# AMC Lab 3 Instruction Deadline: 4.2.2021

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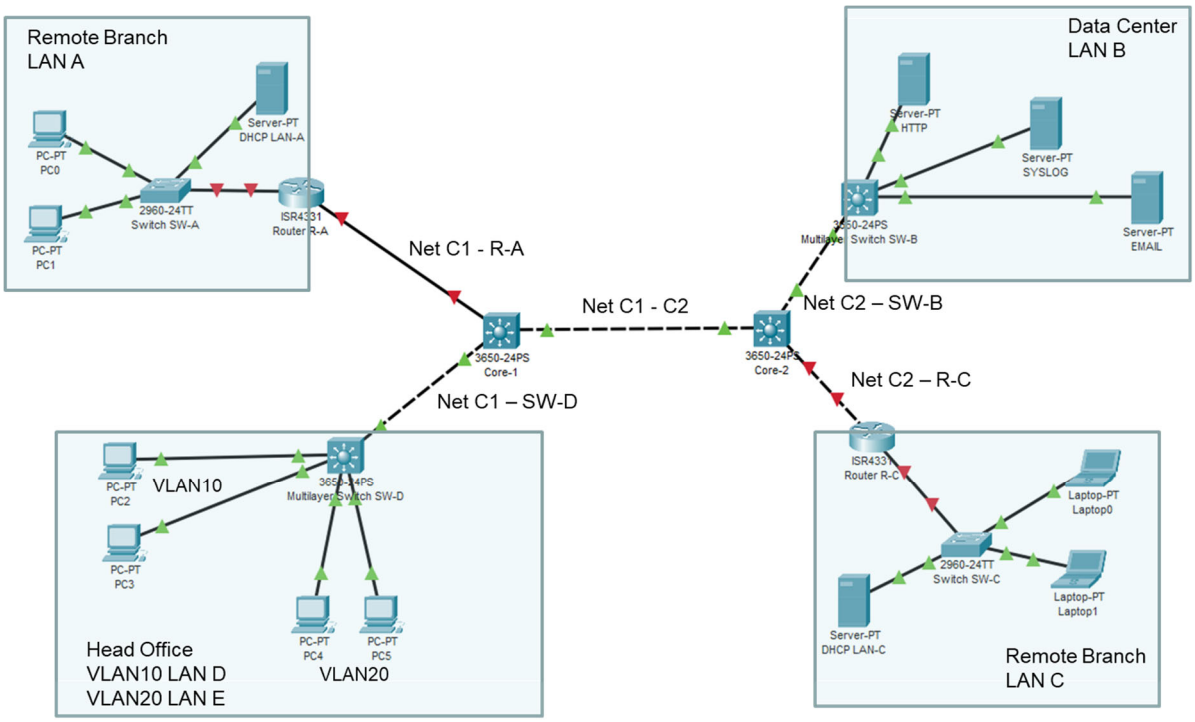
## QoS DiffServ Domain
## for Enterprise IP Network




