Routerlab

Summer semester 2018

Worksheet 8
Group 08

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Question 1

1a

OSPF enabled (adjacent) routers exchange routing information (DD packets) between Master and slave where Master is the router with the highest router ID.

1b

LSA's are sent after adjacencies have been established between OSPF enabled neighbouring routers and it contains state and cost of each directly connected link.

1c

OSPF uses Hello packets to establish and maintain adjacencies. When the Hello packet is not received from the neighbor within the hold time expiration it is considered to be unreachable. The hold time in OSPF is generally 40 seconds.

1d

No, OSPF doesn't suffer from count to infinity problem because unlike RIP it uses link state (based on the Dijkstra Algorithm) and bandwidth for the metric to find out the shortest path instead of number of hops.

1e

The main advantages of Link state routing protocols are they use cost metric to choose the best path through the network and they have faster convergence time (to build the full topology).

1f

The disadvantage is that they require more memory and processing power than distance vector protocols.

1g

No OSPF doesn't rely on TCP or UDP. It forms IP datagrams directly by packaging them by using protocol number 89.

1h

As per RFC 2328 OSPF defines Hello, Database description, Link state request, Link state update and Link state Ack packets where Hello is used to discover and maintain neighbors, Database description summarizes database contents, Link state request to download database, Link state update is to update the database and Link state ack is for flooding acknowledgement.

1i

OSPF defines Router-LSA's (describe state of a router's interfaces to a specific area), Network-LSA's (contain the list of routers connected to a network), Summary-LSA's (describe routes to other areas, but within the same AS, created by area boundary routers) and AS-external-LSA's (describe routes to other ASs, created by AS boundary routers).

1j

Flooding is made reliable by acknowledging each LSA separately and this procedure starts after the link state update packet has been received.

Destination	Next-Hop	Cost
10.1.1.1	*	0
10.1.1.2	link	3
10.1.1.3	link	5
10.1.1.4	10.1.1.2	4
10.1.1.5	10.1.1.3	6
10.1.1.6	10.1.1.2	10

Table 1: Final routing table for 10.1.1.1

Question 2

2a

1. Added Destination = <10.1.1.1,0>;
   Candidate Destination List = <10.1.1.2,3> <10.1.1.3,5>
2. Added Destination = <10.1.1.2,3>;
   Candidate Destination List = <10.1.1.3,5> <10.1.1.4,4>
3. Added Destination = <10.1.1.4,4>;
   Candidate Destination List = <10.1.1.3,5> <10.1.1.5,7>
   <10.1.1.6,10>
4. Added Destination = <10.1.1.3,5>;
   Candidate Destination List = <10.1.1.5,6> <10.1.1.6,10>
5. Added Destination = <10.1.1.5,6>;
   Candidate Destination List = <10.1.1.6,10>
6. Added Destination = <10.1.1.6,10>;
   Candidate Destination List =
7. Done!

2b

For our solution see Table 1.

Question 3

We are using the topology as shown in Figure 1.

Commands to configure ospf- On rc1-

```
lev-rc1(config)#router ospf 88
lev-rc1(config-router)#network 10.8.1.0 0.0.0.255 area 0.0.0.0
lev-rc1(config-router)#network 10.8.2.0 0.0.0.255 area 0.0.0.0
lev-rc1(config-router)#network 10.8.0.0 0.0.0.255 area 0.0.0.0
lev-rc1(config-router)#network 10.8.5.0 0.0.0.255 area 0.0.0.0
lev-rc1(config-router)#network 10.8.7.0 0.0.0.255 area 0.0.0.0
*Jun 24 21:56:22.096: %OSPF-5-ADJCHG: Process 88, Nbr 10.8.5.2 on
    Vlan85 from LOADING to FULL, Loading Done
*Jun 24 21:56:31.316: %OSPF-5-ADJCHG: Process 88, Nbr 10.8.5.2 on
    GigabitEthernet8 from LOADING to FULL, Loading Done
*Jun 24 21:58:06.404: %OSPF-5-ADJCHG: Process 88, Nbr 10.8.0.2 on
    Vlan80 from LOADING to FULL, Loading Done
```

On rj2-

```
root@lev-rj2# edit protocols ospf area 0.0.0.0
[edit protocols ospf area 0.0.0.0]
root@lev-rj2# set interface ge-0/0/0
[edit protocols ospf area 0.0.0.0]
root@lev-rj2# set interface ge-0/0/1
```

