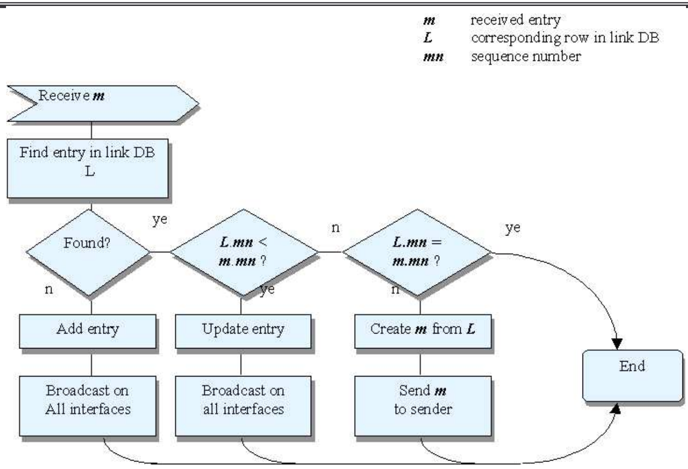
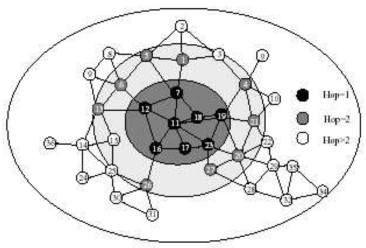
LS Algorithm



Comparison between DV & LS algorithms

	Distance Vector	Link State
Routing algorithm	Bellman-Ford Algorithm	Dijkstra's Algorithm
Route computation	Shortest path	Shortest path
Functionality	Authentication, multicasting, etc.	Multiple metrics, multiple areas, external routes, etc.
Composition		Hello, Exchange and Flooding protocols
Scalability	Small network	Large network
Stability	Stable in small networks	Stable even in large networks
Complexity	Simple	Complex
Loop avoidance	Detected when counting to infinity	Found and removed after keeping LS databases consistent
Others	Over UDP	Over IP

Fisheye State Routing (FSR)



- “Fisheye” technique is proposed by Kleinrock and Stevens
- Based on each node, it divides the network into several scopes according to the number of hops from the local node to other nodes.
- It uses different update period for each scope to reduce the size of information exchanged among the nodes.

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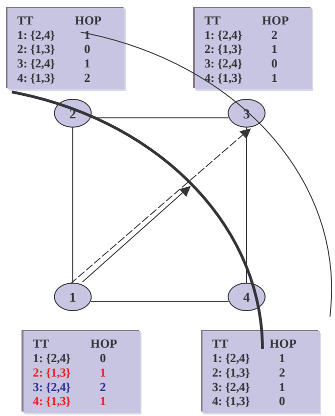
Fisheye State Routing (FSR)



E.g. NODE1

- GTT Table

Entry Number	Destination	Neighbour
1	1	2,3
2	2	1,3
3	3	2,4
4	4	1,3

- Routing Table (**Dijkstra’s Algorithm**)

Destination	Hop
1	0
2	1
3	2
4	1

IntraScope
e.g. = 100ms

InterScope ,
e.g.= 200ms

- Entries in the GTT table are exchanged periodically with **different frequencies** for *IntraScope* and *InterScope* with their **local neighbours only**

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Difference between LS & FSR

- FSR is functionally similar to LS Routing:
  - It maitains a full topology map at each node
  - Shortest paths are computed using this map
- Key difference: the way in which routing information is disseminated
  - LS: link state packets are generated and flooded into the network whenever a node detects a topology change
  - FSR:
    - link state packets are not flooded
    - Instead, nodes maintain a link state table based on the up-to-date information received from neigh boring nodes,
    - Periodically exchange it with their local neighbours only

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Benefits of FSR

- FSR is more desirable for large mobile networks where mobility is high and the bandwidth is low
  - In a wireless environment, a radio link between mobile nodes may experience frequent disconnects and reconnects.
  - LS protocol releases a link state update for each such change, which floods the network and causes excessive overhead,
  - FSR avoids this problem by using periodic , instead of event drive, exchange of topology map, greatly reducing the control message overhead
- Control Overhead is largely reduced in FSR
  - Only fraction of the entries are updated each time.
  - Different exchange periods for different entries in routing table