## Tasks:

**In this AMC lab you design and implement QoS for the enterprise network**

**Tasks** **Enterprise Network PT Topology**

**DiffServ DSCP Mapping**

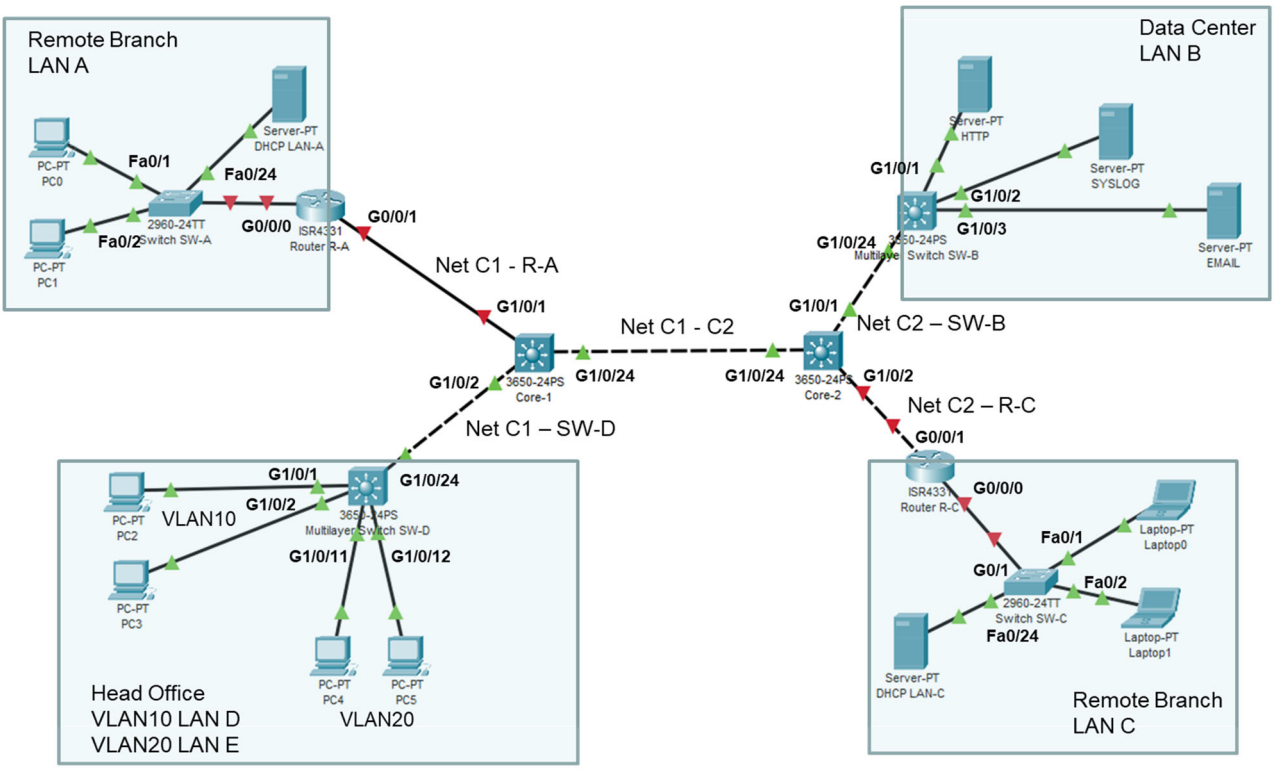
**DiffServ Network Scheduling**

**Implement and Test DiffServ Domain**

**Important Note:** Write your answers in this PDF with red color
- with free Adobe Acrobat you may use Comments/Notes
Do not change the layout of this text
Do not use any other file format.
Do not create archive files

# Task 1 – Enterprise Network PT Topology

## Topology




## Part 1: Baseline PT Topology

### Step 1: Ensure correct PT Topology and Configuration

1. We continue with the PT Topology of AMC Default Lab2. Ensure, that your PT Topology is working correctly. Correct your PT Topology in necessary. The sample solution is given in Ilias.
2. You can check your configurations by some **show** commands in privileged EXEC context:

```
#show ip interface brief
#show interface gx/y/z
#show ip route
#show running-configuration
```

### Step 2: Check Connectivity

You can check connectivity by pinging interfaces. From one sample PC (PC2 in LAN-D) you may ping any other of the 10 networks. The ping must be successful, correct your PT topology, if it is not working.

| | | | |
|---|---|---|---|
| PC2 to SW-D (Default Gateway) works (y/n)? | yes | PC2 to LAN-E works (y/n)? | yes |
| PC2 to C1 works (y/n)? | yes | PC2 to R-A works (y/n)? | yes |
| PC2 to PC0 (LAN-A) works (y/n)? | yes | PC2 to C2 works (y/n)? | yes |
| PC2 to SW-B works (y/n)? | yes | PC2 to HTTP Server (LAN-B) works (y/n)? | yes |
| PC2 to R-C works (y/n)? | yes | PC2 to Laptop0 (LAN-C) works (y/n)? | yes |