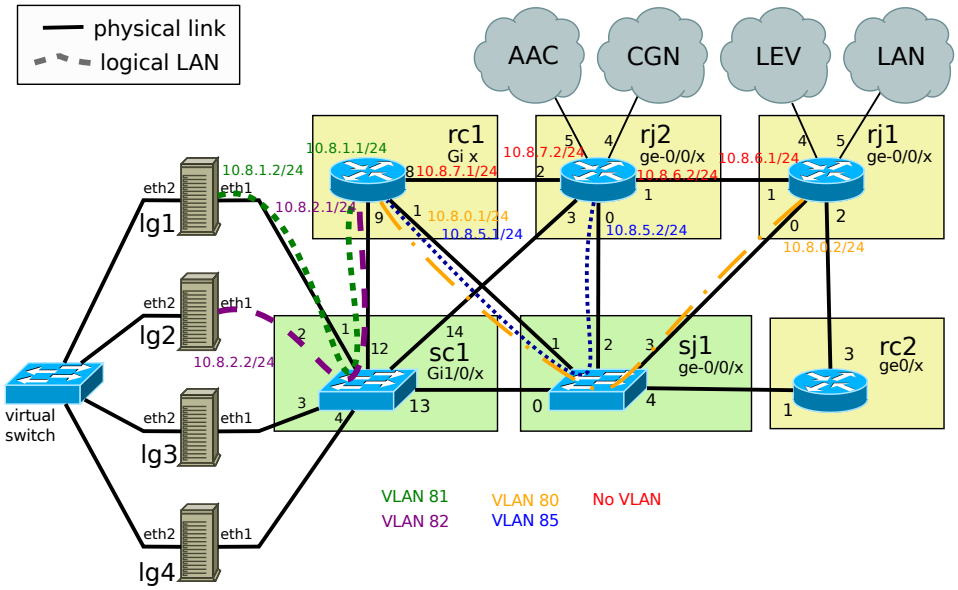

Figure 1: The topology we use for Question 3.

```
[edit protocols ospf area 0.0.0.0]
root@lev-rj2# set interface ge-0/0/2
[edit protocols ospf area 0.0.0.0]
root@lev-rj2# show
interface ge-0/0/0.0;
interface ge-0/0/1.0;
interface ge-0/0/2.0;
[edit protocols ospf area 0.0.0.0]
```

On rj1-

```
root@lev-rj1# edit protocols ospf area 0.0.0.0
[edit protocols ospf area 0.0.0.0]
root@lev-rj1# set interface ge-0/0/0
[edit protocols ospf area 0.0.0.0]
root@lev-rj1# set interface ge-0/0/1
[edit protocols ospf area 0.0.0.0]
root@lev-rj1# show
interface ge-0/0/0.0;
interface ge-0/0/1.0;
[edit protocols ospf area 0.0.0.0]
```

3a

The traceroutes from lg1-

```
root@group08-lg1:~# traceroute 10.8.1.1
traceroute to 10.8.1.1 (10.8.1.1), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  1.225 ms * *
root@group08-lg1:~# traceroute 10.8.2.1
traceroute to 10.8.2.1 (10.8.2.1), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  1.067 ms * *
root@group08-lg1:~# traceroute 10.8.0.1
traceroute to 10.8.0.1 (10.8.0.1), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  1.099 ms * *
root@group08-lg1:~# traceroute 10.8.5.1
traceroute to 10.8.5.1 (10.8.5.1), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  1.029 ms * *
root@group08-lg1:~# traceroute 10.8.7.1
traceroute to 10.8.7.1 (10.8.7.1), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  1.189 ms * *
root@group08-lg1:~# traceroute 10.8.7.2
traceroute to 10.8.7.2 (10.8.7.2), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  0.870 ms  0.827 ms  0.812 ms
 2  10.8.7.2 (10.8.7.2)  3.656 ms  3.625 ms  3.592 ms
root@group08-lg1:~# traceroute 10.8.5.2
traceroute to 10.8.5.2 (10.8.5.2), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  0.874 ms  0.859 ms  0.821 ms
 2  10.8.5.2 (10.8.5.2)  2.878 ms  2.835 ms  2.809 ms
root@group08-lg1:~# traceroute 10.8.6.2
traceroute to 10.8.6.2 (10.8.6.2), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  0.897 ms  0.850 ms  0.809 ms
 2  10.8.6.2 (10.8.6.2)  2.881 ms  2.848 ms  2.809 ms
root@group08-lg1:~# traceroute 10.8.6.1
traceroute to 10.8.6.1 (10.8.6.1), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  0.836 ms  0.808 ms  0.824 ms
 2  10.8.7.2 (10.8.7.2)  1.099 ms  1.051 ms  1.014 ms
```

```
 3  10.8.6.1 (10.8.6.1)  3.514 ms  3.469 ms  3.449 ms
root@group08-lg1:~# traceroute 10.8.0.2
traceroute to 10.8.0.2 (10.8.0.2), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  0.948 ms  0.906 ms  0.869 ms
 2  10.8.0.2 (10.8.0.2)  3.769 ms  3.682 ms  3.656 ms
root@group08-lg1:~# traceroute 10.8.2.2
traceroute to 10.8.2.2 (10.8.2.2), 30 hops max, 60 byte packets
 1  10.8.1.1 (10.8.1.1)  0.767 ms  0.727 ms  0.818 ms
 2  10.8.2.2 (10.8.2.2)  1.192 ms  1.150 ms  1.110 ms
```

