Reading and Understanding the OSPF Database

Options

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Level 7

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Introduction

OSPF, being a link-state protocol, allows for every router in the network to know of every link and OSPF speaker in the entire network. From this picture each router independently runs the Shortest Path First (SPF) algorithm to determine the best path through the network. All of this information is stored in the "Link State Database" (LSDB). Every network engineer has seen the LSDB at some point by running `show ip ospf database` but few actually know how to read the details. By looking only at the LSDB we should have enough information to draw a topology diagram from scratch.

Link State Advertisements

OSPF uses "Link State Advertisements" (LSAs) to provide information about links and link-costs to neighboring OSPF speakers. OSPF defines multiple LSAs, which all serve a different purpose.

LSA Type	Who Generates the LSA?	What is Accomplished?
Type 1 - Router LSA	Every router in every area	How routers advertise their connected interfaces
Type 2 - Network LSA	DRs on all **non**-point-to-point links	The DR collects all the Type 1 LSAs and sends out a single Type 2 representing all of the routers on the link. This is used to build the Shortest Path Tree
Type 3 - Network Summary LSA	Area Border Routers (ABRs)	ABRs send a single LSA representing all of the Type 1 and Type 2 LSAs in an area. This reduces the number of LSAs on the routers in other areas.
Type 4 - ASBR Summary LSA	ABRs connected to an area where external routes (Type 5) are originated	Type 4 LSAs are sent to other areas to build the Shortest Path Tree to an ASBR.
Type 5 - AS External LSA	Routers with the `redistribute` command that are **not** in a NSSA area	This represents any external routes redistributed into OSPF.
Type 7 - NSSA External LSA	Routers with the `redistribute` command that **are** in a NSSA area	Type 5 LSAs are not allowed in Stub Areas. Type 7 LSAs allow external information to pass through NSSA areas.

Building the Topology

Starting on a router named **r120** we can get a high level overview of the network (or at least our Area).

First, who are we (what is our Router ID)?

```
r120#show ip ospf data

            OSPF Router with ID (10.0.0.120) (Process ID 1)
```

Next, who are the other routers in our area?

```
                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count

10.0.0.111      10.0.0.111      600         0x8000023A 0x0092B3 1

10.0.0.112      10.0.0.112      1246        0x80000234 0x009CAC 1
```

```
10.0.0.113      10.0.0.113      148         0x8000022C 0x004399 3

10.0.0.120      10.0.0.120      152         0x80000240 0x0046CB 1
```

This tells us there are four routers in Area 1. The router with RID 10.0.0.113 has 3 links in Area 1, every one else has only 1 link.

Next, who are all of the DRs in this Area? What network segments do they represent?

```
                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum

192.168.1.112   10.0.0.112      1862        0x80000237 0x00D860

192.168.7.113   10.0.0.113      12          0x80000001 0x00E8F5
```

Routers `10.0.0.112` and `10.0.0.113` are the router IDs of the DRs for two segments. `192.168.1.112` and `192.168.7.113` represent the IP address of the DR on that segment. We will see later that if we were to look at the Router LSA for 10.0.0.112, for example, we would see 192.168.1.112 as one of the interfaces owned by that router.

The Summary Network LSAs (Type 3) are generated by the ABRs and will give us information about every segment in the network, outside of our Area. Type 1 and Type 2 LSAs are not flooded beyond an ABR. The ABR is responsible for taking all of the information in Type 1 and Type 2 LSAs and repackaging them into Type 3 LSAs.

```
                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum

10.0.0.119      10.0.0.111      1215        0x8000022A 0x00A845

10.0.0.119      10.0.0.112      1862        0x80000229 0x00A449

192.168.0.0     10.0.0.111      1215        0x80000234 0x00D842

192.168.0.0     10.0.0.112      1862        0x80000233 0x00D446

192.168.2.0     10.0.0.111      1215        0x80000234 0x0027E7

192.168.2.0     10.0.0.112      1862        0x80000233 0x0023EB

192.168.3.0     10.0.0.111      1215        0x80000232 0x008481

192.168.3.0     10.0.0.112      1862        0x80000232 0x007E86

192.168.4.0     10.0.0.111      1215        0x80000232 0x00798B

192.168.4.0     10.0.0.112      1862        0x80000232 0x007390

192.168.5.0     10.0.0.111      1215        0x80000232 0x006E95

192.168.5.0     10.0.0.112      1862        0x80000232 0x00689A

192.168.6.0     10.0.0.111      1215        0x80000231 0x00C930

192.168.6.0     10.0.0.112      1862        0x80000231 0x00C335
```

From this we know Area 1 has two ABRs with RIDs 10.0.0.111 and 10.0.0.112. We also see a total of 7 segments in the entire OSPF network. Each network is seen twice because each ABR generates its own LSA. Two ABRs means two LSAs.

Type 4, Summary Network LSAs are next. These are generated by the ABRs (10.0.0.111 and 10.0.0.112) to represent any routers or ABRs outside of our Area that is passing along Type 5 (external LSAs). This may be a little confusing at this point but it will make more sense when we start working through the topology.

```
               Summary ASB Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum

10.0.0.114      10.0.0.111      1215        0x80000232 0x00E915

10.0.0.114      10.0.0.112      1862        0x80000232 0x00E31A
```

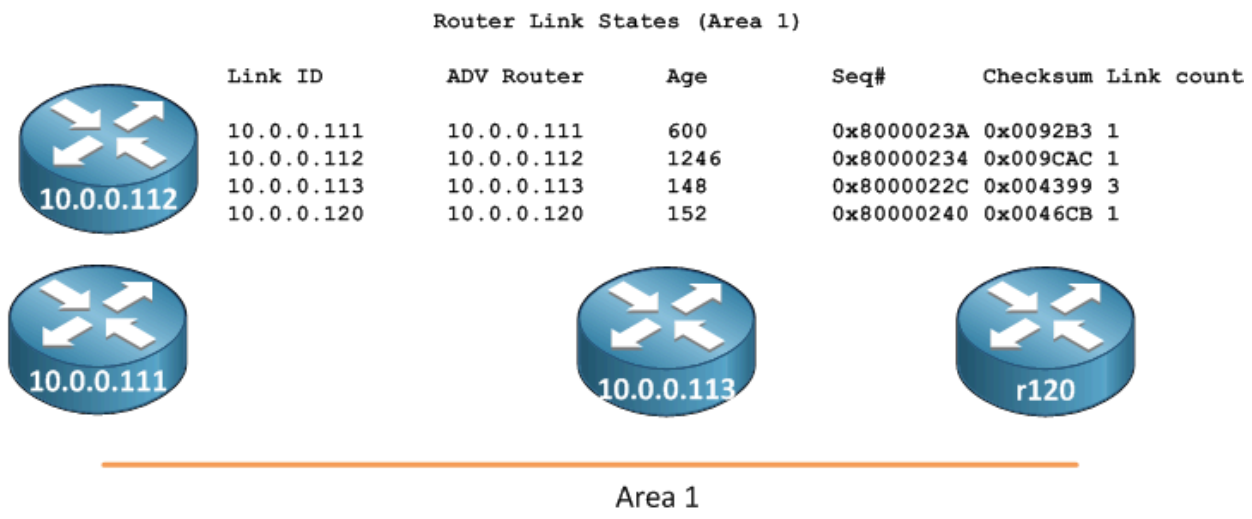
Finally the external routes are represented by Type 5 LSAs.

```
                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
```

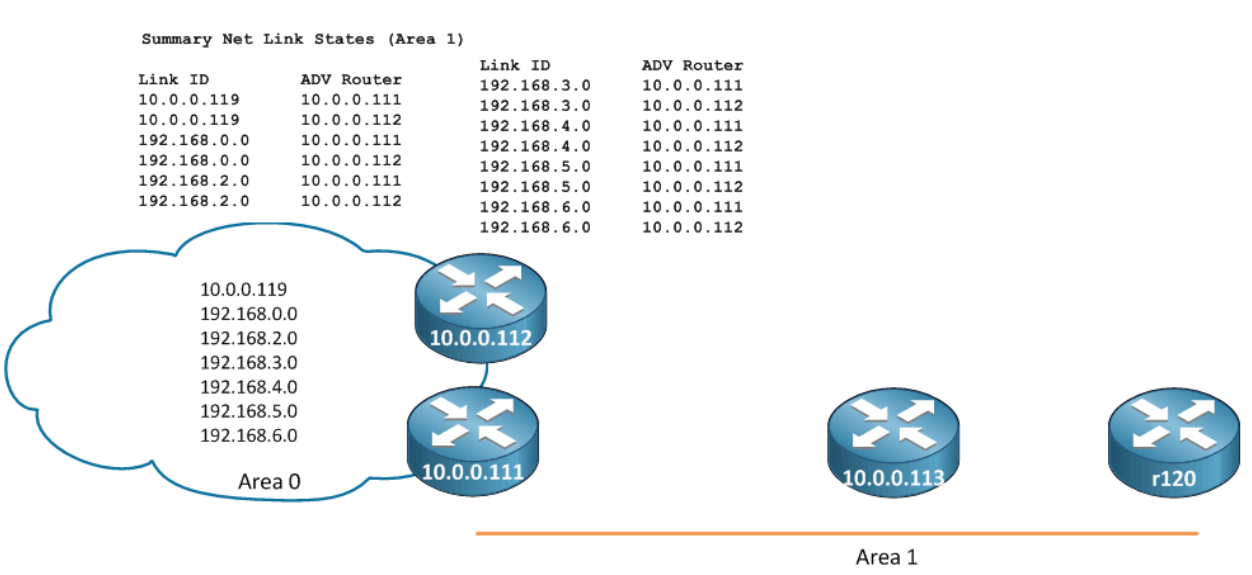
```
172.16.0.113    10.0.0.113      631         0x80000001 0x00F006 0

172.16.0.118    10.0.0.114      678         0x80000001 0x009775 0
```

Here we see two different prefixes being redistributed into OSPF. The ADV Router is either the configured with the `redistribute` command (10.0.0.113) or an ABR connected to a NSSA area where redistribution is happening.

