Chapter 10 Spiral-Multi-Path QoS Routing Protocol in Wireless Mobile Ad-Hoc Networks

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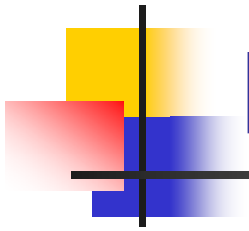
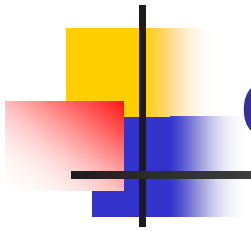


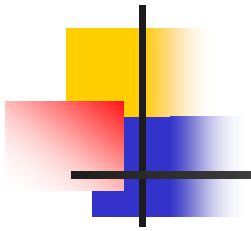
Publication

- **Yuh-Shyan Chen** and Yu-Ting Yu, “Spiral-Multi-Path QoS Routing Protocol in Wireless Mobile Ad-Hoc Networks”, ***IEICE Transactions on Communications***, Vol.E87-B, No.1, pp.104-116, Jan. 2004.



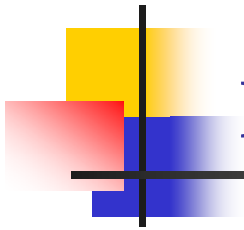
Outline

- Introduction
- Basic Idea
- Our proposed SMPQ Protocol
- Experimental Results
- Conclusion



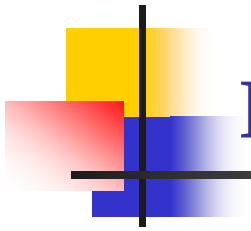
Introduction

- This paper proposes a QoS routing protocol in MANET
  - MAC layer adopts CDMA-over-TDMA scheme (multiple access scheme)
- Two important schemes are integrated
  - Spiral-path
  - Multi-path



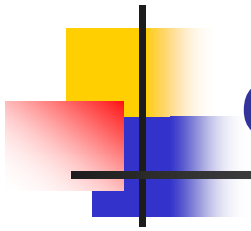
Existing QoS Routing Protocols

- A quite ideal model
  - Ticket-based QoS routing protocol [JSAC99]
  - A Multi-Path QoS Routing Protocol in a Wireless Mobile Ad Hoc Network [ICN'01]
- CDMA-over-TDMA channel model
  - Lin approaches [JSAC99][INFOCOM01]
    - Uni-Path



Motivation

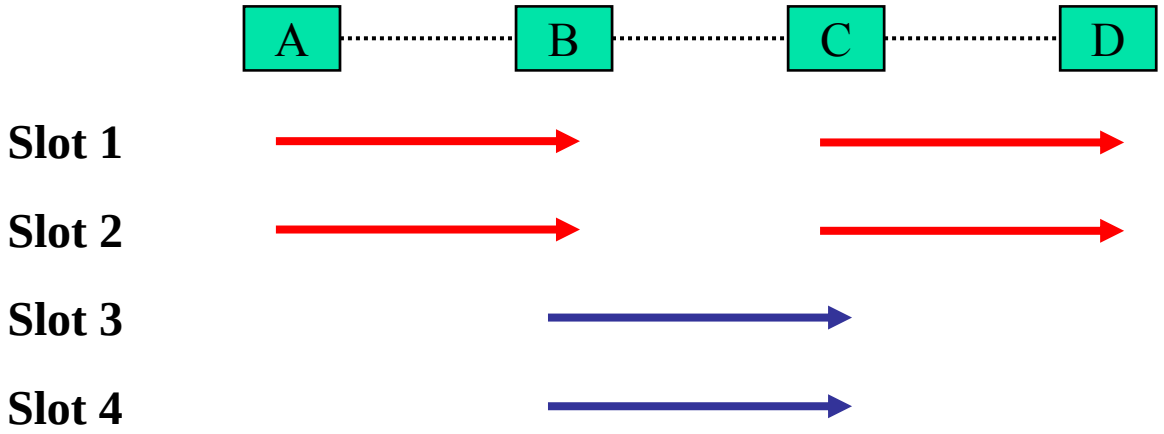
- Design a new routing protocol under CDMA-over-TDMA model with
  - High success rate of a QoS route
  - Mobility-tolerant capability

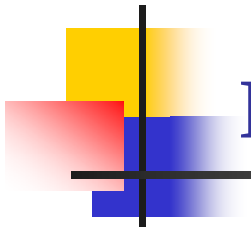


Channel model Assumption

- CDMA-over-TDMA channel model
  - Use an orthogonal code to overcome the hidden-terminal problem
  - The use of a time slot on a link is only dependent of it's one hop neighboring links

CDMA-over-TDMA Model

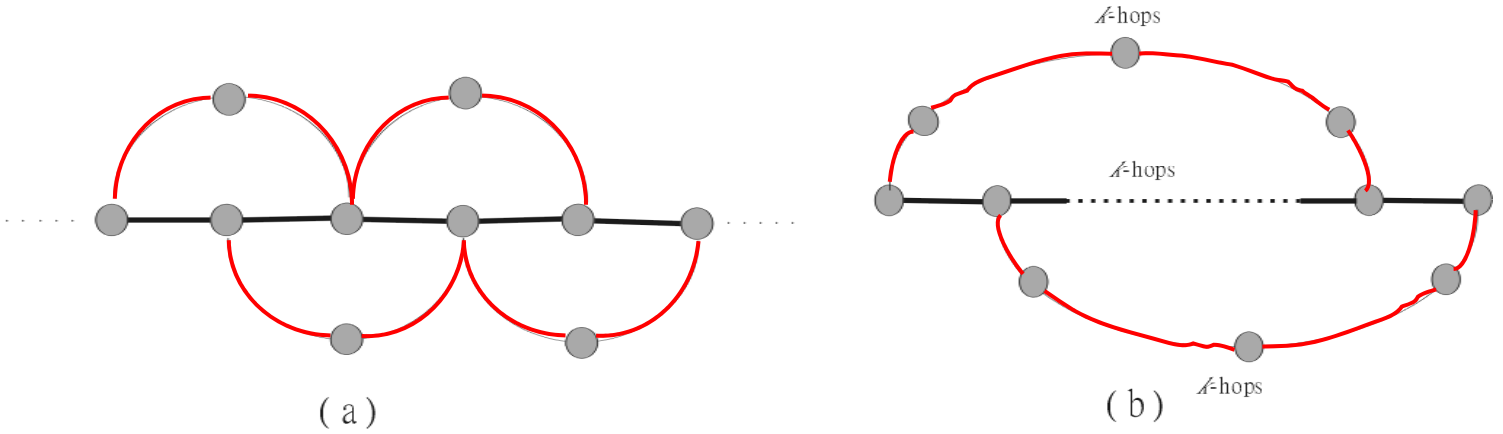




Basic Idea

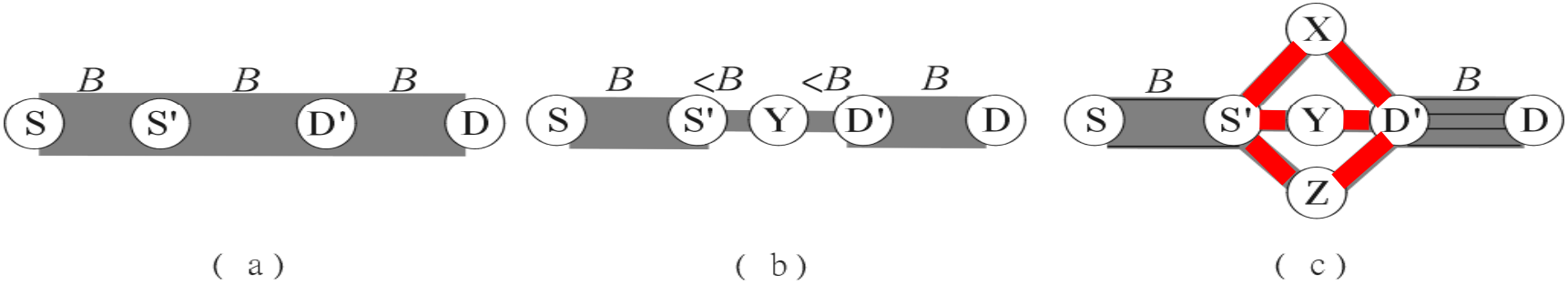
- Propose spiral-multi-path routing by combining
  - spiral-path routing
  - multi-path routing
- Aims
  - High success rate of a QoS route
  - With well mobility-tolerant capability

