Introduction to OSPF

Mark Tinka

Routing and Forwarding

- Routing is not the same as Forwarding
- Routing is the building of maps
  - Each routing protocol usually has its own routing database
  - Routing protocols populate the forwarding table
- Forwarding is passing the packet to the next hop device
  - Forwarding table contains the best path to the next hop for each prefix
  - There is only ONE forwarding table

OSPF Background

- Developed by IETF – RFC1247
  - Designed for Internet TCP/IP environment
- OSPF v2 described in RFC2328/STD54
  - For IPv4 only
- OSPF v3 described in RFC2740
  - For IPv6 only
- Link state/Shortest Path First Technology
- Dynamic Routing
- Fast Convergence
- Route authentication

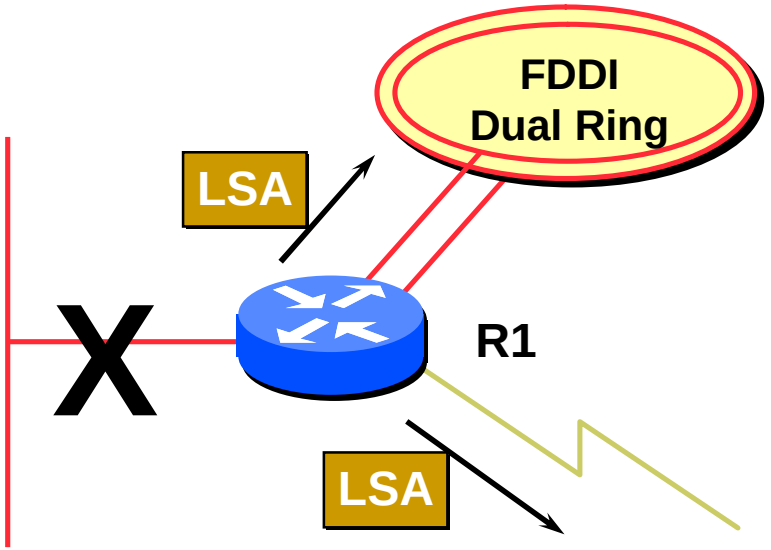
Link State Algorithm

- Each router contains a database containing a map of the whole topology
  - Links
  - Their state (including cost)
- All routers have the same information
- All routers calculate the best path to every destination
- Any link state changes are flooded across the network
  - “Global spread of local knowledge”

Link State Routing

- Automatic neighbour discovery
  - Neighbours are physically connected routers
- Each router constructs a Link State Packet (LSP)
  - Distributes the LSP to neighbours…
  - …using an LSA (Link State Announcement)
- Each router computes its best path to every destination
- On network failure
  - New LSPs are flooded
  - All routers recompute routing table

