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IP Networks & Planning

A Practical Approach to OSPF Link State Advertisements

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1 AN INTRODUCTION TO OSPF ADJACENCY AND LSA TYPES

Open Shortest Path First (OSPF) is a link-state protocol, sets up adjacencies in order to form a network that is communicating. Adjacency is an advanced form of neighborship formed by routers that are willing to exchange routing information after negotiating parameters in an exchange process.

There are 7 steps known till routers get a FULL state in forming the adjacency. See Fig 1.1

DOWN	Hello package is send
Down state stills remain until router has a hello packet back	
INIT	Initialize,checking Hello parameters
TWO-WAY	If needed, DR and BDR election is held
EX-START	Master/Slave election is held
EXCHANGE	Database Description packets are exchanged
LOADING	Link State Req. and Link State Update packets are send
FULL	

Figure 1.1 :OSPF adjacency steps

In each step – the most important roles are being played by the data packets routers send to each other such as

- Hello
- Database description (DBD)
- Link-state request (LSR)
- Link-state update (LSU)
- Link-state acknowledgement (LSAck)

The main motivation why this seminar paper starts with OSPF's forming adjacency is that the reference point for Link State Advertisement (LSA) packets are the data packets which routers send to each other.Most importantly OSPF uses a link-state database (LSDB) in order to build and calculate the shortest path to all known destinations.
It is through the use of the SPF algorithm that the information contained within the LSDB is calculated into routes.

Mechanism works that way:

After setting up FULL state in adjacency, upon realizing or due to any change in routing information, a router will generate a link-state update (LSU) packet.Each Link State Update packet carries a collection of link state advertisements (LSA) one hop further from its origin. Several link state advertisements may be included in a single packet. For a projection to LSU structure please see Fig 1.2