From lg2 -

```
root@group08-lg2:~# traceroute 10.8.1.2
traceroute to 10.8.1.2 (10.8.1.2), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  0.770 ms  0.727 ms  0.747 ms
 2  10.8.1.2 (10.8.1.2)  1.173 ms  1.144 ms  1.113 ms
root@group08-lg2:~# traceroute 10.8.2.1
traceroute to 10.8.2.1 (10.8.2.1), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  1.111 ms * *
root@group08-lg2:~# traceroute 10.8.1.1
traceroute to 10.8.1.1 (10.8.1.1), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  1.074 ms * *
root@group08-lg2:~# traceroute 10.8.0.1
traceroute to 10.8.0.1 (10.8.0.1), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  1.287 ms * *
root@group08-lg2:~# traceroute 10.8.5.1
traceroute to 10.8.5.1 (10.8.5.1), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  1.048 ms * *
root@group08-lg2:~# traceroute 10.8.7.1
traceroute to 10.8.7.1 (10.8.7.1), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  1.115 ms * *
root@group08-lg2:~# traceroute 10.8.7.2
traceroute to 10.8.7.2 (10.8.7.2), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  0.816 ms  0.747 ms  0.717 ms
 2  10.8.7.2 (10.8.7.2)  3.107 ms  3.076 ms  3.031 ms
root@group08-lg2:~# traceroute 10.8.5.2
traceroute to 10.8.5.2 (10.8.5.2), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  0.843 ms  0.789 ms  0.746 ms
 2  10.8.5.2 (10.8.5.2)  3.297 ms  3.268 ms  3.228 ms
root@group08-lg2:~# traceroute 10.8.6.2
traceroute to 10.8.6.2 (10.8.6.2), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  0.954 ms  0.892 ms  0.866 ms
 2  10.8.0.2 (10.8.0.2)  1.205 ms  1.178 ms  1.132 ms
 3  10.8.6.2 (10.8.6.2)  3.402 ms  3.368 ms  3.324 ms
root@group08-lg2:~# traceroute 10.8.6.1
traceroute to 10.8.6.1 (10.8.6.1), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  0.892 ms  0.897 ms  0.855 ms
 2  10.8.6.1 (10.8.6.1)  9.119 ms  9.062 ms  9.044 ms
root@group08-lg2:~# traceroute 10.8.0.2
traceroute to 10.8.0.2 (10.8.0.2), 30 hops max, 60 byte packets
 1  10.8.2.1 (10.8.2.1)  0.939 ms  0.893 ms  0.857 ms
 2  10.8.0.2 (10.8.0.2)  3.126 ms  3.069 ms  3.038 ms
```

3b

We can see in the third to last entry that there are three possible routes stored at rc1 to reach the subnet 10.8.6.0/24:

```
lev-rc1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B -
    BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS
           level-2
       ia - IS-IS inter area, * - candidate default, U - per-user
           static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l -
           LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
C        10.8.0.0/24 is directly connected, Vlan80
L        10.8.0.1/32 is directly connected, Vlan80
C        10.8.1.0/24 is directly connected, GigabitEthernet9.81
L        10.8.1.1/32 is directly connected, GigabitEthernet9.81
C        10.8.2.0/24 is directly connected, GigabitEthernet9.82
L        10.8.2.1/32 is directly connected, GigabitEthernet9.82
C        10.8.5.0/24 is directly connected, Vlan85
L        10.8.5.1/32 is directly connected, Vlan85
O        10.8.6.0/24 [110/2] via 10.8.7.2, 00:21:06, GigabitEthernet8
                     [110/2] via 10.8.5.2, 00:21:06, Vlan85
                     [110/2] via 10.8.0.2, 00:19:22, Vlan80
C        10.8.7.0/24 is directly connected, GigabitEthernet8
L        10.8.7.1/32 is directly connected, GigabitEthernet8
```

3c

All three routes have equal cost (which is why all three are maintained). By default OSPF in cisco and juniper assigns a metric of 1 to every link faster than 100Mbps, which is the case for our Gigabit links. Therefore we see a metric of 2. The direct link towards rj2/rj1 and the final link. The administrative distance also is equal (110, which is the default value for OSPF). OSPF will use all three routes by applying round robin.

Question 4

4a

There are two types of LSAs stored, Router and Network LS. The Link ID can be seen in the provided outputs below.

From rc1-

```
lev-rc1#show ip ospf database

            OSPF Router with ID (10.8.7.1) (Process ID 88)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age         Seq#       Checksum Link
    count
10.8.0.2        10.8.0.2        1436        0x80000003 0x009A04 2
```

```
10.8.5.2        10.8.5.2        1437        0x80000006 0x006CD4 3
10.8.7.1        10.8.7.1        1444        0x80000008 0x009C67 5

                Net Link States (Area 0.0.0.0)

Link ID         ADV Router      Age         Seq#       Checksum
10.8.0.1        10.8.7.1        1444        0x80000001 0x009B43
10.8.5.1        10.8.7.1        1548        0x80000001 0x00A52F
10.8.6.2        10.8.5.2        1437        0x80000001 0x004F8A
10.8.7.1        10.8.7.1        1539        0x80000001 0x008F43
```