MESH: Multi-Eye Spiral-Hopping Protocol in a Wireless Ad Hoc Network



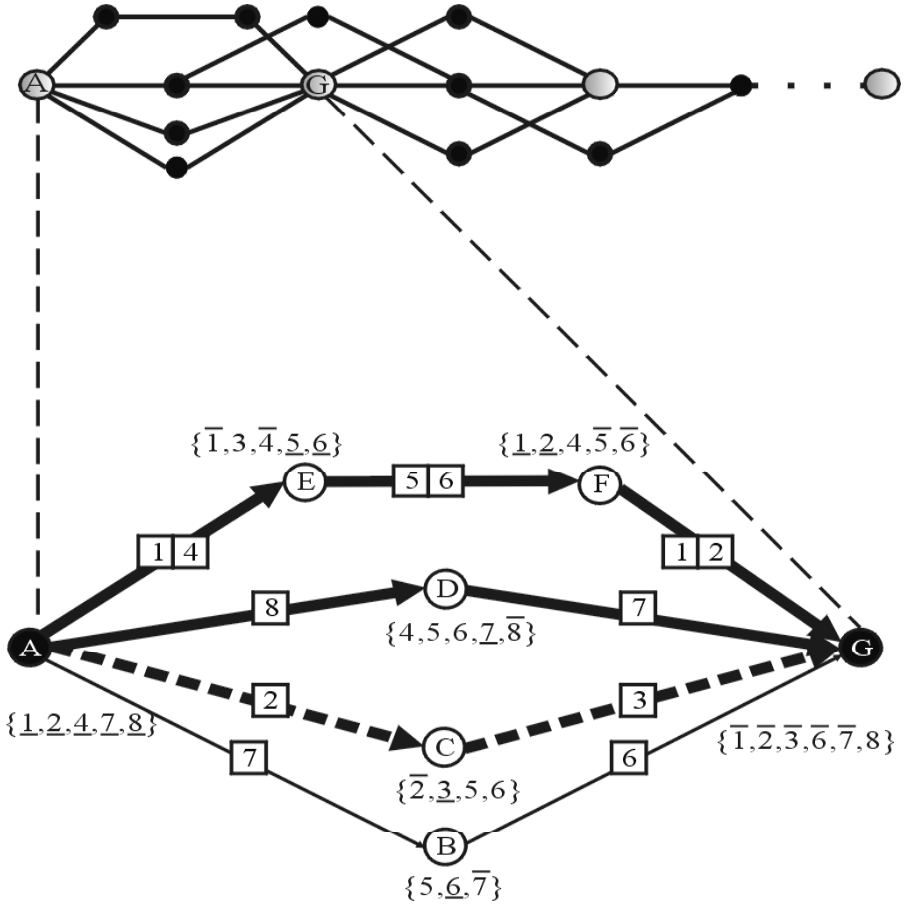
A Spiral-path approach

A Multi-Path QoS Routing Protocol in a Wireless Mobile Ad Hoc Network

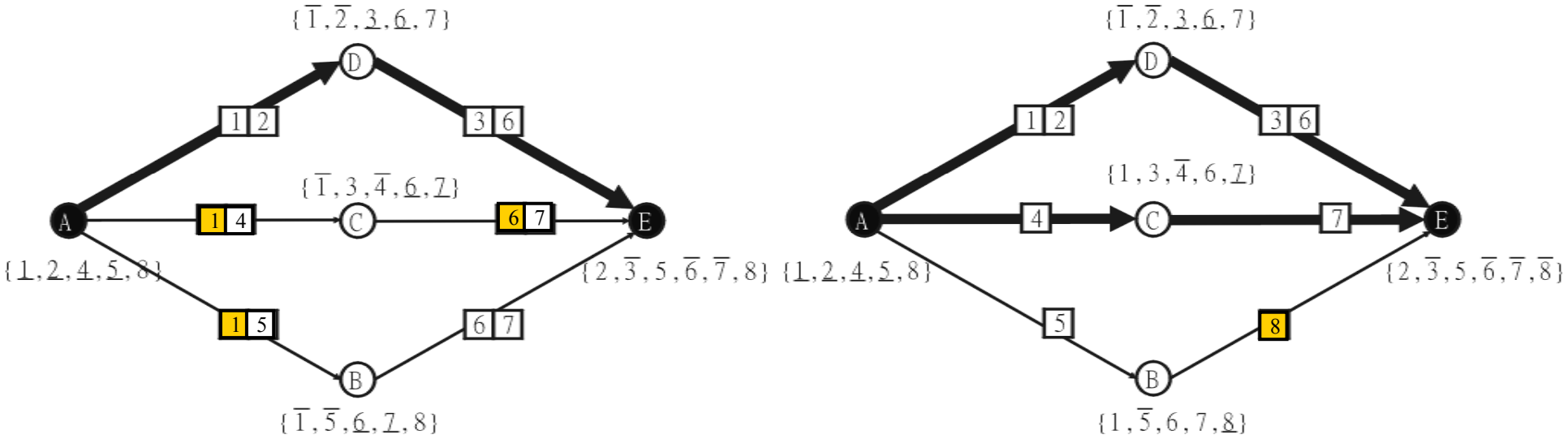


A multi-path approach

Informal definition of *spiral-multi-path*

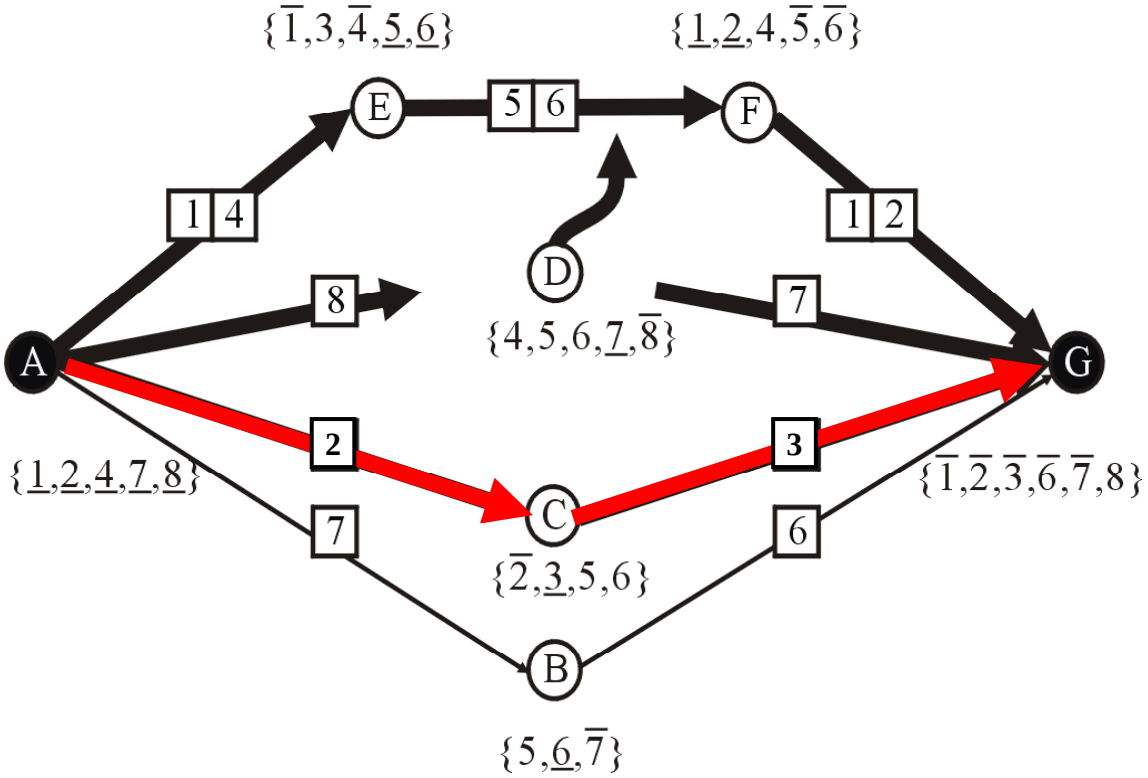


Difference of slot reservation between uni-path and multi-path



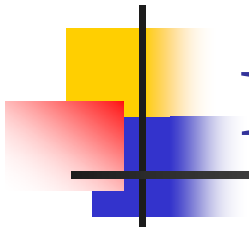
(a) uni-path **(b) multi-path**

Mobility-tolerant capability



Our SMPQ Protocol

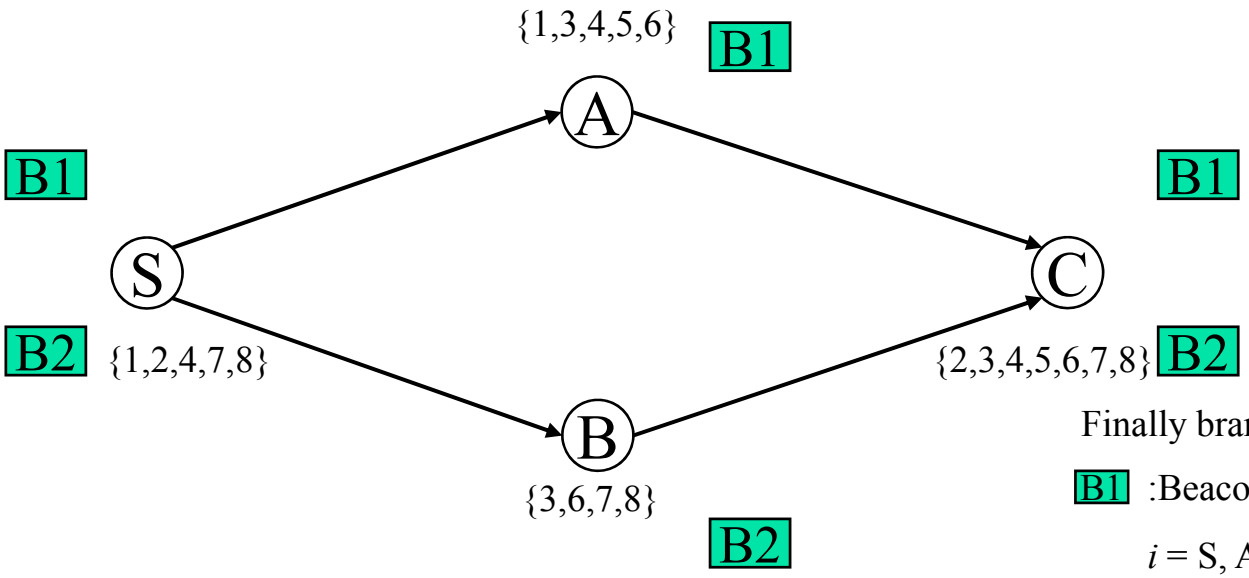
- Phase 1: **Keeping Link Bandwidth**
  - Keep the information of link bandwidth in MANET
- Phase 2: **QoS Route-Discovery Phase**
  - Find the *spiral-multi-path* and reserve time slots
- Phase 3**:QoS Route-Reply Phase**
  - Confirm a final *spiral-multi-path* and send a reply packet
- Phase 4**:QoS Route-Maintenance Phase**



Phase 1: Keeping Link Bandwidth

- The purpose of this phase
  - Keep the information of link bandwidth in MANET
- **Branch Node**
  - If there exist at least two disjoint paths between two nodes, then these two nodes are said as branch nodes
- **Supernode**
  - The gateway nodes between a pair of branch nodes

Identifying operation of *branch node*



Finally branch node C receive

B1 :Beacon$_1$(path_record=[S,A,C], free_slot$_i$)

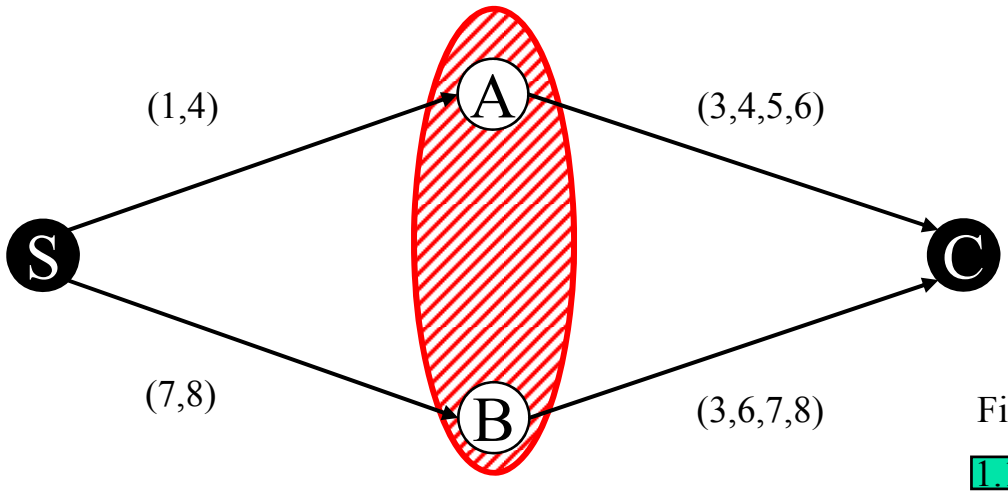
i = S, A, C

B2 :Beacon$_2$(path_record=[S,B,C], free_slot$_i$)

i = S, B, C

:Beacon(hopnumber, path_record, free_slots $_{path\_record[i]}$)

Identifying operation of *Supernode*



Finally branch node C receive

1.1 :Beacon$_1$(path_record=[S,A,C], free_slot$_i$)

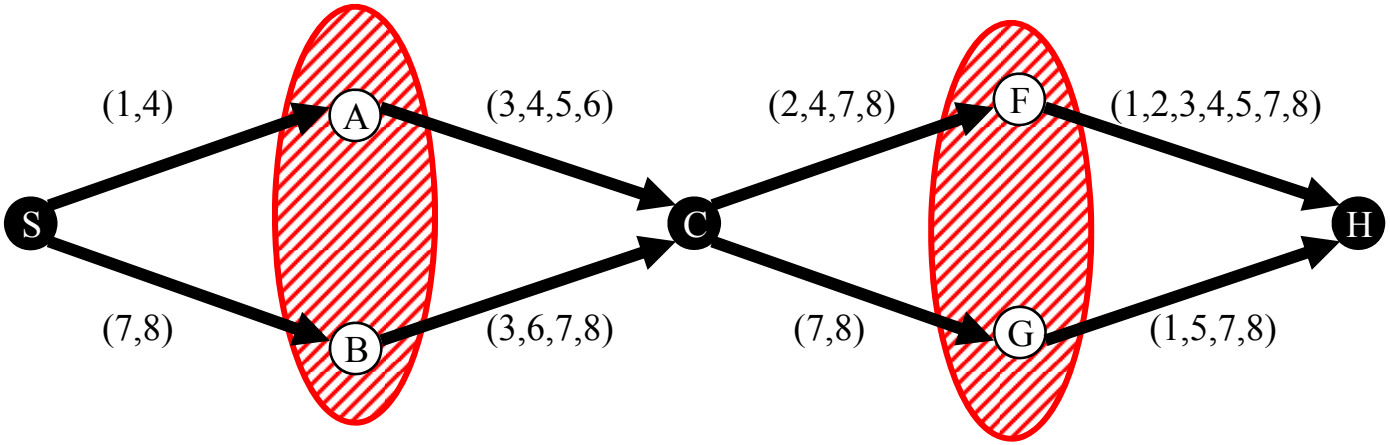
i = S, A, C

1.2 :Beacon$_2$(path_record=[S,B,C], free_slot$_i$)

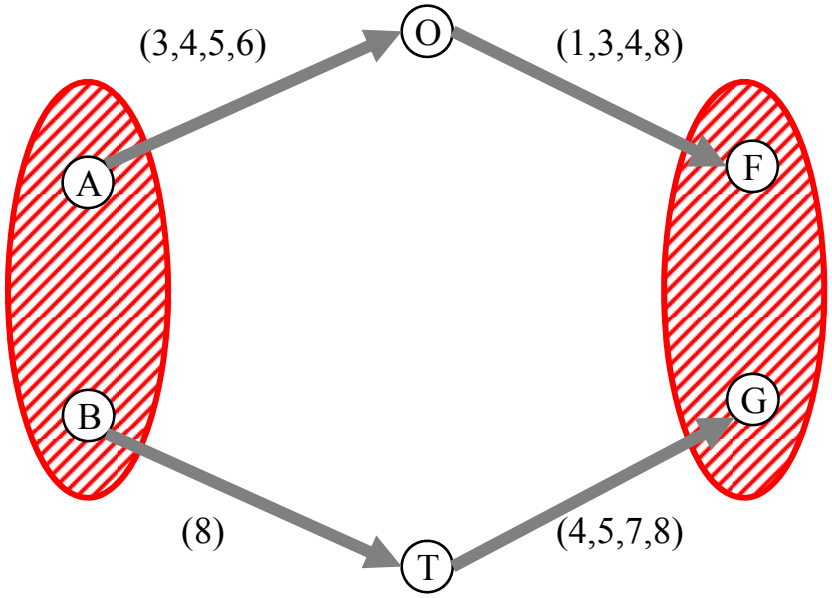
i = S, B, C

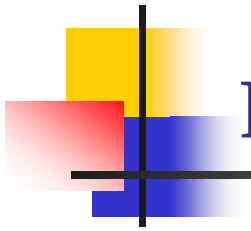
:Beacon(hopnumber, path_record, free_slots $_{path\_record[i]}$)