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       4       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            # Number of link-state advertisements              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Link state advertisement 1                  |
+-                                                             +-+
|                   Link state advertisement 1                  |
+-                                                             +-+
|                   Link state advertisement 1                  |
                              . . .
```

Figure 1.2: Structure of a LSU packet according to RFC

Link State Update packets are multicast on networks that support multicast/broadcast. In order to make the flooding procedure reliable, flooded advertisements are acknowledged in Link State Acknowledgment packets. If re-transmission of certain advertisement is necessary, the retransmitted advertisements are always carried by unicast Link State Update packets.

The advertisement sub-divisions (LSA packets) will represent the collection of all link-states on that router. In general perspective all routers will exchange LSUs by means of the OSPF Flooding protocol. Each router that receives a link-state update will store it in its LSDB and then flood the update to other routers. When the database of each router is updated, then they will re-calculate a shortest path tree to all destinations. The router uses the Shortest Path First (Dijkstra) algorithm to calculate the shortest path tree based on the LSDB. Each destination based on the cumulative cost required to reach that destination will form the IP routing table.

1.1 OSPF HIERARCHICAL ROUTING MECHANISM

Hierarchy is the keyword of being in an order for all the units. Today's constantly growing networks are also creating big complications managing through. A typical scenario for all networks as they grow and more sites are added is that OSPF begin to lose its advantages in this case. For example, the link-state database will continue to grow in size as the number of routers grows. At some point it will become inefficient. The flooding LSAs from a large number of routers can also cause congestion problems – Vertically to this problem we also have one of the best policies formed by collective engineering groups – which is dividing our own Autonomous System (AS) into groups and areas around network elements' common major properties.

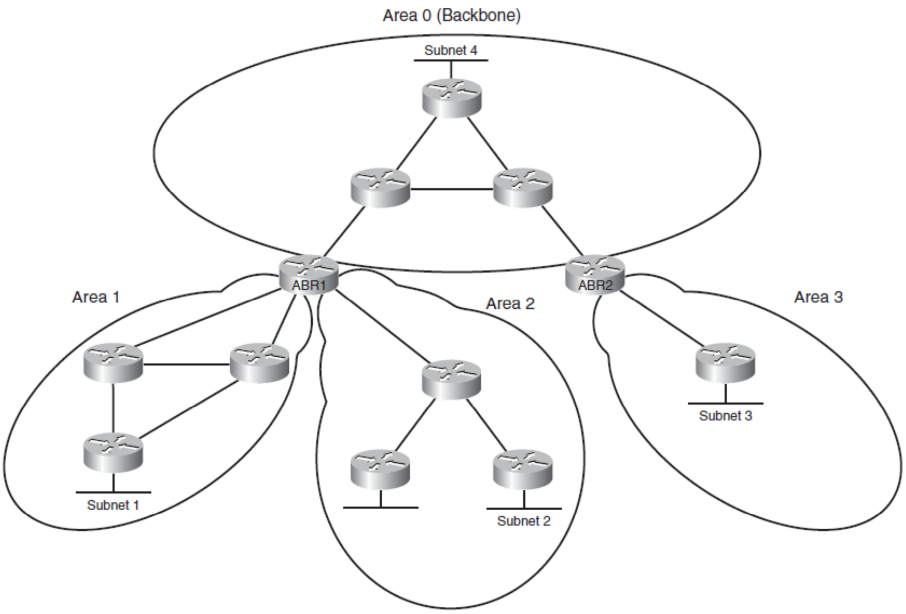

Figure 1.3: Typical OSPF Hierarchical Design

As routers are being grouped into areas, consideration of limiting the number of routers per area is important. Each router will then have a link-state database with entries for each router in its area. Areas are similar to the idea of a subnet that allows simply the routes and networks contained within, can be easily represented by being summarized. In other words; areas are contiguous logical segments of the network that have been grouped together. Through the use of areas within OSPF, the network will be easier to manage and will provide reduction in routing traffic.

1.1.1 Understanding Autonomous System and Areas

An Autonomous System (AS) is a region of the Internet that is administered by a single entity. Autonomous Systems are being formed by routers that have a common routing strategy and can contain several areas within.

The actual routing of information within an Autonomous System takes place in one of three ways:

- If the source and destination addresses of a packet reside within the same area, then Intra-area routing is used.
- If the source and destination addresses of a packet reside within different areas but still within the AS, then inter-area routing is used.
- If the source and destination addresses of a packet reside outside the AS, then external routing is used.

An important note here is that; Routing differs within an autonomous system (intra-area routing) and between Autonomous System (inter-area routing).

As building the network into hierarchical order – the second step after AS are areas:
Areas allow their member routers to run their own link-state database and SPF algorithm. Another saying, a router will run one copy of the link-state database for each area to which it is connected[1]

We can count a few major characteristics of an OSPF Area as following:

- Areas contain a group of contiguous hosts and networks
- Routers have a specified database and run the same SPF algorithm
- Each area is connected to the backbone area known as area 0
- Virtual links can be used

1.2 OSPF ROUTER TYPES

1.2.1 Internal Routers (IRs)

Internal Routers (IRs) are routers whose directly connected networks all belong to the same OSPF area. All of their interfaces stay in the same area. These types of routers will have a single link-state database because they only belong to one area.

[1] actually means: A topologically-classified routing table

1.2.2 Backbone Router (BBRs)

Routers that sit in the sight-line of the backbone area 0 and that have at least one interface connected to area 0, typically have an interface to the backbone area and two other OSPF areas Backbone routers maintain OSPF routing information using the same procedures and algorithms as internal routers. Routers that only have interfaces connecting them to the backbone are also considered BBRs.

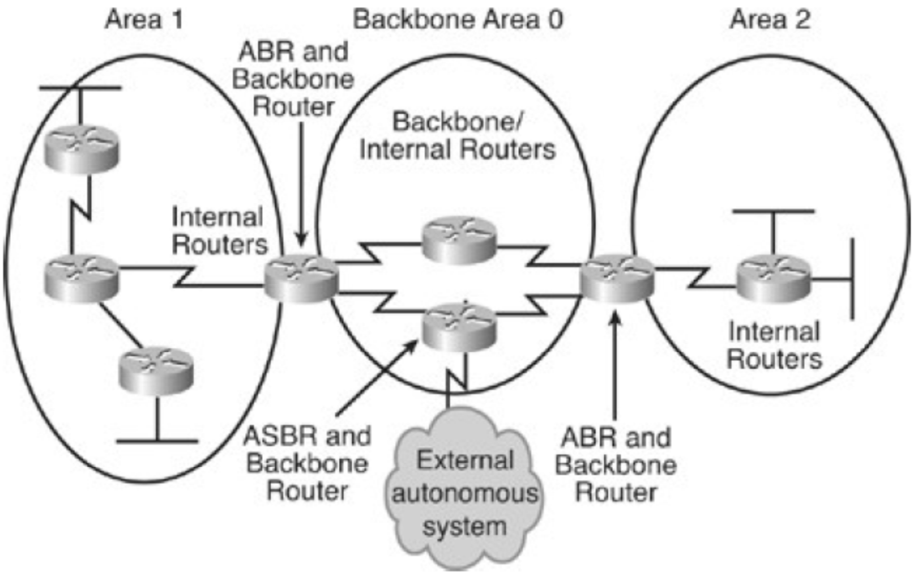

Figure 1.4: Types of OSPF Routers

1.2.3 Area Border Routers (ABRs)

Routers located on the border of one or more OSPF areas are known as ABRs. They are attached to multiple OSPF areas connecting them to the backbone network so can be considered as members of both the OSPF backbone and the attached areas. Consequently ABRs will have multiple copies of the link-state database. There can be multiple ABRs within a network[2]

The router will run one database for each area that will be summarized, and then it will be presented to the backbone for distribution to other areas. Noting that an ABR only sends summarized information to the backbone area, the backbone routers then forward the information to the other ABRs. ABRs are the only point where area address summarization can be configured[3]. ABRs separate LSA flooding zones, and may function as the source of default routes the backbone and another area.

[2] The ideal design is to have each ABR connected to two areas only

[3] to summarize the routing information from the LSDBs of their attached areas

1.2.4 Autonomous System Boundary Router (ASBRs)

Routers that have at least one interface attached to a different routing domain[4]. An OSPF autonomous system consists of all the OSPF areas and the routers within them. ASBRs can redistribute external routes into the OSPF domain and vice-versa.

1.3 LSA TYPES

With the area types are being explained in this section - This major rule has to be declared again is that OSPF routing protocol totally relies on the data update exchanges[5] between adjacent routers. This is the crucial process for being a Network with all the elements in an OSPF discipline.
Briefly to begin with;

- Type 1 LSA - Represents a router
- Type 2 LSA - Represents the pseudonode (designated router) for a multi-Access link
- Type 3 LSA - A network link summary (internal route)
- Type 4 LSA - Represents an ASBR
- Type 5 LSA - A route external to the OSPF domain
- Type 7 LSA - Used in stub areas in place of a type 5 LSA

There are six different and distinct link-state packet formats in use by OSPF, each of which is generated for a different purpose that helps keep the OSPF network routing table intact and accurate.

When a router receives an LSA, it checks its link-state database. If the LSA is new, the router floods the LSA out to its neighbors. After the new LSA is added to the LSA database, the router will rerun the SPF algorithm. This recalculation by the SPF algorithm is absolutely essential to preserving accurate routing tables. The SPF algorithm is responsible for calculating the routing table and any LSA change might also cause a change in the routing table.

[4] such as another OSPF autonomous system or a domain using another routing protocol

[5] This data updates so to be called Link State Advertisements

LSAs are being flooded within detailed flooding decisions. Through flooding LSAs are identified by;

- LS type
- LS sequence number
- LS checksum
- LS age
- Link-State ID
- Advertising Router

Each LSA carries a 16-bit age value, which is set to ZERO when its originated,increasing during flooding.

1.3.1 Router LSA - Type 1

Being created by every router in any type of area.Consists of ;

Router ID
Number of Links
Link Descriptions, such as Link type,neighboring router ID,Router interface addres, ToS [typically not supported today],Metrics
This type of LSA , can be found in any OSPF area type.

1.3.2 Network LSA - Type 2

Like Type 1 Router LSA, also is created by every router in any type of area.Consists of;

Designator Router(DR)'s IP adress
One Subnetmask for DR broadcasting segment
List of Router-IDs of all routers in the broadcast segment

1.3.3 Network Summary LSA – Type 3

Network summary LSA is originated only by an ABR router.Which is logically a gateway between one or more areas and reponsible for network summary exchanges.Consists of;

Destination Network list
Subnet masks list
Metrics for each destination network
Distance Vector routing information

Note that LSA type 3 is not a standart area procedure and can be found in either Stub,Totally-stub,NSSA or Totally-NSSA areas.

1.3.4 ASBR Summary LSA – Type 4

ASBR summary LSA is originated by ABR routers to advertise the network infos to ASBR routers , which acts as a gateway to a different routing domain which is not OSPF[6]
Consist of;

Nearly identical to Type 3 LSA with a slight difference is that; Type 4 LSA destinations are the ASBR routers and not Networks

ABSR Router Ids

Mask of host router

Metric

1.3.5 AS External LSA – Type 5

AS External LSA is originated by ASBRs to maintain the network info connectivity between OSPF and non-OSPF discipliner areas.

General Properties are following:

- Type 5 LSA has additional 2 sub-division
    - AS External LSA type 1 (E1) – for advertising default routes
    - AS External LSA type 2 (E2) – for advertising external routes
- Therefore as understood from the first pick the roles of this LSA are
    - Advertising External routes and
    - Advertising Default routes
- Contains;
    - External Network ID + Mask
    - Metric
    - Next external hop after ASBR

1.3.6 NSSA External LSA - Type 7

LSA Type 7s are originated by ASBRs within NSSA areas.They are almost identical with LSA type 5 with a difference of being flooded only within NSSA areas.They are being converted to type 5 by ABRs on the exit of a NSSA

[6]If the area would be of an OSPF discipline, then router is an ABR and not ASBR ; therefore the process becomes an inter-area OSPF routing mechanism

1.3.7 Other LSA Types

There are a few more LSA types are not really being popularly use
But to sum :

Group Membership LSA – Type 6
  for MOSPF
External Attribute LSA _ Type 8
  Alternative to IBGP
  Should transport the BGP information within an OSPF domain
  Not yet implemented , therefore no RFC

1.4 OSPF AREA TYPES

1.4.1 Standard Area

A standard area is the most basic type of area. Standard areas are the most relaxed and free ones of OSPF areas as every router in the area knows about every route[7].

Standard Area process as simple following:

Type 1 and 2 LSAs are passed between routers to inform the others regarding their own interfaces and their neighbours. Internal routes, communicated by type 3 LSAs, and external routes, being carried on by type 5 LSAs are sent through all standard areas as well as the backbone area, which is a type of standard area. Type 3 LSAs can be sourced by any OSPF router whereas type 5 LSAs only ever comes from autonomous system border routers. Autonomous system border routers are also responsible for generating type 4 LSAs. An area border router that has an interface in that area and an interface in the backbone area will inject the type 4 LSA into the backbone area to ensure the route to the autonomous system border router is known. Type 4 LSAs are only passed internally.

In summary, a standard area can contain LSAs of type 1,2,3,4, and 5

[7]This is just fine if the routers are high-powered enough to store every route and run the SPF calculations without getting bogged down.

1.4.2 Backbone Area

Backbone Areas; are “Area 0”s and carry all the properties of a Standard Area. OSPF uses a central area, area 0, to exchange routes between other areas. This is part of the reason area 0 exists to stop routing loops.

Making the assumption that without an area 0, we can be in danger of a routing loop. But indeed would only be in danger of a routing loop in OSPF if areas that are not area 0, could actually exchange routes between themselves. But they consequently this is a specific design choice. So the majority of the books talk about possible routing loops they are only talking about a hypothetical situation that could occur if OSPF areas were allowed to exchange routes between themselves without the use of an area 0.

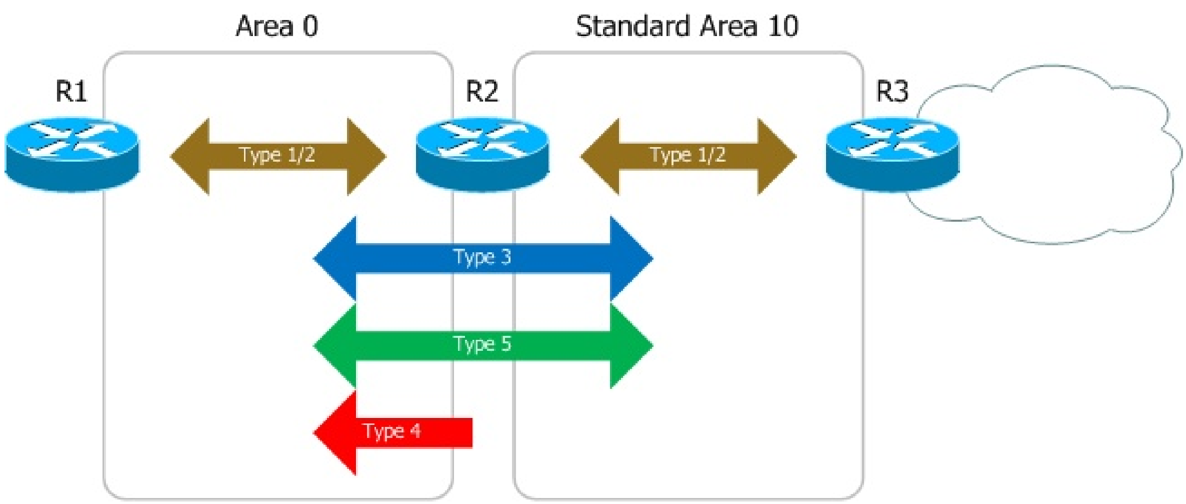

Figure 1.5: Backbone and Standart Areas and LSA exchanges[8]

Standard areas work fine and ensure optimal routing since all routers know about all routes. However, there are often situations when an area has limited access to the rest of the network, and maintaining a full link state database is unnecessary. Additionally, an area may contain low-end routers incapable of maintaining a full database for a large OSPF network. Such areas can be configured to block certain LSA types and become lightweight stub areas.

[8] router R2 here is an ABR and R3 is an ASBR

1.4.3 Stub Area

An area could be referred to as a stub area when there is a single exit point from that area, consequently external routing to outside of the area does not have to take an optimal path because packets can only enter and leave through the Area Border Router.
External networks, such as those redistributed from other protocols into OSPF, are not allowed to be flooded into a stub area. Brilliantly afterwards we can reduce the overall size of the tables within the routers that are inside the stub area.

Configuring a stub area reduces the link-state database size inside an area and reduces the memory requirements of routers inside that area. Routing from these areas to the outside world is based on a default route. They do contain inter-area and intra-area routes.

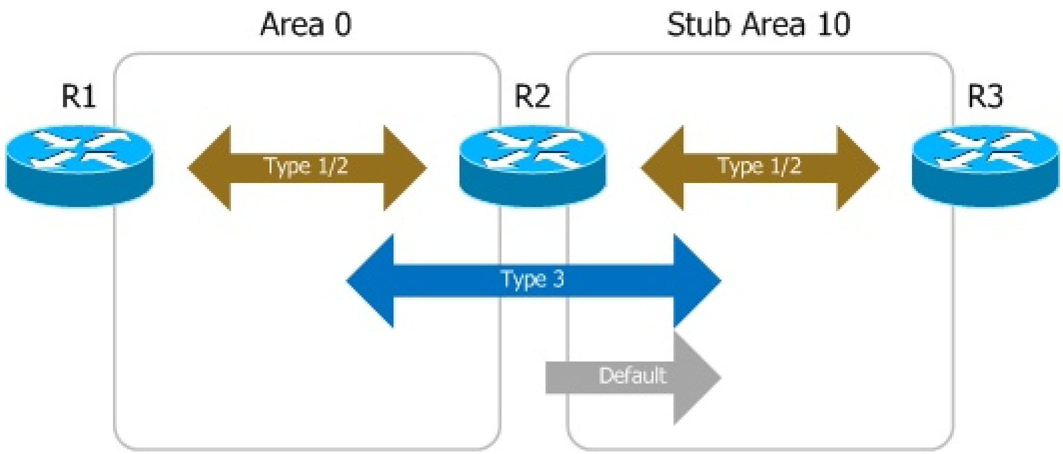

Figure 1.6: Backbone and Stub Areas and LSA exchanges[9]

In this next example, R2 and R3 share a common stub area. Instead of propagating external routes (type 5 LSAs) into the area, the ABR[10] injects a type 3 LSA containing a default route into the stub area. This ensures that routers in the stub area will be able to route traffic to external destinations without having to maintain all of the individual external routes. Because external routes are not received by the stub area, ABRs also do not forward type 4 LSAs from other areas into the stub.
Configured as;

