Adding Multi-class Routing into the Differentiated Services Architurecture

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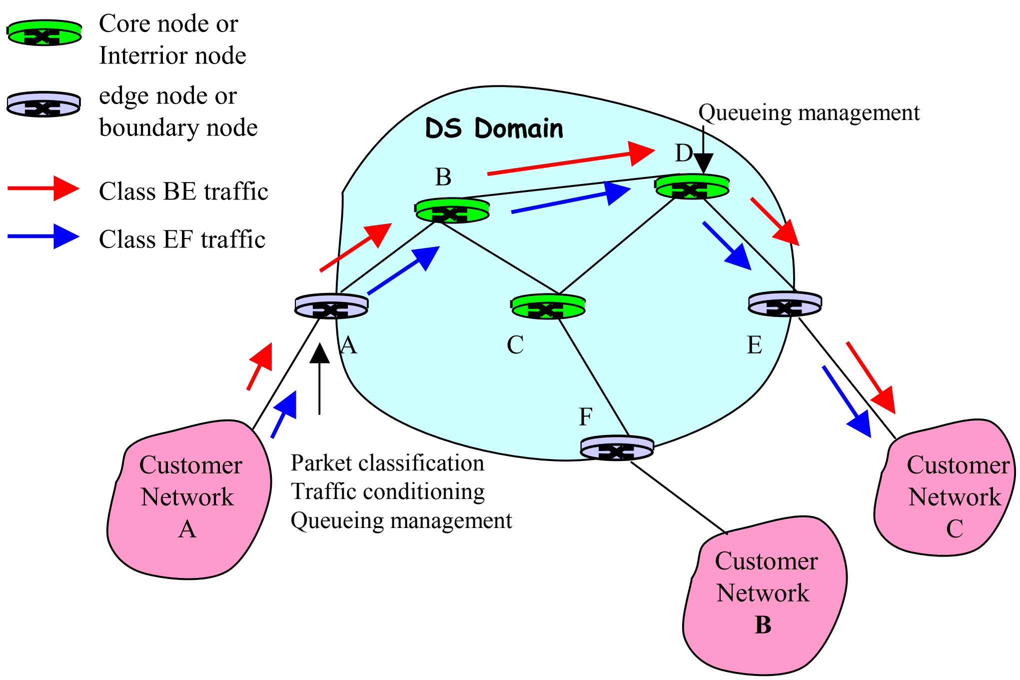
Contents

Introduction

- Best-effort IP networks need Quality of Service (QoS)
- DiffServ model has been a scalable solution to implement QoS in the current IP networks
  - Big problem is an inter-class effect
- Several hop-by-hop QoS based routing algorithms are tried to alleviate the inter-class effect and reasonably distribute network traffic
- Problem: a single routing table
- Our solution: Adding Multi-class routing into DiffServ
  - multiple routing tables
  - multiple hop-by-hop QoS based routing algorithms

