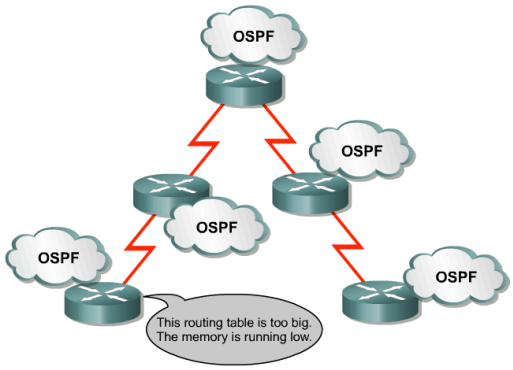
The Network Layer

Routing Algorithms

Open Shortest Path First

- OSPF
  - Replacement for the distance vector routing protocol RIP
  - OSPF is a classless routing protocol that uses the concept of areas for scalability
  - RFC 2328 defines the OSPF metric as an arbitrary value called cost.
    - Cisco IOS uses bandwidth as the OSPF cost metric.
  - Fast convergence

Open Shortest Path First

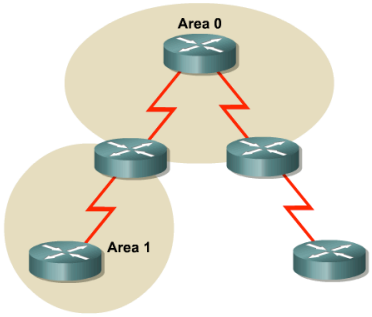


Three issues can overwhelm an OSPF router in a heavily populated OSPF network:

1. ***High demand for router processing and memory resources***
2. ***Large routing tables***
3. ***Large topology tables***

Field studies have shown that a single OSPF area should not stretch beyond 50 routers, although there is no set limit

Open Shortest Path First



The hierarchical topology possibilities of OSPF have the following important advantages:

1.Reduced frequency of SPF calculations
2.Smaller routing tables
3.Reduced link-state update (LSU) overhead

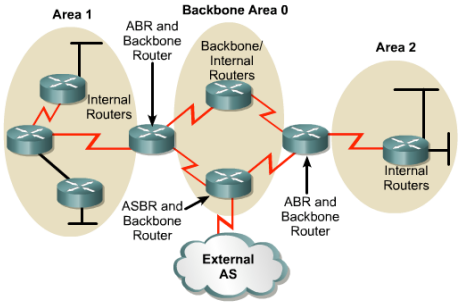
Hierarchical routing increases routing efficiency controlling the type of routing information that flows into and out of an area

OSPF Multi-area Components

Internal router – Routers that have all their interfaces within the same area.

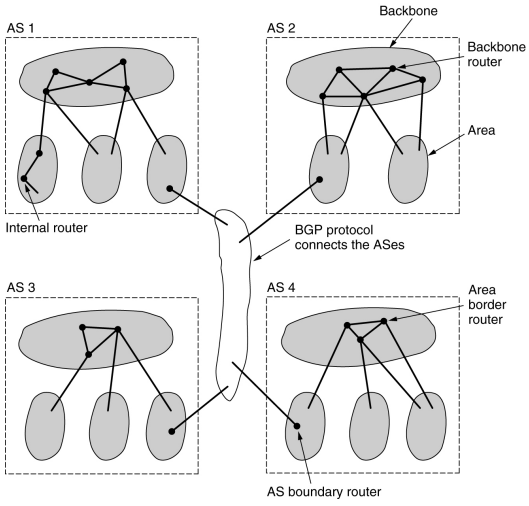
Backbone router – Routers that are attached to the backbone area of the OSPF network .

Area Border Router (ABR) – ABRs are routers with interfaces attached to multiple areas. They maintain separate link-state databases for each area to which they are connected. ABRs summarize information about the attached areas and distribute the information into the backbone. The backbone ABRs then forward the information to all other connected areas. An area can have one or more ABRs.