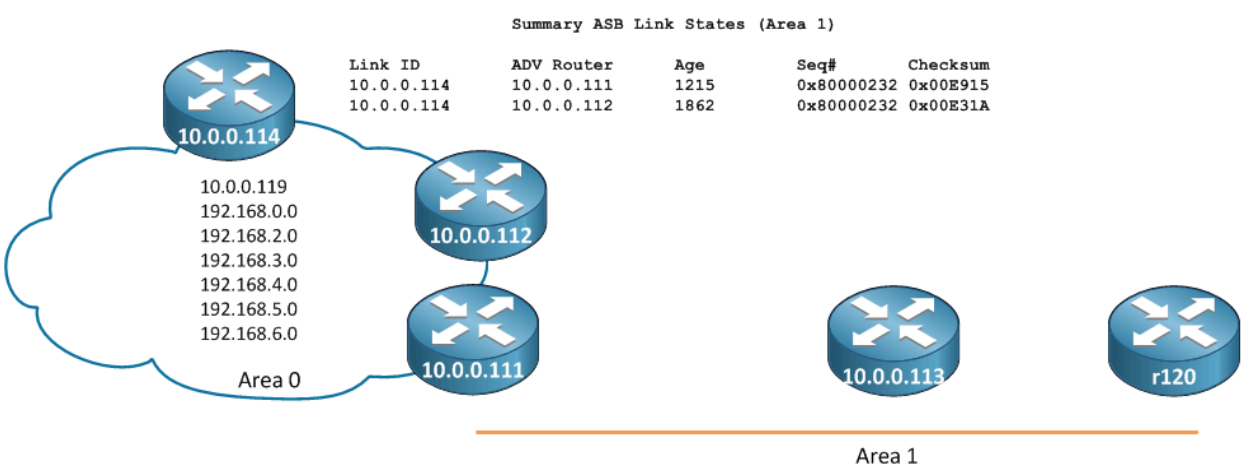
With this information let's build some high level topologies. First, start with what we know from the Type 1 LSAs (all the routers in our area)



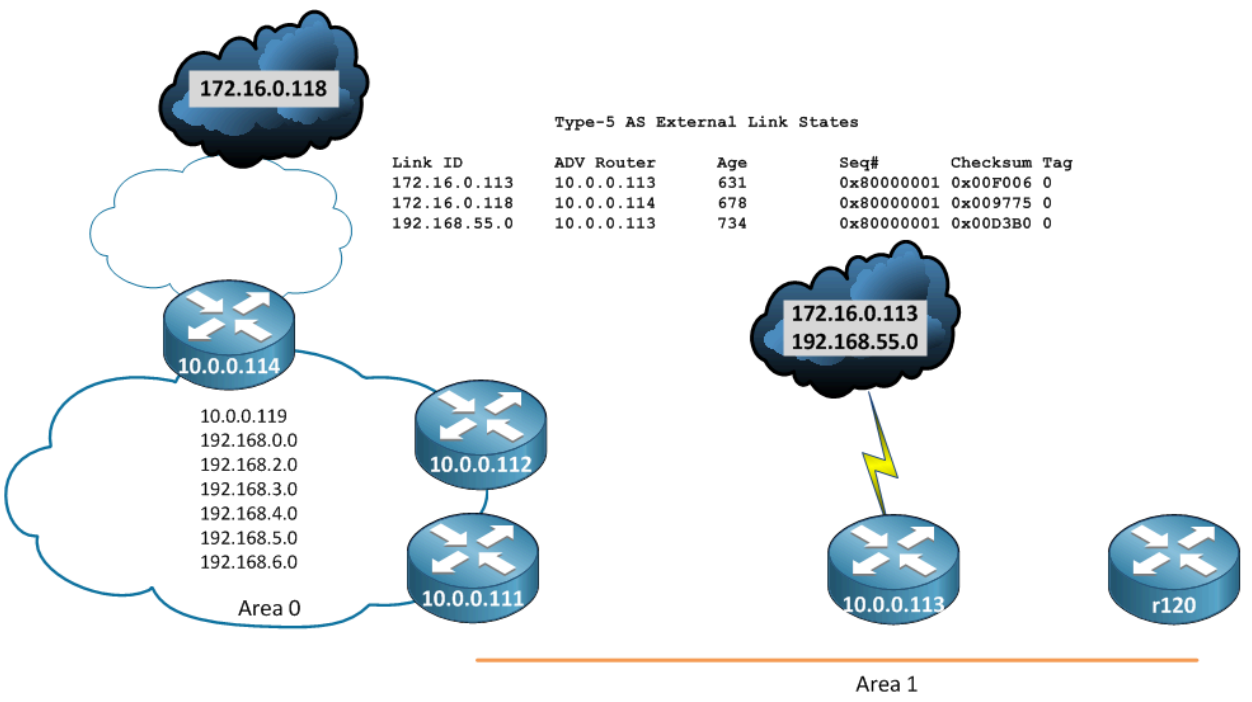
We will skip the Type 2 Network LSAs for now and go to the Type 3 Summary Network LSAs. This gives us the other subnets in the network and the ABRs for Area 1



The Type 4 ASBR Summary LSAs let us know that 10.0.0.114 is also an ABR on Area 0



and finally, the Type 5's tell us about the externals. Using the "ADV Router" field we can figure out where those routes come from.



Just from looking at the summary information in the database we've been able to put a lot of information together. Now we can start looking into the LSAs to get an idea of what the connectivity of Area 1 looks like.

We will start with router **r120**. Since we don't know anything about the links **r120** has, we start with a router with no connections.

To see the connections on **r120** we'll need to look at the Router LSA that is generated by r120 (remember: Router LSAs are represented by the Router ID)

```
r120#show ip ospf database router 10.0.0.120

            OSPF Router with ID (10.0.0.120) (Process ID 1)

                Router Link States (Area 1)

  LS age: 408

  Options: (No TOS-capability, DC)

  LS Type: Router Links

  Link State ID: 10.0.0.120

  Advertising Router: 10.0.0.120

  LS Seq Number: 8000023C

  Checksum: 0x815

  Length: 36

  Number of Links: 1

    Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.7.113

     (Link Data) Router Interface address: 192.168.7.120

      Number of MTID metrics: 0

       TOS 0 Metrics: 10
```

From this we know a few things:

1.) There is a single interface with IP 192.168.7.120

2.) There is a least one other router on this segment with IP 192.168.7.113, and this is the DR

2a.) Because there is a DR, we know this interface is multi-access (not point-to-point)

3.) The Router ID (10.0.0.120) is not advertised in OSPF (becuase there is no link information representing the router ID)