Identifying operation of *branch supernode*



Identifying operation of *branch supernode* and its link bandwidth





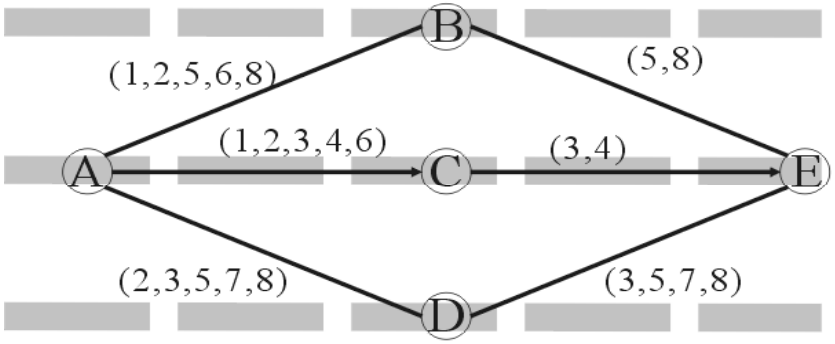
Phase 2: QoS Route-Discovery Phase

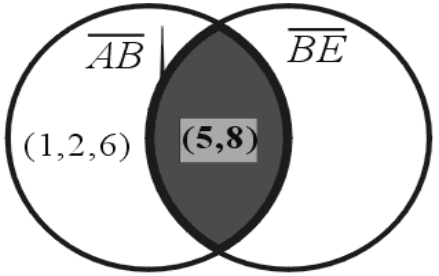
- The purpose of this phase
  - Reserve possible time slots during constructing the *spiral-multi-path*

A basic sub-path bandwidth reservation operation

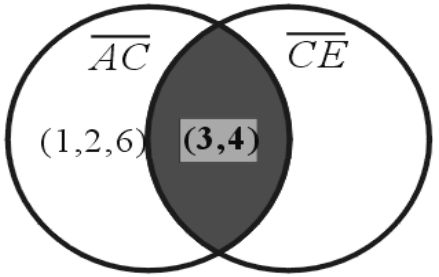
- Check the available bandwidth of each uni-path
- A path with higher maximum sub-path bandwidth has priority
- The slots not in the intersection of links will be reserved first

An example of bandwidth reservation operation

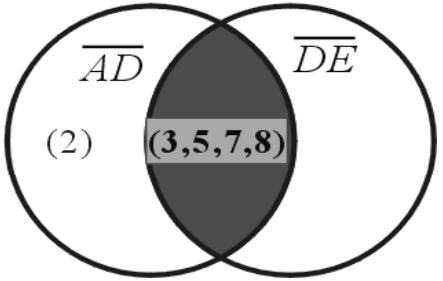




(1,2) (5,8)

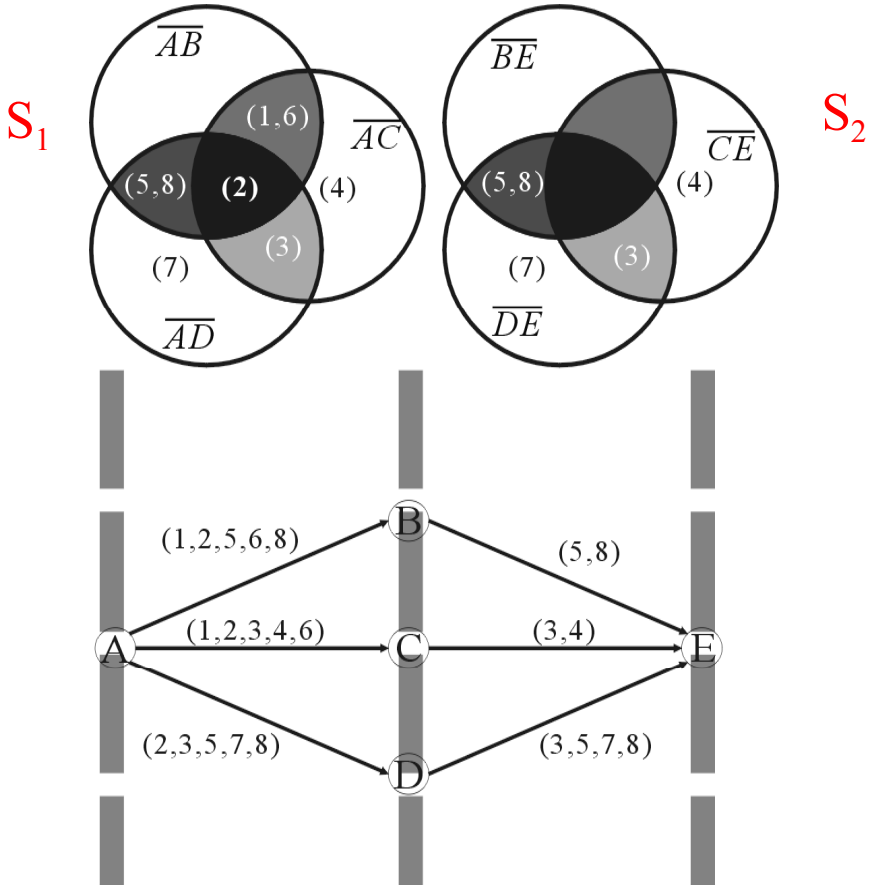


(1,2) (3,4)

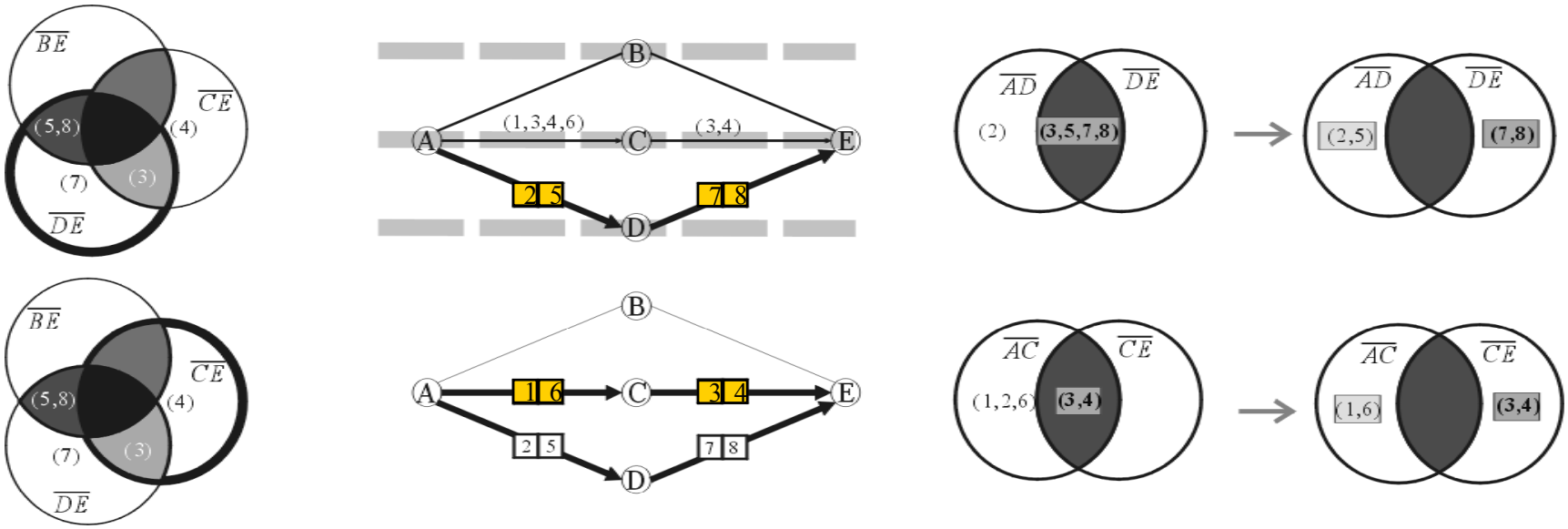


(2,3) (7,8)

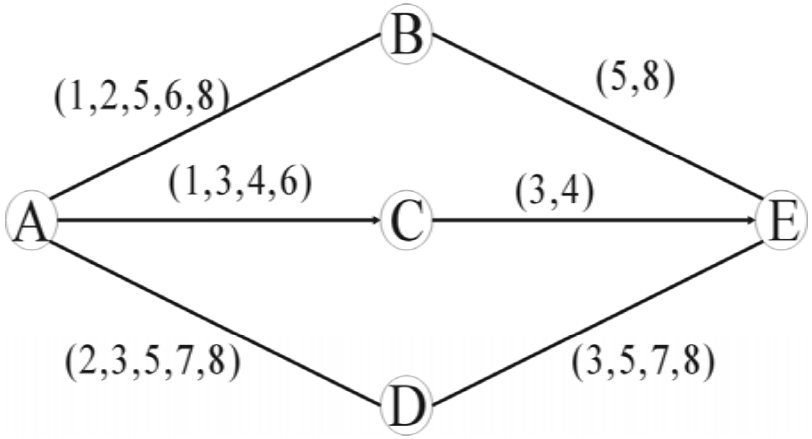
An example of bandwidth reservation operation (con.)



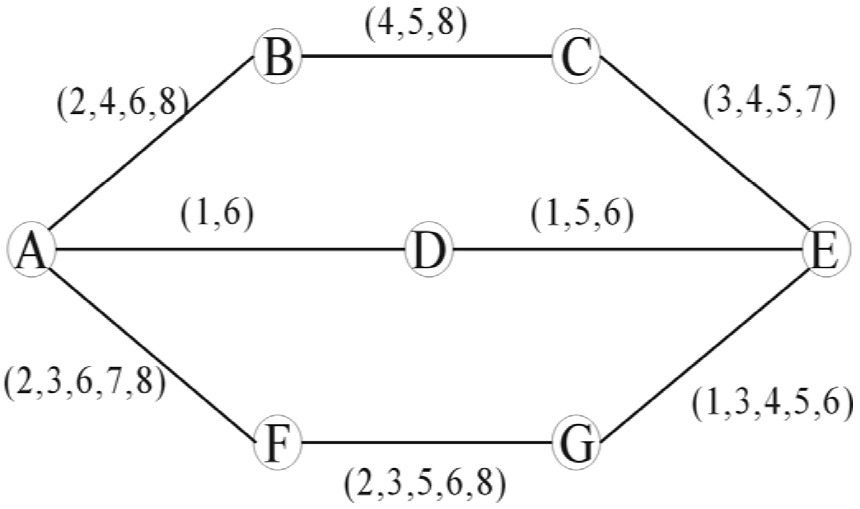
A basic sub-path bandwidth reservation operation (con.)



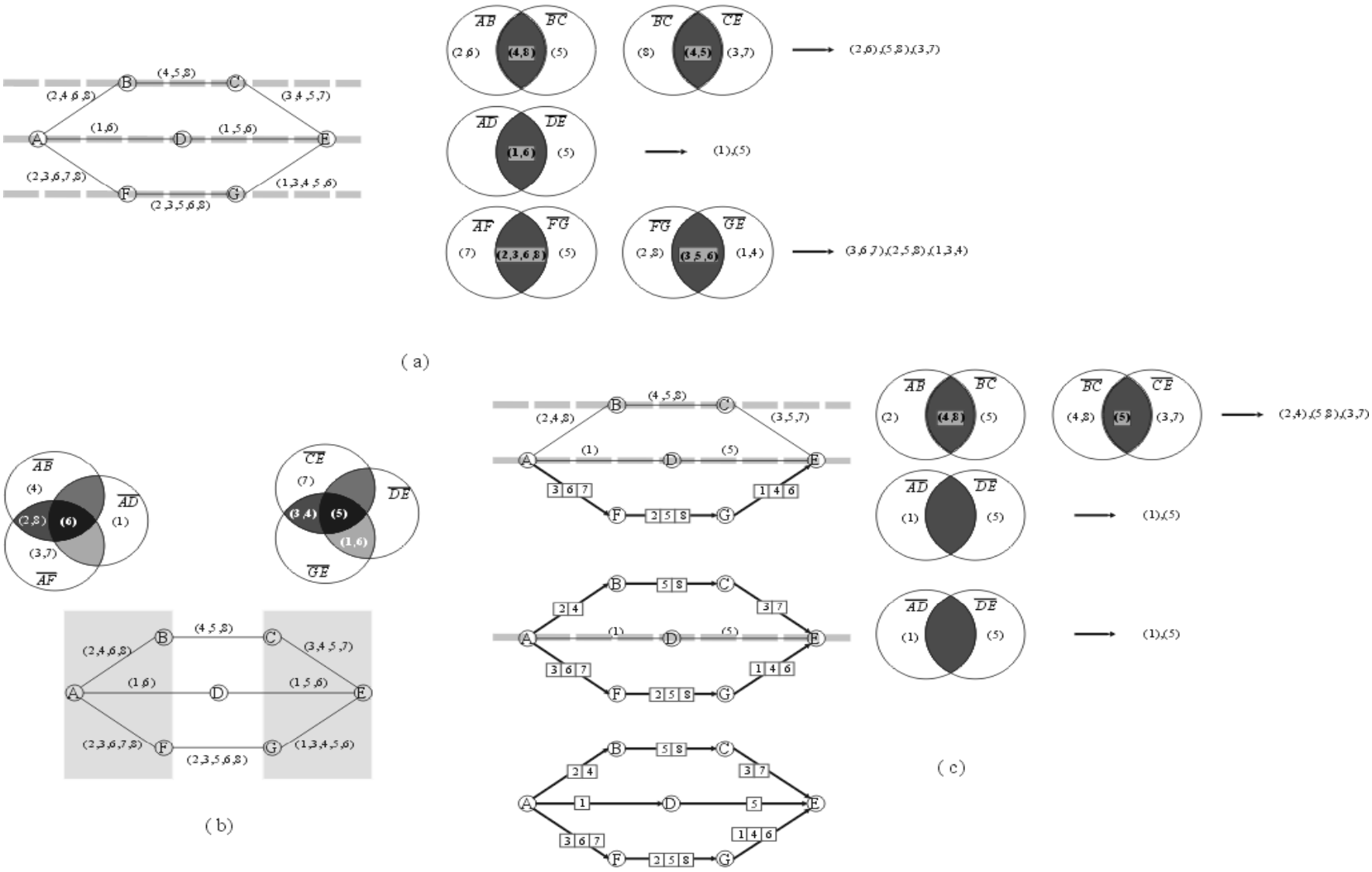
Other example of basic sup-path bandwidth reservation operation