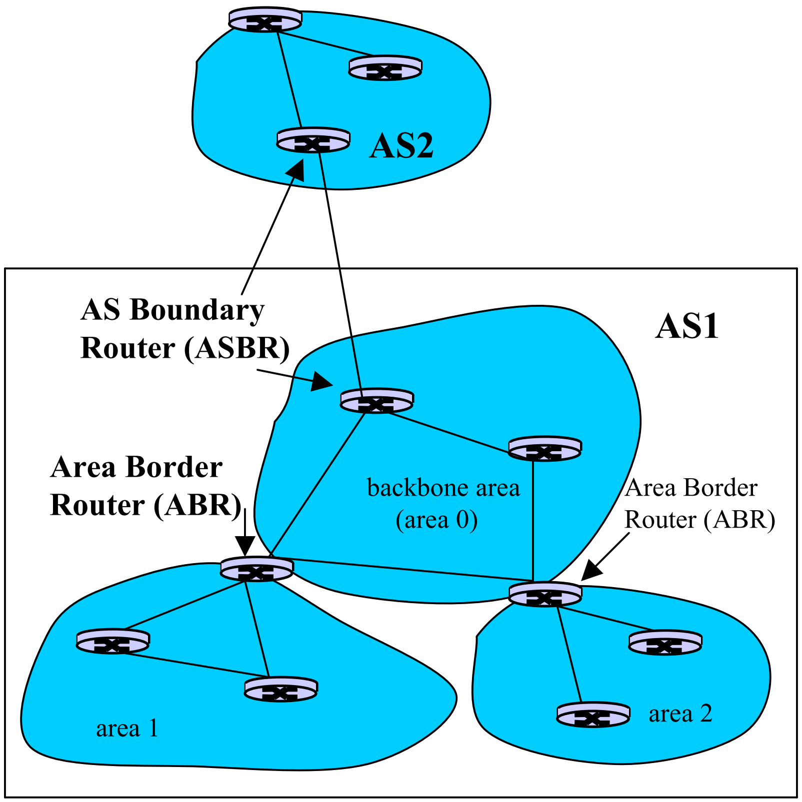
DiffServ



A DiffServ network

- DS domain
  - contiguous DiffServ nodes
  - controlled and managed by the same administration
- DS codepoint
  - a label
  - classify the network traffic
  - Type of Service (TOS) in the IP header
- Per-Hop Behaviors(PHBs)
  - forwarding treatments
  - buffer management and queueing
- Traffic conditioning
  - classifier,marker, meter, shaper/dropper and remarker
- A single routing table

OSPF



- Open shortest path first
- A link-state routing protocol
- A hierarchical topology
  - Area is a group that consists of one or more contiguous networks and hosts
  - ABR creates Summary-LSAs
  - ASBR redistributes external routing information
- OSPF Sub-protocols
  - Hello protocol
  - Database Exchange protocol
  - Flooding protocol

OSPF (cont.)

- Link state advertisements (LSAs)
  - LSAs represent a router's routing information
  - Except for Network-LSA, each type of LSAs only contains a metric
  - Different types of LSAs have their own functions
  - LSAs are stored into the link state database
- Routing table calculation
  - A whole routing table calculation includes the intra-area route calculation, inter-area route calculation and external route calculation
  - OSPF protocol supports incremental update calculations, which are related to inter-area route calculation or external route calculation
  - A real routing algorithm is applied to calculate the intra-area routes
  - A distance-vector approach is used to calculate inter-area routes and external routes

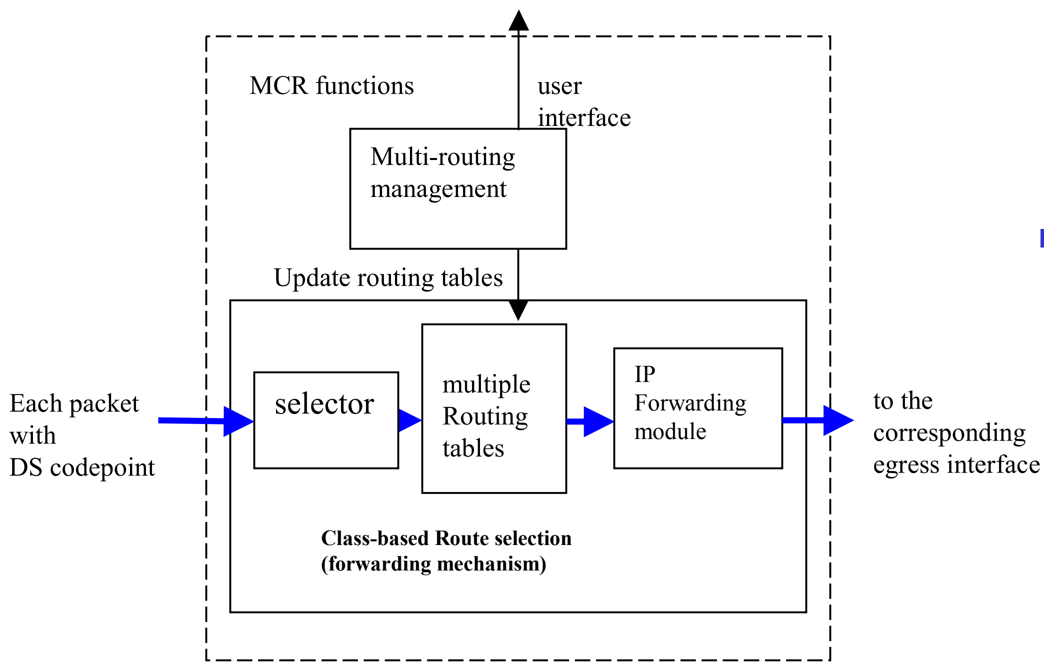
OSPF (cont.)