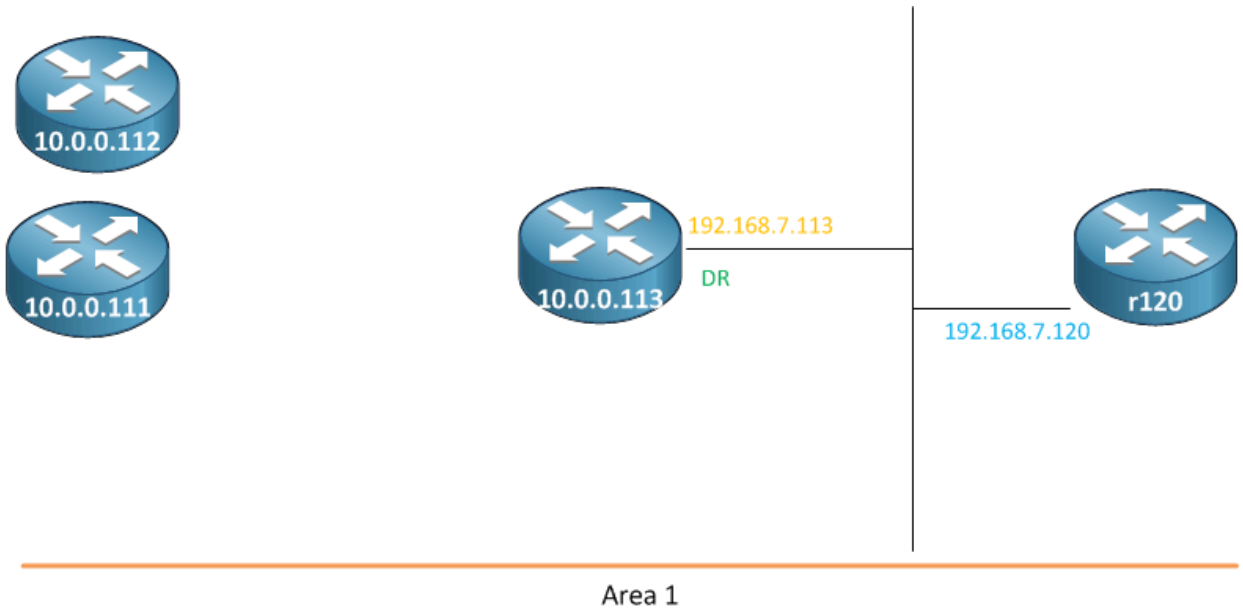
4.) The metric we are advertising is 10

We have an IP and a DR, but we don't know the subnet mask or which router in Area 1 owns the DR IP address. There is where the **Type 2** LSA comes in. Remember the Type 2 is generated by the DR for a segment, and represents that segment, so we look for the segment DR.

```
r120#show ip ospf data network 192.168.7.113

            OSPF Router with ID (10.0.0.120) (Process ID 1)

                Net Link States (Area 1)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 93

  Options: (No TOS-capability, DC)

  LS Type: Network Links

  Link State ID: 192.168.7.113 (address of Designated Router)

  Advertising Router: 10.0.0.113
```

```
      LS Seq Number: 80000004

      Checksum: 0xE2F8

      Length: 32

      Network Mask: /24

            Attached Router: 10.0.0.113

            Attached Router: 10.0.0.120
```

A lot of great information here. First, we see the advertising router, which is the Router ID of the DR. In this case it's 10.0.0.113. Now we know who **r120** is attached to. We also see the network mask (/24) and all of the routers on the segment. In this case only r120 and 10.0.0.113 are on the segment. If there were other routers on this segment we would see their Router IDs in the "Attached Router" list. So let's update the topology diagram.



Now we can look at the **Router LSA** of 10.0.0.113

```
   r120#show ip ospf data router 10.0.0.113

               OSPF Router with ID (10.0.0.120) (Process ID 1)

                   Router Link States (Area 1)

     Routing Bit Set on this LSA in topology Base with MTID 0

     LS age: 395

     Options: (No TOS-capability, DC)

     LS Type: Router Links

     Link State ID: 10.0.0.113

     Advertising Router: 10.0.0.113

     LS Seq Number: 80000256

     Checksum: 0x5465

     Length: 60

     AS Boundary Router

     Number of Links: 3

       Link connected to: a Stub Network

        (Link ID) Network/subnet number: 10.0.0.113

        (Link Data) Network Mask: 255.255.255.255

         Number of MTID metrics: 0

          TOS 0 Metrics: 1

       Link connected to: a Transit Network

        (Link ID) Designated Router address: 192.168.7.113
```

```
(Link Data) Router Interface address: 192.168.7.113

 Number of MTID metrics: 0

  TOS 0 Metrics: 10

Link connected to: a Transit Network

 (Link ID) Designated Router address: 192.168.1.112

 (Link Data) Router Interface address: 192.168.1.113

  Number of MTID metrics: 0

   TOS 0 Metrics: 10
```

Here we see three interfaces: 10.0.0.113, 192.168.7.113 and 192.168.1.113. We see that 10.0.0.113 is a "**Stub Network**". This does not have any relationship to a **Stub** ***Area,*** a "stub network" is simply an interface with no OSPF neighbors on it. We can also see that we are not the DR on the segment for 192.168.1.113. Let's take a look at the **Type 2** for that segment. Remember, the Type 2 is represented by the DR for that segment.

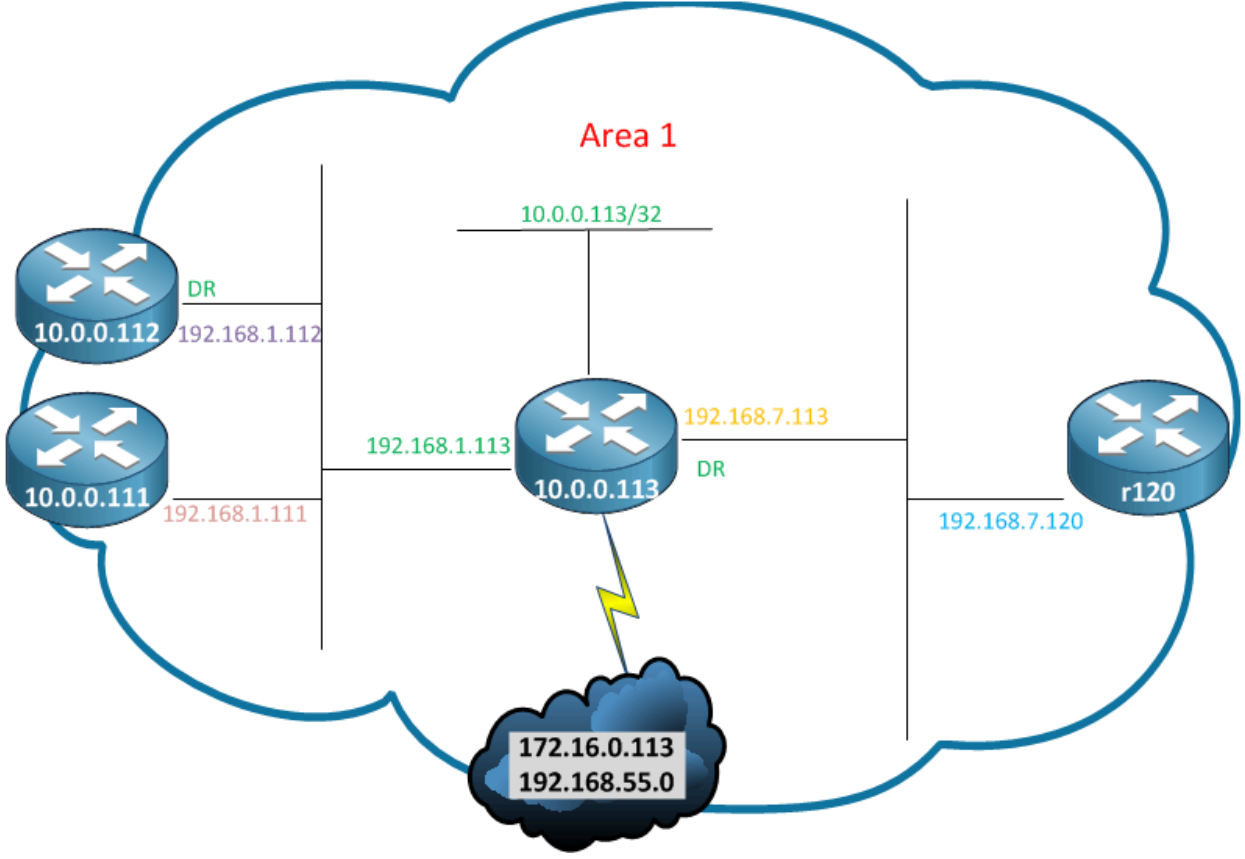
```
r120#show ip ospf data network 192.168.1.112

            OSPF Router with ID (10.0.0.120) (Process ID 1)

                Net Link States (Area 1)

Routing Bit Set on this LSA in topology Base with MTID 0

LS age: 161

Options: (No TOS-capability, DC)

LS Type: Network Links

Link State ID: 192.168.1.112 (address of Designated Router)

Advertising Router: 10.0.0.112

LS Seq Number: 80000261

Checksum: 0x848A

Length: 36

Network Mask: /24

      Attached Router: 10.0.0.112

      Attached Router: 10.0.0.111

      Attached Router: 10.0.0.113
```

We know that routers 10.0.0.112, 10.0.0.111 and 10.0.0.113 are all attached to this segment. Now we can look at the **Router LSAs** for routers 10.0.0.112 and 10.0.0.111. This will provide us with their interface IPs as well as any Stub Networks we haven't seen yet.

```
r120#show ip ospf data router 10.0.0.111

            OSPF Router with ID (10.0.0.120) (Process ID 1)

                Router Link States (Area 1)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 1004

  Options: (No TOS-capability, DC)

  LS Type: Router Links

  Link State ID: 10.0.0.111

  Advertising Router: 10.0.0.111

  LS Seq Number: 80000264
```

```
  Checksum: 0x3EDD

  Length: 36

  Area Border Router

  Number of Links: 1

    Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.1.112

     (Link Data) Router Interface address: 192.168.1.111

      Number of MTID metrics: 0

       TOS 0 Metrics: 10

r120#show ip ospf data router 10.0.0.112

            OSPF Router with ID (10.0.0.120) (Process ID 1)

                Router Link States (Area 1)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 1444

  Options: (No TOS-capability, DC)

  LS Type: Router Links

  Link State ID: 10.0.0.112

  Advertising Router: 10.0.0.112

  LS Seq Number: 8000025E

  Checksum: 0x48D6

  Length: 36

  Area Border Router

  Number of Links: 1

    Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.1.112

     (Link Data) Router Interface address: 192.168.1.112

      Number of MTID metrics: 0

       TOS 0 Metrics: 10
```

Now we know that the DR, 192.168.1.112, is router 10.0.0.112. We know that router 10.0.0.111 is also connected to the 192.168.1.0/24 segment with IP 192.168.1.111. We now know the entire topology for Area 1.