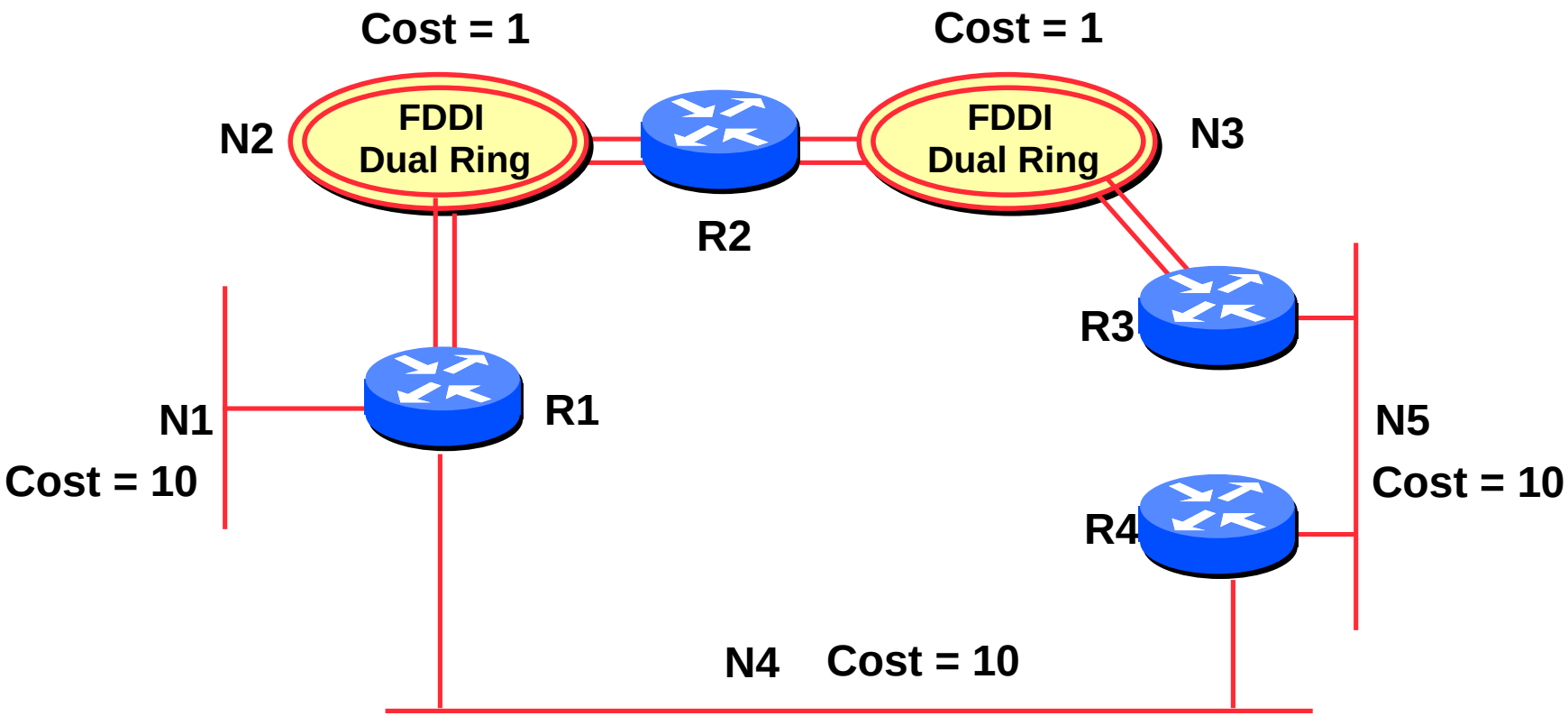
Low Bandwidth Requirements



- Only changes are propagated
- Multicast used on multi-access broadcast networks
  - 224.0.0.5 used for all OSPF speakers
  - 224.0.0.6 used for DR and BDR routers

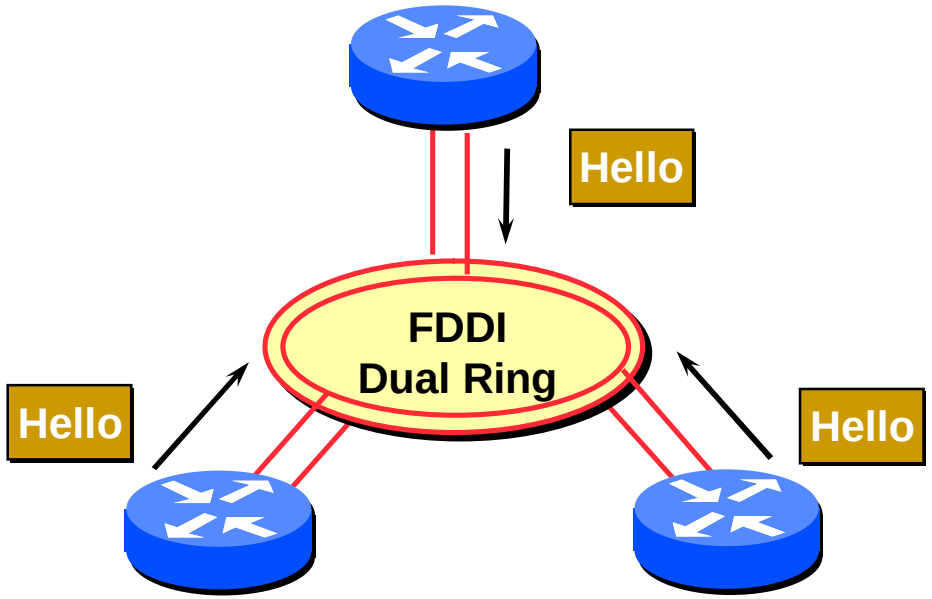
“Shortest Path First”

- The optimal path is determined by the sum of the interface costs



OSPF: How it works

- Hello Protocol
  - Responsible for establishing and maintaining neighbour relationships
  - Elects Designated Router on broadcast networks



OSPF: How it works

- Hello Protocol
  - Hello Packets sent periodically on all OSPF enabled interfaces
  - Adjacencies formed between ***some*** neighbours
- Hello Packet
  - Contains information like Router Priority, Hello Interval, a list of known neighbours, Router Dead Interval, and the network mask

OSPF: How it works

- Trade Information using LSAs
  - LSAs are added to the OSPF database
  - LSAs are passed on to OSPF neighbours
- Each router builds an identical link state database
- SPF algorithm run on the database
- Forwarding table built from the SPF tree

OSPF: How it works

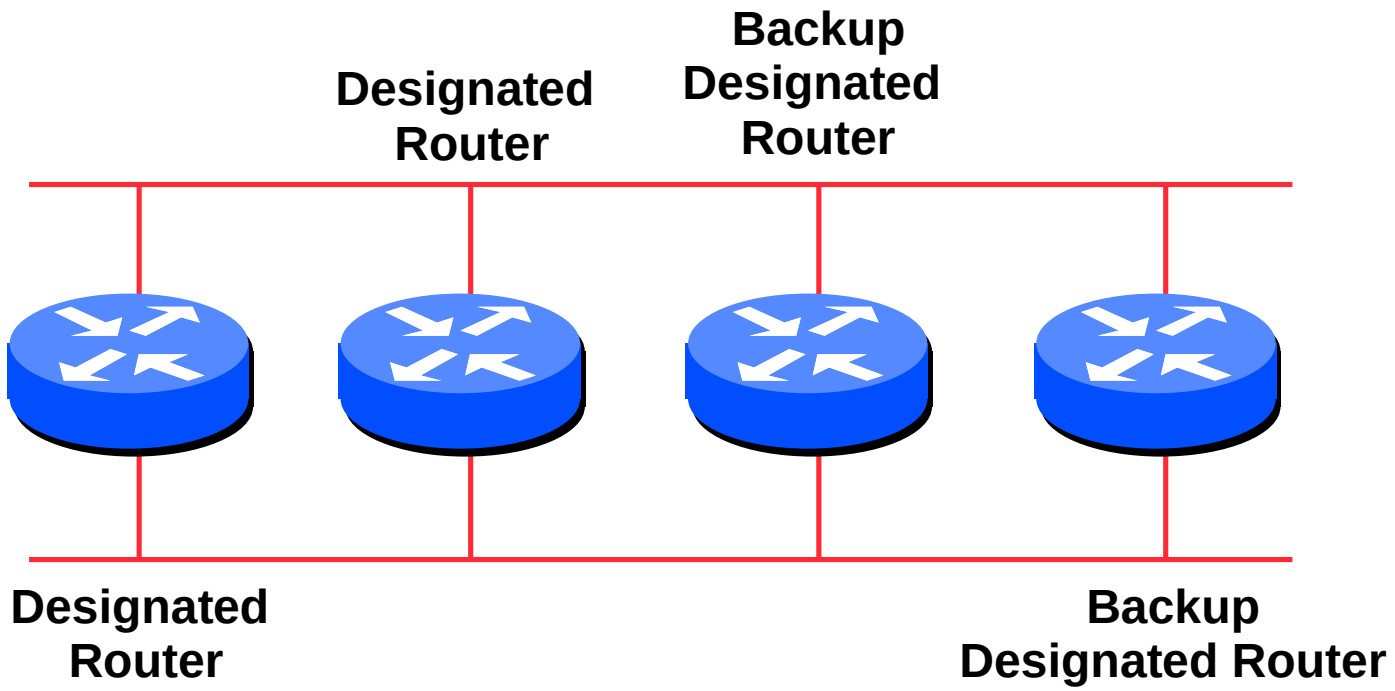
- When change occurs:
  - Announce the change to all OSPF neighbours
  - All routers run the SPF algorithm on the revised database
  - Install any change in the forwarding table