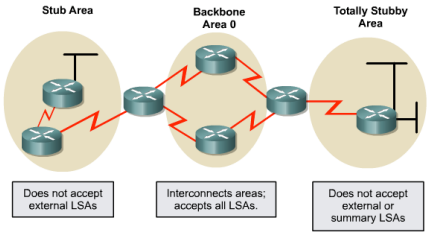
Autonomous System Boundary Router (ASBR) – ASBRs are routers that have at least one interface connected to an external internetwork, another autonomous system, such as a non-OSPF network. These routers can import non-OSPF network information to the OSPF network, and OSPF to non-OSPF. This is referred to as redistribution.

OSPF Multi-area Components



The relation between ASes, backbones, and areas in OSPF.

OSPF Area Types



Standard area – A standard area can accept link updates and route summaries.
Backbone area (transit area) – The central entity to which all other areas connect. The backbone area is always Area 0. All other areas must connect to this area to exchange route information.
Stub area – A stub area is an area that does not accept information about routes external to the autonomous system.
Totally stubby area – A totally stubby area does not accept external autonomous system (AS) routes and summary routes from other areas internal to the autonomous system. Totally stubby areas are a Cisco proprietary feature.
Not-so-stubby area (NSSA) – An NSSA is an area that is similar to a stub area but allows for importing external routes as Type 7 LSAs and translation of specific Type 7 LSA routes into Type 5 LSAs (more on this later…)

OSPF LSA Types

LSA Type	Name	Description
1	Router link entry (O-OSPF)	Generated by each router for each area it belongs to. It describes the states of the link from the router to the area. These are flooded only within a particular area. The link status and cost are two of the descriptors provided. Routes learned by way of Type 1 LSAs are denoted by an O in the routing table.
2	Network link entry (O-OSPF)	Generated by the designated router in multiaccess networks. A Type 2 LSA describes the set of routers attached to a particular network. Type 2 LSAs are flooded only within the area that contains the network. Routes learned by way of Type 2 LSAs are denoted by an O in the routing table.
3	Summary link entry (IA-OSPF)	Originated by ABRs. A Type 3 LSA describes the links between the ABR and the internal routers of a local area. These entries are flooded throughout the back-bone area to the outer ABRs. Type 3 LSAs describe routes to networks within the local area and are sent to the backbone area. Routes learned by way of Type 3 LSAs are denoted by an O in the routing table.

OSPF LSA Types

LSA Type	Name	Description
4	Summary link entry (IA-OSPF)	Originated by ABRs. Types 4 LSAs are flooded throughout the backbone area to the other ABRs. Type 4 LSAs describe reachability to ASBRs. These link entries are not flooded through totally stubby areas. Routes learned by way of Type 4 LSAs are denoted by an IA in the routing table.
5	Autonomous system external link entry (E1-OSPF external Type 1; E2-OSPF external Type 2)	Originated by ASBR. A Type 5 LSA describe routes to destinations external to the autonomous system. These are flooded throughout an OSPF autonomous system except for stub and totally stubby areas. Routes learned by way of Type 5 LSAs are denoted by either an E1 or E2 in the routing table.
6	Multicast OSPF (MOSPF)	Not implemented by Cisco. MOSPF enhances OSPF by letting routers use their link-state databases to build multicast distributions trees for the forwarding of multicast traffic.
7	Autonomous system external link entry (N1-OSPF NSSA external Type 1; N2-OSPF external Type 2)	Originated by an ASBR connected to an NSSA. Type 7 messages can be flooded throughout NSSAs and translated into LSA Type 5 messages by ABRs. Routes learned by way of Type 7 LSAs are denoted by either an N1 or a N2 in the routing table.