We know everything there is to know about Area 1. There is nothing to learn from router 10.0.0.113, since all of the links on that router are discovered. The next point to continue mapping the network would be on one of the ABRs. We will start with 10.0.0.112, or r112. Since r112 is an ABR it will have Type 1, 2, 3 and 4 information for both Area 1 and Area 0. We will want to focus on the Area 0 information. Let's get started by looking at our own Router LSA

```
     OSPF Router with ID (10.0.0.112) (Process ID 1)

               Router Link States (Area 0)

  LS age: 720

  Options: (No TOS-capability, DC)

  LS Type: Router Links

  Link State ID: 10.0.0.112

  Advertising Router: 10.0.0.112

  LS Seq Number: 80000262

  Checksum: 0x20FD

  Length: 36

  Area Border Router

  Number of Links: 1

    Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.0.111

     (Link Data) Router Interface address: 192.168.0.112

      Number of MTID metrics: 0

       TOS 0 Metrics: 10
```

Looks like we only have link 192.168.0.112 in this area, and we are not the DR on this segment. Now we take a look at the Type 2 LSA for this segment.

```
r112#show ip ospf data network 192.168.0.111

            OSPF Router with ID (10.0.0.112) (Process ID 1)

                Net Link States (Area 0)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 388

  Options: (No TOS-capability, DC)
```

```
    LS Type: Network Links

    Link State ID: 192.168.0.111 (address of Designated Router)

    Advertising Router: 10.0.0.111

    LS Seq Number: 80000261

    Checksum: 0x759F

    Length: 36

    Network Mask: /24

          Attached Router: 10.0.0.111

          Attached Router: 10.0.0.110

          Attached Router: 10.0.0.112
```

We see that the advertising router represents the Router ID of the DR, or 10.0.0.111, who we already know is the other ABR for Area 1. We also see that there is a third router on this segment with Router ID 10.0.0.110. Let's get the interface information from 10.0.0.111

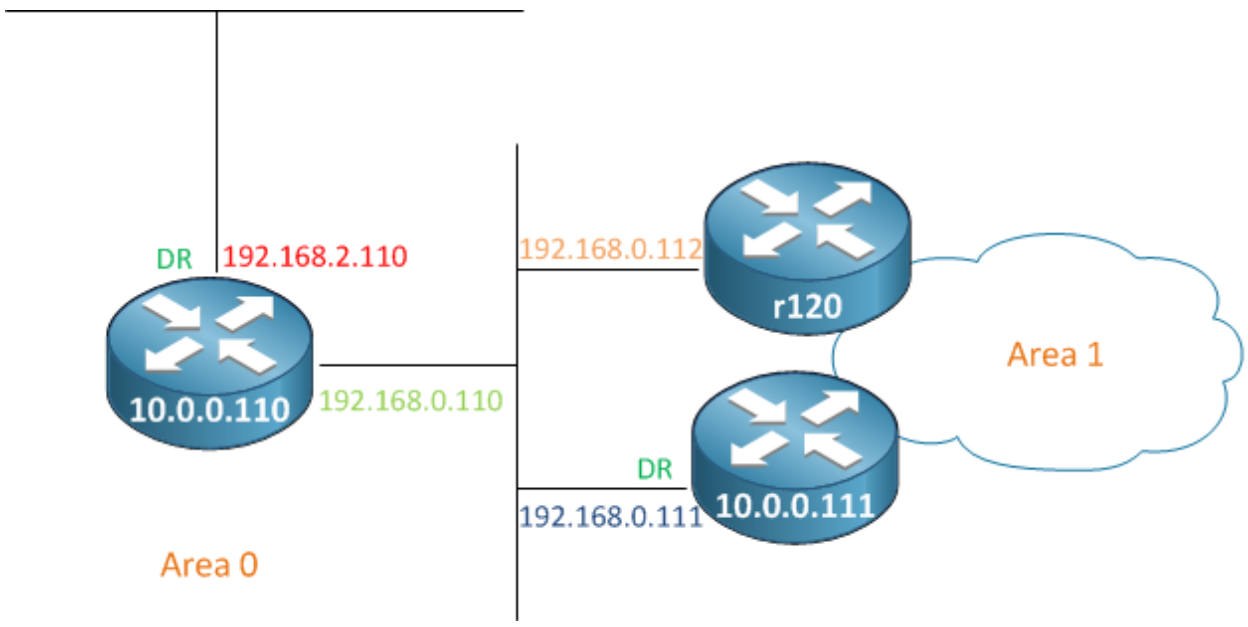
```
   r112#show ip ospf data router 10.0.0.111

               OSPF Router with ID (10.0.0.112) (Process ID 1)

                   Router Link States (Area 0)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 700

  Options: (No TOS-capability, DC)

  LS Type: Router Links

  Link State ID: 10.0.0.111

  Advertising Router: 10.0.0.111

  LS Seq Number: 80000268

  Checksum: 0x1605

  Length: 36

  Area Border Router

  Number of Links: 1

    Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.0.111

     (Link Data) Router Interface address: 192.168.0.111

      Number of MTID metrics: 0

       TOS 0 Metrics: 10
```

One interface here, with IP 192.168.0.111. This is the same segment as r112 and Router 10.0.0.110. Finally, let's look at 10.0.0.110

```
   r112#show ip ospf data router 10.0.0.110

               OSPF Router with ID (10.0.0.112) (Process ID 1)

                   Router Link States (Area 0)

     LS age: 1232

     Options: (No TOS-capability, DC)
```

```
LS Type: Router Links

Link State ID: 10.0.0.110

Advertising Router: 10.0.0.110

LS Seq Number: 80000263

Checksum: 0x4E09

Length: 48

Number of Links: 2

  Link connected to: a Transit Network

   (Link ID) Designated Router address: 192.168.0.111

   (Link Data) Router Interface address: 192.168.0.110

    Number of MTID metrics: 0

     TOS 0 Metrics: 10

  Link connected to: a Transit Network

   (Link ID) Designated Router address: 192.168.2.110

   (Link Data) Router Interface address: 192.168.2.110

    Number of MTID metrics: 0

     TOS 0 Metrics: 10
```

We see that 10.0.0.110 owns the IP 192.168.0.110. We also see a second interface, 192.168.2.110. On this second segment 10.0.0.110 is the DR. Let's up the topology diagram for Area 0:



Let's keep moving down. First, we look at the Type 2 from 192.168.2.110, then we'll look at the Type 1 LSAs from the other routers on this segment.

```
r112#show ip ospf data net 192.168.2.110

            OSPF Router with ID (10.0.0.112) (Process ID 1)

                Net Link States (Area 0)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 781

  Options: (No TOS-capability, DC)

  LS Type: Network Links

  Link State ID: 192.168.2.110 (address of Designated Router)

  Advertising Router: 10.0.0.110

  LS Seq Number: 80000261

  Checksum: 0x1779
```

```
    Length: 32

    Network Mask: /24

          Attached Router: 10.0.0.110

          Attached Router: 10.0.0.114
```

And now the Type 1 for 10.0.0.114

```
  r112#show ip ospf data router 10.0.0.114

              OSPF Router with ID (10.0.0.112) (Process ID 1)

                  Router Link States (Area 0)

    Routing Bit Set on this LSA in topology Base with MTID 0

    LS age: 889

    Options: (No TOS-capability, DC)

    LS Type: Router Links

    Link State ID: 10.0.0.114

    Advertising Router: 10.0.0.114

    LS Seq Number: 80000265

    Checksum: 0x1178

    Length: 48

    Area Border Router

    AS Boundary Router

    Number of Links: 2

      Link connected to: a Stub Network

       (Link ID) Network/subnet number: 192.168.3.0

       (Link Data) Network Mask: 255.255.255.0

        Number of MTID metrics: 0

         TOS 0 Metrics: 10

      Link connected to: a Transit Network

       (Link ID) Designated Router address: 192.168.2.110

       (Link Data) Router Interface address: 192.168.2.114

        Number of MTID metrics: 0

         TOS 0 Metrics: 10
```