From rj2-

```
root@lev-rj2> show ospf database

    OSPF database, Area 0.0.0.0
 Type       ID               Adv Rtr           Seq       Age  Opt  Cksum
      Len
Router    10.8.0.2         10.8.0.2         0x80000003  1623  0x22 0
   x9a04  48
Router   *10.8.5.2         10.8.5.2         0x80000006  1622  0x22 0
   x6cd4  60
Router    10.8.7.1         10.8.7.1         0x80000008  1631  0x22 0
   x9c67  84
Network   10.8.0.1         10.8.7.1         0x80000001  1631  0x22 0
   x9b43  32
Network   10.8.5.1         10.8.7.1         0x80000001  1735  0x22 0
   xa52f  32
Network  *10.8.6.2         10.8.5.2         0x80000001  1622  0x22 0
   x4f8a  32
Network   10.8.7.1         10.8.7.1         0x80000001  1726  0x22 0
   x8f43  32
```

4b

We can see in the output from rc1, that it immediately notices, that the link is down and flushes the network LSA for both sub interfaces. After bringing the interface back up, it immediately uses the direct route again (as we see in the OSPF output).

Debugging output from rc1-

```
lev-rc1#debug ip ospf adj
OSPF adjacency debugging is on
lev-rc1#configure
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
lev-rc1(config)#interface Gi9
lev-rc1(config-if)#shutdown
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Route adjust notification:
   DOWN/DOWN
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Interface going Down
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: 10.8.7.1 address 10.8.1.1
   is dead, state DOWN
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Neighbor change event
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: DR/BDR election
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Elect BDR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Elect DR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Elect BDR 0.0.0.0
```

```
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Elect DR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: DR: none    BDR: none
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Flush network LSA
    immediately
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Remember old DR 10.8.7.1 (
    id)
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.81: Interface state change to
    DOWN, new ospf state DOWN
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Route adjust notification:
    DOWN/DOWN
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Interface going Down
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: 10.8.7.1 address 10.8.2.1
    is dead, state DOWN
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Neighbor change event
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: DR/BDR election
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Elect BDR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Elect DR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Elect BDR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Elect DR 0.0.0.0
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: DR: none    BDR: none
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Flush network LSA
    immediately
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Remember old DR 10.8.7.1 (
    id)
*Jun 24 22:34:13.120: OSPF-88 ADJ   Gi9.82: Interface state change to
    DOWN, new ospf state DOWN
*Jun 24 22:34:15.064: %LINK-5-CHANGED: Interface GigabitEthernet9,
    changed state to administratively down
*Jun 24 22:34:16.064: %LINEPROTO-5-UPDOWN: Line protocol on Interface
    GigabitEthernet9, changed state to down
lev-rc1(config-if)#no shutdown
*Jun 24 22:35:25.152: %LINK-3-UPDOWN: Interface GigabitEthernet9,
    changed state to down
*Jun 24 22:35:28.084: %LINK-3-UPDOWN: Interface GigabitEthernet9,
    changed state to up
*Jun 24 22:35:29.084: %LINEPROTO-5-UPDOWN: Line protocol on Interface
    GigabitEthernet9, changed state to up
*Jun 24 22:35:29.084: OSPF-88 ADJ   Gi9.81: Route adjust notification:
    UP/UP
*Jun 24 22:35:29.084: OSPF-88 ADJ   Gi9.81: Interface going Up
*Jun 24 22:35:29.084: OSPF-88 ADJ   Gi9.81: Interface state change to
    UP, new ospf state WAIT
*Jun 24 22:35:29.084: OSPF-88 ADJ   Gi9.82: Route adjust notification:
    UP/UP
*Jun 24 22:35:29.084: OSPF-88 ADJ   Gi9.82: Interface going Up
*Jun 24 22:35:29.084: OSPF-88 ADJ   Gi9.82: Interface state change to
    UP, new ospf state WAIT
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: end of Wait on interface
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: DR/BDR election
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: Elect BDR 10.8.7.1
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: Elect DR 10.8.7.1
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: Elect BDR 0.0.0.0
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: Elect DR 10.8.7.1
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.82: DR: 10.8.7.1 (Id)   BDR:
    none
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: end of Wait on interface
```

```
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: DR/BDR election
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: Elect BDR 10.8.7.1
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: Elect DR 10.8.7.1
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: Elect BDR 0.0.0.0
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: Elect DR 10.8.7.1
*Jun 24 22:36:09.084: OSPF-88 ADJ   Gi9.81: DR: 10.8.7.1 (Id)   BDR:
    none
```

We deleted the LLDP packets from the output. Before bringing down the link we see the regular Hello messages. After the link is down we see the LS Update sent from rc1 to multicast. After we bring the interface back up, we see the new LS Update from rc1 which contains the new route. We see that after that rj2 forwards this LS Update (changing a few header fields). After that we see the LS ACK from rj2 acknowledging the previous update. Then we see Hello messages again.