```
Router(config-router)# area 10 stub
```

[9] router R2 here is an ABR and R3 is an ASBR

[10] Router R2 is ABR here

A few design tips here:

- Stub areas should have one Area Border router.
- All OSPF routers inside a stub area have to be configured as stub routers because whenever an area is configured as stub, all interfaces that belong to that area will start exchanging hello packets with a flag that indicates that the interface is stub. Actually this is just a bit in the hello packet ("E" bit) that gets set to 0. All routers that have a common segment have to agree on that flag. If the routers don't agree, then they will not become neighbours and routing will not take effect.

1.4.4 Totally-Stubby Area

Like stub areas, totally stubby areas do not receive type 4 or 5 LSAs from their ABRs. However, they also do not receive type 3 LSAs; all routing out of the area relies on the single default route injected by the ABR.

A totally stubby area is being extended from a stub area by configuring all of its ABRs with the parameter: no-summary

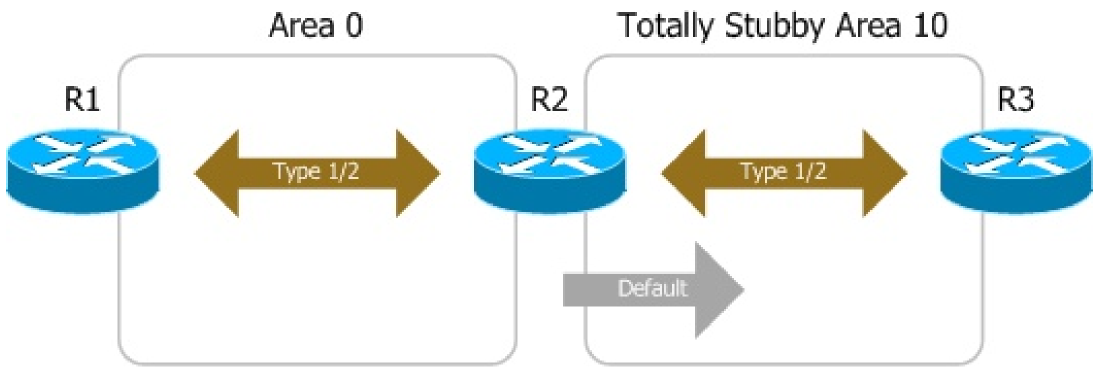

Figure 1.7: Backbone and Totally-Stubby Areas and LSA exchanges

Stub and totally stubby areas can certainly be convenient to reduce the resource utilization of routers in portions of the network not requiring full routing knowledge. However, neither type can contain an ASBR, as type 4 and 5 LSAs are not permitted inside the area.
So to be configured on ABR command of;