(a)



(b)



Other example of basic sup-path bandwidth reservation operation

Path Bandwidth

- **Path bandwidth of a feasible path from S to D**

$$\Rightarrow [\overline{\alpha_1}, \underline{\beta_1}, \overline{\alpha_2}, \underline{\beta_2}, \ldots, \underline{\beta_{k-1}}, \overline{\alpha_k}], i \geq 1$$

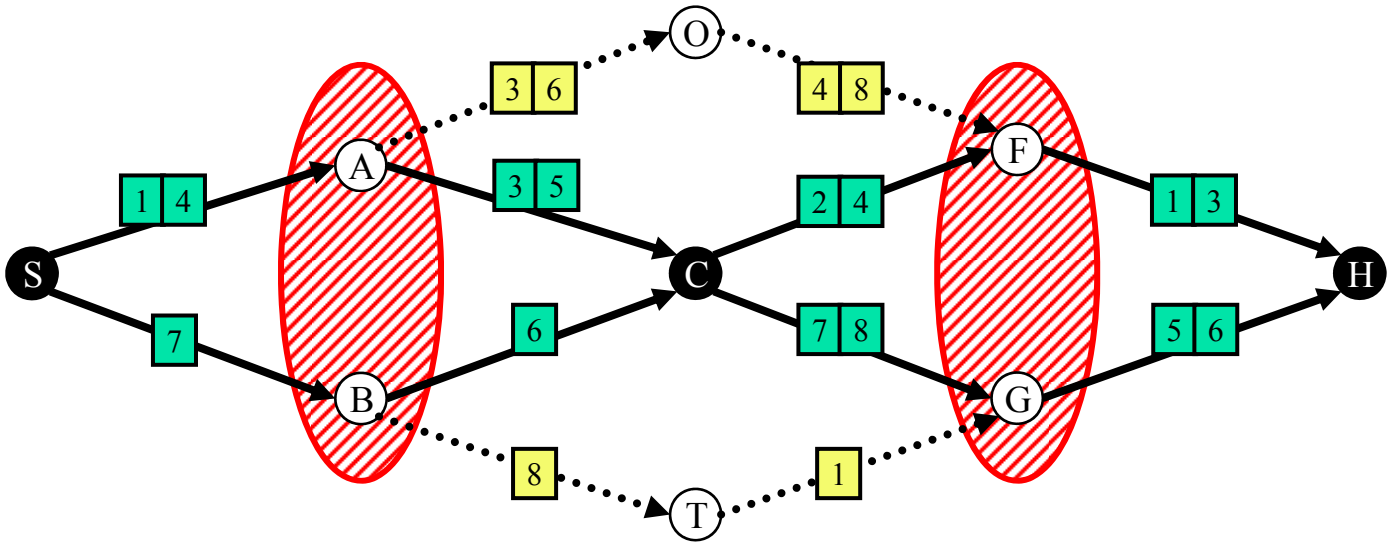
Where

$\overline{\alpha_i}$ is the reservable bandwidth between a pair of branch node

$\underline{\beta_j}$ is the reservable bandwidth between a pair of branch supernodes

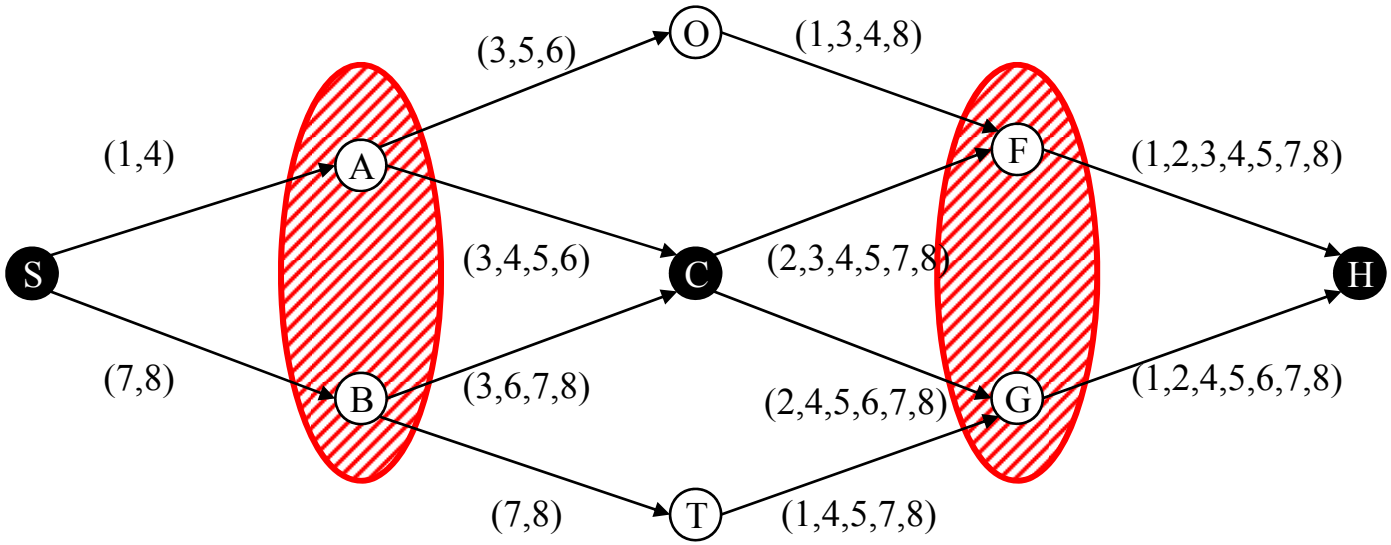
Path Bandwidth—an example of $[\overline{3},\underline{3},\overline{4}]$