Broadcast Networks

- These are network technologies such as Ethernet and FDDI
- Introduces Designated and Backup Designated routers (DR and BDR)
  - Only DR and BDR form full adjacencies with other routers
  - The remaining routers remain in a “2-way” state with each other
    - If they were adjacent, we’d have n-squared scaling problem
  - If DR or BDR “disappear”, re-election of missing router takes place

Designated Router

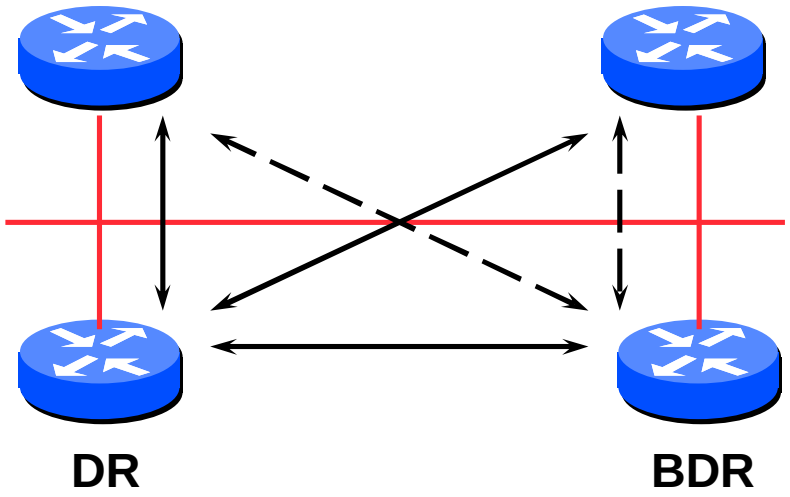
- One per multi-access network
  - Generates network link advertisements for the multi-access network
  - Speeds database synchronisation



Designated Router

- All routers are adjacent to the DR
  - All routers are adjacent to the BDR also
- All routers exchange routing information with DR (..)
  - All routers exchange routing information with the BDR
- DR updates the database of all its neighbours
  - BDR updates the database of all its neighbours
- This scales! *2n* problem rather than having an *n-squared* problem.

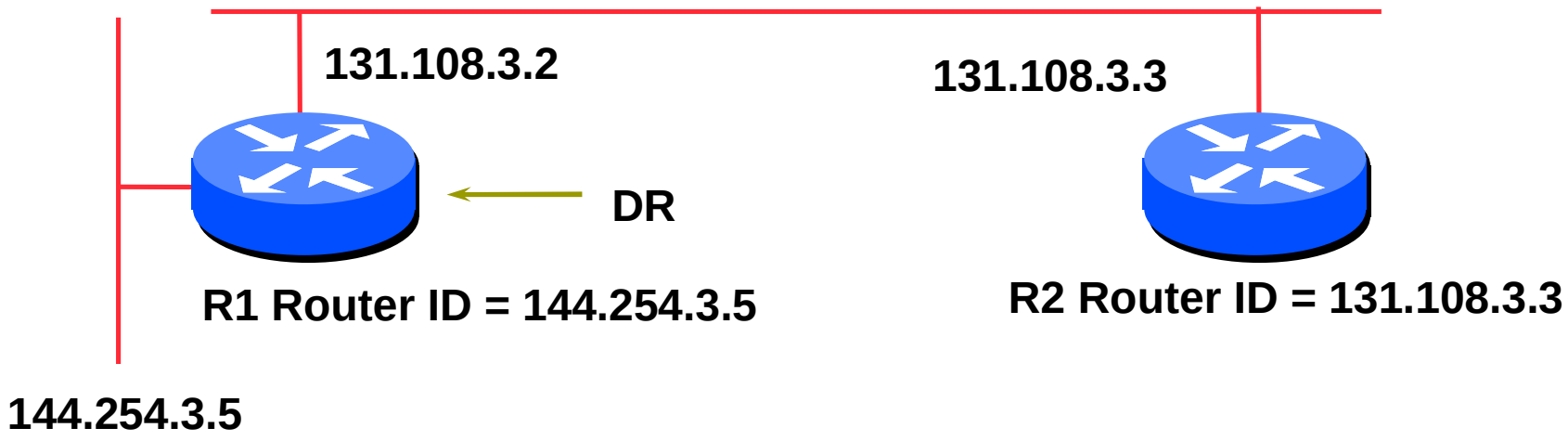
Designated Router



- Adjacencies only formed with DR and BDR
- LSAs propagate along the adjacencies

Designated Router Priority

- Determined by interface priority
- Otherwise by highest router ID
  - (For Cisco IOS, this is address of loopback interface, otherwise highest IP address on router)