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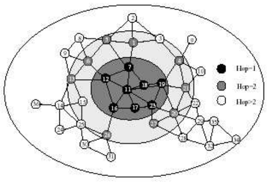
O/H vs. Accuracy



- FSR maintains accurate distance and path quality information about the immediate neighbourhood of a node, with progressively less detail as the distance increases.
- In a moibility environment, a change on a link far away from the source does not necessarily cause a change in the routing table at the source
- Receiving updates about far away nodes at low frequency will not significantly affect the routing accuracy
- **Tradeoff between routing accuracy and control O/H must be taken into account when choosing the scope radii of the fisheye solution**

Simulation Enviornment

- QRS – QoS Routing Simulator
  - QRS is developed on the core of Maryland Routing Simulator (MaRS) by Networking Laboratory, HUT.
  - The aim of QRS is to study the QoS related issues (especially QoS routing) in a QoS_based IP network.)
  - QRS allows the user to configure the parameters of a QoS guaranteed network, control its simulation, log the values of selected parameters, and save, load and modify network configurations.
- LSU algorithms in QRS
  - LSU_PB, LSU_TB, LSU_ECB, LSU_UCB
- FSR-QRS ---QRS extension
  - LSU_FSR algorithm is designed and implemented as an extension to QRS

Performance and Cost Analysis

- **Performance**
  - Total network throughput achieved by real-time traffic with bandwidth requirements
  - The larger the average network throughput is, the better the network performance should be.
  - To get the total network throughput, we log the number of received packets in real-time traffic sinks during the simulation, then simply calculate the sum.

    $\sum_i(N_i*L_i)$, where N is the number of packets received by real-time traffic sinks, L is the size of the packet.
- **Cost**
  - Total processing time consumed by QOSPFs during the simulation time
  - The cost grows large when the total processing time is higher.
  - To get the total cost of the network, we log the total time consumed by each QOSPF in every node, and then simply calculate the sum.

No.	Cost(us)	Action
1	1500	Find the next hop which can accept the required bandwidth
2	100	Check a message from RSVP and decide what to do next
3	1500	Compute the QoS path
4	500	Update the local topology database
5	200	Broadcast the link state information
6	100	Broadcast a message packet
7	1000	Compute normal routing table for best effort traffic

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Simulation Study on different topologies

- Simulation objectives
  - Compare the performance and cost with LSU_PB (Periodical Based) algorithm in QoS routing with FSR_QoS algorithm
  - Find the factors that affect the FSR_QoS routing
  - Investigate how to reduce the cost of QoS routing while keeping the performance on an acceptable level.
- Investigate whether FSR_QoS can reduce cost without losing performance
  - Earn the experience for designing and implementing new Link State Update algorithm.

- Network Topologies
  - Tree
  - Matrix 2*2, 3*3, 4*4
  - ISP

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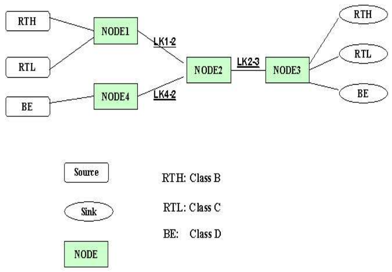
Simulation Result----Tree Topology(1)



Tree Topology Configuration:

- Four nodes
- Three Links: Link Bandwidth = 20Mb/s
- Workload:

1) RTH: One pair of Realtime Traffic (RT) with class B (NODE1à NODE3)

Flow rate is 6Mb/s, ON=30s, OFF=15s

2) RTL: One pair of Realtime Traffic (RT) with class C (NODE1à NODE3)