Requirement=2



Route-discovery operation

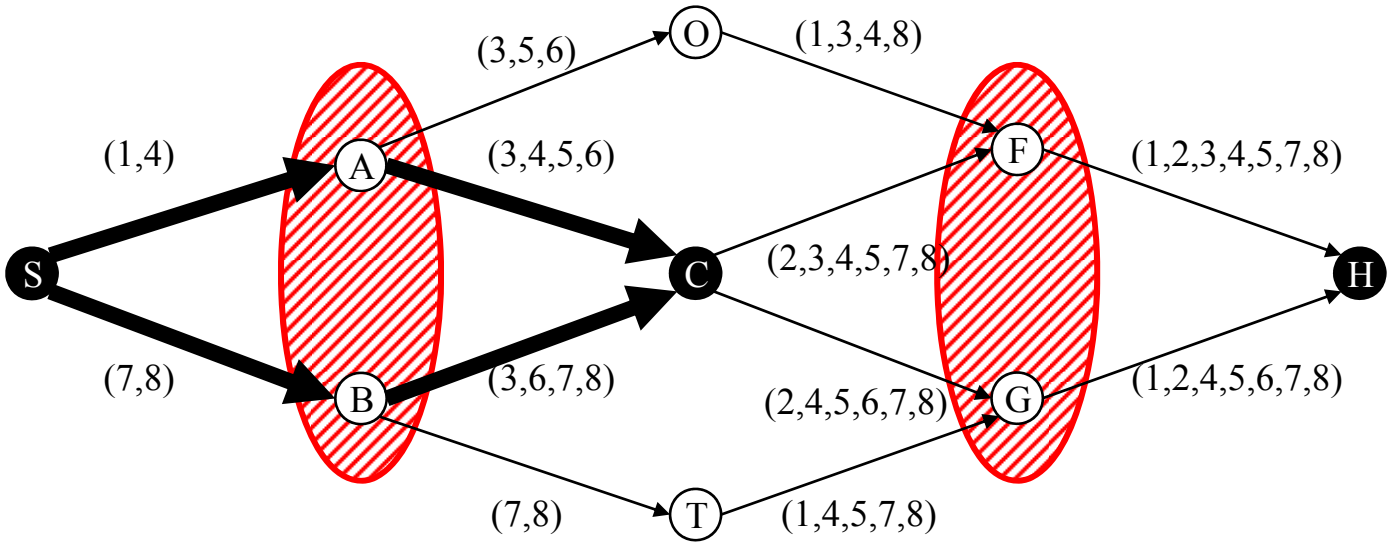
Requirement=2



An example of $[\bar{3},\underline{3},\bar{4}]$

Route-discovery operation

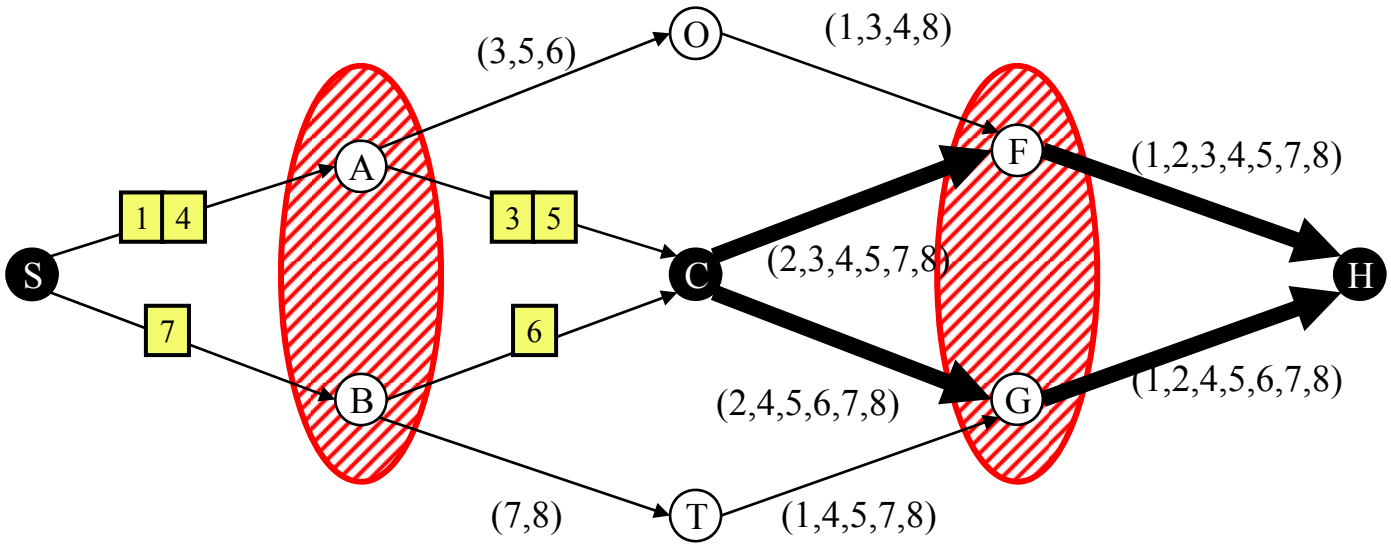
Requirement=2



An example of $[\bar{3},\underline{3},\bar{4}]$

Route-discovery operation

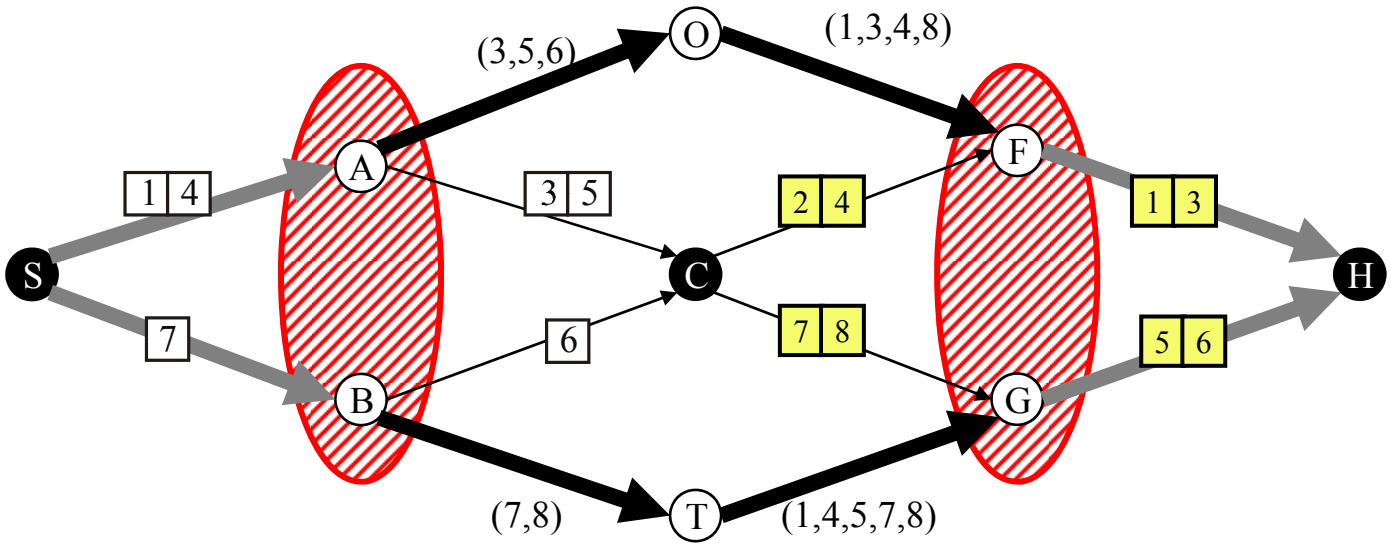
Requirement=2



An example of $[\bar{3},\underline{3},\bar{4}]$

Route-discovery operation

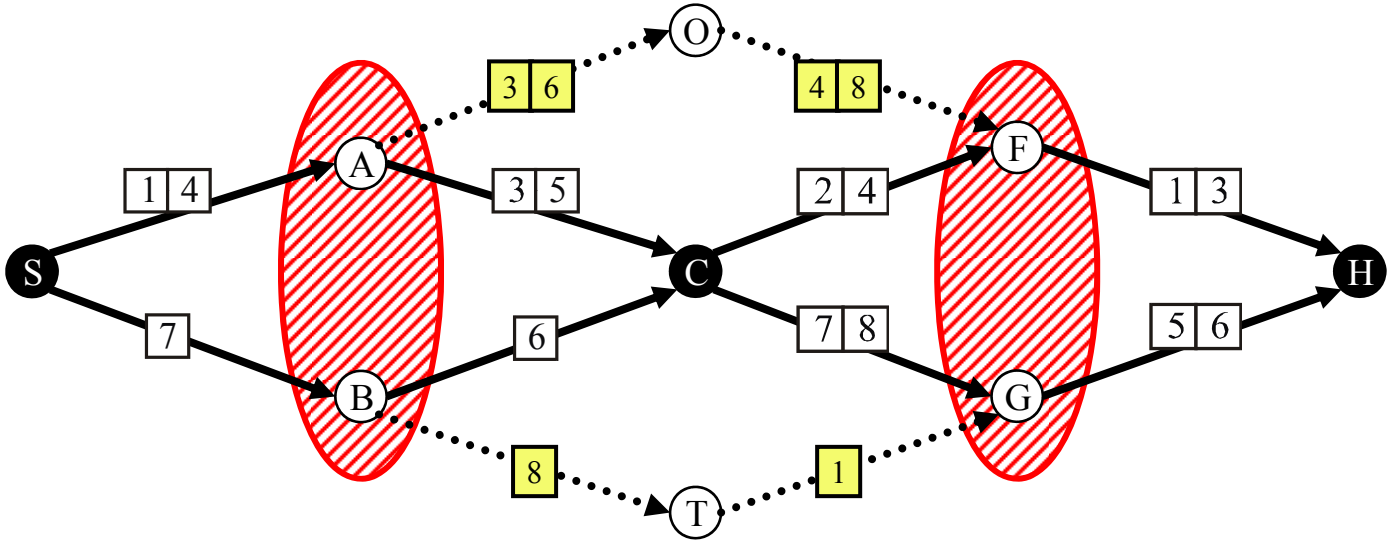
Requirement=2



An example of $[\bar{3},\underline{3},\bar{4}]$

Route-discovery operation

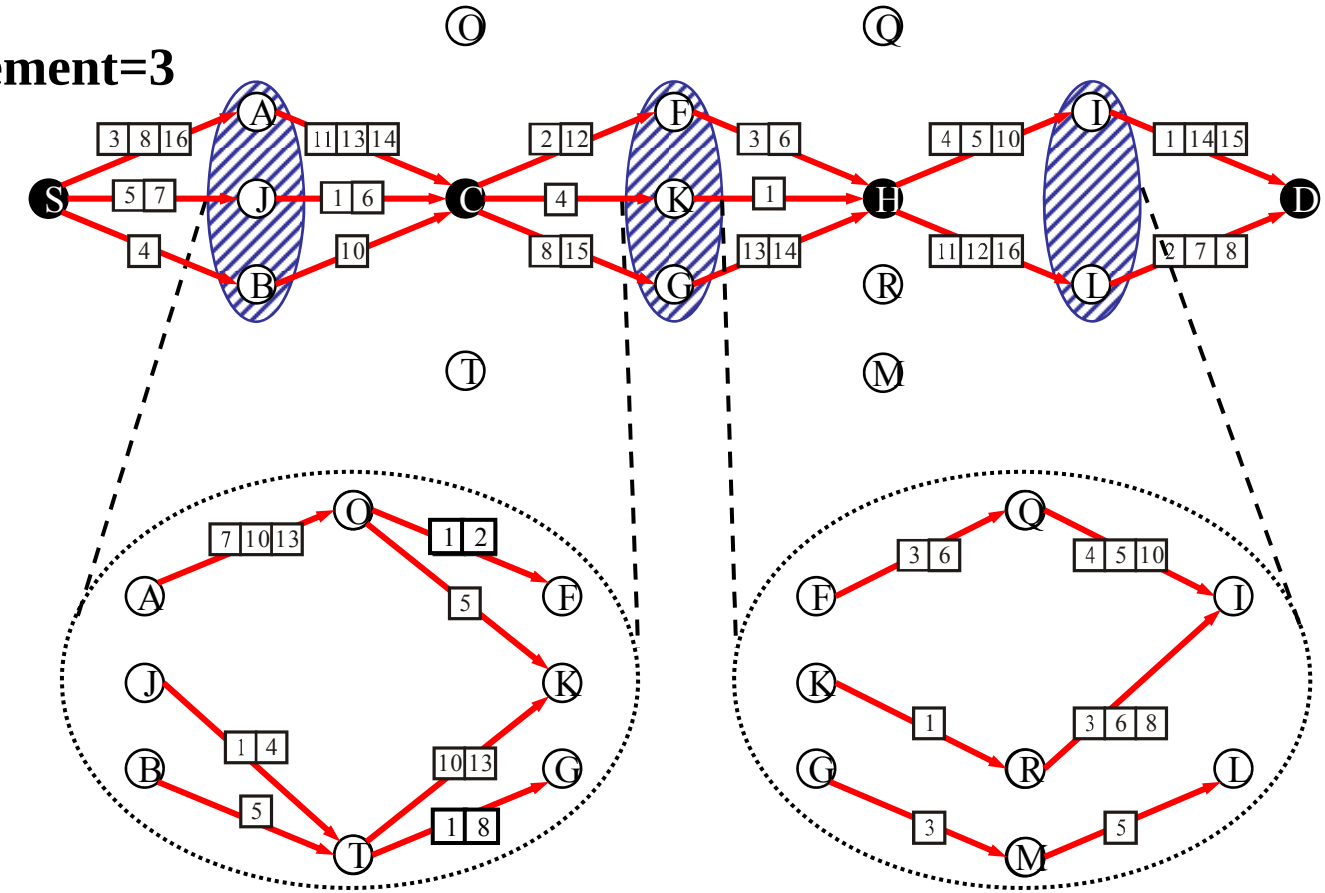
Requirement=2

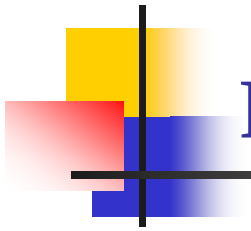


An example of $[\bar{3},\underline{3},\bar{4}]$

A spiral-multi-path with path bandwidth $[\overline{6},\underline{6},\overline{5},\underline{5},\overline{6}]$

Requirement=3





Phase 3: QoS Route-Reply Phase

- The purpose of this phase
  - Confirm a final *spiral-multi-path* and send a reply packet

Route-reply operation

- **Path bandwidth** ⇨ $[\overline{\alpha}_1, \underline{\beta}_1, \overline{\alpha}_2, \underline{\beta}_2, \ldots, \underline{\beta}_{k-1}, \overline{\alpha}_k], i \geq 1$
  - **Mobility-tolerant capability for gateway node:**

    A spiral-multi-path satisfies condition,

    $$[\overline{\alpha}_j]_i \geq \gamma, \text{ for all } 1 \leq j \leq k$$

  - **Mobility-tolerant capability for branch node:**

    A spiral-multi-path satisfies condition,

    $$[\underline{\beta}_j]_i \geq \gamma, \text{ for all } 1 \leq j \leq k-1$$

  where γ is the time slot requirement

Route-reply operation (con.)

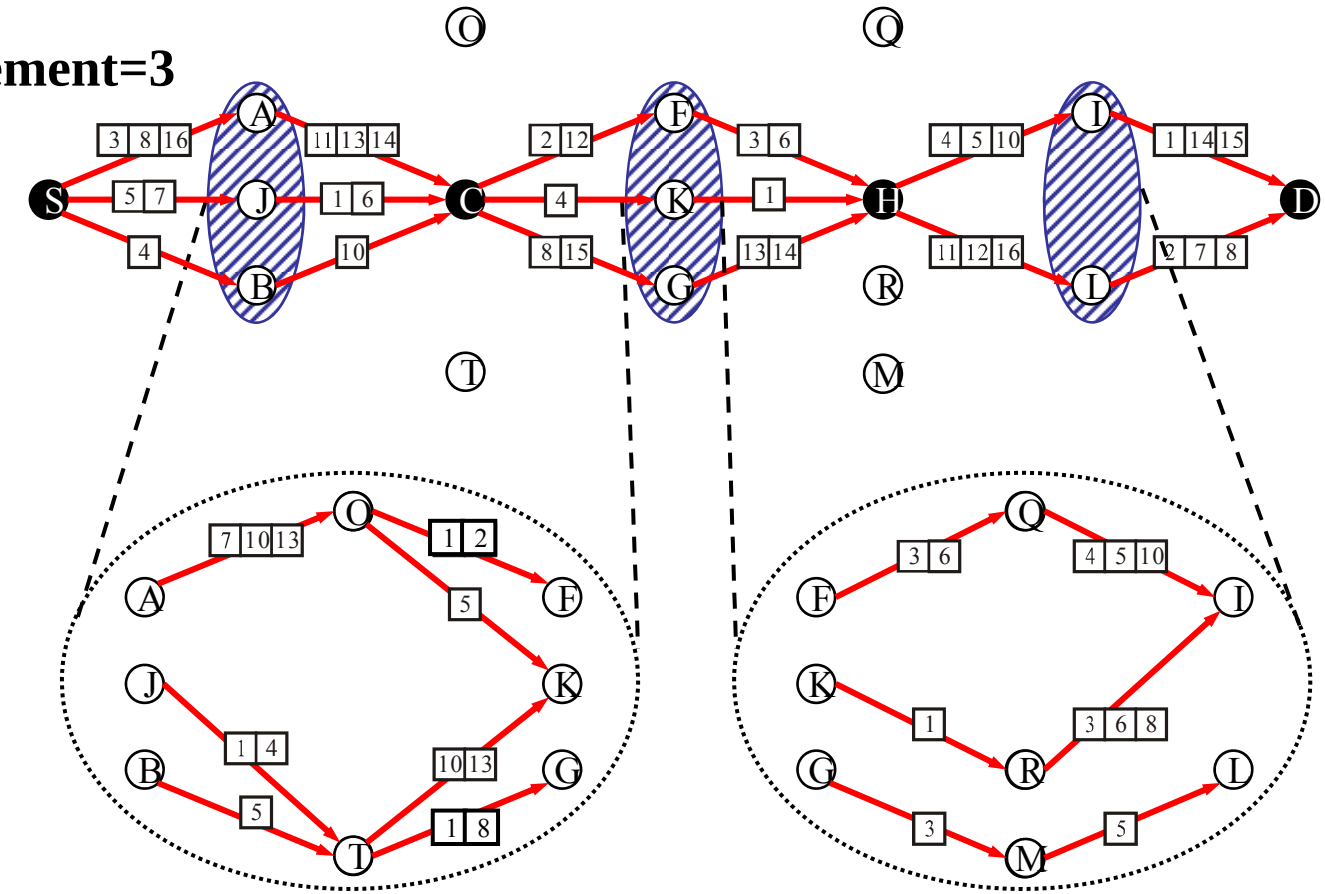
- **Selecting path decision:**

$$EB_{av} = \overline{EB}_{av} + \underline{EB}_{av} = \frac{\sum_{i=1}^{k} \left| \overline{\alpha}_i - \gamma \right|}{k} + \frac{\sum_{i=1}^{k-1} \left| \underline{\beta}_i - \gamma \right|}{k-1}$$

The higher the value is, the high QoS route stability will be

An example of $[\overline{6},\underline{6},\overline{5},\underline{5},\overline{6}]$

Requirement=3



An example of $[\overline{6},\underline{6},\overline{5},\underline{5},\overline{6}]$