Path Calculation Order

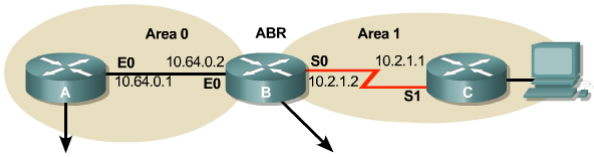
- Intra-area routes
- Interarea routes
- External destinations

The order in which paths are calculated is as follows:

1. All routers first calculate the paths to destinations within their area and add these entries into the routing table. These are learned by way of Type 1 and Type 2 LSAs.
2. All routers then calculate the paths to the other areas within the internetwork. These paths are learned by way of inter-area route entries, or Type 3 and Type 4 LSAs. If a router has an inter-area route to a destination and an intra-area route to the same destination, the intra-area route is kept.
3. All routers, except those that are in any of the stub area types, then calculate the paths to the AS external, Type 5, destinations.

At this point, a router can reach any network within or outside the OSPF autonomous system.

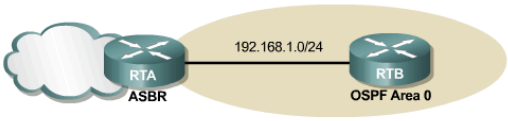
Configuring OSPF ABRs



Interface Ethernet0
Ip add 10.64.0.1 255.255.255.0
!
…
Router ospf 77
Network 10.64.0.0 0.0.0.255 area 0

Interface Ethernet0
Ip add 10.64.0.2 255.255.255.0
!
…
Interface Serial0
Ip add 10.2.1.2 255.255.255.0
!
…
Router ospf 50
Network 10.64.0.0 0.0.0.255 area 0
Network 10.2.1.0 0.0.0.255 area 1

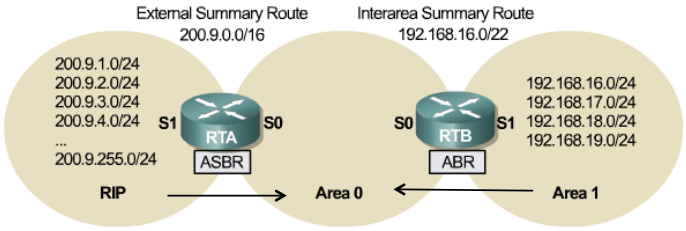
Configuring OSPF ASBR




```
RTA(config)#router rip
RTA(config-router)#network 10.0.0.0
RTA(config-router)#exit
RTA(config)#router ospf 1
RTA(config-router)#network 192.168.1.0 0.0.0.255 area 0
RTA(config-router)#redistribute rip
RTA(config-router)#^z

RTA#show ip ospf
Routing Process "ospf 1" with ID 192.168.1.2
Supports only single TOS(TOS0) routes
It is an autonomous system boundary router (ASBR)
redistributing external routes from rip, including
subnets in redistribution.
<output omitted>
```

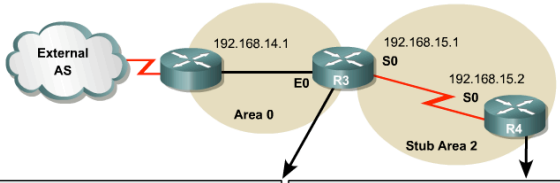
OSPF Route Summarization




```
RTA(config)#router ospf 1
RTA(config-router)#summary-address
200.9.0.0 255.255.0.0
```

```
RTB(config)#router ospf 1
RTB(config-router)#area 1 range
192.168.16.0 255.255.252.0
```

Configuring a Stub Area




```
R3#

interface Ethernet 0
ip address 192.168.14.1 255.255.255.0
interface Serial 0
ip address 192.168.15.1 255.255.255.0

router ospf 100
network 192.168.14.0 0.0.0.255 area 0
network 192.168.15.0 0.0.0.255 area 2
area 2 stub
```