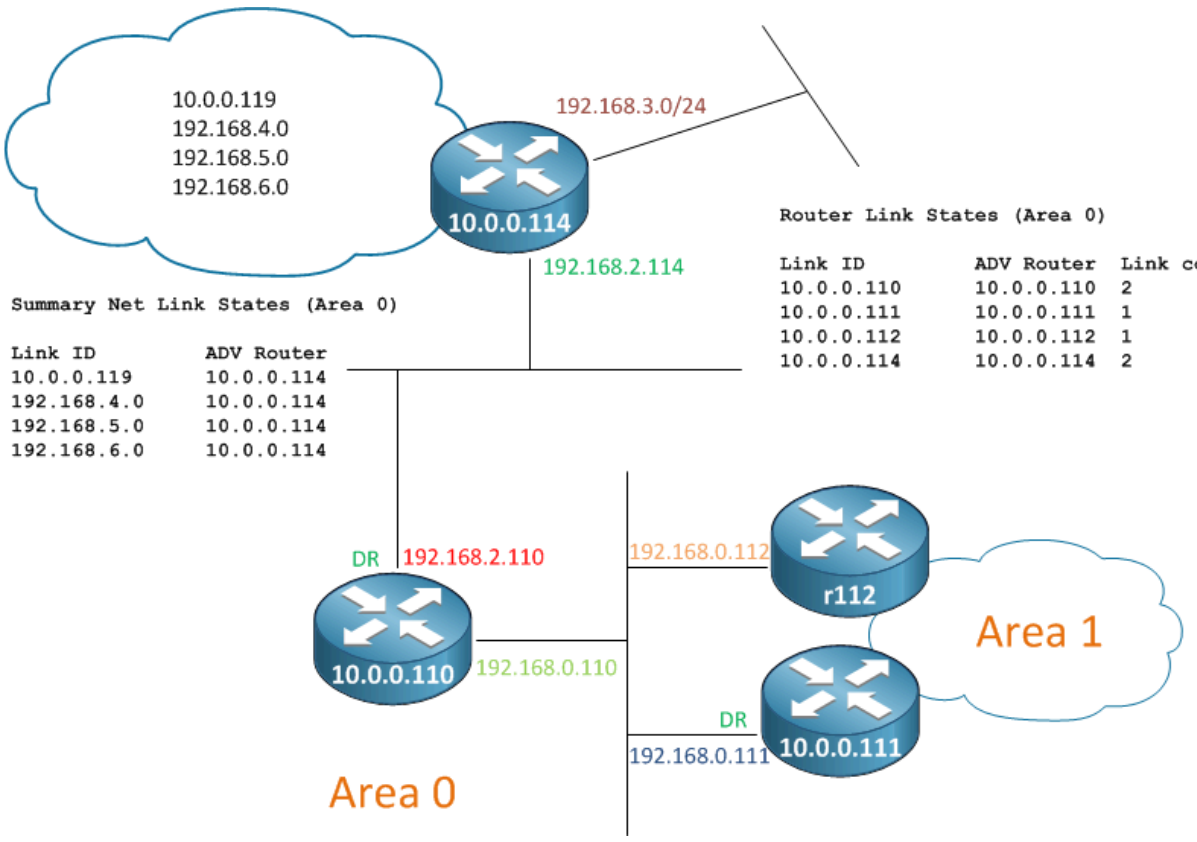
We have two links again, one connected to the segment with 10.0.0.110 and a new segment. Again, notice that the segment 192.168.3.0 is a *Stub Network*, so there are no other OSPF speakers on this link. Now, before we think we've finished up, we haven't looked at the **Type 3** LSAs that are generated by ABRs. We don't know if there is another ABR in Area 0, so let's look

```
                Summary Net Link States (Area 0)

  Link ID         ADV Router      Age         Seq#       Checksum

  10.0.0.113      10.0.0.111      397         0x80000264 0x004394

  10.0.0.113      10.0.0.112      17          0x80000264 0x003D99

  10.0.0.119      10.0.0.114      1276        0x80000258 0x00715F

  192.168.1.0     10.0.0.111      397         0x80000263 0x006F7B
```

```
192.168.1.0     10.0.0.112      792         0x80000262 0x006B7F
192.168.4.0     10.0.0.114      1036        0x80000261 0x0040A6
192.168.5.0     10.0.0.114      1036        0x80000261 0x0035B0
192.168.6.0     10.0.0.114      1036        0x80000260 0x00904B
192.168.7.0     10.0.0.111      397         0x80000265 0x008D4B
192.168.7.0     10.0.0.112      17          0x80000265 0x008750
```

Before addressing the new routes here, you can see the Type 3 LSAs in Area 0 that are generated by the two ABRs, 10.0.0.111 and 10.0.0.112. These routes here are all of the routes in Area 1, that we just described. This is how an ABR hides the details of an Area from the rest of the network.

We see four new networks all coming from the ABR 10.0.0.114. Now we can update our topology diagram of Area 0.



Again, we need to jump to our ABR to see what's going on in the rest of the network.

On **r114** things get interesting. Looking at the LSAs we see that **r114** is in 3 areas.

```
r114# show ip ospf data | i States
                Router Link States (Area 0)
                Net Link States (Area 0)
                Summary Net Link States (Area 0)
                Summary ASB Link States (Area 0)
                Router Link States (Area 2)
                Net Link States (Area 2)
                Summary Net Link States (Area 2)
                Router Link States (Area 3)
                Net Link States (Area 3)
                Summary Net Link States (Area 3)
                Type-7 AS External Link States (Area 3)
                Type-5 AS External Link States
```

But things look a little fishy in Area 2 and Area 3. Notice that Area 2 has no "Summary ASB Link States" (Type 4). Also notice that Area 3 has "Type-7 AS External Link States".

Let's start with Area 2.

If we are in an area that does not have any Type 4 LSAs, that area can not have external routes. OSPF works by linking the information carried in a Type-4 LSA to the information carried in the Type-5 LSA to build a tree. OSPF Stub areas do not allow any external information, matching this description. We can assume that Area 2 is a **Stub Area**.

Again, let's get a lay of the land by looking at the Router LSA summaries.

```
                Router Link States (Area 2)

   Link ID         ADV Router      Age         Seq#       Checksum Link count

   10.0.0.114      10.0.0.114      23          0x8000026C 0x00B250 1

   10.0.0.115      10.0.0.115      1584        0x80000269 0x00B350 1

   10.0.0.116      10.0.0.116      745         0x8000026E 0x00F225 2

   10.0.0.119      10.0.0.119      706         0x8000026B 0x0074E7 2
```

We can see there are four routers in the area. 10.0.0.116 and 10.0.0.119 both have two links.

Now let's look at our Router LSA

```
   r114#show ip ospf data router 10.0.0.114



      Router Link States (Area 2)

LS age: 1234

Options: (No TOS-capability, DC)

LS Type: Router Links

Link State ID: 10.0.0.114

Advertising Router: 10.0.0.114

LS Seq Number: 80000265

Checksum: 0xC049

Length: 36

Area Border Router

Number of Links: 1

  Link connected to: a Transit Network

   (Link ID) Designated Router address: 192.168.5.114

   (Link Data) Router Interface address: 192.168.5.114

    Number of MTID metrics: 0

     TOS 0 Metrics: 10
```

Now the Type-2, Network LSA

```
   r114#show ip ospf data net 192.168.5.114

            OSPF Router with ID (10.0.0.114) (Process ID 1)

                Net Link States (Area 2)

     Routing Bit Set on this LSA in topology Base with MTID 0

     LS age: 1312

     Options: (No TOS-capability, DC)

     LS Type: Network Links

     Link State ID: 192.168.5.114 (address of Designated Router)

     Advertising Router: 10.0.0.114
```