# Task 2 – DiffServ DSCP Mapping

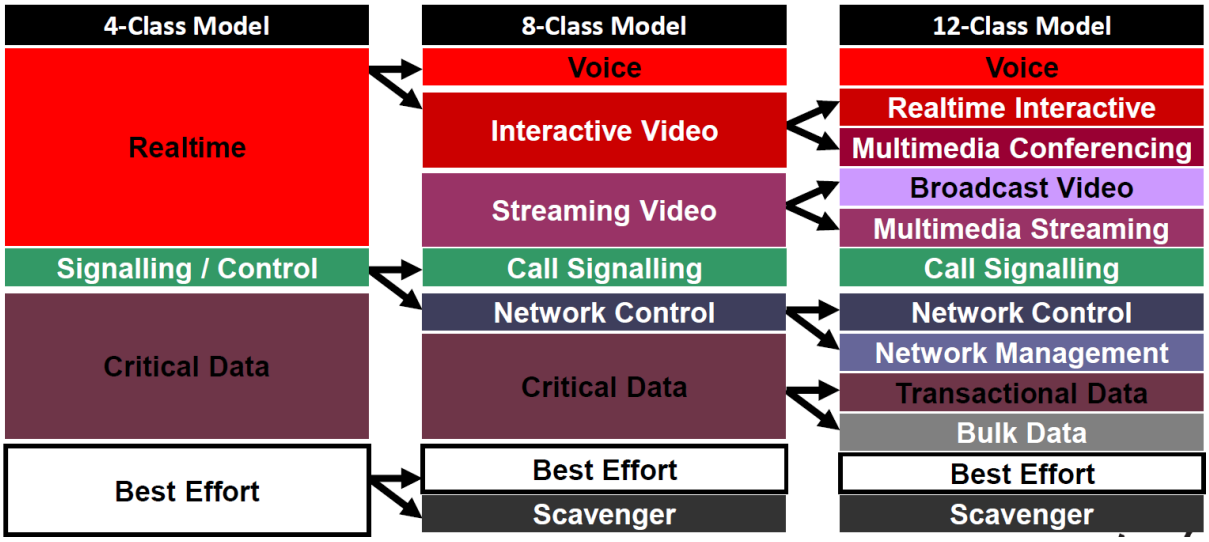
## Part 1: Services and DiffServ Classes

### List of Services

The following services shall be operated in your Enterprise network.

| Service | Description | Requirement |
|---|---|---|
| Service1 | Telephony with SIP signaling and RTP voice encapsulation | Minimum delay network scheduling for streaming media, guaranteed 8 Mbps streaming media throughput to and from any LAN. Peer-to-Peer RTP traffic is allowed.<br>800 kbps high priority Call Signaling Traffic per client LAN. Any SIP signaling traffic is pin-point routed to the central VoIP Call Server at IP address 172.16.2.130 in the Data Center |
| Service2 | Websocket access to the HTTP Enterprise Server for Enterprise Resource Planning (ERP) | 120 Mbps guaranteed ERP High-Throughput Transactional Data Traffic between any client LAN and the ERP Server (IP address 172.16.2.129). |
| Service3 | Network Management traffic (Operations, Administration, and Maintenance (OAM)) using ICMP and SSH between Data Center connecting to any network device or client LAN. | Up to 10 Mbps guaranteed management traffic from any LAN to any other network device or LAN. Admins may be connected in any LAN. |
| Service4 | Any other traffic | In minimum 40 Mbps throughput guaranteed on any link in periods of high load. |

We follow the 12-Class DiffServ Model which separates 12 different service classes.



More detailed, we will use the Application to PHB to DSCP mapping proposed in RFC 4594 to select adequate PHB and DCSP values for different services.