Debugging output from rj2-

```
root@lev-rj2> monitor traffic interface ge-0/0/2 detail
Address resolution is ON. Use <no-resolve> to avoid any reverse lookup
    delay.
Address resolution timeout is 4s.
Listening on ge-0/0/2, capture size 1514 bytes

Reverse lookup for 10.8.7.1 failed (check DNS reachability).
Other reverse lookup failures will not be reported.
Use <no-resolve> to avoid reverse lookups on IP addresses.

05:58:16.966550  In IP (tos 0xc0, ttl   1, id 22670, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.1 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.7.1, Backbone Area, Authentication Type: none
            (0)
        Options [External, LLS]
          Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
              1
          Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
          Neighbor List:
            10.8.5.2
          LLS: checksum: 0xfff6, length: 3
            Extended Options (1), length: 4
              Options: 0x00000001 [LSDB resync]
05:58:18.553279 Out IP (tos 0xc0, ttl   1, id 59783, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.2 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.5.2, Backbone Area, Authentication Type: none
            (0)
        Options [External, LLS]
          Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
              128
          Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
          Neighbor List:
            10.8.7.1
          LLS: checksum: 0xfff6, length: 3
            Extended Options (1), length: 4
              Options: 0x00000001 [LSDB resync]
05:58:22.786778  In IP (tos 0xc0, ttl   1, id 22672, offset 0, flags [
    none], proto: OSPF (89), length: 108) 10.8.7.1 > 224.0.0.5: OSPFv2,
     LS-Update, length 88
```

```
        Router-ID 10.8.7.1, Backbone Area, Authentication Type: none
          (0), 1 LSA
          LSA #1
          Advertising Router 10.8.7.1, seq 0x8000000a, age 1s, length
            40
            Router LSA (1), LSA-ID: 10.8.7.1
            Options: [External, Demand Circuit]
            Router LSA Options: [none]
              Neighbor Network-ID: 10.8.7.1, Interface Address:
                10.8.7.1
                topology default (0), metric 1
              Neighbor Network-ID: 10.8.5.1, Interface Address:
                10.8.5.1
                topology default (0), metric 1
              Neighbor Network-ID: 10.8.0.1, Interface Address:
                10.8.0.1
                topology default (0), metric 1
05:58:25.970608  In IP (tos 0xc0, ttl   1, id 22677, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.1 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.7.1, Backbone Area, Authentication Type: none
          (0)
        Options [External, LLS]
          Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
            1
          Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
          Neighbor List:
            10.8.5.2
          LLS: checksum: 0xfff6, length: 3
            Extended Options (1), length: 4
              Options: 0x00000001 [LSDB resync]
05:58:27.275542 Out IP (tos 0xc0, ttl   1, id 59818, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.2 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.5.2, Backbone Area, Authentication Type: none
          (0)
        Options [External, LLS]
          Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
            128
          Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
          Neighbor List:
            10.8.7.1
          LLS: checksum: 0xfff6, length: 3
            Extended Options (1), length: 4
              Options: 0x00000001 [LSDB resync]


--- HERE WE DELETED SOME HELLO PACKETS ---


05:59:31.590014 Out IP (tos 0xc0, ttl   1, id 60008, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.2 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.5.2, Backbone Area, Authentication Type: none
          (0)
        Options [External, LLS]
```

```
        Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
            128
        Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
        Neighbor List:
          10.8.7.1
        LLS: checksum: 0xfff6, length: 3
          Extended Options (1), length: 4
            Options: 0x00000001 [LSDB resync]
05:59:33.587225  In IP (tos 0xc0, ttl   1, id 22698, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.1 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
      Router-ID 10.8.7.1, Backbone Area, Authentication Type: none
          (0)
      Options [External, LLS]
        Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
            1
        Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
        Neighbor List:
          10.8.5.2
        LLS: checksum: 0xfff6, length: 3
          Extended Options (1), length: 4
            Options: 0x00000001 [LSDB resync]
05:59:38.751424  In IP (tos 0xc0, ttl   1, id 22701, offset 0, flags [
    none], proto: OSPF (89), length: 132) 10.8.7.1 > 224.0.0.5: OSPFv2,
     LS-Update, length 112
      Router-ID 10.8.7.1, Backbone Area, Authentication Type: none
          (0), 1 LSA
        LSA #1
        Advertising Router 10.8.7.1, seq 0x8000000b, age 1s, length
            64
          Router LSA (1), LSA-ID: 10.8.7.1
          Options: [External, Demand Circuit]
          Router LSA Options: [none]
            Neighbor Network-ID: 10.8.7.1, Interface Address:
                10.8.7.1
              topology default (0), metric 1
            Neighbor Network-ID: 10.8.5.1, Interface Address:
                10.8.5.1
              topology default (0), metric 1
            Neighbor Network-ID: 10.8.0.1, Interface Address:
                10.8.0.1
              topology default (0), metric 1
            Stub Network: 10.8.2.0, Mask: 255.255.255.0
              topology default (0), metric 1
            Stub Network: 10.8.1.0, Mask: 255.255.255.0
              topology default (0), metric 1
05:59:38.754801 Out IP (tos 0xc0, ttl   1, id 60028, offset 0, flags [
    none], proto: OSPF (89), length: 132) 10.8.7.2 > 224.0.0.5: OSPFv2,
     LS-Update, length 112
      Router-ID 10.8.5.2, Backbone Area, Authentication Type: none
          (0), 1 LSA
        LSA #1
        Advertising Router 10.8.7.1, seq 0x8000000b, age 2s, length
            64
          Router LSA (1), LSA-ID: 10.8.7.1
          Options: [External, Demand Circuit]
```

```
            Router LSA Options: [none]
              Neighbor Network-ID: 10.8.7.1, Interface Address:
                  10.8.7.1
                topology default (0), metric 1
              Neighbor Network-ID: 10.8.5.1, Interface Address:
                  10.8.5.1
                topology default (0), metric 1
              Neighbor Network-ID: 10.8.0.1, Interface Address:
                  10.8.0.1
                topology default (0), metric 1
              Stub Network: 10.8.2.0, Mask: 255.255.255.0
                topology default (0), metric 1
              Stub Network: 10.8.1.0, Mask: 255.255.255.0
                topology default (0), metric 1
05:59:39.760761 Out IP (tos 0xc0, ttl   1, id 60038, offset 0, flags [
    none], proto: OSPF (89), length: 64) 10.8.7.2 > 224.0.0.5: OSPFv2,
    LS-Ack, length 44
        Router-ID 10.8.5.2, Backbone Area, Authentication Type: none
            (0)
          Advertising Router 10.8.7.1, seq 0x8000000b, age 1s, length
              64
            Router LSA (1), LSA-ID: 10.8.7.1
            Options: [External, Demand Circuit]
05:59:41.278688 Out IP (tos 0xc0, ttl   1, id 60040, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.2 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.5.2, Backbone Area, Authentication Type: none
            (0)
        Options [External, LLS]
          Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
              128
          Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
          Neighbor List:
            10.8.7.1
          LLS: checksum: 0xfff6, length: 3
            Extended Options (1), length: 4
              Options: 0x00000001 [LSDB resync]
05:59:43.151189  In IP (tos 0xc0, ttl   1, id 22706, offset 0, flags [
    none], proto: OSPF (89), length: 80) 10.8.7.1 > 224.0.0.5: OSPFv2,
    Hello, length 60 [len 48]
        Router-ID 10.8.7.1, Backbone Area, Authentication Type: none
            (0)
        Options [External, LLS]
          Hello Timer 10s, Dead Timer 40s, Mask 255.255.255.0, Priority
              1
          Designated Router 10.8.7.1, Backup Designated Router 10.8.7.2
          Neighbor List:
            10.8.5.2
          LLS: checksum: 0xfff6, length: 3
            Extended Options (1), length: 4
              Options: 0x00000001 [LSDB resync]
^C
61 packets received by filter
0 packets dropped by kernel
```