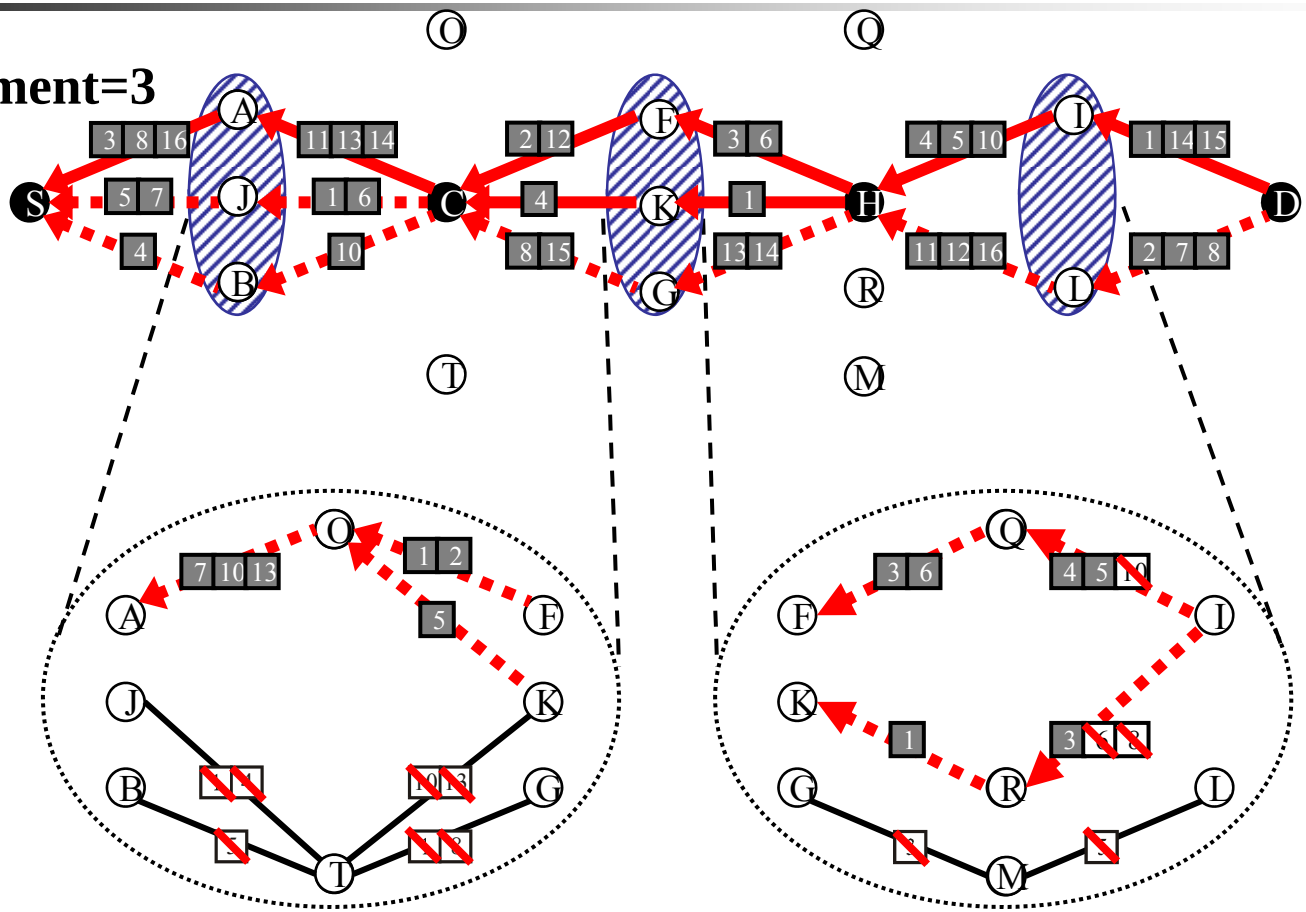
Ex. $[\overline{6},\underline{6},\overline{5},\underline{5},\overline{6}]$

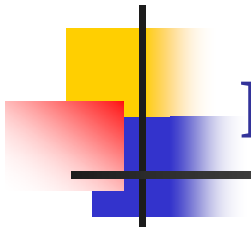
$$\Rightarrow EB_{av} = \overline{EB}_{av} + \underline{EB}_{av} = \frac{|6-3|+|5-3|+|6-3|}{3} + \frac{|6-3|+|5-3|}{2}$$

$$= 5.16$$

QoS Route-Reply operation

Requirement=3



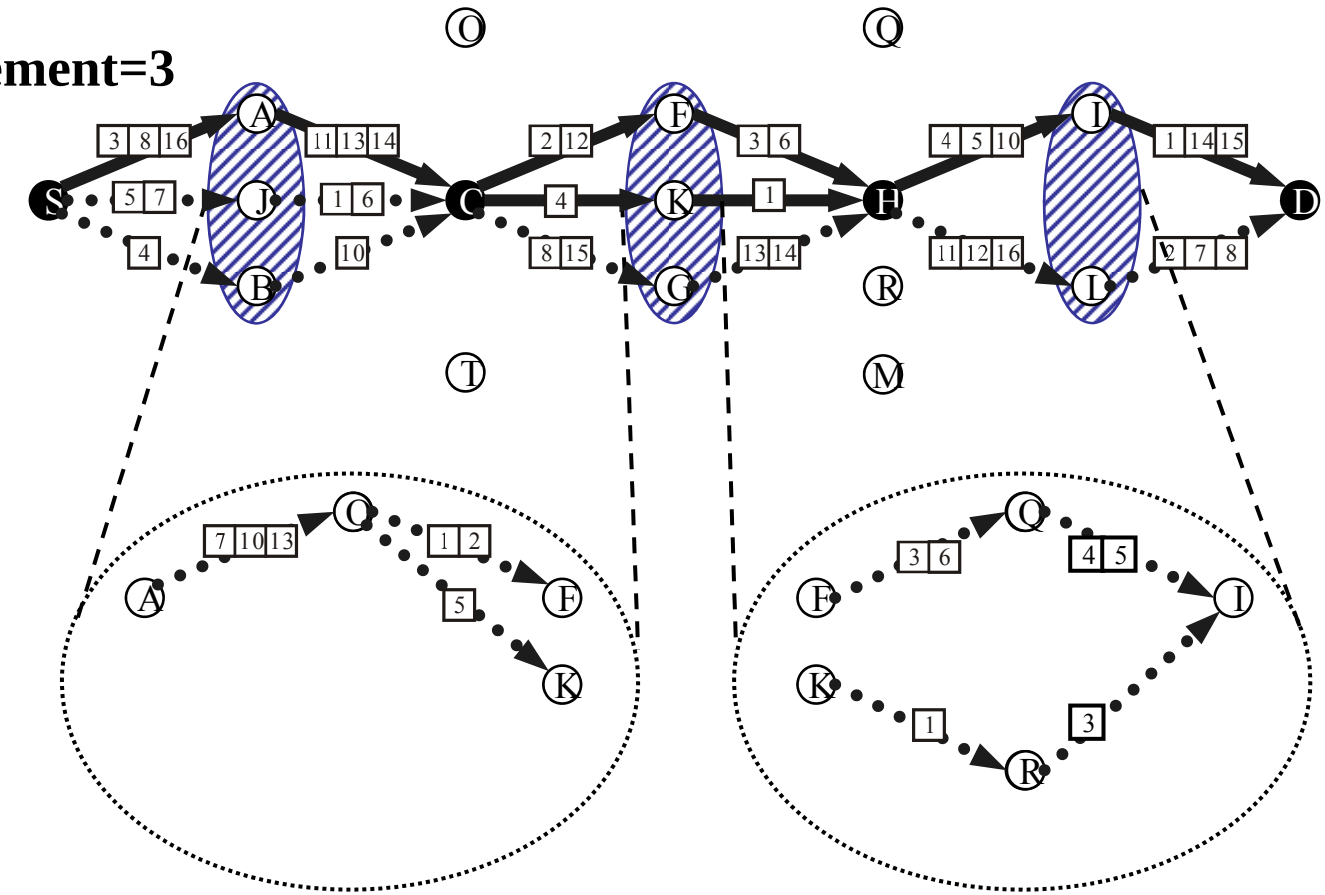


Phase 4: QoS Maintenance Phase

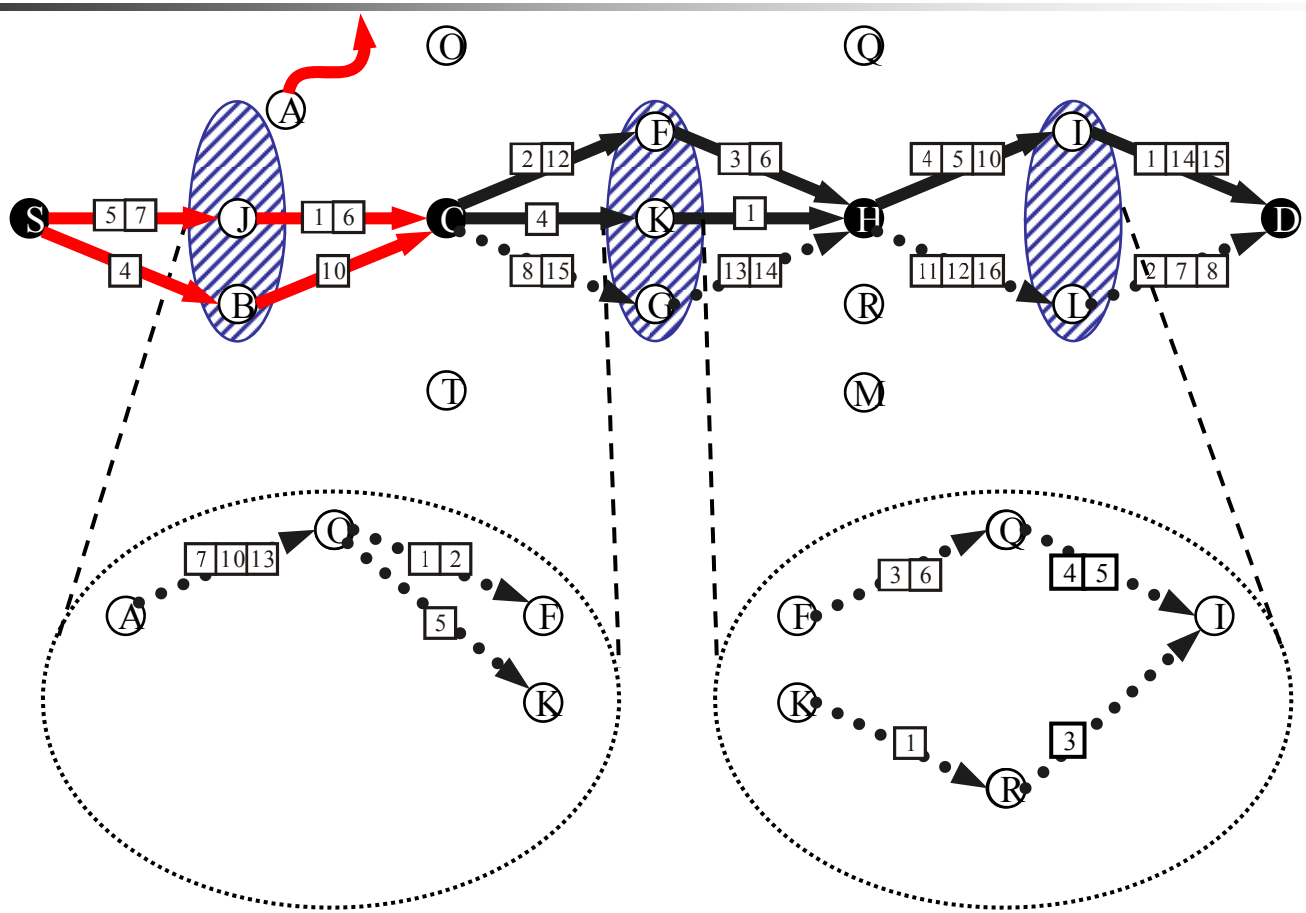
- Our main contribution is to provide the on-line route-recovery capability