- OSPF convergence
  - A fast, loop-less convergence
  - Two stages:
    - Flood the updated LSAs throughout an area or a whole routing domain
    - Recalculate the routing table
  - The number of LSAs has an impact on the OSPF convergence
- OSPF can be extended to support new functions or mechanisms

Link-state Routing Algorithms

- In OSPF, Dijkstra's algorithm is used as a routing algorithm
- Several hop-by-hop QoS based routing algorithms
  - Shortest Path with the hop count metric (**SP**)
    - SP computes a shortest path tree with the *hop count metric*
  - Bandwidth-inversion Shortest Path (**BSP**)
    - BSP establishes a shortest path tree with the sum of the inversed *bandwidth*
  - Widest-Shortest Path (**WSP**)
    - WSP calculates a shortest path tree that the path to each destination is the minimum *hop count* among all feasible paths. If several such paths exist, the one with the maximum *bandwidth* is used for the destination
  - Enhanced Bandwidth-inversion Shortest Path (**EBSP**)
    - It is the extension to the BSP algorithm
    - EBSP introduces a "penalty" factor θ into the weight function of the BSP algorithm

MCR Scheme



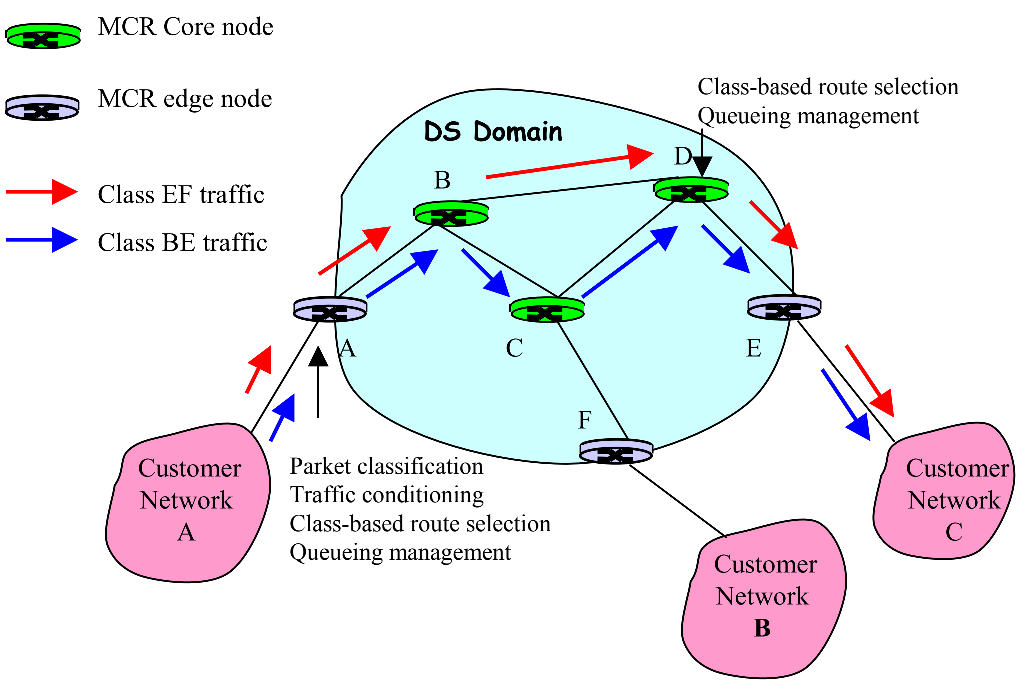
Functions of the MCR scheme

- Multi-Class Routing scheme
  - In a network, each router can provide different routing tables computed by various routing algorithms for delivering different class traffic
- Each router has two new functions:
  - Multi-routing management
    - collect routing information
    - calculate multiple routing tables
    - control routing algorithms
    - update routing tables
  - Class-based route selection
    - make the route selection based on the DS codepoint in each packet's IP header