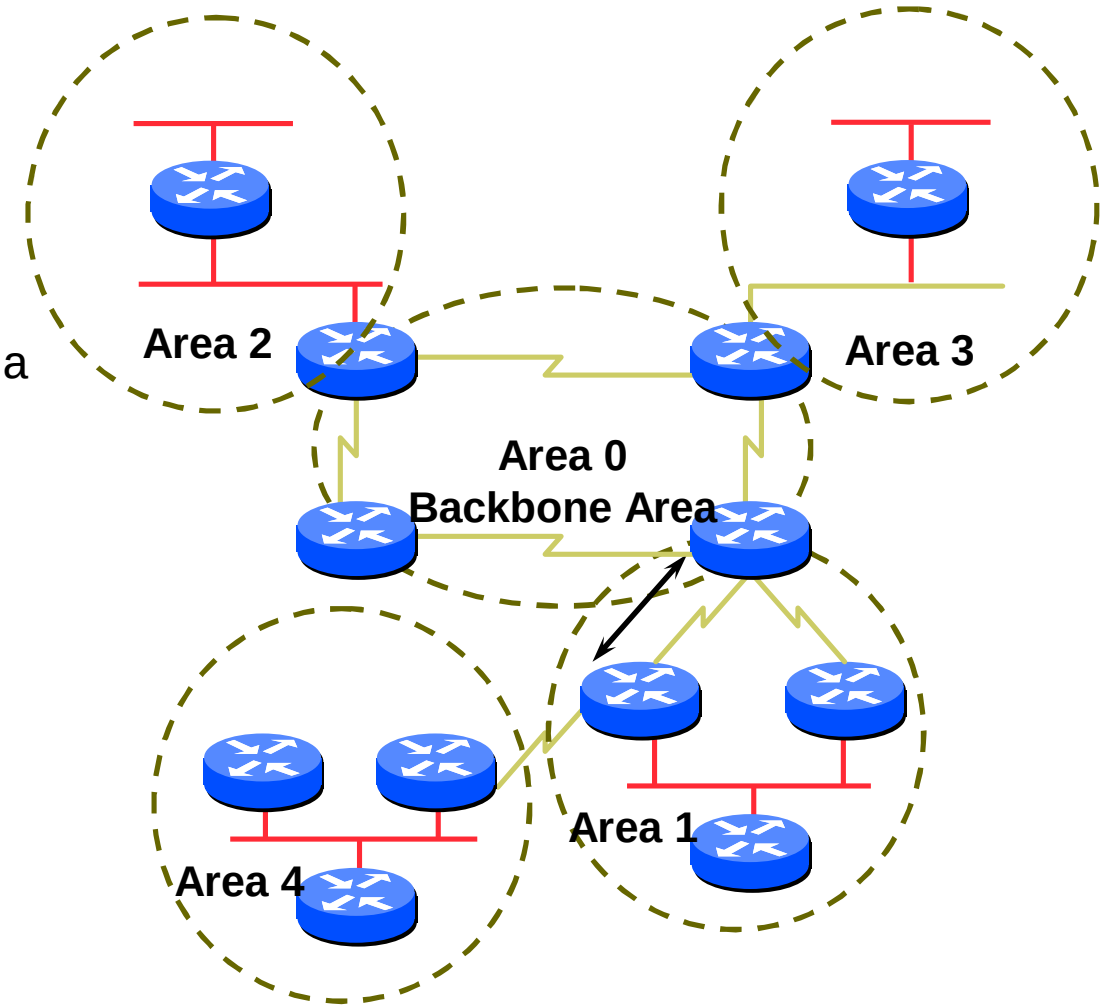


More Advanced OSPF

- OSPF Areas
- Virtual Links
- Router Classification
- OSPF route types
- External Routes
- Route authentication
- Equal cost multipath

OSPF Areas

- Group of contiguous hosts and networks
- Per area topological database
  - Invisible outside the area
  - Reduction in routing traffic
- Backbone area contiguous
  - All other areas must be connected to the backbone
- Virtual Links