Tolerating failed gateway node

Requirement=3

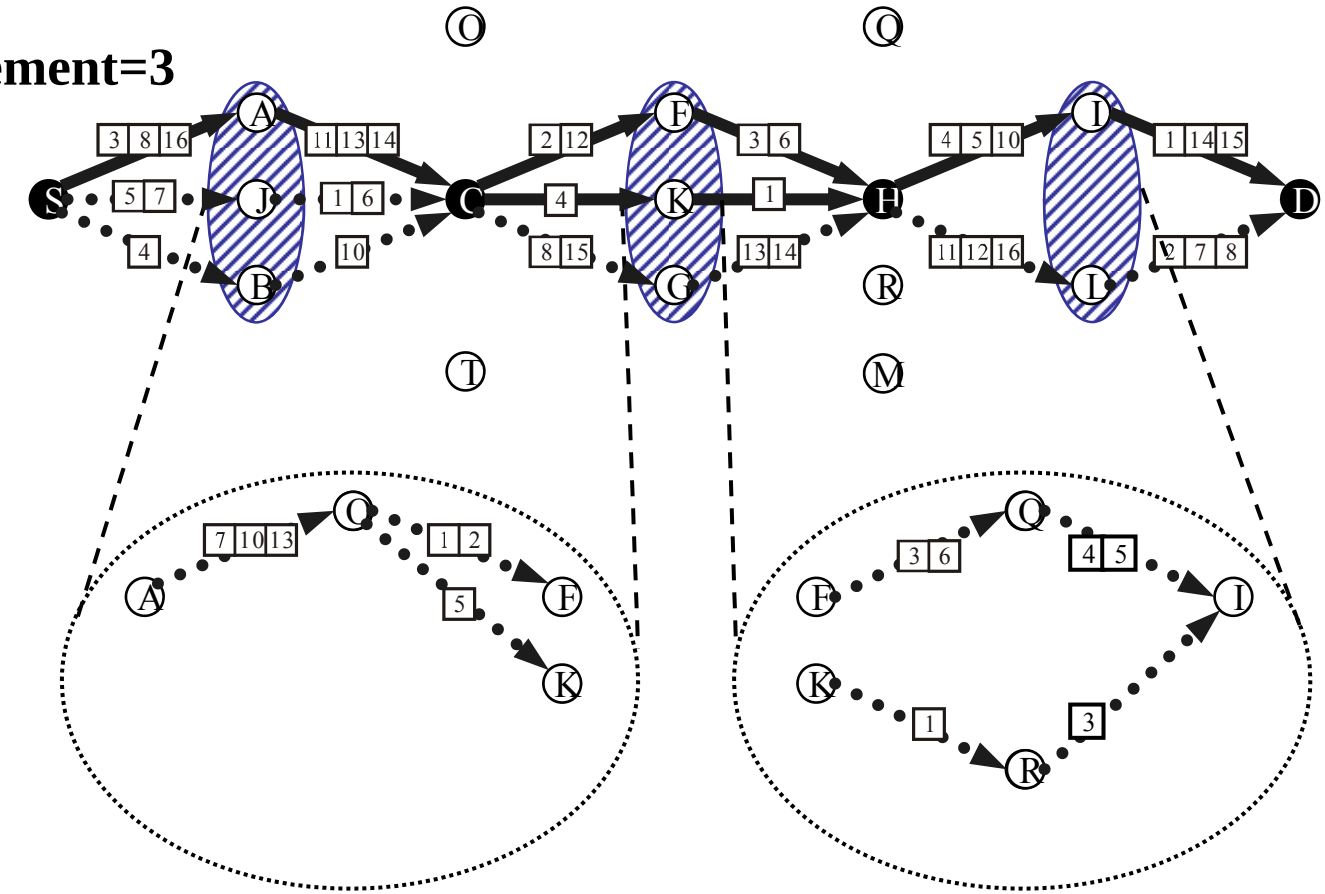


Tolerating failed gateway node

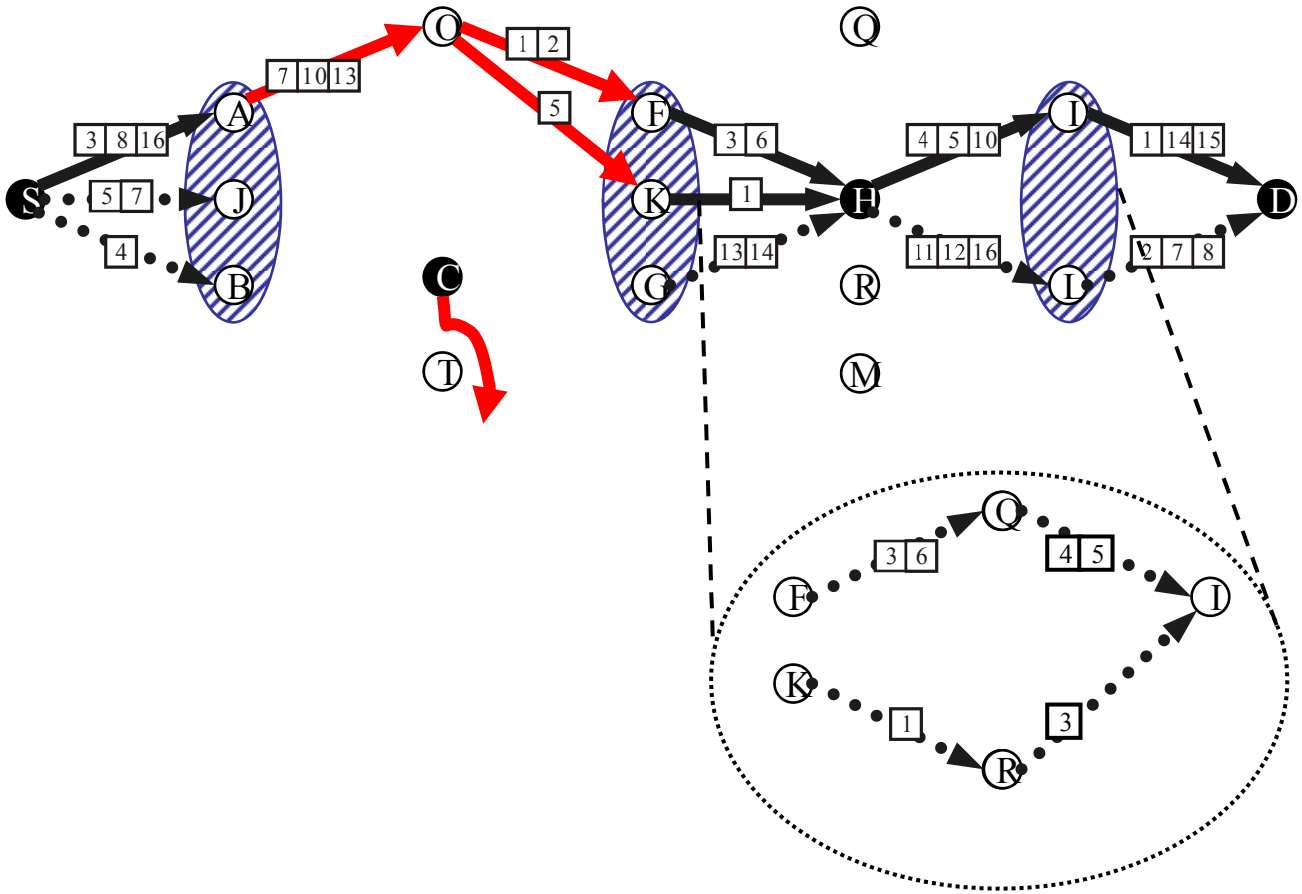


Tolerating failed branch node

Requirement=3



Tolerating failed branch node



Experimental Results - The parameters of our simulation platform

- The simulation platform is simulated in 1000×1000 m^2
- The number of mobile hosts is from 20 to 40
- The total number of time slots of each link is 8, 12 and 16
- Three different bandwidth requirement are 1, 2, 4, each called Lin-1, Lin-2, Lin-4 and SMPQ-1, SMPQ-2, and SMPQ-4
- The network bandwidth are low(25%), medium(50%), and high(75%)

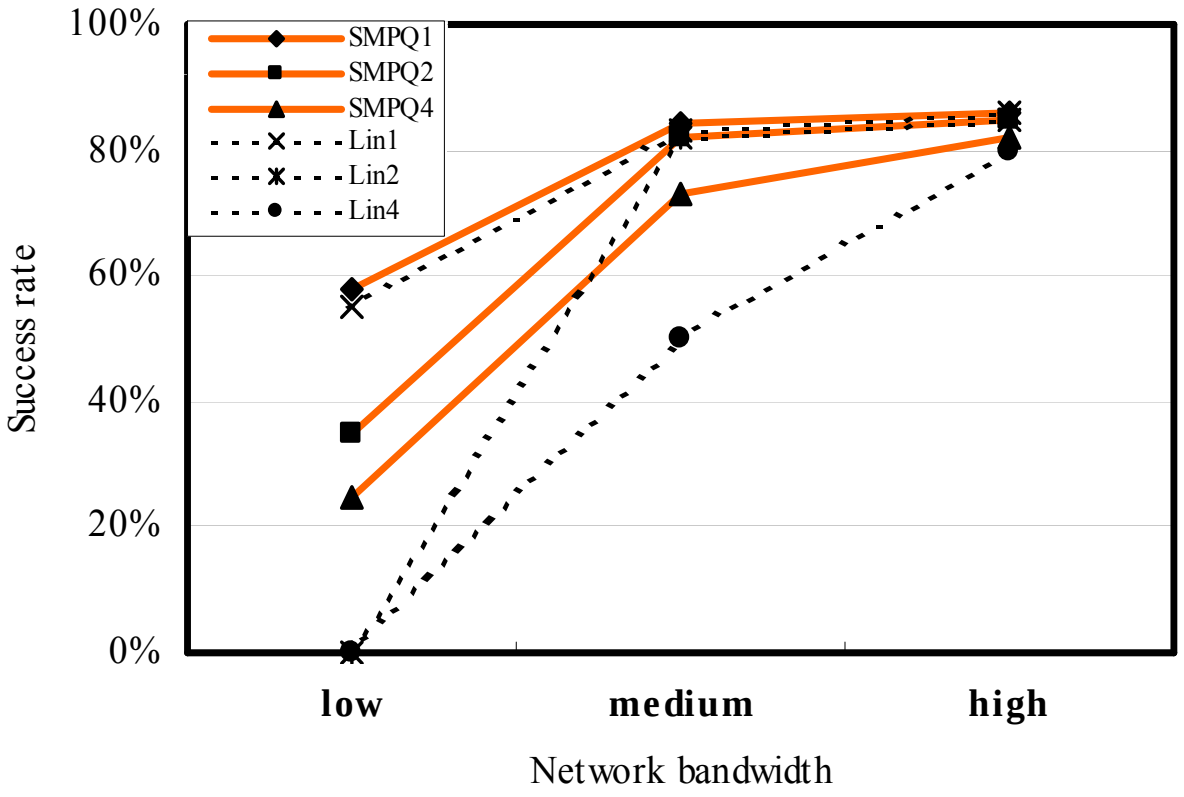
Experimental Results - Performance Metrics

- Success_Rate(SR):
  - the number of successful QoS route requests divided by the total number of QoS route requests from source to destination
- Slot_Utilization(SU):
  - the average slot utilization of every link in all QoS routes
- Overhead (OH):
  - the number of packets used for constructing and maintaining the QoS route from source to destination

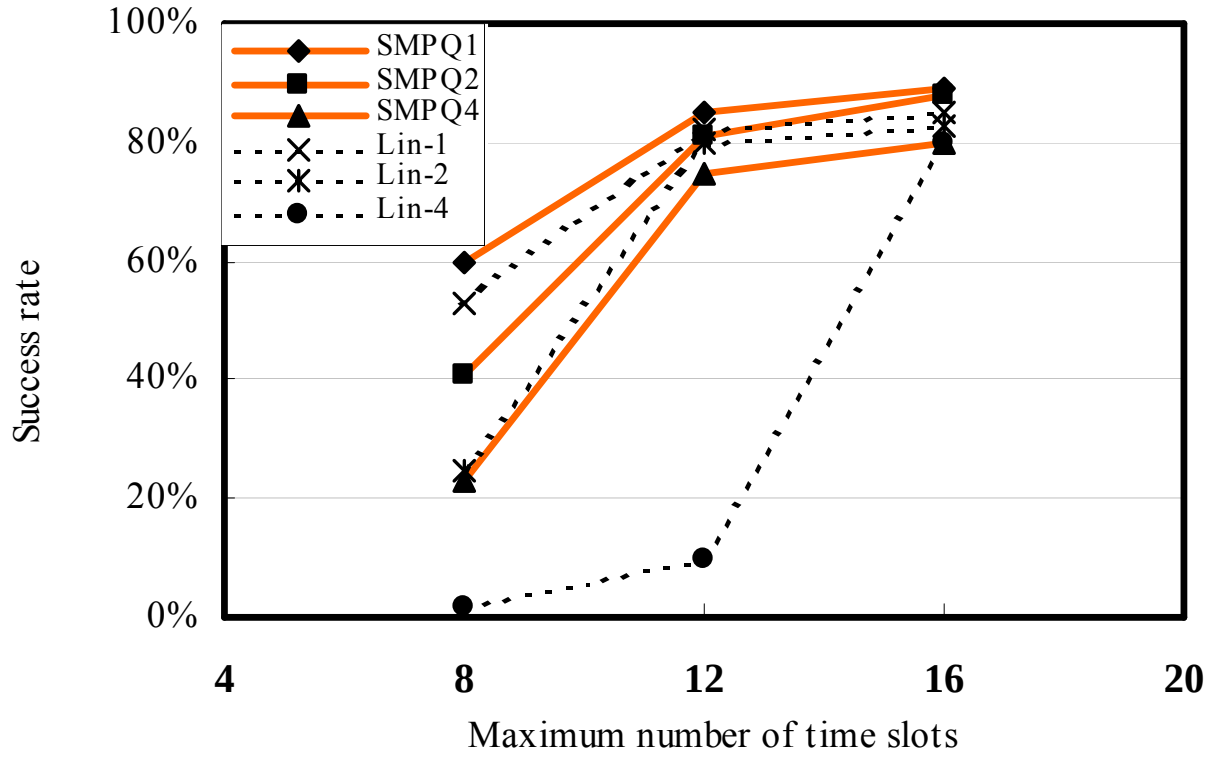
Performance of *Success_Rate(SR)*

- Effects of *Network Bandwidth*
  - Our scheme has higher SR than the Lin's when the network bandwidth is low
  - More Bandwidth, high SR
- Effects of *Maximum Number of Time Slots*
  - Our scheme has higher SR than the Lin 's
  - More Time Slots, high SR