4c

rj2 only sends one LS-UPDATE packet (apart from HELLO and LS-ACK). This is a forwarding of the LS-UPDATE it previously received from rc1. It uses LSA-ID 10.8.7.1 (ROUTER LSA #1) and the IP datagram ID is 60028.

4d

Yes, LSA #1 (LSA-ID: 10.8.7.1) is exchanged completely.

4e

Before bringing the interface down rc1 is the DR (because it is actually the only router attached to the respective network segment). When the interface is brought down, we can see, that the NeighborChange Event is triggered and new elections for BDR and DR are held, in which none is selected. This is because the ospf state changes from FULL to DOWN, where there can be no DR. Then the interface is brought up again and rc1 becomes the DR again. During the election the ospf state changes to WAIT. After the election the state is back to FULL as in the beginning, because there are no neighbors in the segments.

Question 5

5a

Actually we can see, that the route the datagram takes, DOES change. This is because rc1 only stores routing information for the prefix /24 (because this is what rj1 and rj2 announce). Therefore round robin was chosen in our first traceroute and round robin selected the path over rj2 (because rc1 did not know the topology (compare the routing table of rc1 from above). This time the increased cost of the link makes sure that the path over rj1 is chosen, which is why we only see two hops.

```
lev-rc1(config)#interface Gi8
lev-rc1(config-if)#ip ospf cost 100

root@group08-lg1:~# traceroute 10.8.6.1
traceroute to 10.8.6.1 (10.8.6.1), 30 hops max, 60 byte packets
 1  * * *
 2  10.8.6.1 (10.8.6.1)  3.250 ms  3.188 ms  3.169 ms
```

Old traceroute from question 3:

```
traceroute to 10.8.6.1 (10.8.6.1), 30 hops max, 60 byte packets
1  10.8.1.1 (10.8.1.1)  0.836 ms  0.808 ms  0.824 ms
2  10.8.7.2 (10.8.7.2)  1.099 ms  1.051 ms  1.014 ms
3  10.8.6.1 (10.8.6.1)  3.514 ms  3.469 ms  3.449 ms
```

5b

We can now see that the route to reach 10.8.6.0/24 using 10.8.7.2 as the next-hop has been deleted. This is because the cost is higher and OSPF only stores multiple routes if they have the same cost.

```
lev-rc1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B -
    BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
```

```
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS
            level-2
        ia - IS-IS inter area, * - candidate default, U - per-user
            static route
        o - ODR, P - periodic downloaded static route, H - NHRP, l -
            LISP
        + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
C        10.8.0.0/24 is directly connected, Vlan80
L        10.8.0.1/32 is directly connected, Vlan80
C        10.8.1.0/24 is directly connected, GigabitEthernet9.81
L        10.8.1.1/32 is directly connected, GigabitEthernet9.81
C        10.8.2.0/24 is directly connected, GigabitEthernet9.82
L        10.8.2.1/32 is directly connected, GigabitEthernet9.82
C        10.8.5.0/24 is directly connected, Vlan85
L        10.8.5.1/32 is directly connected, Vlan85
O        10.8.6.0/24 [110/2] via 10.8.5.2, 01:05:21, Vlan85
                     [110/2] via 10.8.0.2, 01:03:37, Vlan80
C        10.8.7.0/24 is directly connected, GigabitEthernet8
L        10.8.7.1/32 is directly connected, GigabitEthernet8
```

5c

The backbone is the special Area 0, also named 0.0.0.0.