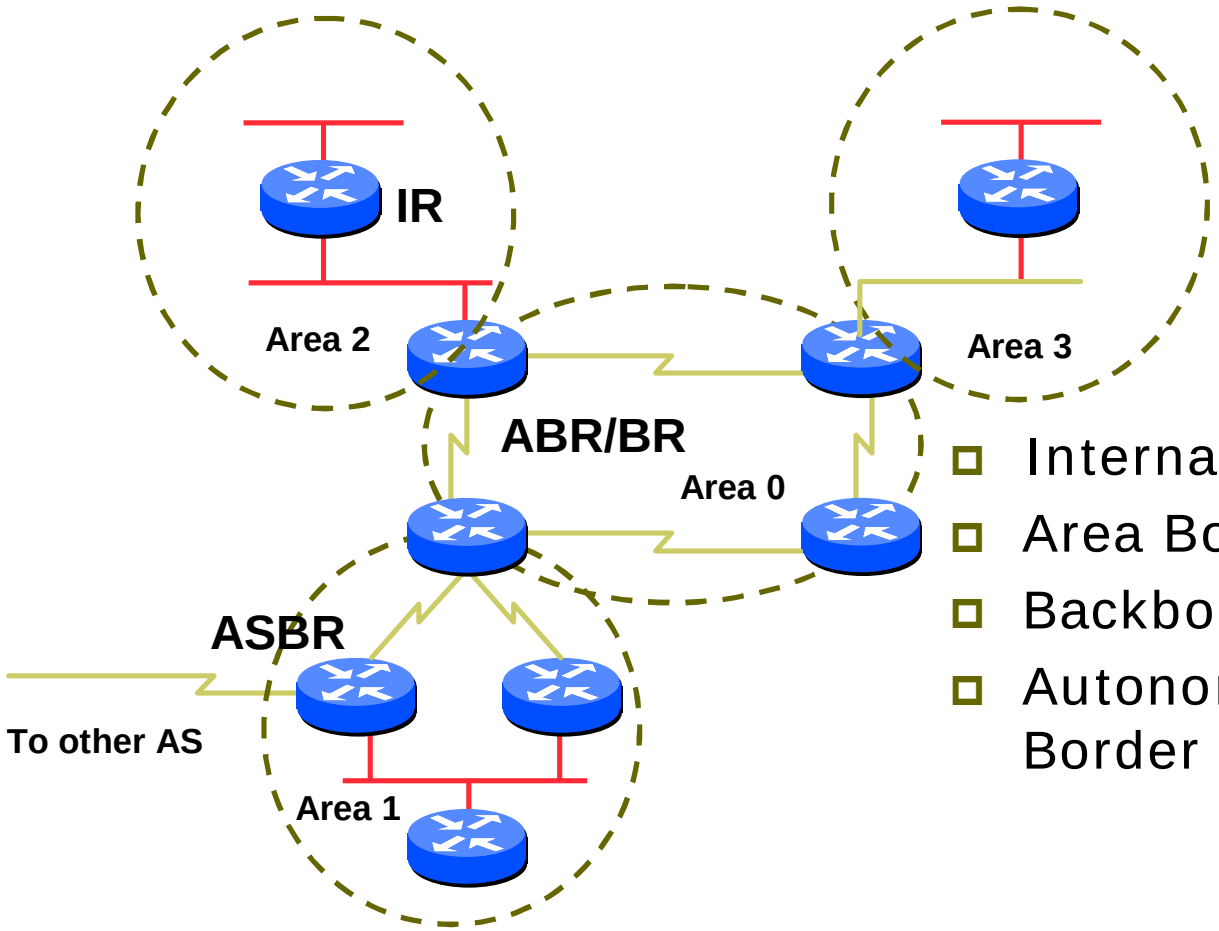
OSPF Areas

- Reduces routing traffic in area 0
- Consider subdividing network into areas
  - Once area 0 is more than 10 to 15 routers
  - Once area 0 topology starts getting complex
- Area design often mimics typical ISP core network design
- Virtual links are used for “awkward” connectivity topologies (…)

Virtual Links

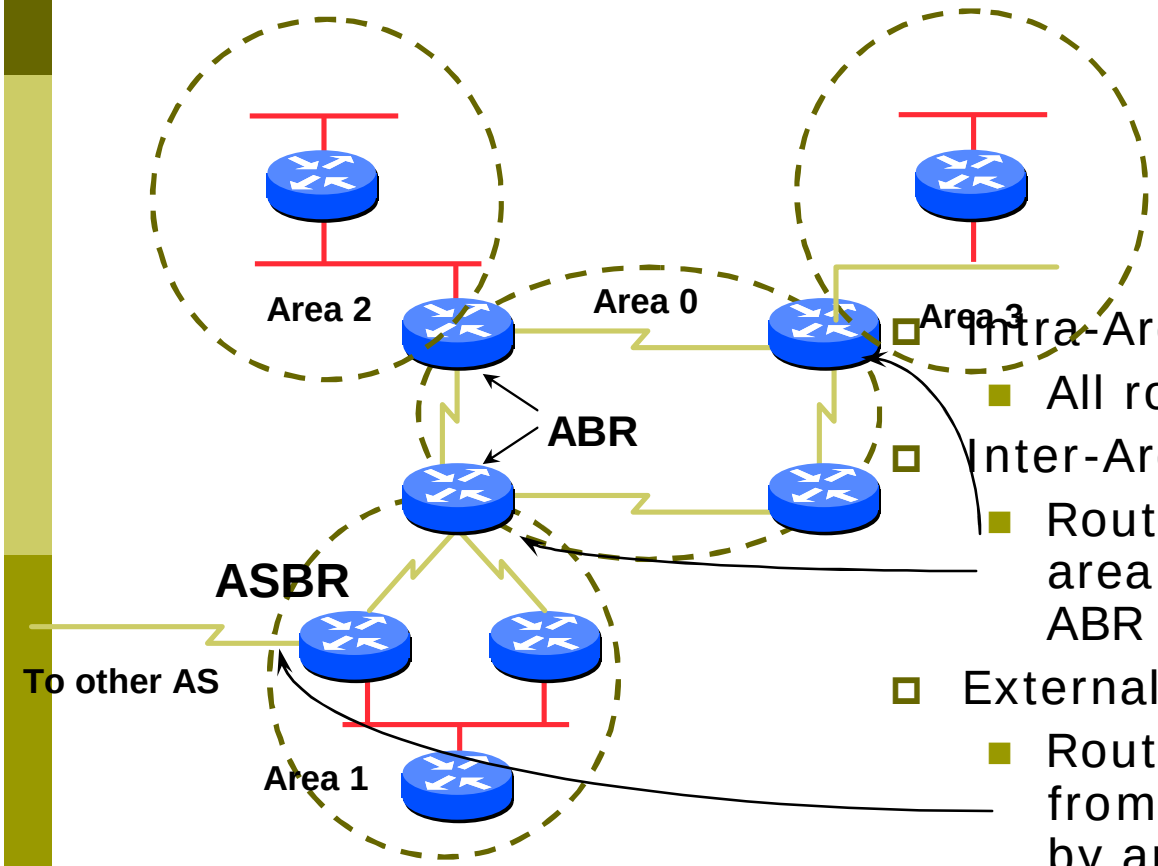
- OSPF requires that all areas MUST be connected to area 0
- If topology is such that an area cannot have a physical connection to a device in area 0, then a virtual link must be configured
- Otherwise the disconnected area will only be able to have connectivity to its immediately neighbouring area, and not the rest of the network