MCR Approaches

- We can use different MCR approaches for the multi-routing management.
- Static MCR
  - A simple approach
  - Link weights, such as hop count and bandwidth, are assigned by the administrator
  - Produces a minimal impact on the convergence
  - Cannot reflect the real network status
- Dynamic MCR
  - Distributed or centrialized
  - Link weights are automatically measured based on time T or a significan event
  - Promptly reflect the network status
  - Result in a frequent convergence process and increasing packet loss
  - Take the time T into consider

MCR DiffServ



An exmaple of the MCR DiffSer network

- We add Multi-class routing scheme into the DiffServ architecture
- called MCR DiffServ
- In a MCR DiffServ network, a node
  - keeps the same functions as a traditional DiffServ node has.
  - selects the corresponding routing table based on DS codepoint
  - looks up the nexthop for each packet by using the selected routing table

OSPF with MCR Extensions

- Goals of design of OSPF with MCR extensions is
  - To implement the multi-routing management function
  - To provide two routing tables
  - To support static MCR approach and dynamic MCR approaches
  - To limit the additions to the standard OSPF version 2 protocol
  - To minimize the impact on the original OSPF, such as code and convergence, etc.

OSPF with MCR Extensions 2

- We create MCR optional capability for OSPF
  - M-bit is introduced into the Option field as an indicator of the MCR capability

M	**unused**	DC	EA	N/P	MC	E	**unused**

The modified Options format

  - The modified Option field will be used by all Hello packets, Database Description packets and all LSAs

OSPF with MCR Extensions 3

- Encoding Extended TOS
  - Goal: to make extended TOSs distinguish from the standard definition in RFC1349
  - 72 is defined for bandwidth
- Encoding Bandwidth Resource
  - Problem: the metric field in Router-LSAs is only 16 bits long.
  - Assumption: the maximum bandwidth is 10 Gbits/s
  - Solution:

    TOS metric = bandwidth / 159.59 (kbits/s)

OSPF with MCR Extensions 4

- OSPF packets
  - None of the formats of OSPF packets needs to be changed
- Modified LSA formats
  - Each type of LSAs, except for Network-LSAs, contain two metrics: TOS 0 metric and TOS 72 metric
- New types of Summary-LSA
  - Each routing table has its own types of Summary-LSAs
  - For example, type 12 and type 13 Summary-LSAs are used for the second routing table