```
Router(config-router)# area 10 stub no-summary
```

Throughout this command, TSA blocks external routes and summary routes from entering the area. This leaves the default route and intra-area routes as the only types being advertised throughout the area. This is most complete summarization technique possible in OSPF and results in extremely small routing tables made up only of networks found with the area. To solve this problem, and in what is arguably the worst naming decision ever made, Cisco introduced the concept of a not-so-stubby area (NSSA)

1.4.5 Not-so-Stubby Area

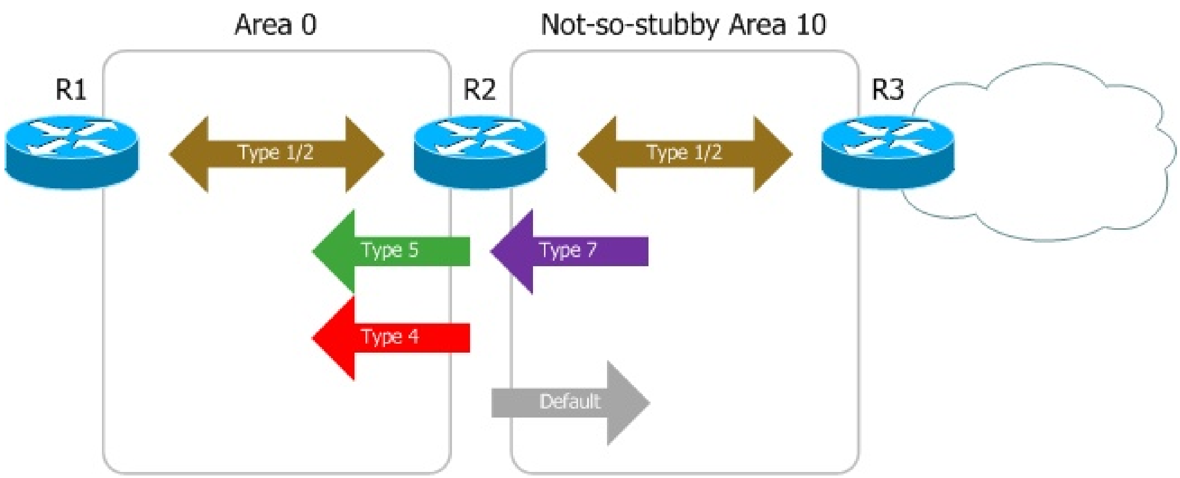

Figure 1.8: Backbone and Not-so-stubby Areas and LSA exchanges

An NSSA makes use of type 7 LSAs, which are essentially type 5 LSAs in disguise. This allows an ASBR to advertise external links to an ABR, which converts the type 7 LSAs into type 5 before flooding them to the rest of the OSPF domain. An NSSA can function as either a stub or totally stubby area. To designate a normal (stub) NSSA, all routers in the area must be so configured:

```
Router(config-router)# area 10 nssa
```

Type 3 LSAs will pass into and out of the area. Unlike a normal stub area, the ABR will not inject a default route into an NSSA unless explicitly configured to do so. As traffic cannot be routed to external destinations without a default route, you'll probably want to include one by appending

```
default-information-originate
Router(config-router)# area 10 nssa default-information-originate
```

The ABR of a totally stubby NSSA (or not-so-totally-stubby area, if you prefer) injects a default route without any further configuration.

2 SIMULATION SCENARIOS AND ANALYSIS OF FINDINGS

2.1 Scenario 1

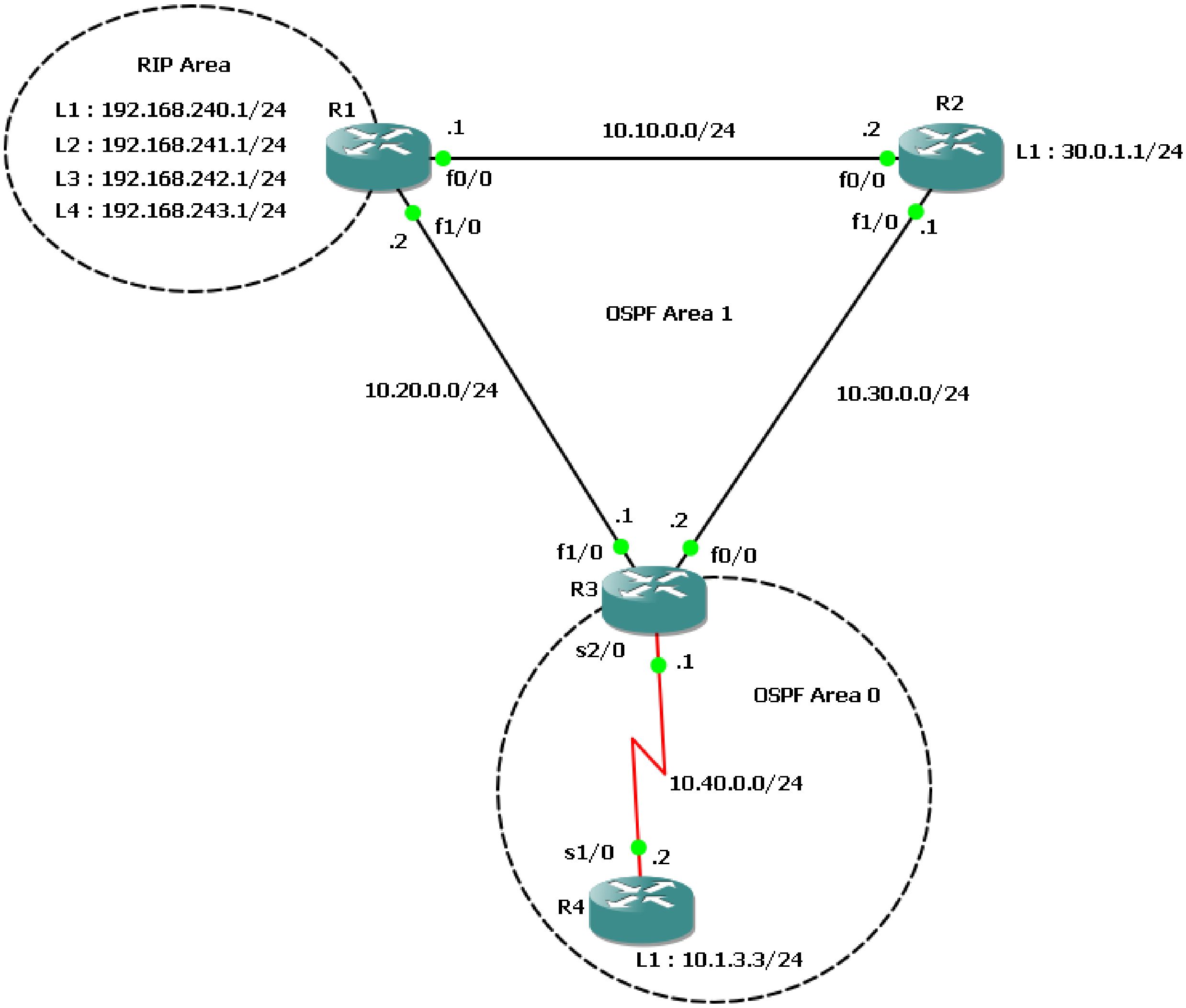

Figure 2.1 :Standart OSPF areas and Multi-Protocol Routing Topology

This scenario contains two standard OSPF areas and a RIP area and their connections in between.

As method;

- ✓ End-to end connectivity has been established, ping tests succeeded
- ✓ RIP Networks are choosen to be injected into the OSPF Networks with the metric of 30
- ✓ All routers in all scenarios are configured with an enable secret : class

*Please see the topology print-outs of GNS3 Project1 added in appendix

The route print-out of other edge R4 router :