Classification of Routers



- Internal Router (IR)
- Area Border Router (ABR)
- Backbone Router (BR)
- Autonomous System Border Router (ASBR)

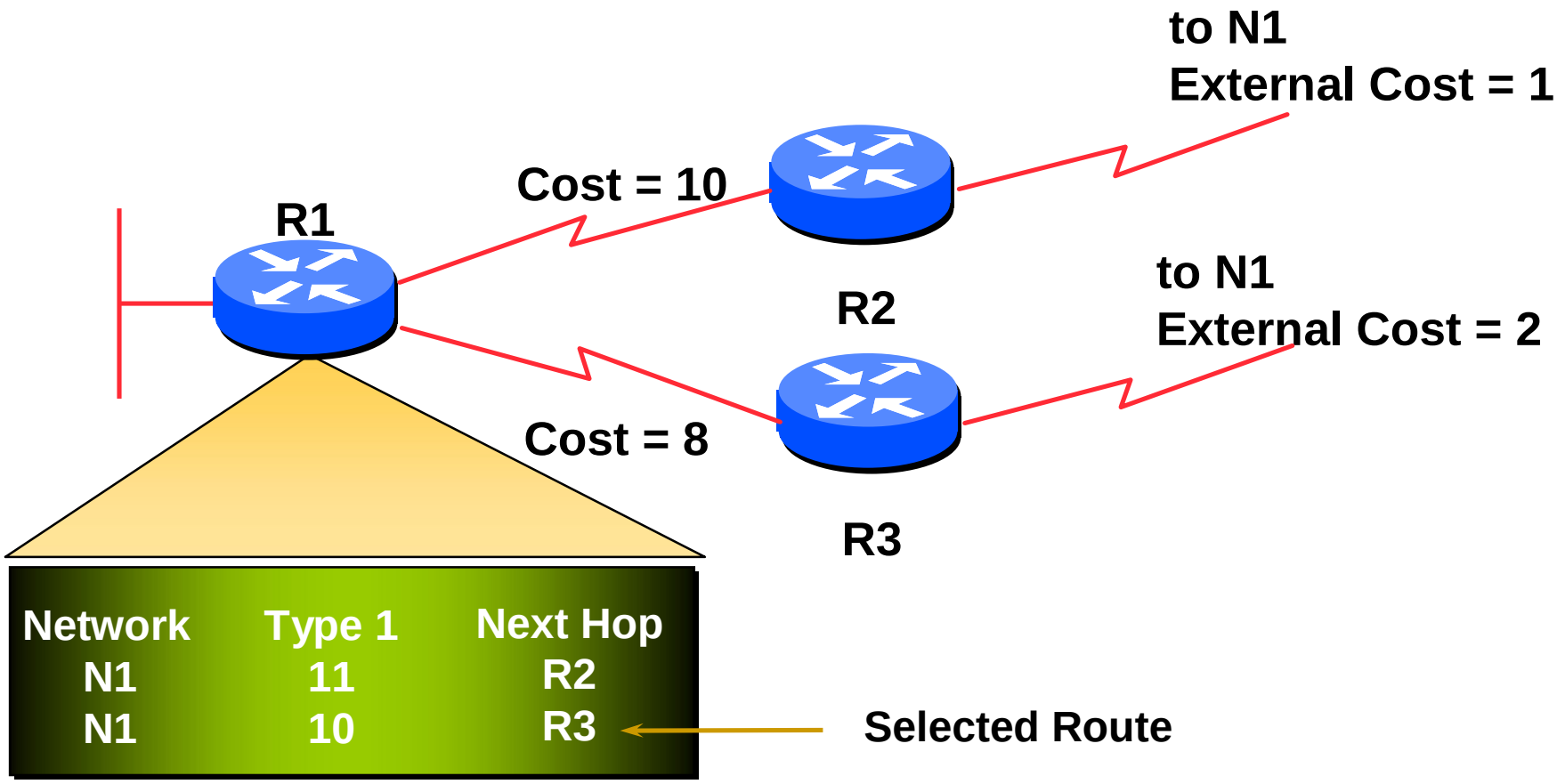
OSPF Route Types



- Intra-Area route
  - All routes inside an area
- Inter-Area route
  - Routes advertised from one area to another area by an ABR
- External route
  - Routes imported into OSPF from another routing protocol by an ASBR