Effects of *Network Bandwidth*



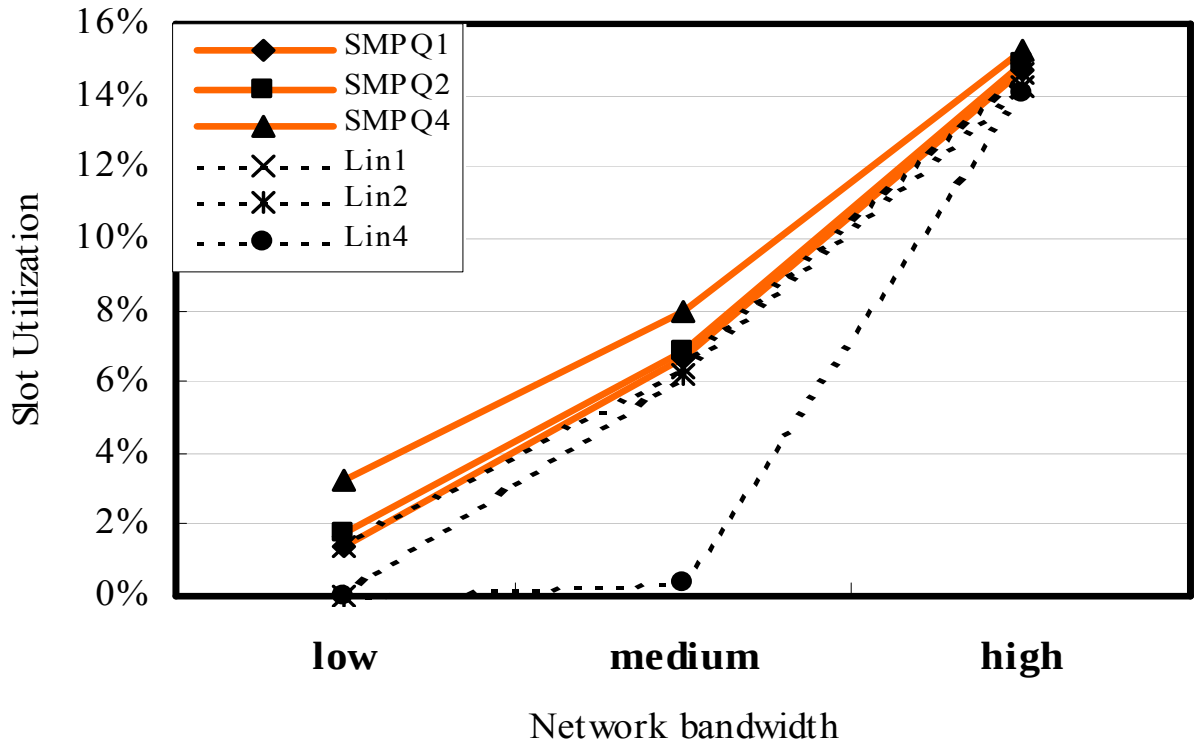
Effects of *Maximum Number of Time Slots*



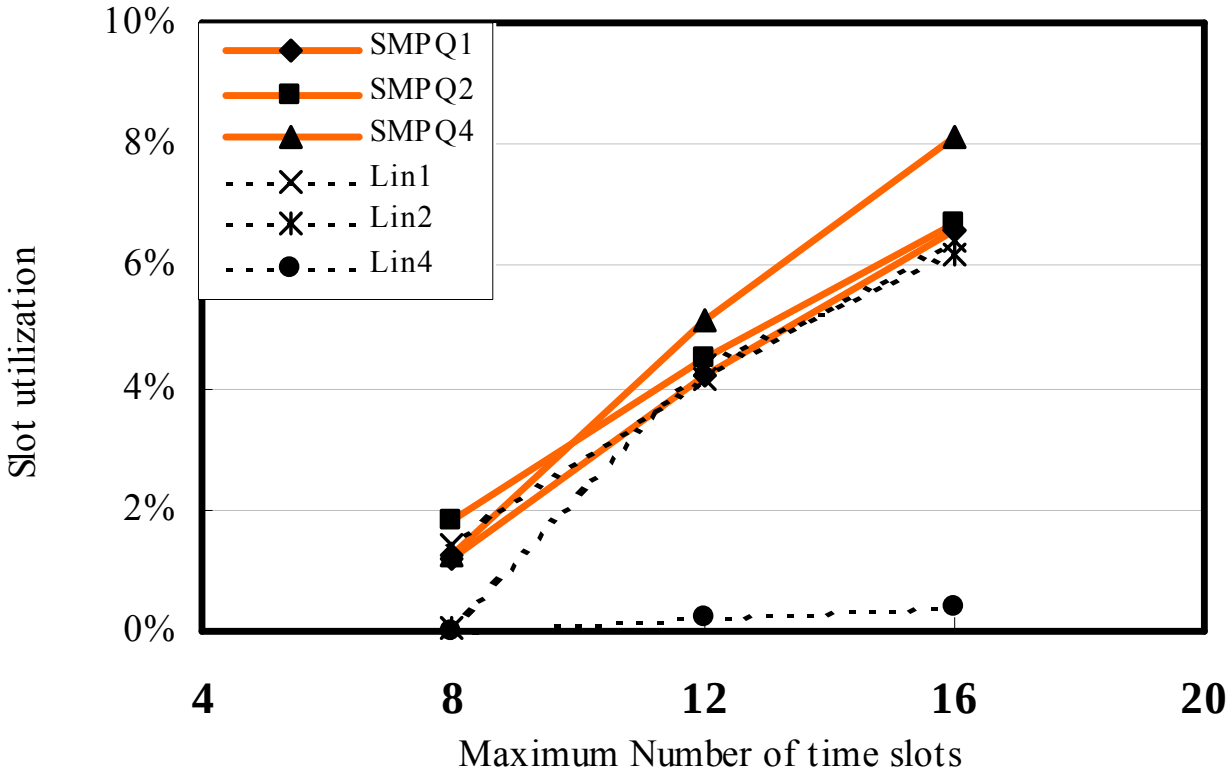
Performance of *Slot_Utilization(SU)*

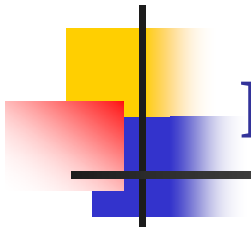
- Effects of *Network Bandwidth*
  - Our scheme has higher SU than the Lin's
  - As γ increases, SU of
    - our scheme increases
    - Lin's scheme decreases
- Effects of *Maximum Number of Time slots*
  - Our scheme has higher SU than the Lin's

Effects of *Network Bandwidth*



Effects of *Maximum Number of Time Slots*

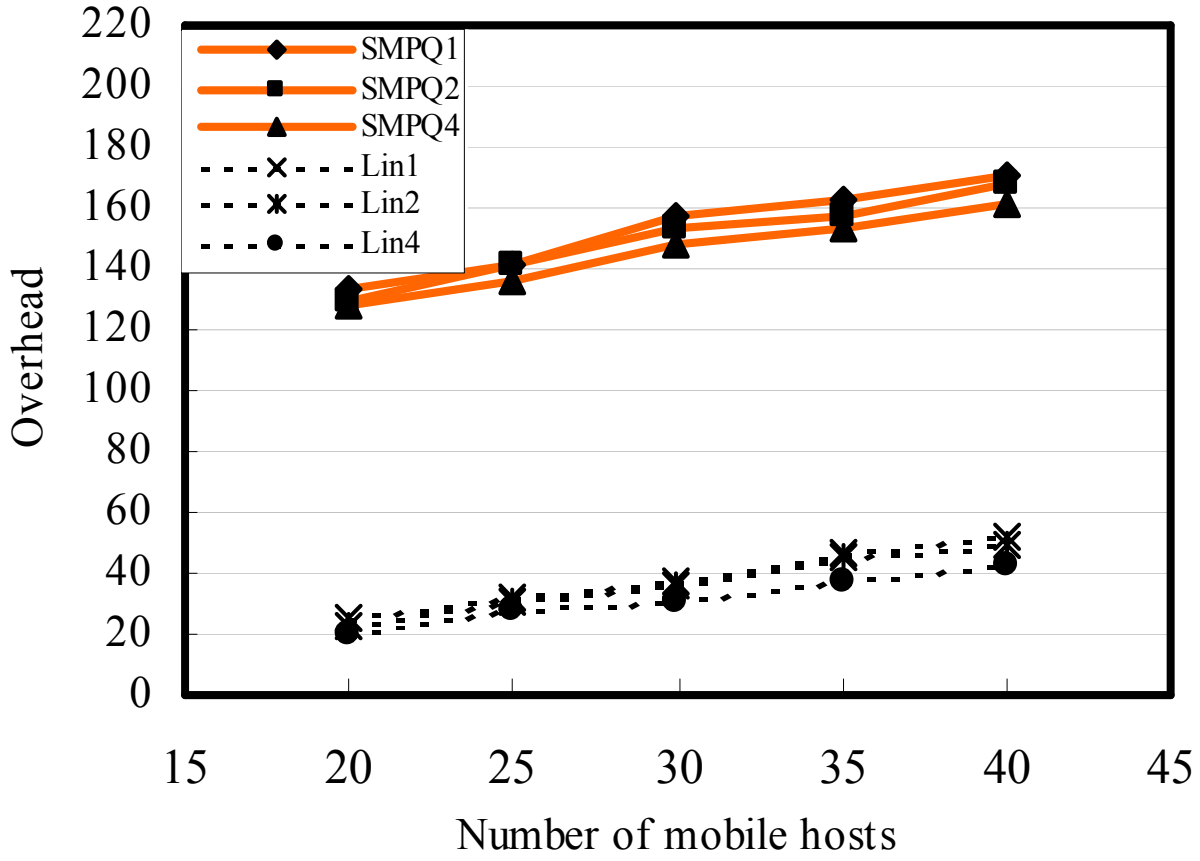




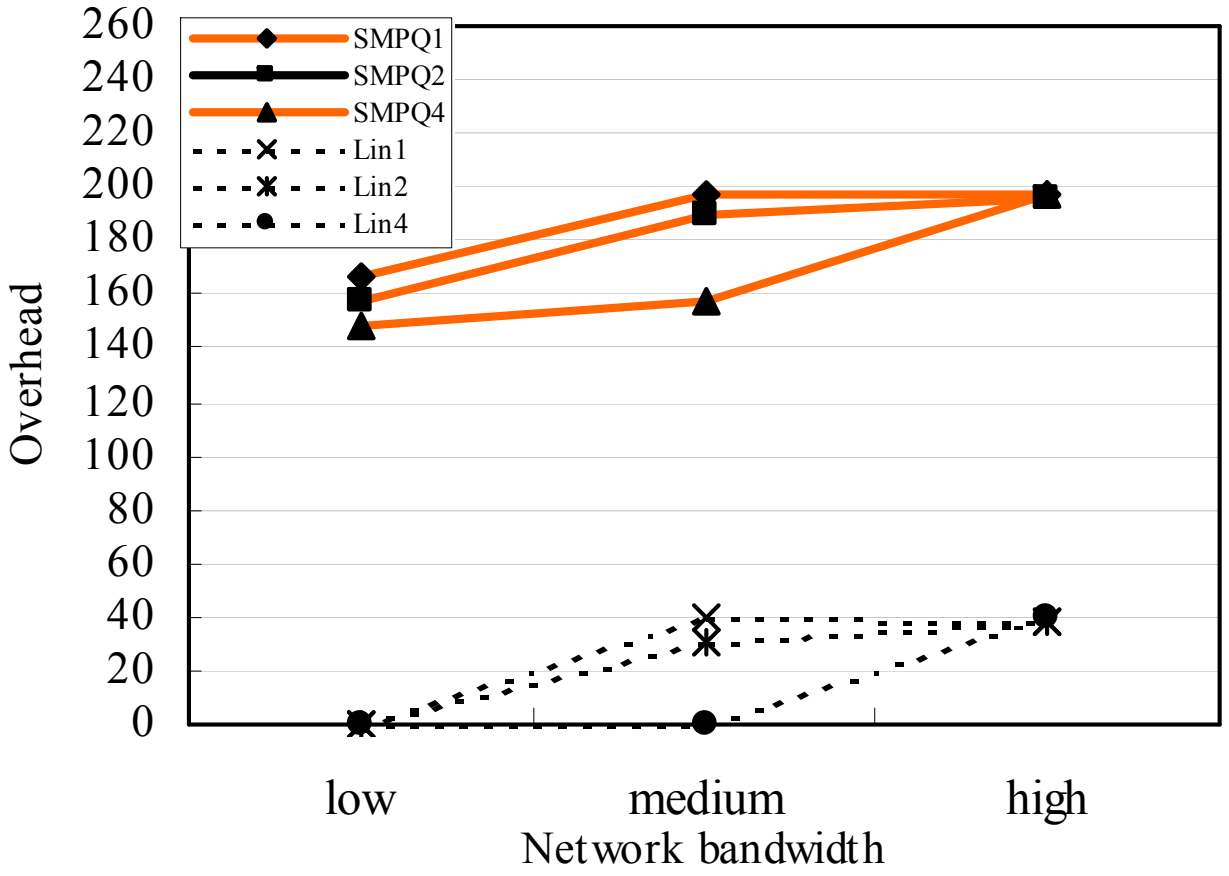
Performance of *OverHead(OH)*

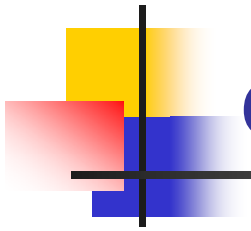
- Effects of *Number of Mobile Hosts*
  - Our scheme has higher OH than the Lin's
  - More Mobile Hosts, high OH
- Effects of *Network Bandwidth*
  - Our scheme has higher OH than the Lin's

Effects of *Number of Mobile Hosts*



Effects of *Network Bandwidth*





Conclusions

- An efficient On-demand QoS routing protocol is presented in a MANET by using
  - Spiral-path enhance the QoS route- robustness and route stability
  - Multi-path promotes the success rate of finding the QoS route