EF: Expedited Forwarding

AF: Assured Forwarding

CSx: DiffServ Class Selector x, which maps to the IP Precedence (IPP) (e.g. CS1: IPP = 1, CS6: IPP = 6)

DF: Default Class, maps to BE

| Application | L3 Classification | | IETF |
|---|---|---|---|
| | PHB | DSCP | RFC |
| Network Control | CS6 | 48 | RFC 2474 |
| VoIP Telephony | EF | 46 | RFC 3246 |
| Call Signaling | CS5 | 40 | RFC 2474 |
| Multimedia Conferencing | AF41 | 34 | RFC 2597 |
| Real-Time Interactive | CS4 | 32 | RFC 2474 |
| Multimedia Streaming | AF31 | 26 | RFC 2597 |
| Broadcast Video | CS3 | 24 | RFC 2474 |
| Low-Latency Data | AF21 | 18 | RFC 2597 |
| OAM | CS2 | 16 | RFC 2474 |
| High-Throughput Data | AF11 | 10 | RFC 2597 |
| Best Effort | DF | 0 | RFC 2474 |
| Low-Priority Data | CS1 | 8 | RFC 3662 |

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RFC 4594 Marking Recommendations

### Step 1: Create Application to PHB to DSCP Mapping

1. Create a table with the mapping of Service Requirements to the per-hop-behavior (PHB) label and the DSCP values according to RFC 4594. This is a part of a Quality-of-Service document for any DiffServ QoS implementation.
2. Map Services or Sub-Services, if one service consists of several parts, to the appropriate PHB and DSCP of RFC 4594.
3. Define all mappings in sequence from Service 1 to Service 4.

   If more than one type of IP flow is used in one service, use one line per IP flow.

| Service | Sub-Service<br>Protocol and Server Port | PHB | DSCP |
|---|---|---|---|
| Service1 | SIP (port 5060) | CS5 | 40 |
| | RTP (RTP Ports e.g. 7078, 7079) | EF | 46 |
| Service2 | HTTP (Port 80) | AF11 | 10 |
| Service3 | ICMP | CS2 | 16 |
| | TCP (Port 22) | CS2 | 16 |
| Service4 | Any (any Port) | DF (BE) | 0 |

## Part 2: Edge and Core Routers

1. All devices in LANs are untrusted. Thus we have to create trusted traffic inside of our DiffServ domain. Check and classify which devices are edge routers (ingress, egress) and which devices are interior routers.
2. Check in the table which routers mark IP flows and which routers use defined network scheduling mechanisms.

| Router | Router Classification | Marking | Defined Network Scheduling |
|---|---|---|---|
| R-A | Edge Router | X | X |
| SW-D | Edge Router | X | X |
| Core-1 | Interior Router | | X |
| Core-2 | Interior Router | | X |
| SW-B | Edge Router | X | X |
| R-C | Edge Router | X | X |

## Part 3: Identify IP Flows and create class-maps for Marking

### Step 1: Display ACLs and class-maps

1. In upcoming tasks, you will work with ACLs and class-maps and create sample implementation at router R-A.
2. You can check these configurations by additional **show** commands in privileged EXEC context:

```
#show access-list
#show class-map
```

### Step 2: Map PHB and DSCP to Marking Classes

We will have the following classes, predefined for your network.