OSPF with MCR extensions 5

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            LS age             |    Options    |       1       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link State ID                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Advertising Router                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     LS sequence number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         LS checksum           |             length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    0    |V|E|B|        0      |            # links            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Link ID                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Data                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     # TOS     |            metric             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      TOS      |        0      |          TOS metric           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Link ID                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Data                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
```

extended TOS

72

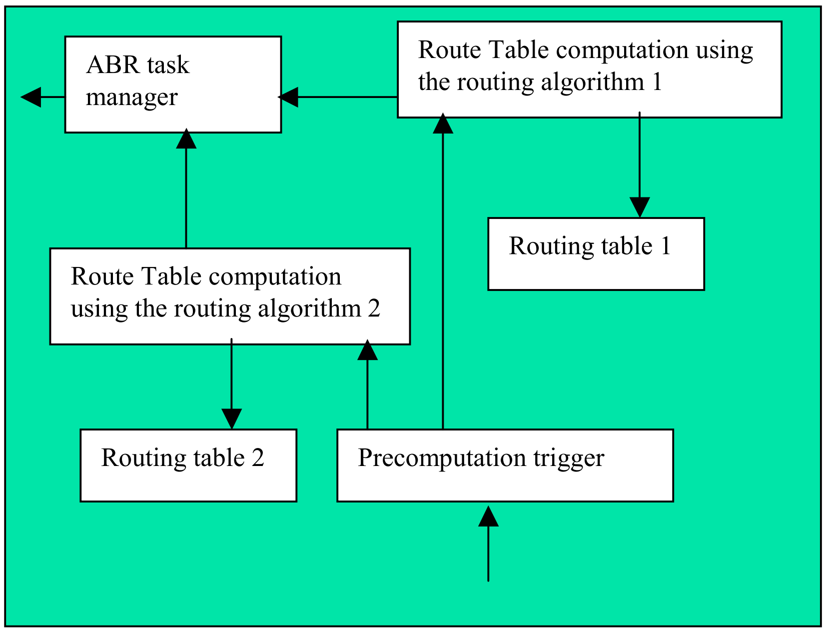
link's bandwidth

MCR Router-LSA format

OSPF with MCR Extensions 6

- Software architecture
  - Major original OSPF modules keep unchanged
  - Some new modules are introduced
    - More than one route table computation module
    - Precomputation trigguer module
  - Some modules are extended or modified in order to handle new types of LSAs and new routing tables
    - ABR task manager module
    - Local interface status manager module, etc.

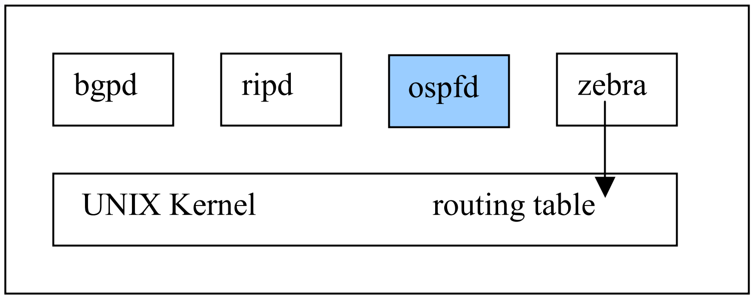
OSPF with MCR Extension 7



Part of software architecture

- ABR task manager module
  - Be in charg of creating Summary-LSAs and performing the route summarization for one routing table
  - Be extended
- Precomputation trigguer module
  - Be responsible for correctly trigger routing table calculations
  - A new module
- Route table computation module
  - Provide the whole routing table calculation and the incremental update calculation
  - Use a specific routing algorithm
  - More than one route table computation module in the software architecture

Static MCR Implementation



Zebra system architecture

- Zebra Software
  - a multi-process architecture
  - a collection of several separate daemons
- zebra is the kernel routing table manager
- ospfd is the daemon for OSPF protocol

- Static MCR implementation
  - Major core Zebra OSPF functions remain unchanged
  - Some important data structures are modified, such as ospf
  - Several functions are modified in order to support MCR capability
  - a lot of new functions are created
  - bandwidth of a link can be configured through VTY commands

Testing

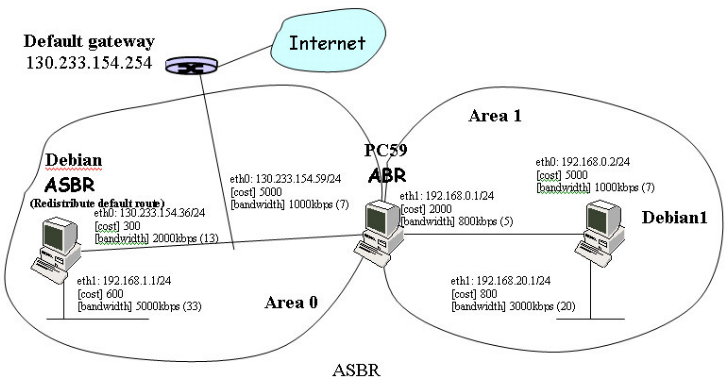


Figure 6.1: A basic function testing environment

- A hierarchical topology
- We used it to do following tests:
  - Basic function test
  - Pre-computation trigger test
  - Route summarization test

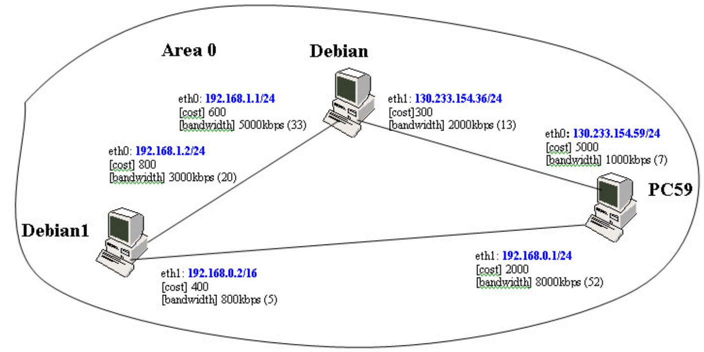


Figure 6.3: A multi-path test environment

- A triangle topology
- We used it to do Multi-path test
  - Routes to the same destination are different in diverse routing tables

Results of Test

- Basic function test