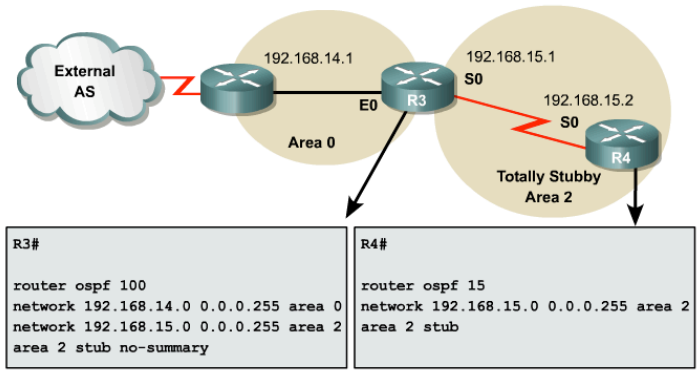
```
R4#

interface Serial 0
ip address 192.168.15.2 255.255.255.0

router ospf 15
network 192.168.15.0 0.0.0.255 area 2
area 2 stub
```

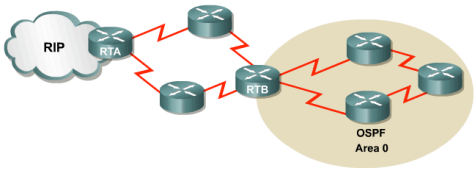
A stub or totally stubby area typically has a single exit point out of the area.
An ASBR cannot be internal to a stub area
Area is not the backbone Area 0.

Configuring a Totally Stubby Area

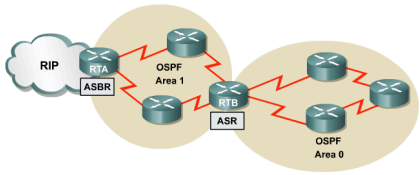


A totally stubby area is one that blocks external routes and summary routes (inter-area routes) from going into the area (Type 4 and 5 LSAs). This way, intra-area routes and the default of 0.0.0.0 are the only routes injected into that area.

Configuring NSSA areas

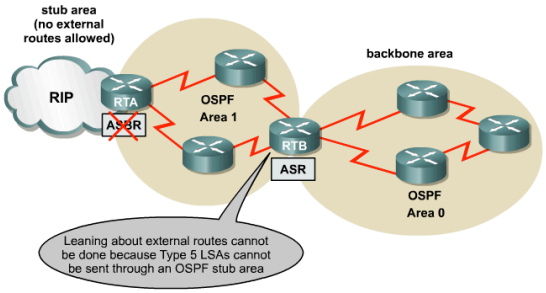


RIP routes should be redistributed in OSPF



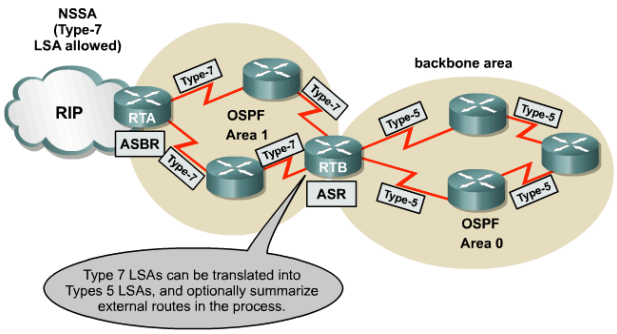
Ideal Solution!

Configuring NSSA areas



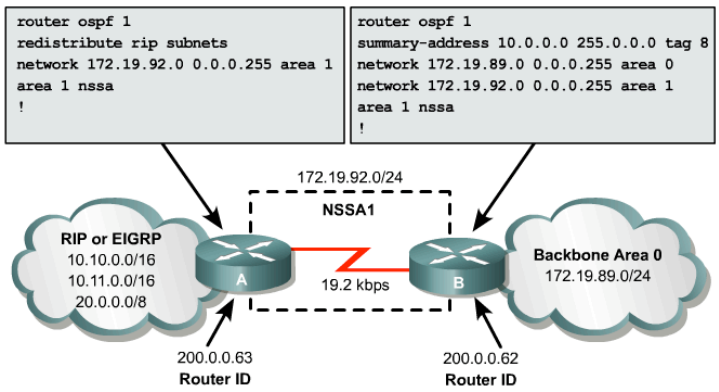
What if the routers in Area 1 cannot handle the load of a standard area?
Configure the area as Stub or Totally Stubby.
But no ASBR allowed!