1. Complete the table with the defined PHB and DSCP values.

| Class | IP Flows | PHB | DSCP |
|---|---|---|---|
| VOIP | Telephony Streaming | EF | 46 |
| SIG | Telephony Signaling | CS5 | 40 |
| ERP | ERP Data | AF11 | 10 |
| OAM | OAM Data | CS2 | 16 |
| class-default | Best Effort Data , any unmatched Data | DF | 0 |

### Step 3: Create a class-map for class SIG using ACL

1. Define a sample extended ACL **number 100** for Router R-A, interface g0/0/0 incoming traffic, to match SIP signaling traffic. Document the required ACL command here.
2. Note the single SIP server host destination IP address and port number.

```
access-list 100 permit udp 172.16.2.0 0.0.0.63 host 172.16.2.130 eq 5060
```

3. Define the corresponding class-map SIG and record this class-map here:

```
class-map SIG
  match access-group 100
```

### Step 4: Create a class-map for class ERP using ACL

1. Define a sample extended ACL **number 101** for Router R-A, interface g0/0/0 incoming traffic, to match ERP traffic. Document the required ACL command here.
2. Note the single HTTP server host destination IP address and port number.

```
access-list 101 permit tcp 172.16.2.0 0.0.0.63 host 172.16.2.129 eq 80
```

3. Define the corresponding class-map ERP and record this class-map here:

```
class-map ERP
  match access-group 101
```

### Step 5: Create a class-map for class OAM using ACL

1. **Note1:** Admins may be connected in any LAN and like to reach any device in the network.
2. **Note2:** All network devices and devices in LANs shall be reachable by ICMP and shall run an SSH server. This may require a detailed view into the source and destination ports, which are checked per ACL instruction line.
3. **Note3**: You may have more than one line per protocol in one ACL.
4. Define a sample extended ACL **number 102** for Router R-A, interface g0/0/0 incoming traffic, to match OAM traffic. Document the required ACL commands here.

```
access-list 102 permit icmp 172.16.2.0 0.0.0.63 any
access-list 102 permit tcp 172.16.2.0 0.0.0.63 any eq 22
access-list 102 permit tcp 172.16.2.0 0.0.0.63 eq 22 any
```

5. Define the corresponding class-map OAM and record this class-map here:

```
class-map OAM
  match access-group 102
```

### Step 6: Create a class-map for class VOIP using NBAR

Network-Based Application Recognition (NBAR) is a classification engine that recognizes and classifies a wide variety of protocols and applications. When NBAR recognizes and classifies a protocol or application, the network can be configured to apply the appropriate quality of service (QoS) for that application or traffic with that protocol.
**Note**: NBAR uses the match command option **protocol** inside a class-map definition.

1. Define a class-map VOIP for Router R-A, using NBAR to match Voice-over-IP streaming traffic.
2. **Note**: Check the required protocol only.

```
class-map VOIP
  match protocol rtp
```

### Step 7: Check ACLs

1. Use the **show access-list** command at Router R-A to display ACLs.
2. Record which ACLs are defined.

   access-list 100

   access-list 101

   access-list 102

### Step 8: Check class-maps

1. Use the **show class-map** command at Router R-A to display class-maps.
2. Record which class-maps are defined.

   class-map class-default

   class-map VOIP

   class-map SIG

   class-map ERP

   class-map OAM

3. From the displayed class-maps, which matching mechanism is used for class class-default?

```
Class Map match-any class-default (id 0)
  Match any
```

# Task 3 – DiffServ Network Scheduling

## Part 1: Define Network Scheduling

### Step 1: Map PHB and DSCP to Forwarding Classes

We will have the following classes, predefined for your network.

**Note**: Marking is only executed at ingress interfaces. Network scheduling must be executed at any forwarding network device interface. Execution of NBAR or Extended ACLs require higher computing power. It is less resource consuming just to check the DSCP field in IP packets. For this reason, we define new class-maps for forwarding purposes.