```
Router-LSA
LS age: 1016
  Options: 130
  Flags: 0x2 : ASBR
  LS Type: router-LSA
  Link State ID: 192.168.1.1
  Advertising Router: 192.168.1.1
  LS Seq Number: 80000004
  Checksum: 0xc4fa
  Length: 56
   Number of Links: 2

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 130.233.154.59
     (Link Data) Router Interface address: 130.233.154.36
      Number of TOS metrics: 1
       TOS 0 Metric: 300
       TOS [72] Metric: 13

    Link connected to: Stub Network
     (Link ID) Net: 192.168.1.0
     (Link Data) Network Mask: 255.255.255.0
      Number of TOS metrics: 1
       TOS 0 Metric: 600
       TOS [72] Metric: 33
```

- Multi-path test

```
debian1_ospfd# show ip ospf route
============ OSPF network routing table ============
N    130.233.154.0/24      [1100] area: 0.0.0.0
                           via 192.168.1.1, eth1
N    192.168.0.0/24        [400] area: 0.0.0.0
                           directly attached to eth0
N    192.168.1.0/24        [800] area: 0.0.0.0
                           directly attached to eth1

============ OSPF router routing table =============

============ OSPF external routing table ===========

============ OSPF BSP network routing table ============
N    130.233.154.0/24      [8318] area: 0.0.0.0
                           via 192.168.1.1, eth1
N    192.168.0.0/24        [9578] area: 0.0.0.0
                           via 192.168.1.1, eth1
N    192.168.1.0/24        [3277] area: 0.0.0.0
                           directly attached to eth1

============ OSPF BSP router routing table =============

============ OSPF BSP external routing table ===========
```

Conclusions

- Based on our OSPF with MCR extensions, the static MCR approach is implemented for the MCR DiffServ system
- Distinct routing algorithms can be used to compute the different routing tables. The routes to the same destination could be different in the diverse routing tables
- A new routing table is added into the OSPF code
- To decrease the number of Summary-LSAs, the route summarization mechanism should be implemented for each routing table
- To prevent any unnecessary whole routing table calculation, the incremental update calculation is needed for each routing algorithm
- To avoid any unnecessary routing calculation, the pre-computation trigger should correctly determine which routing algorithm is executed

Future work

- Different dynamic MCR approaches need to be further discussed and designed
- Approaches to Measure link weights, such as delay and residual bandwidth, need to be determined since the measurement of link weights could have an impact on the convergence
- The local interface status manager module is implemented by means of the dynamic MCR approaches
- New methods to encode bandwidth are needed because our encoding method is not suitable for the dynamic MCR approaches
- One or more QoS routing algorithms are implemented in the OSPF code supporting the MCR capability
- Performance and scalability of different MCR approaches are tested in different network environments

Thank you