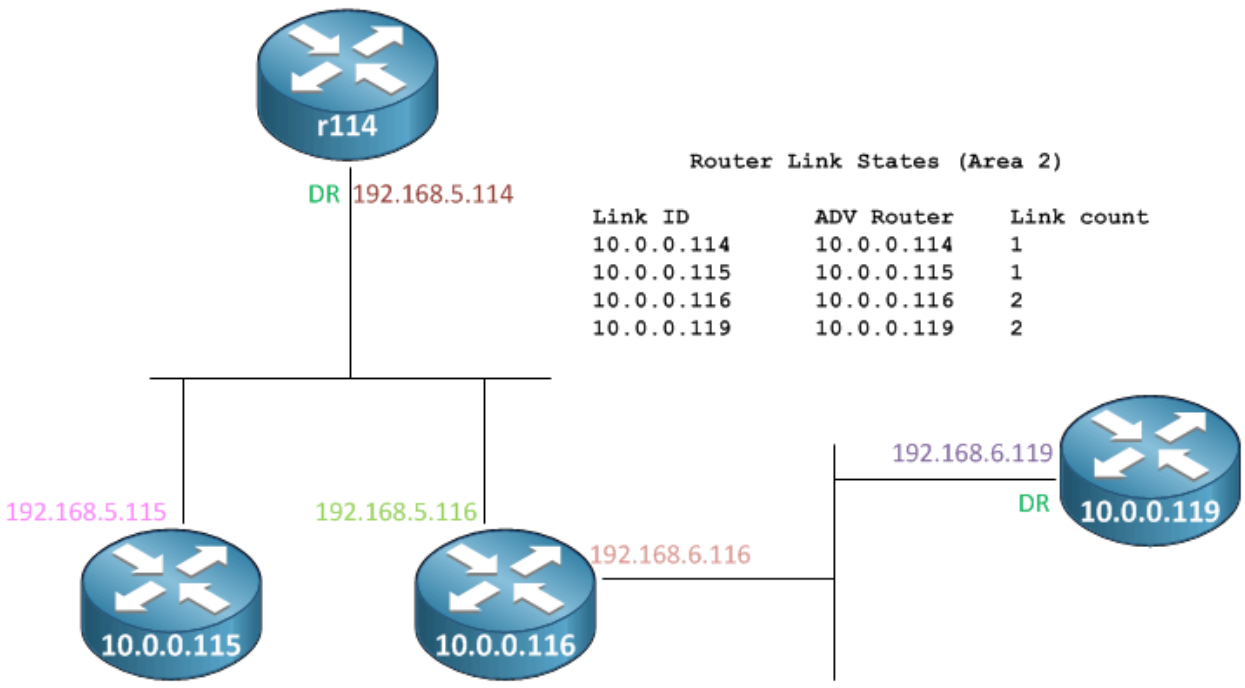
```
    LS Seq Number: 80000263

    Checksum: 0xD429

    Length: 36

    Network Mask: /24

          Attached Router: 10.0.0.114

          Attached Router: 10.0.0.115

          Attached Router: 10.0.0.116
```

Next, the Router LSA (Type-1) of our **Attached Routers**

```
  r114#show ip ospf data router 10.0.0.115

             OSPF Router with ID (10.0.0.114) (Process ID 1)

                 Router Link States (Area 2)

    LS age: 1000

    Options: (No TOS-capability, DC)

    LS Type: Router Links

    Link State ID: 10.0.0.115

    Advertising Router: 10.0.0.115

    LS Seq Number: 80000263

    Checksum: 0xBF4A

    Length: 36

    Number of Links: 1

      Link connected to: a Transit Network

       (Link ID) Designated Router address: 192.168.5.114

       (Link Data) Router Interface address: 192.168.5.115

        Number of MTID metrics: 0

         TOS 0 Metrics: 10

r114#show ip ospf data router 10.0.0.116

           OSPF Router with ID (10.0.0.114) (Process ID 1)

               Router Link States (Area 2)

LS age: 269

Options: (No TOS-capability, DC)

LS Type: Router Links

Link State ID: 10.0.0.116

Advertising Router: 10.0.0.116

LS Seq Number: 80000268

Checksum: 0xFE1F

Length: 48

Number of Links: 2

  Link connected to: a Transit Network

   (Link ID) Designated Router address: 192.168.5.114
```

```
    (Link Data) Router Interface address: 192.168.5.116

     Number of MTID metrics: 0

     TOS 0 Metrics: 10

  Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.6.119

     (Link Data) Router Interface address: 192.168.6.116

      Number of MTID metrics: 0

       TOS 0 Metrics: 10
```

Let's digest this here. First 10.0.0.115 has a single interface with IP 192.168.5.115. Next we see 10.0.0.116 with two interfaces, 192.168.5.116 and 192.168.6.116. Let's update the topology and then take a look at the segment with DR 192.168.6.119. This must be the router 10.0.0.119, the only router in Area 2 we haven't looked at yet.

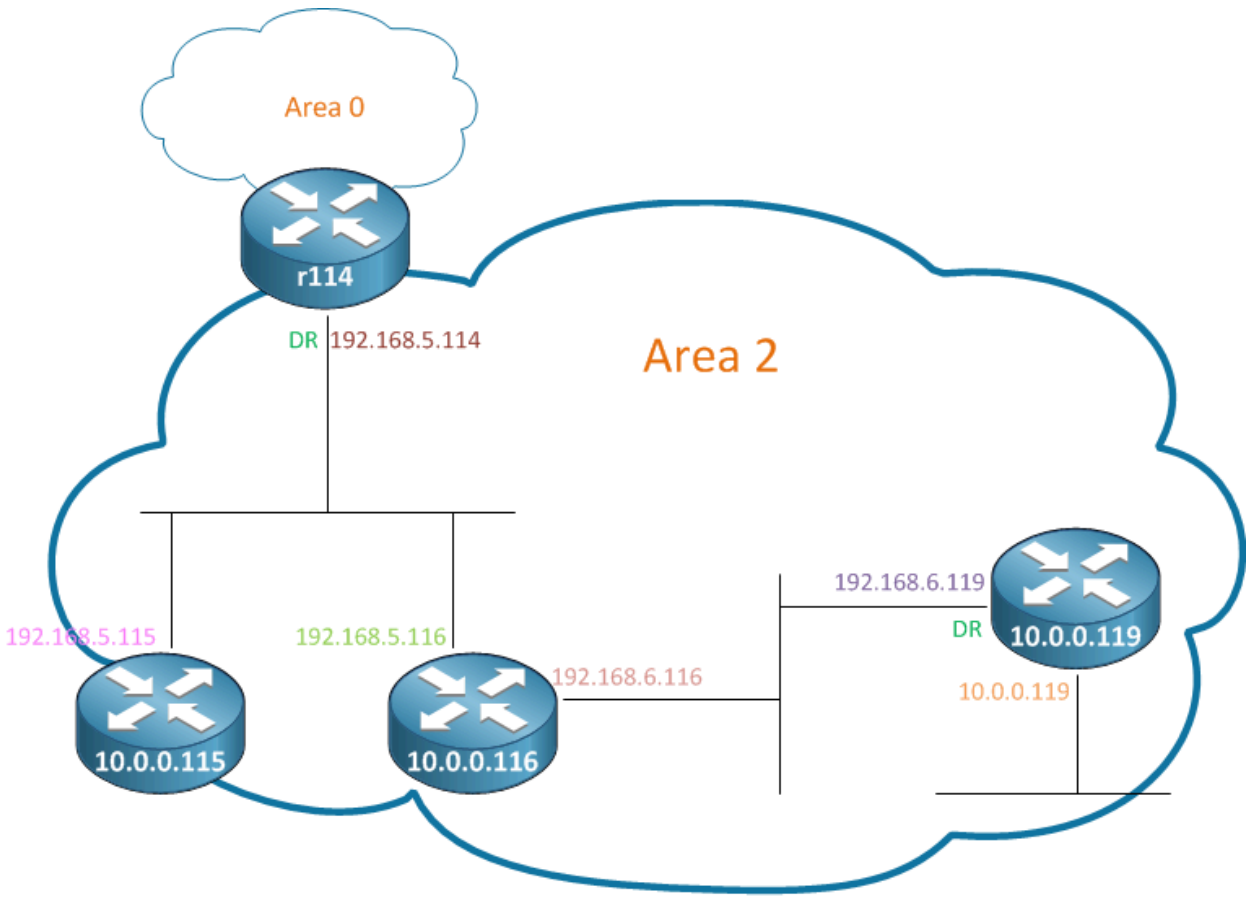


Remember that routers 10.0.0.116 and 10.0.0.119 both had two links. We have discovered the two links on 10.0.0.116, but we still have one link on 10.0.0.119 to find, so let's look at the Type-1 for 10.0.0.119

```
r114#show ip ospf data router 10.0.0.119

            OSPF Router with ID (10.0.0.114) (Process ID 1)

                Router Link States (Area 2)

  LS age: 1272

  Options: (No TOS-capability, DC)

  LS Type: Router Links

  Link State ID: 10.0.0.119

  Advertising Router: 10.0.0.119

  LS Seq Number: 8000026B

  Checksum: 0x74E7

  Length: 48

  Number of Links: 2

    Link connected to: a Stub Network

     (Link ID) Network/subnet number: 10.0.0.119

     (Link Data) Network Mask: 255.255.255.255

      Number of MTID metrics: 0

       TOS 0 Metrics: 1

    Link connected to: a Transit Network
```

```
(Link ID) Designated Router address: 192.168.6.119

(Link Data) Router Interface address: 192.168.6.119

 Number of MTID metrics: 0

  TOS 0 Metrics: 10
```

Now we have discovered all of the links in Area 2. Because Area 2 still receives Type-3 LSAs, it will know about all of the links in the OSPF network. The only thing it will not have will be the external routes that are injected into OSPF.