5d

No it is not possible to span four areas, because all inter-area traffic is routed through the backbone (even though this might be just one router that is part of source and destination area and therefore also part of the backbone). So in the source area intra-area routing will be used to reach an area border or backbone router. Then the traffic will be routed in the backbone area and after that again intra-area routing will be used in the destination area. Since no traffic can be routed directly from area to area, it is not possible to span four areas.

5e

There are four classes of routers:

- Internal routers (all directly connected networks belonging to the same area)
- Area border routers (directly connected to at least two areas)
- Backbone routers (have an interface to the backbone area (such as all area border routers for example))
- AS boundary routers (exchange routing information with other ASs and advertise it internally; this can be any kind of the three previous classes of routers)

5f

The changes we made to the topology are displayed in Figure 2. We brought down the link between sc1 and rc1 and instead configured VLANs between rj1 and lg1 and lg2 respectively. We configured the areas as indicated. Note that we made both networks between rj2 and rc1 part of the backbone (10.8.5.0/24 and 10.8.7.0/24 and of course 10.8.0.0/24 (rc1-rj1)). For the exact configurations please have a look at the configuration files we include in our submission.

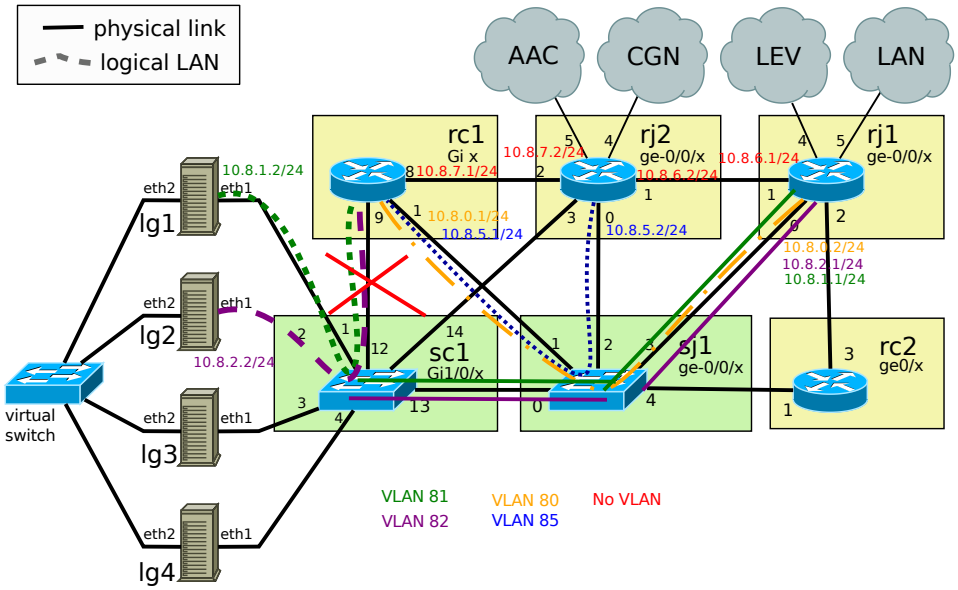

Figure 2: The topology we use for Question 5.

We can see that rc1 routes traffic to lg1 via rj1:

```
lev-rc1#traceroute 10.8.1.2
Type escape sequence to abort.
Tracing the route to 10.8.1.2
VRF info: (vrf in name/id, vrf out name/id)
  1 10.8.0.2 0 msec 0 msec 0 msec
  2 10.8.1.2 0 msec 0 msec 0 msec

lev-rc1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B -
    BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS
           level-2
       ia - IS-IS inter area, * - candidate default, U - per-user
           static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l -
           LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 9 subnets, 2 masks
C        10.8.0.0/24 is directly connected, Vlan80
L        10.8.0.1/32 is directly connected, Vlan80
O IA     10.8.1.0/24 [110/2] via 10.8.0.2, 00:08:41, Vlan80
O IA     10.8.2.0/24 [110/2] via 10.8.0.2, 00:08:41, Vlan80
C        10.8.5.0/24 is directly connected, Vlan85
L        10.8.5.1/32 is directly connected, Vlan85
O IA     10.8.6.0/24 [110/2] via 10.8.5.2, 00:09:07, Vlan85
                     [110/2] via 10.8.0.2, 00:08:41, Vlan80
C        10.8.7.0/24 is directly connected, GigabitEthernet8
L        10.8.7.1/32 is directly connected, GigabitEthernet8
```

5g

The route is selected, because we brought down interface 9 on rc1. So it does not have a direct link any longer. Since rc1 is part of the backbone it is announced the routes by rj1 which is also part of the backbone and an ABR (that knows the routes of area 1 and 2 which it advertises to rc1).