Flow rate is 9Mb/s, ON=20s, OFF=20s

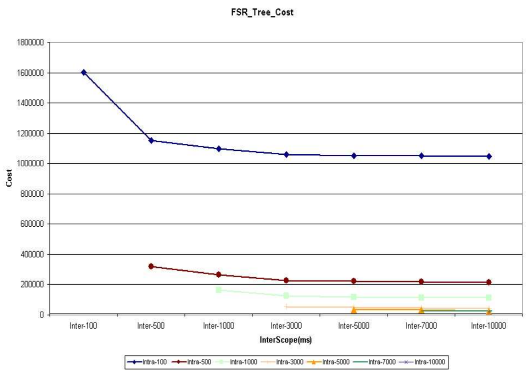
3) BE: One paire of simple traffic (ST) (NODE4à NODE3)

Flow rate is 10Mb/s

So, the total rate of all workloads is larger than the bandwidth of LK2-3, i.e. 20Mb/s.

We run the simulation for 100 seconds.

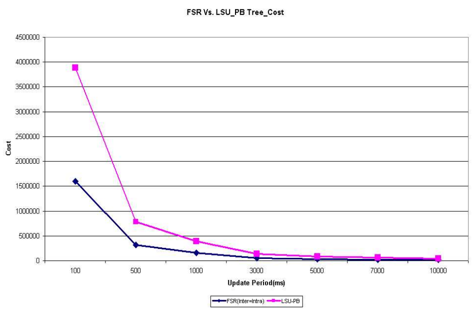
Simulation Result----Tree Topology(2)



LSU_FSR Result:

- Cost becomes smaller when the interscope update period becomes larger.
- Cost becomes smaller with the increase of intrascope update period.

Simulation Result----Tree Topology(3)



LSU_PB & LSU_FSR

(Intrascoep update period = interscope update period)

- We compare the middle value of LSU_FSR with LSU_PB
- LSU_FSR's cost is smaller than LSU_PB, which shows the benefits of FSR.

" The reason why FSR reduces O/H is that only a fraction of the entries are updated each time. In a two-level fisheye hierarchy, the smaller radius, the smaller fraction of entries updated in the 'fast' interval, and the lower the control O/H".

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Simulation Result----Tree Topology(4)

- Conclusion
  - Total throughput is exactly same for any update period. This is because route information is very accurate in the small network.
  - FSR can achieve better cost performance than LSU_PB

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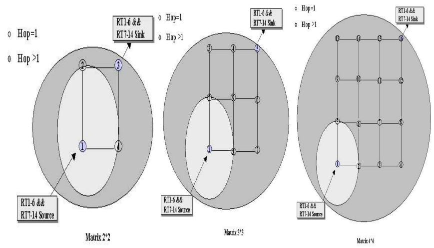
Simulation Result----Matrix Topology



Common configurations for each topology:

- Link: Link Bandwidth = 20Mb/s
- Workload

1) 14 realtime traffic pairs from the start NODE1 to another site NODE.

2) Flow rate of each pair is 3Mb/s.

3) Traffic ON time is 20 seconds, and OFF time is 10 seconds.

We run the simulation for 100 seconds

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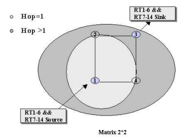
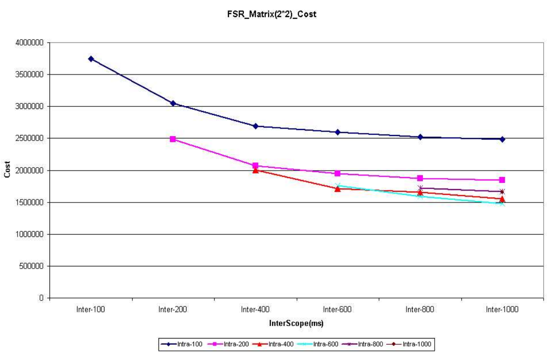
Matrix 2*2---Cost(1)





LSU_FSR Result:

- The cost with fixed intraScope update period decreases with the increasing of InterScope Update period