Configuring NSSA areas

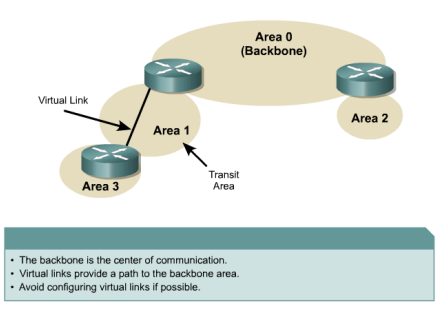


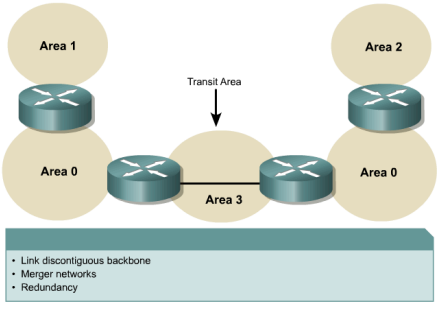
With a NSSA Type-7 LSAs are flooded through the area
RTB translate them into Type-5 LSAs

Configuring NSSA areas



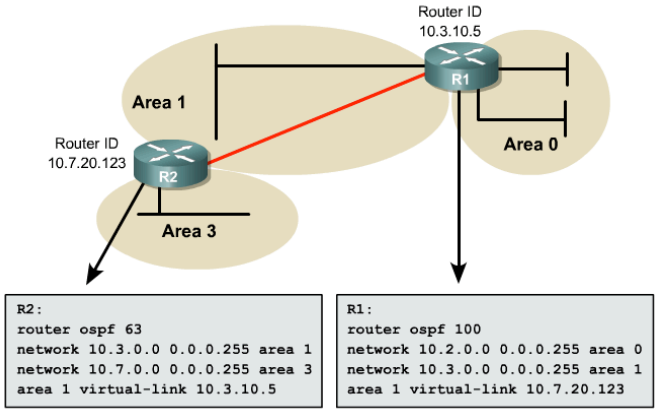
Meeting the Backbone Area Requirements





There are situations when a new area is added after the OSPF internetwork has been designed, and it is not possible to provide that new area with direct access to the backbone.
In these cases, a **virtual link** can be defined to provide the needed connectivity to the backbone area

Meeting the Backbone Area Requirements




```
R2:
router ospf 63
network 10.3.0.0 0.0.0.255 area 1
network 10.7.0.0 0.0.0.255 area 3
area 1 virtual-link 10.3.10.5
```

```
R1:
router ospf 100
network 10.2.0.0 0.0.0.255 area 0
network 10.3.0.0 0.0.0.255 area 1
area 1 virtual-link 10.7.20.123
```

OSPF multi-area

Command	Description
`show ip ospf border-routers`	Displays the internal OSPF routing table entries to an ABR.
`show ip ospf virtual-links`	Displays parameters about the current state of OSPF virtual links.
`show ip ospf process-id`	Displays information about each area to which the router is connected, and indicates whether the router is an ABR, an ASBR, or both. The process ID is a user-defined identification parameter. It is locally assigned and can be any positive integer number. The number used here is the number assigned administratively when enabling the OSPF routing process.
`show ip ospf database`	Displays the link-state database. This command can include 12 different optional keywords. For a complete description of these keywords, see www.cisco.com/univercd

OSPF multi-area LAB