```
R4#sh ip route
Codes: 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, E - EGP
       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

Gateway of last resort is not set

O E2 192.168.243.0/24 [110/30] via 10.40.0.1, 00:09:18, Serial1/0
O E2 192.168.242.0/24 [110/30] via 10.40.0.1, 00:09:31, Serial1/0
O E2 192.168.241.0/24 [110/30] via 10.40.0.1, 00:09:40, Serial1/0
O E2 192.168.240.0/24 [110/30] via 10.40.0.1, 00:09:54, Serial1/0
     10.0.0.0/24 is subnetted, 5 subnets
O IA    10.10.0.0 [110/66] via 10.40.0.1, 01:29:48, Serial1/0
C       10.1.3.0 is directly connected, Loopback1
O IA    10.30.0.0 [110/65] via 10.40.0.1, 01:34:57, Serial1/0
O IA    10.20.0.0 [110/65] via 10.40.0.1, 01:29:38, Serial1/0
C       10.40.0.0 is directly connected, Serial1/0
     30.0.0.0/32 is subnetted, 1 subnets
O IA    30.0.1.1 [110/66] via 10.40.0.1, 01:01:11, Serial1/0
```

Noting that in this topology R1 is an ASBR router connecting RIP and OSPF domains together. And also injecting the RIP networks with Metric 30 into OSPF as LSA Type 5 and its E2 type advertising External Routes.

Metric Injection to RIP Networks is done as following:

```
R1(config)#router ospf 1
R1(config-router)# redistribute connected metric 30
```

Redistribute – should be read as: Get those routes somewhere-else
And through this information – which makes the thing easier – we can read the whole command as: „Spread those routes that you get somewhere else into the ospf process with the label of 30“

```
R4#show ip ospf database

            OSPF Router with ID (10.1.3.3) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.3.3        10.1.3.3        113         0x80000007 0x0011AF 3
10.40.0.1       10.40.0.1       114         0x80000006 0x00F6CA 2

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.0.0       10.40.0.1       1647        0x80000005 0x00F8F6
10.20.0.0       10.40.0.1       1647        0x80000007 0x007272
10.30.0.0       10.40.0.1       1890        0x80000005 0x00FDDE
30.0.1.1        10.40.0.1       114         0x80000003 0x005B8A

                Summary ASB Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.3.1        10.40.0.1       1138        0x80000002 0x0034C4

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
192.168.240.0   10.0.3.1        876         0x80000001 0x00CA63 0
192.168.241.0   10.0.3.1        864         0x80000001 0x00BF6D 0
192.168.242.0   10.0.3.1        855         0x80000001 0x00B477 0
192.168.243.0   10.0.3.1        842         0x80000001 0x00A981 0
```

As we have a look at the edge router R4, we can see;

Router Link States (Area 0) corresponds LSA Type 1
Summary Net Link States (Area 0) corresponds LSA Type 2
Summary ASB Link States (Area 0) corresponds LSA Type 3
And therefore as was explained we can clearly see LSA Type 5 injecting RIP routes

2.2 Scenario 2

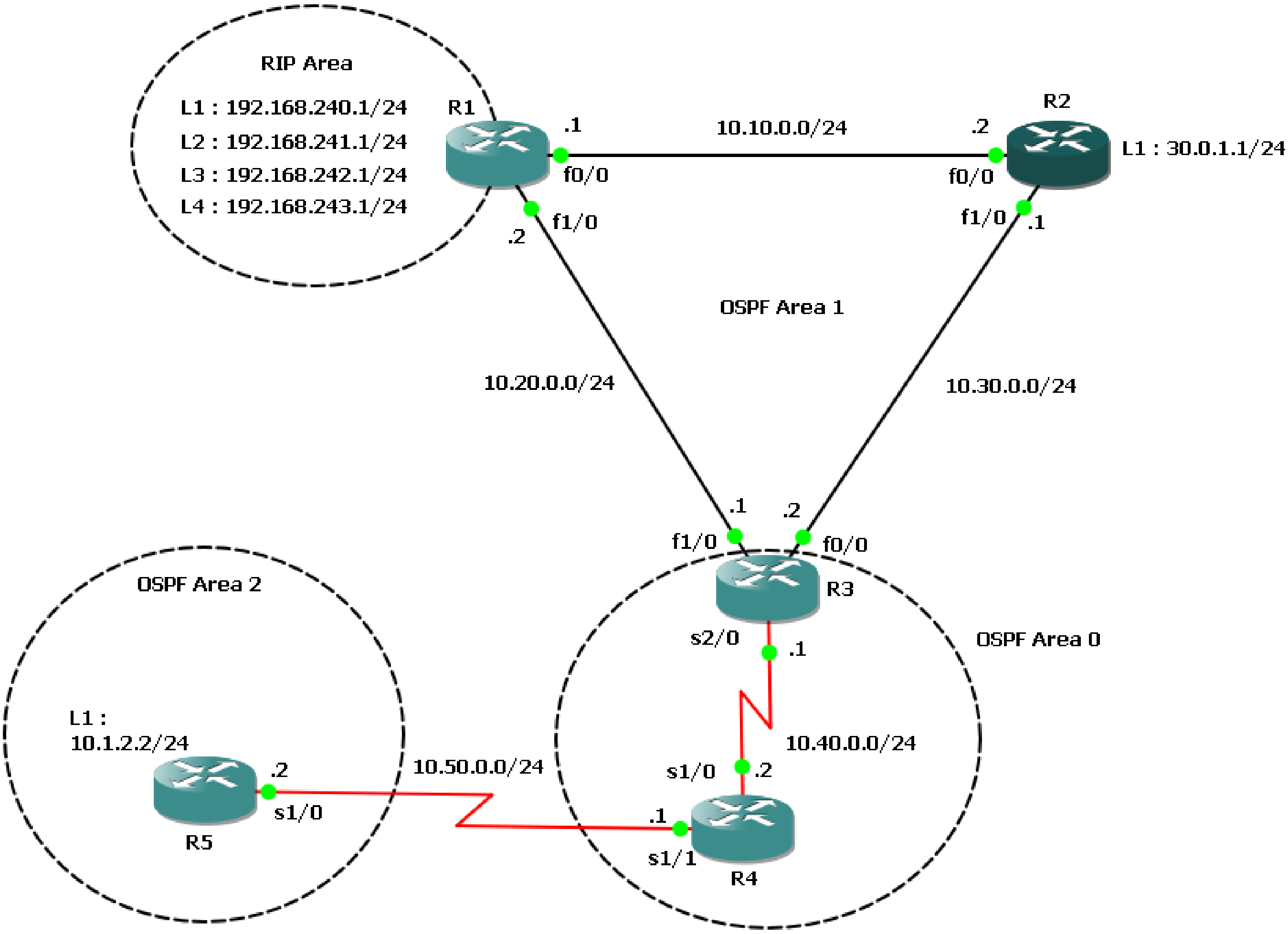

Figure 2.2: Stub area 2 , Multi-Protocol Routing Topology

This scenario contains 2 standard areas [Area 0 and Area 1] and one Stub Area [Area 2] of OSPF in addition one RIP area and their connections in between.

As method;

- ✓ End-to end connectivity has been established, ping tests succeeded
- ✓ RIP Networks are choosen to be injected into the OSPF Networks with the metric of 30
- ✓ All routers in all scenarios are configured with an enable secret : class
- ✓ Area 2 , is chosen to be a Stub Area

*Please see the topology print-outs of GNS3 Project2 added in appendix

A closer look to the stub router R5