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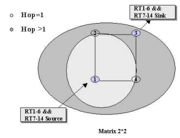
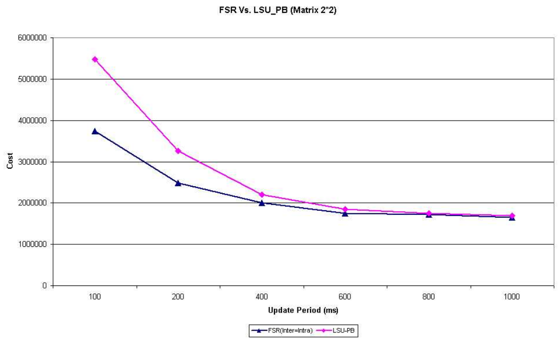
Matrix 2*2---Cost(2)

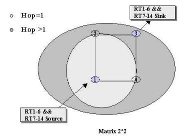


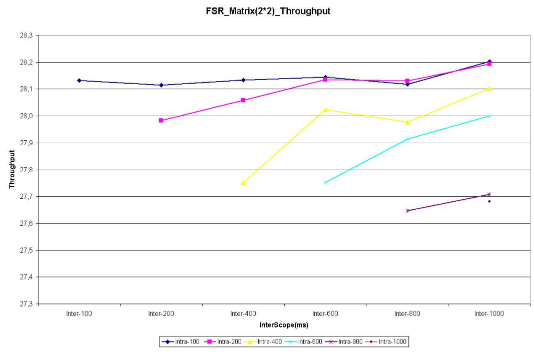


LSU_FSR & LSU_PB Result:

- When interScope update period is equal to Intrascope update period, the cost of FSR is smaller than that of LSU-PB

Matrix 2*2---Performance(1)

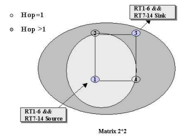


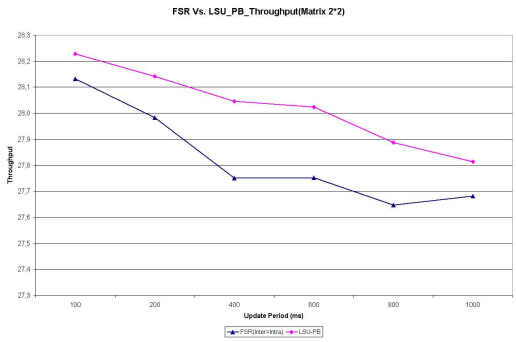


LSU_FSR Result:

- Throughput varies very slightly when the Intrascope update period is small, while varies more when Intrascope update period becomes large.

Matrix 2*2---Performance(2)





LSU_FSR & LSU_PB Result:

- Trends of throughput of both FSR and LSU-PB are same, while the total throughput of FSR is smaller than LSU_PB.

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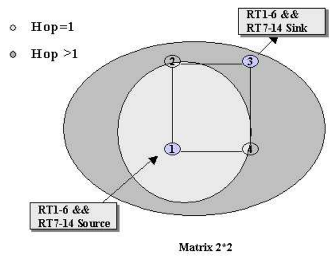
Matrix 2*2---Conclusion



As a conclusion,
In the case of matrix2*2, FSR achieves less cost and comparable performance than LSU_PB.

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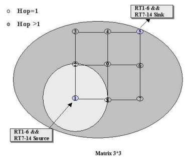
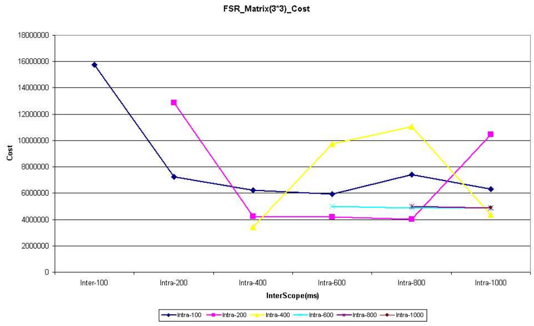
Matrix 3*3---Cost(1)





LSU_FSR Result:

- Cost varies not regularly as the small network of matrix 2*2.