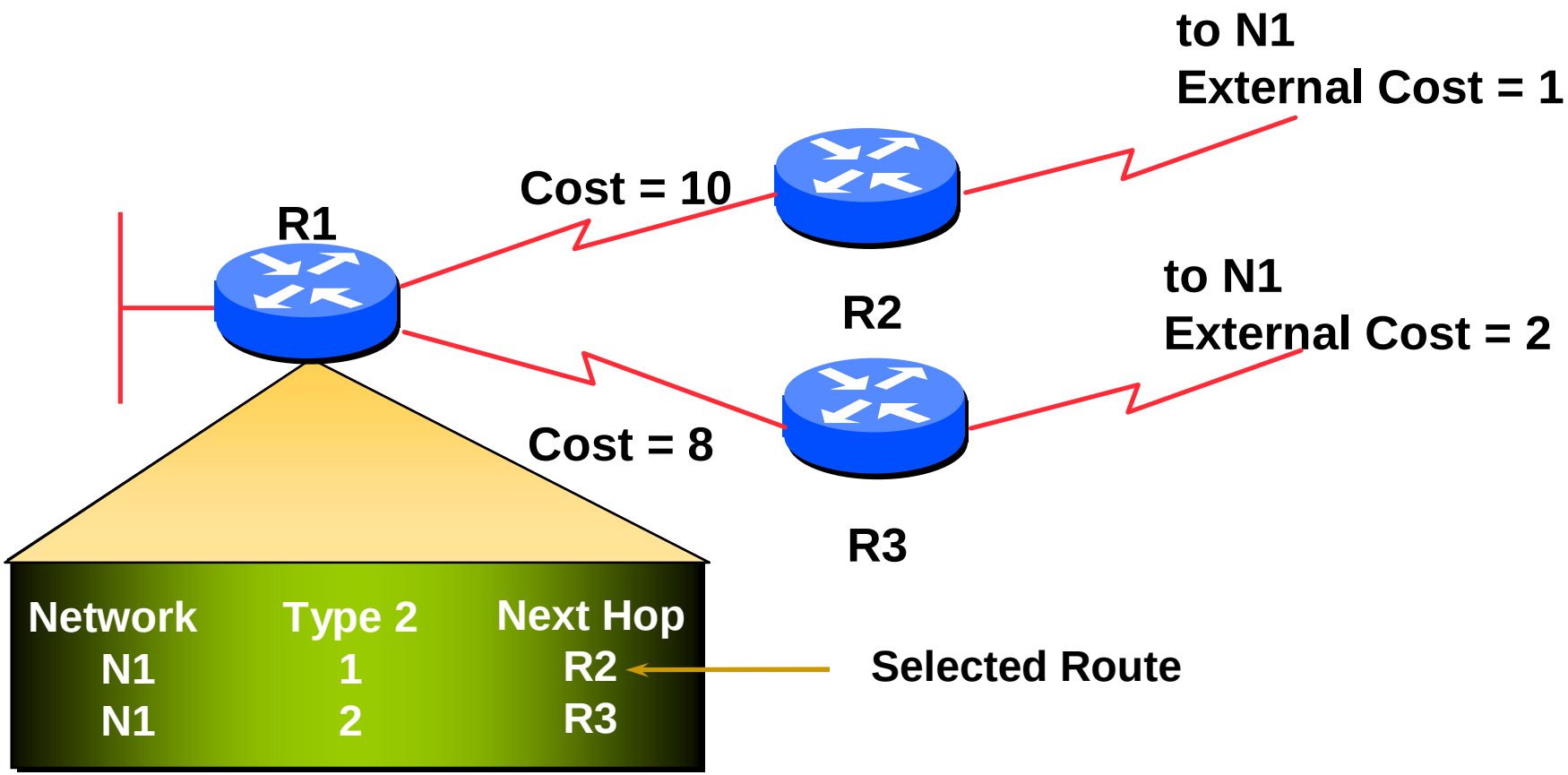
External Routes

- Type 1 external metric: metrics are added to the summarised internal link cost



External Routes

- Type 2 external metric: metrics are compared without adding to the internal link cost



Route Authentication

- Now recommended to use route authentication for OSPF
  - ...and all other routing protocols
- Susceptible to denial of service attacks
  - OSPF runs on TCP/IP
  - Automatic neighbour discovery
- Route authentication – Cisco example:

```
router ospf <pid>
 network 192.0.2.0 0.0.0.255 area 0
 area 0 authentication
interface ethernet 0/0
 ip ospf authentication-key <password>
```

Equal Cost Multipath

- If *n* paths to same destination have equal cost, OSPF will install *n* entries in the forwarding table
  - Loadsharing over the *n* paths
  - Useful for expanding links across an ISP backbone
    - Don’t need to use hardware multiplexors
    - Don’t need to use static routing

Summary

- Link State Protocol
- Shortest Path First
- OSPF operation
- Broadcast networks
  - Designated and Backup Designated Router
- Advanced Topics
  - Areas, router classification, external networks, authentication, multipath

OSPFv3

OSPFv3 overview

- OSPF for IPv6
- Based on OSPFv2, with enhancements
- Distributes IPv6 prefixes
- Runs directly over IPv6
- Ships-in-the-night with OSPFv2

OSPFv3 / OSPFv2 Similarities

- Basic packet types
  - Hello, DBD, LSR, LSU, LSA
- Mechanisms for neighbor discovery and adjacency formation
- Interface types
  - P2P, P2MP, Broadcast, NBMA, Virtual
- LSA flooding and aging
- Nearly identical LSA types

V2, V3 Differences

OSPFv3 runs on a Link instead of per IP Subnet

- A link by definition is a medium over which two nodes can communicate at link layer
- In IPv6 multiple IP subnet can be assigned to a link and two nodes in different subnet can communicate at link layer therefore OSPFv3 is running per link instead of per IP subnet
- An Interface connect to a link and multiple interface can be connected to a link

V2, V3 Differences (Cont.)

Support of Multiple Instances per Link

- New field (instance) in OSPF packet header allow running multiple instance per link
- Instance ID should match before packet being accepted
- Useful for traffic separation, multiple areas per link and AF (see later)

V2, V3 Differences (Cont.)

Address Semantic Change in LSA

- Router and Network LSA carry only topology information
- Router LSA can be split across multiple LSAs; Link State ID in LSA header is a fragment ID
- Intra area prefix are carried in a new LSA payload called intra-area-prefix-LSAs
- Prefix are carried in payload of inter-area and external LSA

V2, V3 Differences (Cont.)

Generalization of Flooding Scope

- In OSPFv3 there are three flooding scope for LSAs (link-local scope, area scope, AS scope) and they are coded in LS type explicitly
- In OSPFv2 initially only area and AS wide flooding was defined; later opaque LSAs introduced link local scope as well

V2, V3 Differences (Cont.)