```
R5#show ip route
Codes: 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, E - EGP
       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

Gateway of last resort is 10.50.0.1 to network 0.0.0.0

     10.0.0.0/24 is subnetted, 6 subnets
O IA    10.10.0.0 [110/130] via 10.50.0.1, 00:03:45, Serial1/0
C       10.1.2.0 is directly connected, Loopback1
O IA    10.30.0.0 [110/129] via 10.50.0.1, 00:03:45, Serial1/0
O IA    10.20.0.0 [110/129] via 10.50.0.1, 00:03:45, Serial1/0
O IA    10.40.0.0 [110/128] via 10.50.0.1, 00:03:45, Serial1/0
C       10.50.0.0 is directly connected, Serial1/0
     30.0.0.0/32 is subnetted, 1 subnets
O IA    30.0.1.1 [110/130] via 10.50.0.1, 00:03:45, Serial1/0
O*IA 0.0.0.0/0 [110/65] via 10.50.0.1, 00:03:45, Serial1/0
```

AND

```
R5#show ip ospf database

            OSPF Router with ID (10.1.2.2) (Process ID 1)

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.2.2        10.1.2.2        315         0x80000008 0x00CA0B 3
10.1.3.3        10.1.3.3        315         0x80000005 0x00FDF8 2

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
0.0.0.0         10.1.3.3        347         0x80000001 0x002805
10.10.0.0       10.1.3.3        347         0x80000002 0x00B71F
10.20.0.0       10.1.3.3        347         0x80000002 0x003598
10.30.0.0       10.1.3.3        347         0x80000002 0x00BC07
10.40.0.0       10.1.3.3        347         0x80000002 0x003A80
30.0.1.1        10.1.3.3        347         0x80000002 0x0016B4
```

Normally iproute command shows us the connected nodes of the relevant router. Basically what to take into consideration here is that the RIP routes are not exist in the table. As also can be seen in the ip ospf database printout, only LSA type 1 and type 2 are allowed within the Stub Area.

Literally, in normal conditions – R5 could not have been communicating with the routers that are not in the IP route list.

Making some checks to the RIP routes afterwards;

```
R5#ping 192.168.240.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.240.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/72/100 ms

R5#ping 192.168.241.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.241.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/75/132 ms

R5#ping 192.168.242.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.242.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/44/72 ms

R5#ping 192.168.243.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.243.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/75/120 ms
```

The ping printouts tell us R5 can communicate with the RIP routes.

But then how could it be possible?

As it's been discussed in the previous sections; Stub areas never let LSA Type 5 that does outer routing protocols to be injected, into their areas. `O*IA` term in the print out tells us that the Stub router has a default route for all the inter-area communication via OSPF.

The communication with outer routing protocols is done either by the standard area or backbone area routers.In this particular example; R5 makes the interface to R4 as default route for all the connections apart from the iproute table.

Please see the IP route printout of R4 to see that whole connections throughout the network are held

```
R4#show ip route
Codes: 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, E - EGP
       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

Gateway of last resort is not set

O E2 192.168.243.0/24 [110/30] via 10.40.0.1, 00:04:51, Serial1/0
O E2 192.168.242.0/24 [110/30] via 10.40.0.1, 00:04:51, Serial1/0
O E2 192.168.241.0/24 [110/30] via 10.40.0.1, 00:04:51, Serial1/0
O E2 192.168.240.0/24 [110/30] via 10.40.0.1, 00:04:51, Serial1/0
     10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
O IA    10.10.0.0/24 [110/66] via 10.40.0.1, 00:04:51, Serial1/0
O       10.1.2.2/32 [110/65] via 10.50.0.2, 00:04:51, Serial1/1
O IA    10.30.0.0/24 [110/65] via 10.40.0.1, 00:04:51, Serial1/0
O IA    10.20.0.0/24 [110/65] via 10.40.0.1, 00:04:51, Serial1/0
C       10.40.0.0/24 is directly connected, Serial1/0
C       10.50.0.0/24 is directly connected, Serial1/1
     30.0.0.0/32 is subnetted, 1 subnets
O IA    30.0.1.1 [110/66] via 10.40.0.1, 00:04:51, Serial1/0
```

2.3 Scenario 3

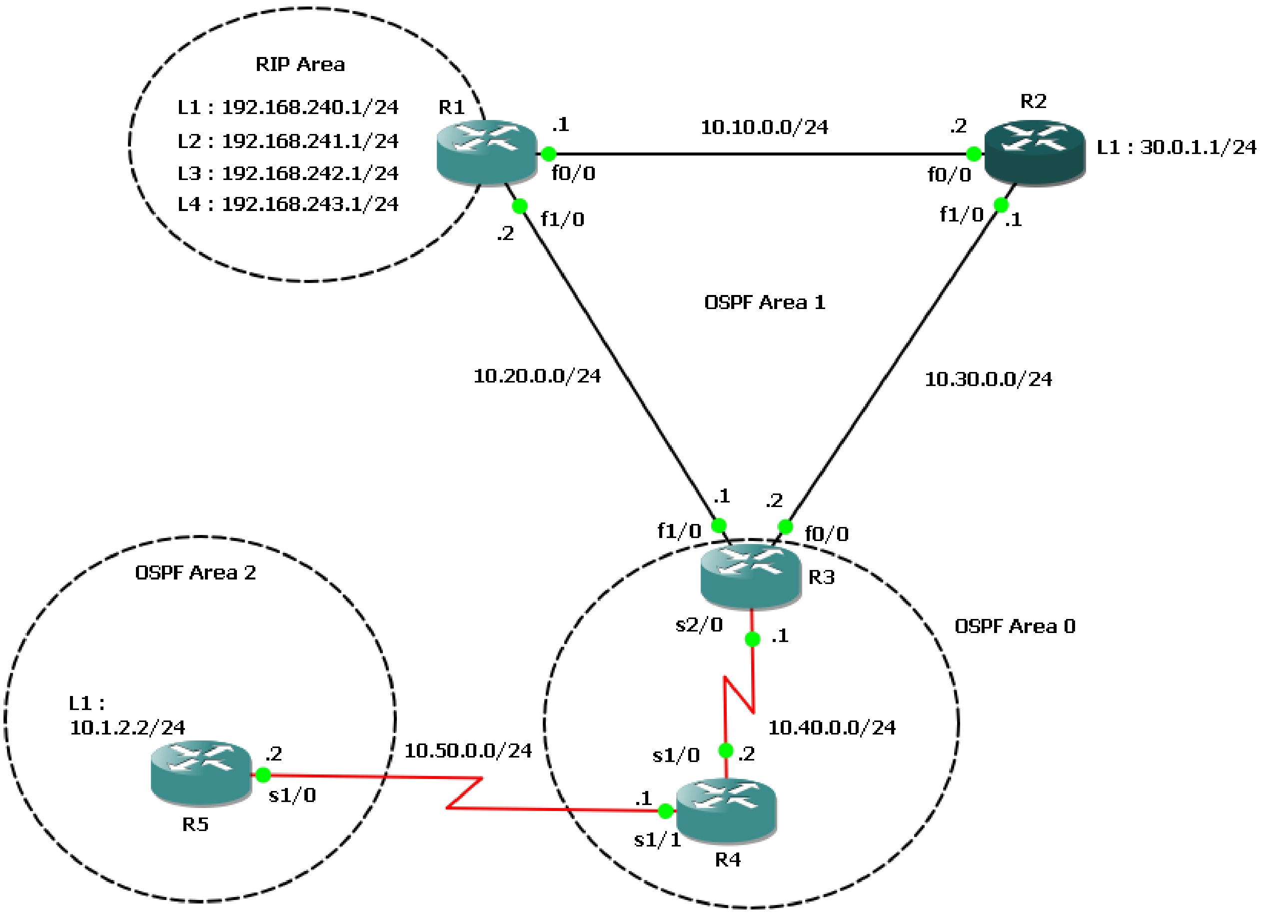

Figure 2.3: NSSA area 2, Multi-Protocol Routing Topology

This scenario contains two standard areas [Area 0 and Area 1] and one NSSA Area [Area 2] of OSPF in addition one RIP area and their connections in between.

As method;

- ✓ End-to end connectivity has been established, ping tests succeeded
- ✓ RIP Networks are choosen to be injected into the OSPF Networks with the metric of 30
- ✓ All routers in all scenarios are configured with an enable secret : class
- ✓ Area 2 , is chosen to be a Not-so-stubby Area

*Please see the topology print-outs of GNS3 Project3 added in appendix

Having a closer look at NSSA router R5;