This is due to the reason that though FSR reduces the cost resulted from the "Broadcast the link state information" & "Broadcast a message packet", as shown in slide 19, other cost such as "Find the next hop which can accept the required bandwidth" may increase. When the network is larger, the routing information becomes more and more inaccurate. As FSR does not flood the packets, the nodes far from the center nodes can only get routing change after several update periods. As a result, this leads to the failures of routing requests, which causes more re-requests and more routing cost.

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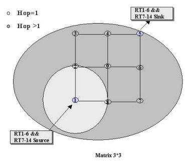
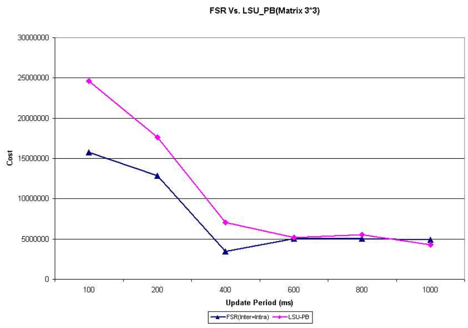
Matrix 3*3---Cost(2)





LSU_FSR & LSU_PB Result:

- Compared with LSU_PB, LSU_FSR's cost is still smaller than LSU_PB as we have expected.
- But as the increase of Intrascope update period, the cost may increase at some point as what we explained in previous item.

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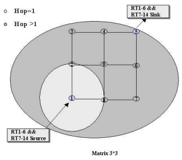
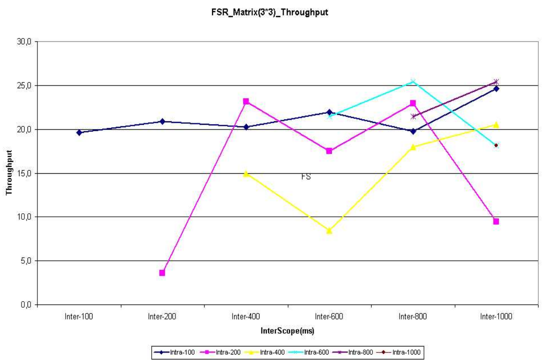
Matrix 3*3---Performance(1)





LSU_FSR Result:

- Throughput varies slightly when intrascope Update period is very small.
- With the increasing of intrascope update period, the throughput varies a lot with the interscope update period.
- This shows inaccuracy of routing in FSR leads to more failures of traffic requests.

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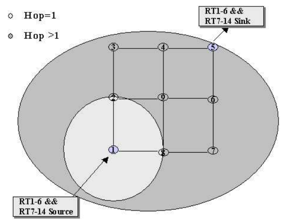
Matrix 3*3 --- Conclusion



Matrix 3*3

As a conclusion,
with the increase of network size, FSR can achieve smaller cost than LSU_PB but may cause variation of throughput and cost, which requires a suitable set of FSR parameters should be found for best performance and cost ratio.

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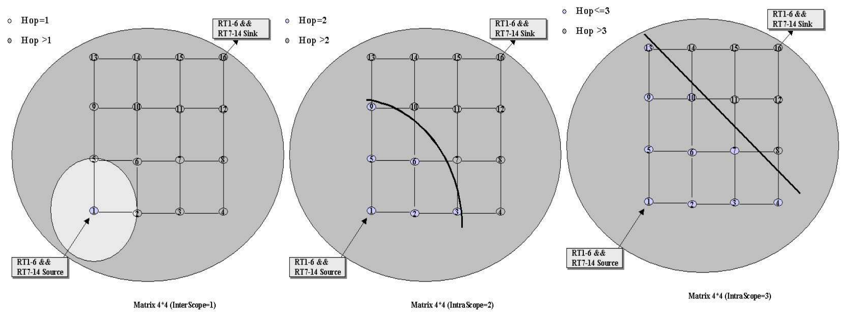
Matrix 4*4---Topology



- For Matrix 4*4, we investigate the simulation results while the size of intrascope increases from 1 to 3 as Figure above(given the node on the left corner is the center node).
- We aim to study whether the increase of the size of intrascope can have any positive impact on the performance of FSR.