1. Complete the table with the defined PHB and DSCP values.

| IP Flows | Class for Network Scheduling | PHB | DSCP |
|---|---|---|---|
| Telephony Streaming | PREMIUM | EF | 46 |
| Telephony Signaling | SIGNAL | CS5 | 40 |
| OAM Data | HIGH | AF11 | 10 |
| ERP Data | MEDIUM | CS2 | 16 |
| Best Effort Data | class-default | DF | 0 |

### Step 2: Map Network Queueing Mechanism to Forwarding Classes

1. Define the network scheduling mechanism to meet the requirements of the **List of Services**.

| Class for Network Scheduling | Network Scheduling Mechanism |
|---|---|
| PREMIUM | Priority Queueing (PQ) |
| SIGNAL | Class-based Weighted Fair Queueing (CBWFQ) |
| HIGH | Class-based Weighted Fair Queueing (CBWFQ) |
| MEDIUM | Class-based Weighted Fair Queueing (CBWFQ) |
| class-default | Class-based Weighted Fair Queueing (CBWFQ) |

### Step 3: Create traffic matrix for bandwidth requirements

1. Each class requires some bandwidth according to the **List of Services**.
   - On some links aggregated bandwidth requirements must be calculated.
   - For bandwidth requirement calculation, note that only 2 LANs are connected to Multilayer Switch Core-2.
   - Take into account pin-point routing and peer-to-peer routing.
   - The link to the Data Center (LAN B) also has 8 Mbps bandwidth for VoIP media streaming.
   - Best effort traffic always gets a minimum of 40 Mbps on **any** link.

   Define the bandwidth requirements in kbps for each network link

| | Service Bandwidth Requirement (in kbps) | | | | |
|---|---|---|---|---|---|
| Class for Network Scheduling | R-A to Core-1 | R-C to Core-2 | SW-D to Core-1 | Core-1 to Core-2 | SW-B to Core-2 |
| PREMIUM | 8000 | 8000 | 16000 | 16000 | 8000 |
| SIGNAL | 800 | 800 | 1600 | 2400 | 3600 |
| HIGH | 10000 | 10000 | 20000 | 30000 | 10000 |
| MEDIUM | 120000 | 120000 | 240000 | 360000 | 480000 |
| class-default | 40000 | 40000 | 40000 | 40000 | 40000 |

**Note**: All throughput requirements are full duplex.

Notes:

- Between Core-1 and Core-2, only 16 Mbps VoIP traffic is possible in maximum, because on the right side there are only 2 LANs.
- Signaling traffic is aggregated from left to right for pin-point-routing to server 172.16.2.130.
- ERP traffic is aggregated from left to right for pin-point-routing to server 172.16.2.129.
- Class-default has a guarantee for 40 Mbps on any link
- Any class may get as much as possible (CBWFQ) except class PREMIUM because of PQ

# Part 2: Create policy-maps for Network Scheduling

1. In upcoming tasks, you will work with **sample policy-maps in router R-A.**
2. You can check these configurations by additional **show** commands in privileged EXEC context:

```
#show policy-map
#show policy-map interface <interface-id>
```

### Step 1: Create a policy-map for class PREMIUM

1. Define a sample policy-map for class PREMIUM in router R-A for Link R-A to Core-1. Document this policy-map:

```
policy-map QOS
  class PREMIUM
    priority 8000
```

### Step 2: Create a policy-map for class SIGNAL

1. Define a sample policy-map for class SIGNAL in router R-A for Link R-A to Core-1. Document this policy-map:

```
policy-map QOS
  class PREMIUM
    bandwidth 800
```

### Step 3: Create a policy-map for class HIGH

1. Define a sample policy-map for class HIGH in router R-A for Link R-A to Core-1. Document this policy-map:

```
policy-map QOS
  class HIGH
    bandwidth 120000
```

### Step 4: Create a policy-map for class MEDIUM

1. Define a sample policy-map for class MEDIUM in router R-A for Link R-A to Core-1. Document this policy-map:

```
policy-map QOS
  class MEDIUM
    bandwidth 10000
```

### Step 5: Create a policy-map for class class-default

1. Define a sample policy-map for class class-default in router R-A, valid on any link. Document this policy-map:

```
policy-map QOS
  class class-default
    bandwidth 40000
```

### Step 6: Check policy-maps

1. Use the show policy-map command to display policy-maps.
2. Record which policy-maps are defined.

   One policy-map QoS for network scheduling.