Remember that r114 was in three Areas: Area 0, Areas 2 and Area 3. Before digging into Area 3, let's take another look at the LSAs that exist in Area 3.

```
r114#show ip ospf data | i Area 3

                Router Link States (Area 3)

                Net Link States (Area 3)

                Summary Net Link States (Area 3)

                Type-7 AS External Link States (Area 3)
```

We see Type 1 (`Router Link States`), Type 2 (`Net Link State`), Type 3 (`Summary Net Link`) and Type 7 (`Type-7 AS External`). Similar to Area 2, we do not see Type 4 or Type 5 LSAs. However we see Type-7 LSAs, which only exist in **Not So Stubby Areas** (NSSA). In a normal Stub area external route information is not allowed. NSSA areas allow us to have all of the features of a Stub area (no externals from other parts of the network) while still allowing external information to be originated in this area. To accomplish this, NSSA areas do not allow Type-5 (normal external LSAs) and use a special Type-7 LSAs. When the Type-7 arrives on the ABR (**r114** in this case), the ABR must convert this Type-7 to a Type-5 for the rest of the network. We'll take a look at this process in a little while.

First, let's see how many routers and links are in Area 3

```
                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count

10.0.0.114      10.0.0.114      1610        0x80000335 0x00B37A 1

10.0.0.117      10.0.0.117      1344        0x80000333 0x00A881 1

10.0.0.118      10.0.0.118      802         0x80000332 0x00AE77 1
```

We have 3 routers, each with 1 link. Now, as always, take a look at our Type-1

```
r114#show ip ospf data router 10.0.0.114

                Router Link States (Area 3)

  LS age: 723
```

```
Options: (No TOS-capability, DC)

LS Type: Router Links

Link State ID: 10.0.0.114

Advertising Router: 10.0.0.114

LS Seq Number: 80000334

Checksum: 0xB579

Length: 36

Area Border Router

AS Boundary Router

Number of Links: 1

  Link connected to: a Transit Network

   (Link ID) Designated Router address: 192.168.4.117

   (Link Data) Router Interface address: 192.168.4.114

    Number of MTID metrics: 0

     TOS 0 Metrics: 10
```

A single link with IP 192.168.4.114 and DR 192.168.4.117. Now the Type-2

```
r114#show ip ospf data net 192.168.4.117

            OSPF Router with ID (10.0.0.114) (Process ID 1)

                Net Link States (Area 3)

  Routing Bit Set on this LSA in topology Base with MTID 0

  LS age: 635

  Options: (No TOS-capability, DC)

  LS Type: Network Links

  Link State ID: 192.168.4.117 (address of Designated Router)

  Advertising Router: 10.0.0.117

  LS Seq Number: 80000330

  Checksum: 0xCE50

  Length: 36

  Network Mask: /24

        Attached Router: 10.0.0.117

        Attached Router: 10.0.0.114

        Attached Router: 10.0.0.118
```

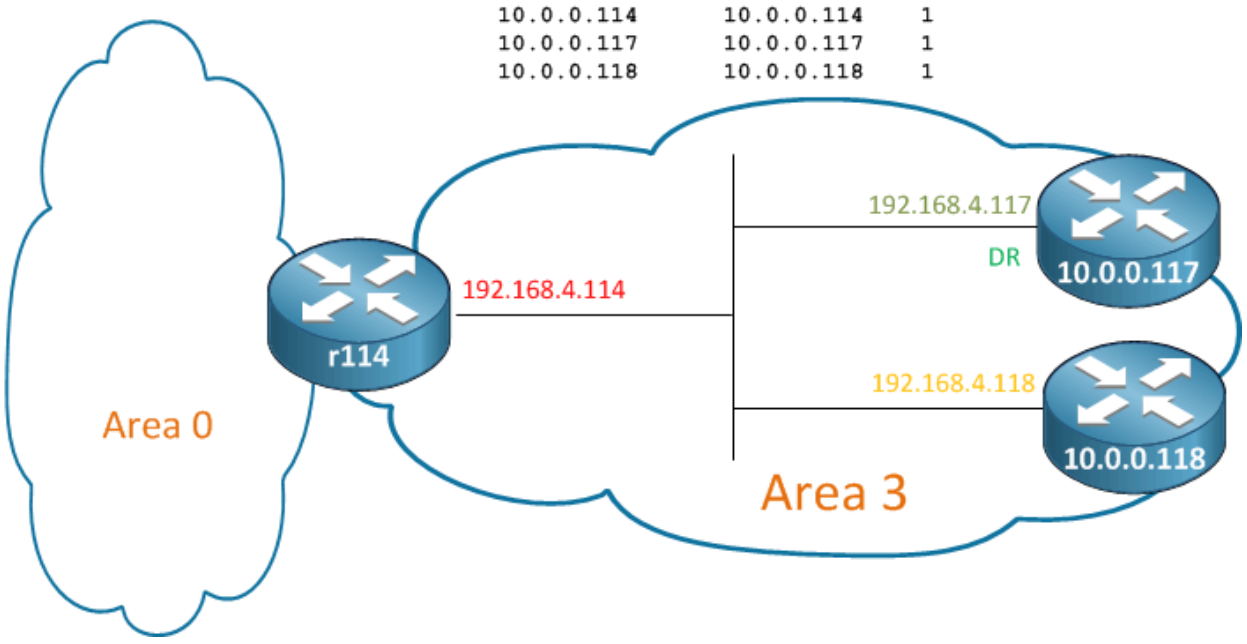
Here are three routers attached to this segment. **r114**, the DR and a third router. Now the Type-1 LSAs for the other routers.

```
r114#show ip ospf data router 10.0.0.117

           OSPF Router with ID (10.0.0.114) (Process ID 1)

               Router Link States (Area 3)

  LS age: 794

  Options: (No TOS-capability, DC)

  LS Type: Router Links
```

```
  Link State ID: 10.0.0.117

  Advertising Router: 10.0.0.117

  LS Seq Number: 80000333

  Checksum: 0xA881

  Length: 36

  Number of Links: 1

    Link connected to: a Transit Network

     (Link ID) Designated Router address: 192.168.4.117

     (Link Data) Router Interface address: 192.168.4.117

      Number of MTID metrics: 0

       TOS 0 Metrics: 10

r114#show ip ospf data router 10.0.0.118

            OSPF Router with ID (10.0.0.114) (Process ID 1)

                Router Link States (Area 3)

Routing Bit Set on this LSA in topology Base with MTID 0

LS age: 257

Options: (No TOS-capability, DC)

LS Type: Router Links

Link State ID: 10.0.0.118

Advertising Router: 10.0.0.118

LS Seq Number: 80000332

Checksum: 0xAE77

Length: 36

AS Boundary Router

Number of Links: 1

  Link connected to: a Transit Network

         (Link ID) Designated Router address: 192.168.4.117

         (Link Data) Router Interface address: 192.168.4.118

          Number of MTID metrics: 0

           TOS 0 Metrics: 10
```

We see IPs 192.168.4.118 and 192.168.4.117. Here's the topology for Area 3.

```
                Router Link States (Area 3)

Link ID         ADV Router      Link count
10.0.0.114      10.0.0.114      1
10.0.0.117      10.0.0.117      1
10.0.0.118      10.0.0.118      1
```



But let's not forget about the Type-7 LSAs we saw earlier. Because these are Type-7, we are not looking at *external* LSAs but *nssa-external* LSAs

```
r114#show ip ospf data nssa-external

            OSPF Router with ID (10.0.0.114) (Process ID 1)

                Type-7 AS External Link States (Area 3)

Routing Bit Set on this LSA in topology Base with MTID 0

LS age: 952

Options: (No TOS-capability, Type 7/5 translation, DC)

LS Type: AS External Link

Link State ID: 172.16.0.118 (External Network Number )

Advertising Router: 10.0.0.118

LS Seq Number: 800000FF

Checksum: 0xEC13

Length: 36

Network Mask: /32

      Metric Type: 2 (Larger than any link state path)

      MTID: 0

      Metric: 20

      Forward Address: 192.168.4.118

      External Route Tag: 0
```