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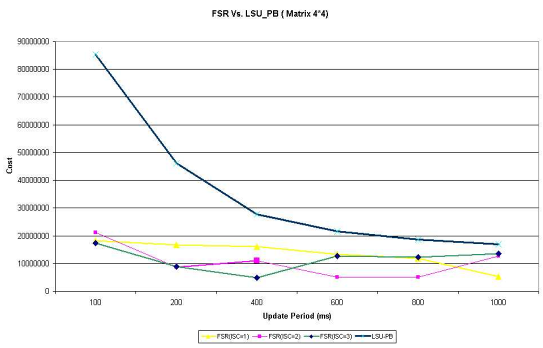
Matrix 4*4---Cost



LSU_FSR & LSU_PB Result:

- Whatever intrascope size is 1, 2 or 3, cost of FSR is smaller than LSU_PB.
- The reason is obvious and the results are what we expected.
- The cost varies smoothly with the increasing of update period, which shows the benefit of FSR.

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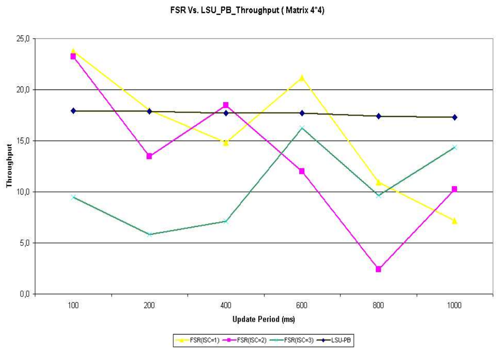
Matrix 4*4 ---Throughput



LSU_FSR & LSU_PB Result:

- For LSU_PB, total throughput of varies smoothly and slightly with the increasing of update period.
- For LSU_FSR, with different size of intrascope, FSR still achieves better performance than LSU_PB if we select a suitable set of parameters.

E.g. (100,100) for intrascope size =1,
(600,600) for intrascope size =2
(600,600) for intrascope size =3

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Matrix 4*4 ---Conclusion

As a conclusion,

- In case of matrix 4*4, the cost and throughput largely depend on the values of FSR parameters.
- It is necessary to select a set of parameters that can achieve better performance and cost ratio, i.e.ratio = performance/cost.

E.g. The ratio can be maximized in such values as

(100,100) for intrascope size = 1
(100,100) for intrascope size = 2
(600, 600) for intrascope size = 3

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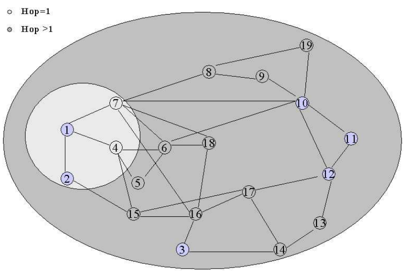
ISP---Topology



Configuration for ISP topology:

- Link: Link Bandwidth = 20Mb/s
- Workload

1 1) 18 realtime traffic pairs distributed as following:

Source Node: NODE1 & NODE2 & NODE3

Sink Node: NODE10 & NODE11 & NODE12

2) For each pair of Source and Sink node, we have configured two pairs of realtime traffic: one is class type B, another is class type C Traffic ON time is 20 seconds, and OFF time is 10 seconds.

3) Flow rate is 6Mb/s.

We run the simulation for 100 seconds

ISP topology has more realistic for studying the performance and cost for different LSU algorithms. It has been widely used in the study of QoS routing.

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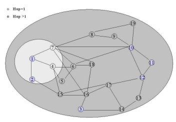
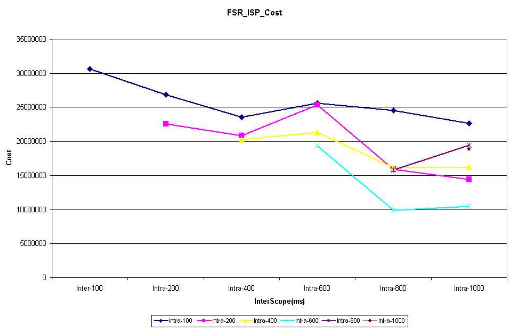
ISP---Cost(1)



For intrascope=1



LSU_FSR Result:

- Cost becomes smaller when the interscope update period becomes larger.
- Cost becomes smaller with the increase of intrascope update period.