   ```
   policy-map QOS
   ```

# Task 4 – Implement and Test DiffServ Domain

## Part 1: Configure Edge Routers R-A and R-C

### Step 1: Create class-maps for Marking all IP flows

1. Use class names and requirements of ACL or NBAR according to **Task2**.
2. Care about source and destination IP addresses and port numbers!

### Step 2: Create and activate policy-map MARK for Marking

1. Set the DSCP values in all classes according to **Task2**.
2. Overwrite DSCP values of incoming IP packets, even for BE traffic.

### Step 3: Create class-maps for Forwarding all DSCP-marked IP flows

1. Use class names according to **Task3**.

### Step 4: Create and activate policy-maps QOS for Forwarding

1. Apply the Network Scheduling Mechanisms with suitable Bandwidth calculation according to **Task3**.

### Step 5: Check policy-maps

1. Check policy-am at router R-C.
2. Record which policy-maps are implemented for BE traffic.

   Two policy-maps: one for network scheduling and one for IP packet marking

   ```
   policy-map MARK
   ```

   ```
   policy-map QOS
   ```

## Part 2: Configure Edge Routers SW-B and SW-D

**Note1**: Before applying NBAR, multiservice switches shall have Cisco Express Forwarding (CEF) enabled. CEF is switched-on by the command **ip cef** or **IP cef distributed** in privileged EXEC mode.

**Note2**: QoS shall be configured at router interface g1/0/24 instead of ingress switchport interfaces. Therefore, you configure one combined policy-map MARK_QOS

### Step 1: Create combined class-maps for Marking and QoS Forwarding.

1. Class names shall be VOIP, SIG, ERP, OAM, and class-default according to **Task2**.
2. Care about source and destination IP addresses and port numbers!

### Step 2: Create and activate policy-map MARK_QOS for Forwarding at interface g1/0/24

1. Apply the Network Scheduling Mechanisms with suitable Bandwidth calculation according to **Task3**.
2. In the same policy-map, set the DSCP values according to **Task2**.
3. Overwrite DSCP values of incoming IP packets, even for BE traffic.

   BTW: Only one policy-map has been implemented, setting DSCP for marking an in addition perform network scheduling.

   ```
   policy-map MARK_QOS
   ```

## Part 3: Configure Core Routers Core-1 and Core-2

**Note1**: Before applying NBAR, multiservice switches shall have Cisco Express Forwarding (CEF) enabled. CEF is switched-on by the command **ip cef** or **IP cef distributed** in privileged EXEC mode.

### Step 1: Create class-maps for Forwarding all DSCP-marked IP flows

1. Trust internal DSCP values.
2. Use class names according to **Task3**.

### Step 2: Create and activate policy-maps for Forwarding

1. **Note:** Any forwarding interface at core routers must get rules for Forwarding.
   - Interface g1/0/1: Core-1: policy-map **QOS11** Core2: policy-map **QOS21**
   - Interface g1/0/2: Core-1: policy-map **QOS12** Core2: policy-map **QOS22**
   - Interface g1/0/24: Core-1: policy-map **QOS13** Core2: policy-map **QOS23**
2. Apply the Network Scheduling Mechanisms with bandwidth calculation from traffic matrix.
3. **For exercise purposes**:
   - Class **HIGH** on the link between Core-1 and Core-2, shall be **shaped** at average CIR in **addition**.
   - The shaped bandwidth shall be the same as required bandwidth for class HIGH on this link.

   BTW: Only one policy-map has been implemented just performing network scheduling.

   ```
   policy-map QOS
   ```

## Part 4: Save running-configurations

1. When you checked the correct implementation of the complete DiffServ Domain save your running configuration to the startup-configuration at any network device.
   Use the **copy running-config startup-config** command.
2. Save your PacketTracer file.