```
R5#show ip route
Codes: 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, E - EGP
       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

Gateway of last resort is 10.50.0.1 to network 0.0.0.0

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.2.0 is directly connected, Loopback1
O IA    10.30.0.0 [110/129] via 10.50.0.1, 00:00:13, Serial1/0
O IA    10.20.0.0 [110/129] via 10.50.0.1, 00:00:13, Serial1/0
O IA    10.40.0.0 [110/128] via 10.50.0.1, 00:00:16, Serial1/0
C       10.50.0.0 is directly connected, Serial1/0
O*N2 0.0.0.0/0 [110/1] via 10.50.0.1, 00:00:06, Serial1/0
```

AND

```
R5#show ip ospf database

            OSPF Router with ID (10.1.2.2) (Process ID 1)

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.2.2        10.1.2.2        96          0x80000002 0x00C1E5 3
10.50.0.1       10.50.0.1       96          0x80000002 0x001087 2

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.0.0       10.50.0.1       56          0x80000001 0x00D8CA
10.20.0.0       10.50.0.1       46          0x80000003 0x005246
10.30.0.0       10.50.0.1       41          0x80000001 0x00DDB2
10.40.0.0       10.50.0.1       98          0x80000001 0x005B2C
30.0.1.1        10.50.0.1       46          0x80000002 0x003561

                Type-7 AS External Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         10.50.0.1       103         0x80000001 0x00F145 0
```

```
R4#sh ip ospf database

            OSPF Router with ID (10.50.0.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.40.0.1       10.40.0.1       755         0x80000002 0x005940 2
10.50.0.1       10.50.0.1       166         0x80000003 0x005239 2

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.2.2        10.50.0.1       110         0x80000001 0x006B44
10.10.0.0       10.40.0.1       720         0x80000001 0x0001F2
10.20.0.0       10.40.0.1       715         0x80000003 0x007A6E
10.30.0.0       10.40.0.1       705         0x80000003 0x0002DC
10.50.0.0       10.50.0.1       760         0x80000001 0x003D46
30.0.1.1        10.40.0.1       710         0x80000002 0x005D89

                Summary ASB Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.243.1   10.40.0.1       720         0x80000001 0x00ACFC

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.2.2        10.1.2.2        125         0x80000004 0x00BDE7 3
10.50.0.1       10.50.0.1       126         0x80000005 0x000A8A 2

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.0.0       10.50.0.1       167         0x80000003 0x00D4CC
10.20.0.0       10.50.0.1       167         0x80000005 0x004E48
10.30.0.0       10.50.0.1       167         0x80000005 0x00D5B6
10.40.0.0       10.50.0.1       167         0x80000003 0x00572E
30.0.1.1        10.50.0.1       167         0x80000004 0x003163

                Type-7 AS External Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         10.50.0.1       167         0x80000001 0x00F145 0

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
192.168.240.0   192.168.243.1   777         0x80000001 0x00825B 0
192.168.241.0   192.168.243.1   777         0x80000001 0x007765 0
192.168.242.0   192.168.243.1   777         0x80000001 0x006C6F 0
192.168.243.0   192.168.243.1   777         0x80000001 0x006179 0
```

In this particular example; From the R4 and R5 router printouts – We can clearly see that Type 7 LSA type that is NSSA area oriented only – is being generated also by only ASBR routers.R4 as an ASBR router on the way of Area 0 will transform LSA type 7 packages to LSA type 5 packages and only afterwards let them in. This is Cisco specific enlargement property for the Stub areas.So its been cleary detected here that when Stub areas don’t except LSA types 4,5;Nssa areas would except LSA type 5 only as LSA type 7.

3 Appendix A – Multiarea OSPF quick config guide

Reminders;

- Only ABRs and ASBRs can make summary announcements
- ABRs don't let LSAs type 1 and type 2 in – They can only pass through by being transformed into type 3
- ASBRs would let external routes as LSA type 5.

STUB AREA CONFIG:

ABR	CLIENT(s)
area 1 stub	area 1 stub

- ASBRs don't exits in this area
- LSAs type 4 and type 5 are not allowed

TOTALLY STUB AREA CONFIG:

ABR	CLIENT(s)
area 1 stub no-summary	area 1 stub

- ASBRs don't exits in this area
- LSAs type 3, type 4 and type 5 are not allowed

NSSA AREA CONFIG:

ABR	CLIENT(s)
area 1 nssa	area 1 nssa

- LSAs type 4 and type 5 are not allowed
- LSA type 5 is only allowed as type 7

Totally - NSSA AREA CONFIG:

ABR	CLIENT(s)
area 1 nssa no-summary	area 1 nssa

- LSAs type 3, type 4 and type 5 are not allowed
- LSA type 7 is only allowed as type 5

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4 Appendix B – Project 1 config files

```
--------------------------------------- R1 ------------------------------------
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$I6OD$I30Ho.nRxf.qFH/DNIFv10
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 192.168.240.1 255.255.255.0
 no clns route-cache
!
interface Loopback2
 ip address 192.168.241.1 255.255.255.0
 no clns route-cache
!
interface Loopback3
 ip address 192.168.242.1 255.255.255.0
 no clns route-cache
!
interface Loopback4
 ip address 192.168.243.1 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 ip address 10.10.0.1 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.20.0.2 255.255.255.0
 duplex auto
```

```
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 redistribute connected metric 30
 network 10.10.0.0 0.0.0.255 area 1
 network 10.20.0.0 0.0.0.255 area 1
!
router rip
 version 2
 network 192.168.0.0
 no auto-summary
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