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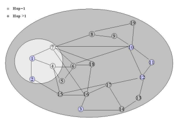
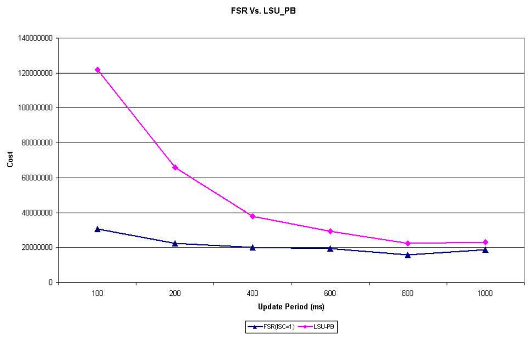
ISP---Cost(2)



For intrascope=1



LSU_FSR & LSU_PB Result:

- Cost of LSU_FSR is smaller than LSU_PB. Especially when the intrascope/interscope update period is small
- The result is exactly what we expected.

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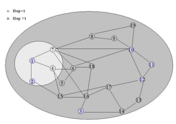
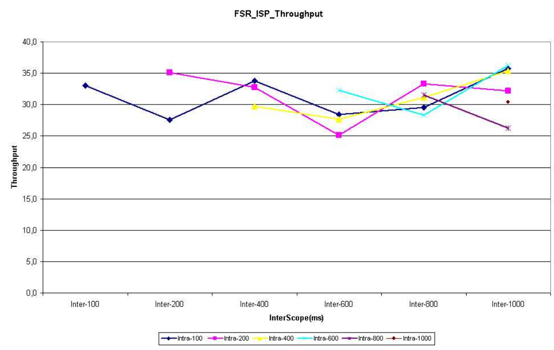
ISP---Throughput(1)



For intrascope=1



LSU_FSR Result:

- Total throughput of FSR varies slightly with the different intrascope update period and interscope update period.
- It's normal as explained before.

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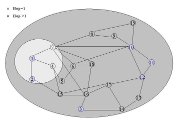
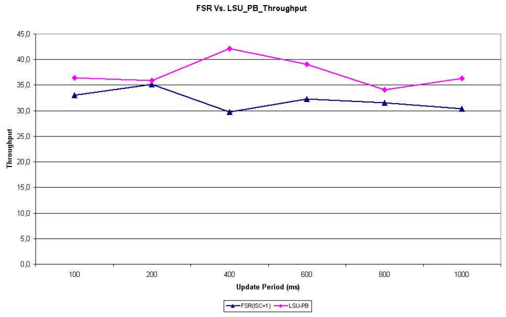
ISP---Throughput(2)



For intrascope=1

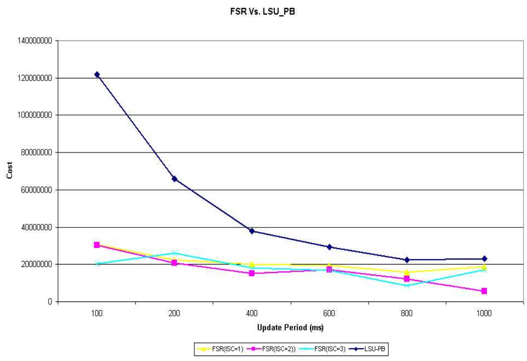


LSU_FSR & LSU_PB Result:

- Total throughput of FSR varies smoothly and a little smaller than LSU_PB.
- It's reasonable because of the inaccuracy routing information of FSR than LSU_PB, as explained in Matrix topologies.