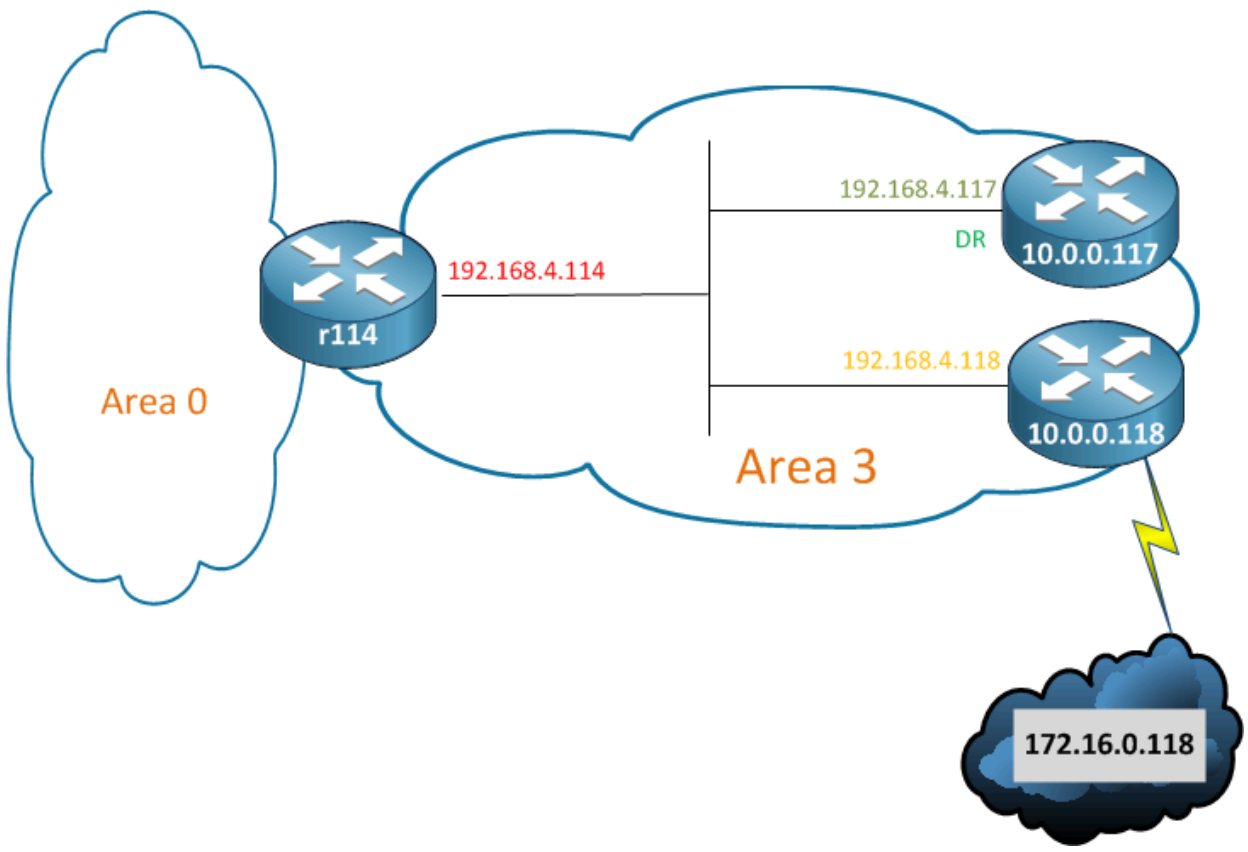
This is the LSA representing the external network 172.16.0.118/32. Within this area the routers should send traffic for this destination to the Forwarding Address of 192.168.4.118. Once the LSA arrives on the ABR, r114, it will be converted into a Type-5 LSA and sent to all other areas (that aren't stubs, meaning that Area 2 will not see this LSA). We can confirm this by looking at the Type-5 LSAs

```
r114#show ip ospf data external 172.16.0.118

            OSPF Router with ID (10.0.0.114) (Process ID 1)

                Type-5 AS External Link States

  LS age: 146

  Options: (No TOS-capability, DC)

  LS Type: AS External Link

  Link State ID: 172.16.0.118 (External Network Number )

  Advertising Router: 10.0.0.114
```

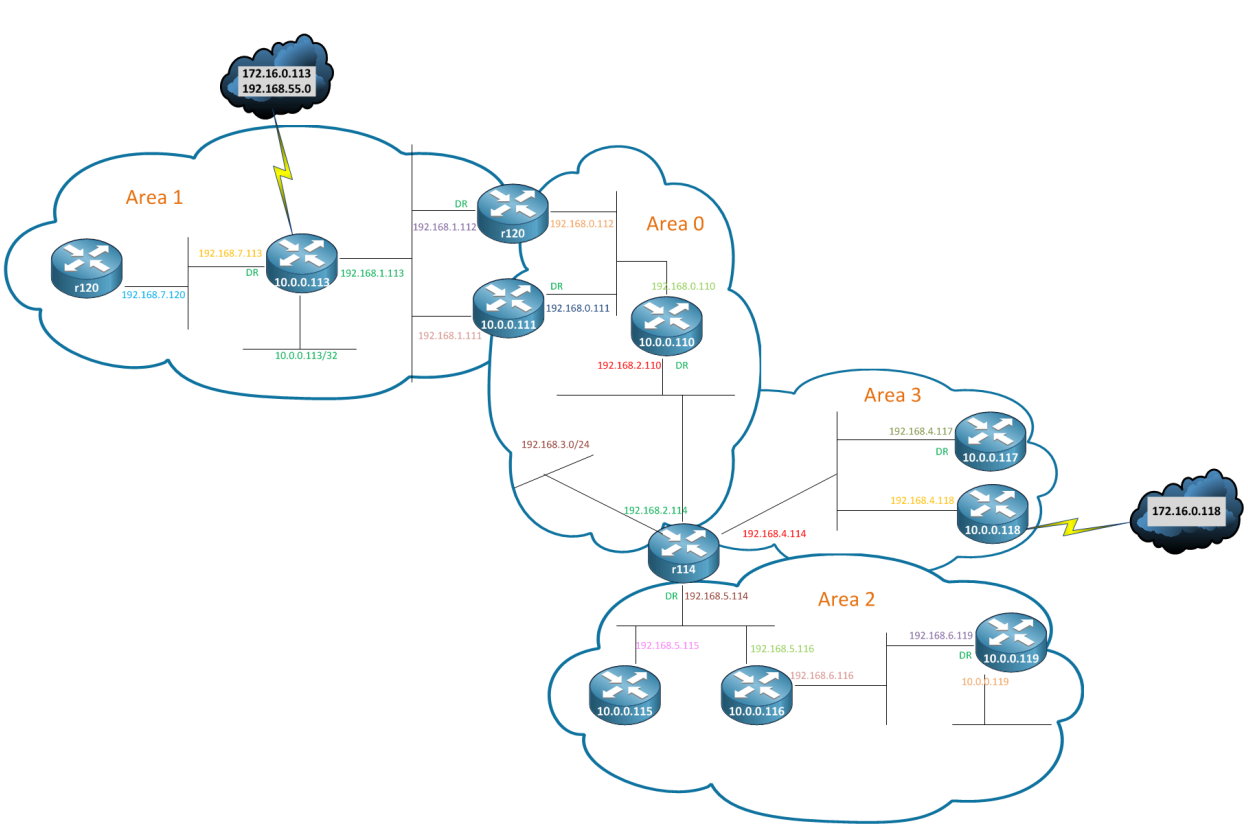
```
LS Seq Number: 80000101

Checksum: 0x9477

Length: 36

Network Mask: /32

      Metric Type: 2 (Larger than any link state path)

      MTID: 0

      Metric: 20

      Forward Address: 192.168.4.118

      External Route Tag: 0
```

Here we see the Type-5 originated not by 10.0.0.118, like the Type-7, but by 10.0.0.114. This is due to the Type-7 to Type-5 conversion. Since **r114** is generating a new LSA it sets itself as the Advertising Router. You'll also notice that the *Forwarding Address* has remained the same. When other routers in the network build the tree to reach this external destination they will build to the best ABR to reach this network (since it would be part of a Type-3 LSA). For more information on Forwarding Addresses, there is a **great doc** on Cisco.com.

With all of this information we can finish the topology for Area 3



and then for the entire OSPF network.



Summary

Hopefully reading the OSPF topology is a little more clear now. The less obvious takeaways are how OSPF scales by hiding topology information. You noticed that in an area we have a large number of Type 1 and Type 2 LSAs. Outside of that area there is only a single Type-3 LSA generated by each ABR. We can also use **Stub Areas** to hide external information, keeping even less information in the LSDB of the routers in those areas.

Finally, think about how each LSA type links together. OSPF's SPF algorithm links different pieces of information together. For a router in Area 1 to reach the external route in Area 3, it has to look at the Type-5 that represents the external route. Then it has to look at the Type-4 representing the ABR on the area that the ASBR lives in. Then we have to look at the Type-3 to get to that remote ABR. Finally we look at the Type-1 and Type-2 LSAs in our area to determine how to get to our closest ABR.

Each LSA serves a specific purpose and they all fit together to supply end-to-end connectivity.

Routing Protocols

ccie igp ospf route routing