--------------------------------------- R2 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R2
!
boot-start-marker
boot-end-marker
```

```
!
enable secret 5 $1$H6fa$4drfSu../5UcP/U0PA7/50
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 30.0.1.1 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 ip address 10.10.0.2 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.30.0.1 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 network 10.10.0.0 0.0.0.255 area 1
 network 10.30.0.0 0.0.0.255 area 1
 network 30.0.1.0 0.0.0.255 area 1
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
```

```
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

--------------------------------------- R3 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R3
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$.4YE$K0aPxfHOqRF/4usFd.Gfk0
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface FastEthernet0/0
 ip address 10.30.0.2 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.20.0.1 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
```

```
 no clns route-cache
!
interface Serial2/0
 ip address 10.40.0.1 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 network 10.20.0.0 0.0.0.255 area 1
 network 10.30.0.0 0.0.0.255 area 1
 network 10.40.0.0 0.0.0.255 area 0
!
ip classless
!
no ip http server
!
!
!
```

```
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

-------------------------------------- R4 -----------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R4
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$.I6r$26ONiMnWwFTLTM2Fq3bID1
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 10.1.3.3 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 no ip address
 shutdown
```

```
 duplex half
 no clns route-cache
!
interface Serial1/0
 ip address 10.40.0.2 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/1
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 network 10.1.3.0 0.0.0.255 area 0
 network 10.40.0.0 0.0.0.255 area 0
!
ip classless
!
no ip http server
!
!
!
```

```
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

5 Appendix C – Project 2 config files

```
 ---------------------------------------- R1 ------------------------------------
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$I6OD$I30Ho.nRxf.qFH/DNIFv10
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 192.168.240.1 255.255.255.0
 no clns route-cache
!
interface Loopback2
 ip address 192.168.241.1 255.255.255.0
 no clns route-cache
!
interface Loopback3
 ip address 192.168.242.1 255.255.255.0
 no clns route-cache
!
interface Loopback4
 ip address 192.168.243.1 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 ip address 10.10.0.1 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.20.0.2 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
```

```
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 redistribute connected metric 30
 network 10.10.0.0 0.0.0.255 area 1
 network 10.20.0.0 0.0.0.255 area 1
!
router rip
 version 2
 network 192.168.0.0
 no auto-summary
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

--------------------------------------- R2 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$H6fa$4drfSu../5UcP/U0PA7/50
!
```

```
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 30.0.1.1 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 ip address 10.10.0.2 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.30.0.1 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 network 10.10.0.0 0.0.0.255 area 1
 network 10.30.0.0 0.0.0.255 area 1
 network 30.0.1.0 0.0.0.255 area 1
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
```

```
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end

--------------------------------------- R3 ------------------------------------
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R3
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$.4YE$K0aPxfHOqRF/4usFd.Gfk0
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface FastEthernet0/0
 ip address 10.30.0.2 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.20.0.1 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
interface Serial2/0
 ip address 10.40.0.1 255.255.255.0
```

```
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 network 10.20.0.0 0.0.0.255 area 1
 network 10.30.0.0 0.0.0.255 area 1
 network 10.40.0.0 0.0.0.255 area 0
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
```

```
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

```
-------------------------------------- R4 -----------------------------------
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R4
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$.I6r$26ONiMnWwFTLTM2Fq3bID1
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
 no clns route-cache
!
interface Serial1/0
 ip address 10.40.0.2 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/1
 ip address 10.50.0.1 255.255.255.0
```

```
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 area 2 stub
 network 10.40.0.0 0.0.0.255 area 0
 network 10.50.0.0 0.0.0.255 area 2
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
```

```
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 no login
!
!
end
```

--------------------------------------- R5 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R5
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$zqYH$vKg9ooN5jLDDnoRMg6QzP/
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 10.1.2.2 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
 no clns route-cache
!
interface Serial1/0
 ip address 10.50.0.2 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/1
 no ip address
```

```
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 area 2 stub
 network 10.1.2.0 0.0.0.255 area 2
 network 10.50.0.0 0.0.0.255 area 2
!
ip classless
!
no ip http server
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
```

```
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

6 Appendix D – Project 3 config files

```
  --------------------------------------- R1 ------------------------------------
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$I6OD$I30Ho.nRxf.qFH/DNIFv10
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 192.168.240.1 255.255.255.0
 no clns route-cache
!
interface Loopback2
 ip address 192.168.241.1 255.255.255.0
 no clns route-cache
!
interface Loopback3
 ip address 192.168.242.1 255.255.255.0
 no clns route-cache
!
interface Loopback4
```

```
 ip address 192.168.243.1 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 ip address 10.10.0.1 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.20.0.2 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 redistribute connected metric 30
 network 10.10.0.0 0.0.0.255 area 1
 network 10.20.0.0 0.0.0.255 area 1
!
router rip
 version 2
 network 192.168.0.0
 no auto-summary
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

-------------------------------------- R2 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$H6fa$4drfSu../5UcP/U0PA7/50
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 30.0.1.1 255.255.255.0
 no clns route-cache
!
interface FastEthernet0/0
 ip address 10.10.0.2 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
 ip address 10.30.0.1 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 network 10.10.0.0 0.0.0.255 area 1
 network 10.30.0.0 0.0.0.255 area 1
 network 30.0.1.0 0.0.0.255 area 1
!
ip classless
!
no ip http server
!
```

```
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

--------------------------------------- R3 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R3
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$.4YE$K0aPxfHOqRF/4usFd.Gfk0
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface FastEthernet0/0
 ip address 10.30.0.2 255.255.255.0
 duplex half
 no clns route-cache
!
interface FastEthernet1/0
```

```
 ip address 10.20.0.1 255.255.255.0
 duplex auto
 speed auto
 no clns route-cache
!
interface FastEthernet1/1
 no ip address
 shutdown
 duplex auto
 speed auto
 no clns route-cache
!
interface Serial2/0
 ip address 10.40.0.1 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial2/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
```

```
 network 10.20.0.0 0.0.0.255 area 1
 network 10.30.0.0 0.0.0.255 area 1
 network 10.40.0.0 0.0.0.255 area 0
!
ip classless
!
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end

  --------------------------------------- R4 ------------------------------------
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R4
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$.I6r$26ONiMnWwFTLTM2Fq3bID1
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
```

```
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
 no clns route-cache
!
interface Serial1/0
 ip address 10.40.0.2 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/1
 ip address 10.50.0.1 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 area 2 nssa default-information-originate
 network 10.40.0.0 0.0.0.255 area 0
 network 10.50.0.0 0.0.0.255 area 2
!
ip classless
!
```

```
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 no login
!
!
end
```

--------------------------------------- R5 ------------------------------------

```
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R5
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$zqYH$vKg9ooN5jLDDnoRMg6QzP/
!
ip subnet-zero
ip cef
!
!
no ip domain-lookup
!
no mpls traffic-eng auto-bw timers frequency 0
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 10.1.2.2 255.255.255.0
 no clns route-cache
!
```

```
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
 no clns route-cache
!
interface Serial1/0
 ip address 10.50.0.2 255.255.255.0
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/1
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/4
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/5
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/6
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
interface Serial1/7
 no ip address
 shutdown
 serial restart-delay 0
 no clns route-cache
!
router ospf 1
 log-adjacency-changes
 area 2 nssa
 network 10.1.2.0 0.0.0.255 area 2
 network 10.50.0.0 0.0.0.255 area 2
!
ip classless
!
```

```
no ip http server
!
!
!
!
!
!
control-plane
!
!
dial-peer cor custom
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 no login
!
!
end
```