ISP---Cost (3)

For intrascope=1&2&3

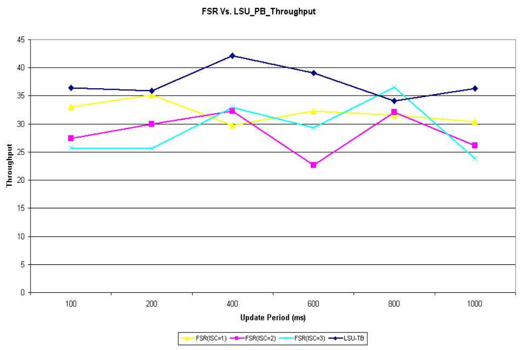


LSU_FSR & LSU_PB Result:

- Whatever intrascope size is 1, 2 or 3, cost of LSU_FSR is smaller than LSU_PB.
- The reason is obvious and the results are what we expected.
- The cost varies smoothly with the increasing of update period, which shows the benefit of FSR.

ISP---Throughput (3)

For intrascope=1&2&3

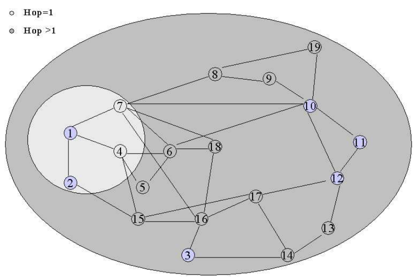


LSU_FSR & LSU_PB Result:

- For LSU_PB, throughput varies smoothly and slightly with the increasing of update period.
- For LSU_FSR, with different size of intrascope, FSR still achieves better performance than LSU_PB if we select a suitable set of parameters.

E.g. (200,200) for intrascope size =1
(800,800) for intrascope size =2
(800,800) for intrascope size =3

ISP ---Conclusion



As a conclusion,

- In case of ISP, the cost and throughput largely depend on the values of FSR parameters.
- It is necessary to select a set of parameters that can achieve better performance and cost ratio, i.e.ratio = performance/cost.

E.g. the ratio can be maximized in such values as
(200,200) for intrascope size =1
(800,800) for intrascope size =2
(800, 800) for intrascope size =3

Conclusions & Future Work (1)

1) In general FSR can achieve better performance and lower cost than LSU_PB.
2) The performance of FSR may depend on the topologies.

   In our simulations, FSR achieve very good performance in some topologies, e.g., tree, matrix 2*2, and ISP. However, the performance of FSR may vary in some topologies, e.g., matrix 3*3.
3) For matrix-type size network, when network size is small fisheye routing algorithm can reduce the cost without decreasing the network performance. When network size becomes larger, fisheye routing algorithm can reduce the cost but may achieve varied. With the increase of intrascope and interscope period, the cost of FSR decreases for small-size matrix networks. However, when the network increases, with the increase of intrascope and interscope period, the cost may vary, especially in matrix 4*4 topology.
4) FSR algorithm achieves good performance and lower cost in an ISP network, which has more practical meaning. FSR achieves lower cost than LSU_PB and comparable throughput as LSU_PB.
5) The size of intrascope has little impact on the performance and cost
6) In particular, in all simulations, FSR achieve higher performance and lower cost than LSU_PB when both interscope and intrascope are small.

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Conclusions & Future Work (2)

1) Which cost item affects the total cost mostly; with the increasing of network size, which cost item increases sharply that make the FSR's cost increased. During the simulations, we need to log the cost of each cost item for different topologies and study each cost item separately.
2) Investigate on the size of intrascope.

   In this paper, we studied Matrix 4*4 and ISP for different size of intrascope. More simulations on more larger network topologies can be studied for different size of intrascope.
3) Investigate on the number of scopes.

   Since it's hard to determine how many scopes should be for what topologies and how big a scope is, we simplify our studying to set the number of scopes to 2 in this paper. For more scopes, it's our next-step work
4) Investigate which factor affects the performance of FSR in some topologies, e.g., matrix.
5) More simulations on topologies that is more close to real network.
6) We focus on the comparison between FSR and LSU_PB in this paper. We give a brief introduction to LSU_TB, ECB, UCB. More simulations can be studied to investigate on the comparison FSR with LSU_TB, ECB, UCB.
7) We need to think about more advanced LSU algorithm based on our FSR study, which can reduce the cost without decreasing network performance.

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