5h

All three routers (rj2, rj1 and rc1) are backbone routers. rj1 is an ABR, because it forms part of area 1 and and area 2. rj2 forms part of area 0 (backbone) and area 1 and therefore also is an ABR. rc1 only is part of the backbone and therefore not an ABR.

5i

We can now see Router LS, Net LS and Summary Net LS. The latter are new compared to what we saw in 4d (only Router and Net LS). The Summary Net LS exist because they are advertised by the ABRs (rj2 and rj1). The ABRs only provide summaries of area 1 and area 2 to the backbone router rc1. Therefore we see the new LS type.

```
lev-rc1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B -
    BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS
           level-2
       ia - IS-IS inter area, * - candidate default, U - per-user
           static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l -
           LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 9 subnets, 2 masks
C        10.8.0.0/24 is directly connected, Vlan80
L        10.8.0.1/32 is directly connected, Vlan80
O IA     10.8.1.0/24 [110/2] via 10.8.0.2, 00:12:02, Vlan80
O IA     10.8.2.0/24 [110/2] via 10.8.0.2, 00:12:02, Vlan80
C        10.8.5.0/24 is directly connected, Vlan85
L        10.8.5.1/32 is directly connected, Vlan85
O IA     10.8.6.0/24 [110/2] via 10.8.5.2, 00:12:28, Vlan85
                     [110/2] via 10.8.0.2, 00:12:02, Vlan80
C        10.8.7.0/24 is directly connected, GigabitEthernet8
L        10.8.7.1/32 is directly connected, GigabitEthernet8


lev-rc1#  show ip ospf database

            OSPF Router with ID (10.8.7.1) (Process ID 88)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age         Seq#       Checksum Link
    count
10.8.0.2        10.8.0.2        662         0x80000006 0x00CC10 1
10.8.5.2        10.8.5.2        688         0x8000000D 0x009582 2
10.8.6.2        10.8.6.2        758         0x80000003 0x00FD64 1
10.8.7.1        10.8.7.1        661         0x8000000E 0x000ED2 3

                Net Link States (Area 0.0.0.0)

Link ID         ADV Router      Age         Seq#       Checksum
10.8.0.2        10.8.0.2        662         0x80000002 0x00D210
10.8.5.2        10.8.5.2        688         0x80000001 0x00A72D
10.8.7.2        10.8.5.2        146         0x80000002 0x008F42

                Summary Net Link States (Area 0.0.0.0)

Link ID         ADV Router      Age         Seq#       Checksum
10.8.1.0        10.8.0.2        662         0x80000004 0x00F819
10.8.2.0        10.8.0.2        729         0x80000002 0x00F121
10.8.2.0        10.8.5.2        723         0x80000001 0x00DA33
10.8.6.0        10.8.0.2        724         0x80000002 0x00C549
```

```
10.8.6.0        10.8.5.2        723         0x80000002 0x00A267
10.8.6.0        10.8.6.2        757         0x80000002 0x009B6D
```

5j

We change the configuration of rj1 as indicated:

```
[edit protocols ospf]
root@lev-rj1# show
area 0.0.0.1 {
    interface ge-0/0/1.0;
    interface ge-0/0/0.82;
    interface ge-0/0/0.81;
}
area 0.0.0.0 {
    interface ge-0/0/0.80;
}

[edit protocols ospf]
```

Then we use this command on both rj2 and rj1 to create the area-range:

```
set protocols ospf area 0.0.0.1 area-range 10.8.0.0/16
```

Here we can see that the same route is selected:

```
lev-rc1#traceroute 10.8.1.2
Type escape sequence to abort.
Tracing the route to 10.8.1.2
VRF info: (vrf in name/id, vrf out name/id)
  1 10.8.0.2 0 msec 0 msec 0 msec
  2 10.8.1.2 0 msec 0 msec 0 msec
```

But we can see the aggregation in the routing table:

```
lev-rc1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B -
    BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS
           level-2
       ia - IS-IS inter area, * - candidate default, U - per-user
           static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l -
           LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 3 masks
O IA     10.8.0.0/16 [110/2] via 10.8.0.2, 00:10:01, Vlan80
C        10.8.0.0/24 is directly connected, Vlan80
L        10.8.0.1/32 is directly connected, Vlan80
C        10.8.5.0/24 is directly connected, Vlan85
L        10.8.5.1/32 is directly connected, Vlan85
C        10.8.7.0/24 is directly connected, GigabitEthernet8
L        10.8.7.1/32 is directly connected, GigabitEthernet8
```

Included Files

q05-config-rc1.txt, q05-config-sj1.txt, q3-working-config-sc1.txt, q05-config-rj1.txt, q3-working-config-rc1.txt, q3-working-config-sj1.txt, q05-config-rj2.txt, q3-working-config-rj1.txt, q05-config-sc1.txt, q3-working-config-rj2.txt