## Part 5: Test DiffServ QoS Domain

### Step 1: Close your PT file and restart your PT file

- By this step, all devices will reboot and all dynamic buffers and parameters will be reset.

**Step 2: Check initial DSCP mapping in router R-A**

1. At Router R-A display the policy-map statistics of interface g0/0/0. Record how many packets have been marked in different traffic classes:

- VOIP 0 matches, 0 packets marked
- SIG 0 matches, 0 packets marked
- ERP 0 matches, 0 packets marked
- OAM 0 matches, 0 packets marked
- class-default 12 matches, 0 packets marked

2. Display the Router R-A policy-map statistics of interface g0/0/1. Record how many packets have been scheduled in different traffic classes:

- PREMIUM 0 matches
- SIGNAL 0 matches
- HIGH 0 matches
- MEDIUM 0 matches
- class-default 1 match

**Step 3: Check DSCP mapping following some ICMP requests**

1. From PC0 ping the server at IP address 172.16.2.130.
2. Display the Router R-A policy-map statistics of interface g0/0/1. Record how many packets have been scheduled in different traffic classes:

1st Ping (4 ICMP messages, unsuccessful because ARP matching must be performed first.)

- HIGH 3 IP packets (3 ICMP Echo)
- class-default 2 IP packets (1 ICMP Echo)

2nd Ping (4 ICMP messages, 3 x successful))

- HIGH 7 IP packets (3 plus 4 ICMP Echo)
- class-default 2 IP packets (1 ICMP Echo from before)

3. Display the Multilayer Switch Core-2 policy-map statistics of interface g1/0/1. Record how many packets have been scheduled in different traffic classes:

1st Ping attempt

- HIGH 0 IP packets
- class-default 1 IP packet

2nd Ping attempt

- HIGH 2 IP packets
- class-default 2 IP packets

### Step 4: Check DSCP mapping following some HTTP requests

1. From Laptop0 use the Web Browser to request a Website from HTTP server at IP address 172.16.2.129.
2. Display the Router R-C policy-map statistics of interface g0/0/1. Record how many packets have been scheduled in different traffic classes:

   Note: The number of matches might be different in individual implementations, but there shall be in minimum 4 matches for the HTTP request (3 Packets TCP Session Setup and one Packet HTTP GET Request).

- HIGH 0 IP packets
- MEDIUM 7 IP packets
- class-default 10 IP packets

3. Display the Multilayer Switch Core-2 policy-map statistics of interface g1/0/1. Record how many packets have been scheduled in different traffic classes:

- HIGH 2 IP packets
- MEDIUM 6 IP packets (new)
- class-default 2 IP packets

4. Display the Multilayer Switch SW-B policy-map statistics of interface g1/0/24. Record how many packets have been scheduled in different traffic classes:

- ~~HIGH~~ (OAM) 1 IP packets
- ~~MEDIUM~~ (ERP) 3 IP packets
- class-default 2 IP packets

   How many HTTP-Request have been sent to the HTTP-Server?

   Only one HTTP request (HTTP Get), the other IP packets with port 80 were for TCP connection setup.

   How many HTTP-Responses have been sent from the HTTP-Server?

   One HTTP response (HTTP 200 OK), but in total 3 IP packets for TCP connection and HTTP.

### Step 5: Demonstrate preemptive priority for VoIP

With the network devices in DN.Lab, you would have to demonstrate, that your DiffServ Domain is working correctly.

This final task cannot be performed in PacketTracer and is skipped here..

## Checkout

When you successfully finished this Lab

1. Save your results and answers **in this PDF file** and rename the file **AMC-Lab3-Results.pdf**.
2. Save the running configuration of **Router Core-2,** and of **Multilayer Switch SW-D** in one text file (**AMC-Lab3-Core-2_SW-D.txt**).
3. Upload these two files, **AMC-Lab3-Results.pdf** and **AMC-Lab3-Core-2_SW-D.txt** in Ilias.