Explicit Handling of Unknown LSA

- The handling of unknown LSA is coded via U-bit in LS type
- When U bit is set, the LSA is flooded with the corresponding flooding scope, as if it was understood
- When U bit is clear, the LSA is flooded with link local scope
- In v2 unknown LSA were discarded

V2, V3 Differences (Cont.)

Authentication is Removed from OSPF

- Authentication in OSPFv3 has been removed
  - OSPFv3 relies on IPv6 authentication header since OSPFv3 runs over IPv6
- AuthType and Authentication field in the OSPF packet header have been suppressed
- AH (Authentication Header) provides authentication
- ESP (Encapsulating Security Payload) provides encryption & integrity
- ESP, if used alone, provides both authentication and encryption
- AH supported from 12.3T
- ESP supported from 12.4T

V2, V3 Differences (Cont.)

OSPF Packet format has been changed

- The mask field has been removed from Hello packet
- IPv6 prefix is only present in payload of Link State update packet

V2, V3 Differences (Cont.)

Two New LSAs Have Been Introduced

- Link-LSA has a link local flooding scope and has three purposes:
  - Provides router link-local address
  - Lists all IPv6 prefixes attached to link
  - Assert collection of option bits for Router LSA
- Intra-area-prefix-LSA to advertise router's IPv6 address within the area

Configuring OSPFv3 in Cisco IOS

- Similar to OSPFv2
  - Prefixing existing Interface and Exec mode commands with "**ipv6**"
- Interfaces configured directly
  - Replaces **network** command
  - (Also available in OSPFv2 from IOS 12.4 and most recent 12.0S and 12.2SB, 12.2SR releases).
  - (Called the "Area Command in Interface Mode for OSPFv2" feature).
- "Native" IPv6 router mode
  - Not a sub-mode of **router ospf**

Configuration modes in OSPFv3

- Entering router mode

  [no] ipv6 router ospf <process ID>

- Entering interface mode

  [no] ipv6 ospf <process ID> area <area ID>

- Exec mode

  show ipv6 ospf [<process ID>]

  clear ipv6 ospf [<process ID>]

OSPFv3 Specific Attributes – IOS

- Configuring area range

  [no] area <area ID> range <prefix>/<prefix length>

- Showing new LSA

  show ipv6 ospf [<process ID>] database link

  show ipv6 ospf [<process ID>] database prefix

- Configuring authentication
  - Under ipv6 router ospf:

    area 0 authentication ipsec spi 256 md5 <passwd>

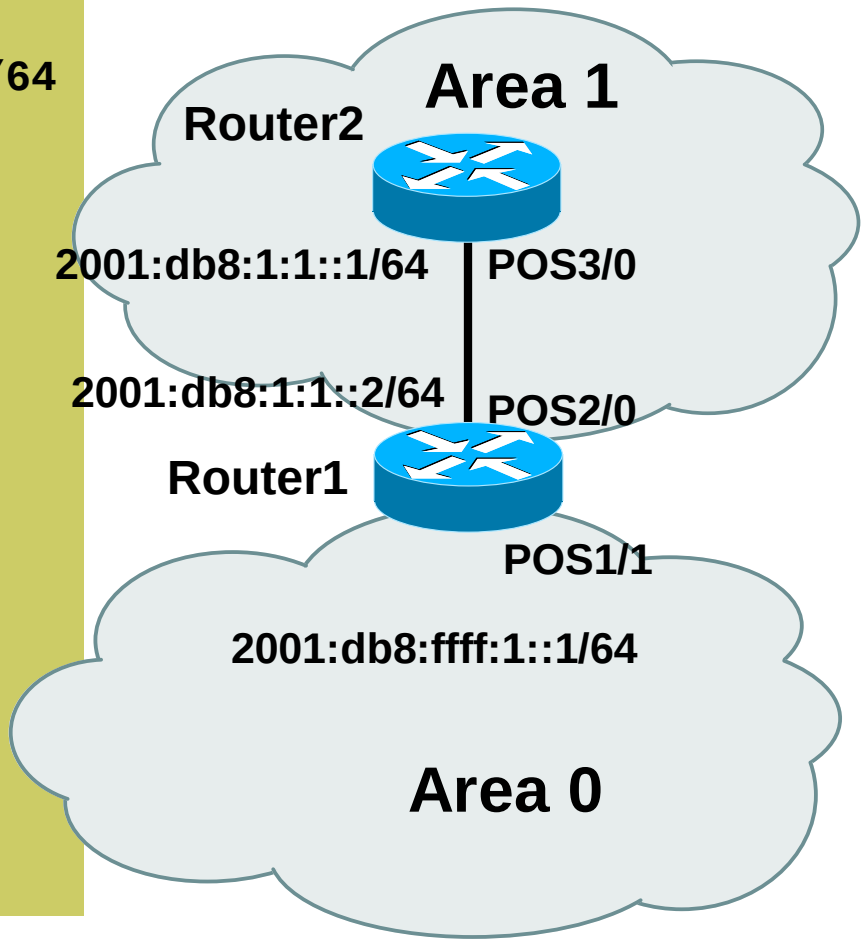
  - Under interface:

    ipv6 ospf authentication ipsec spi 256 md5 <passwd>

OSPFv3 Configuration Example

```
Router1#
interface POS1/1
 ipv6 address 2001:db8:FFFF:1::1/64
 ipv6 ospf 100 area 0
!
interface POS2/0
 ipv6 address 2001:db8:1:1::2/64
 ipv6 ospf 100 area 1
!
ipv6 router ospf 100


Router2#
interface POS3/0
 ipv6 address 2001:db8:1:1::1/64
 ipv6 ospf 100 area 1
!
ipv6 router ospf 100
```



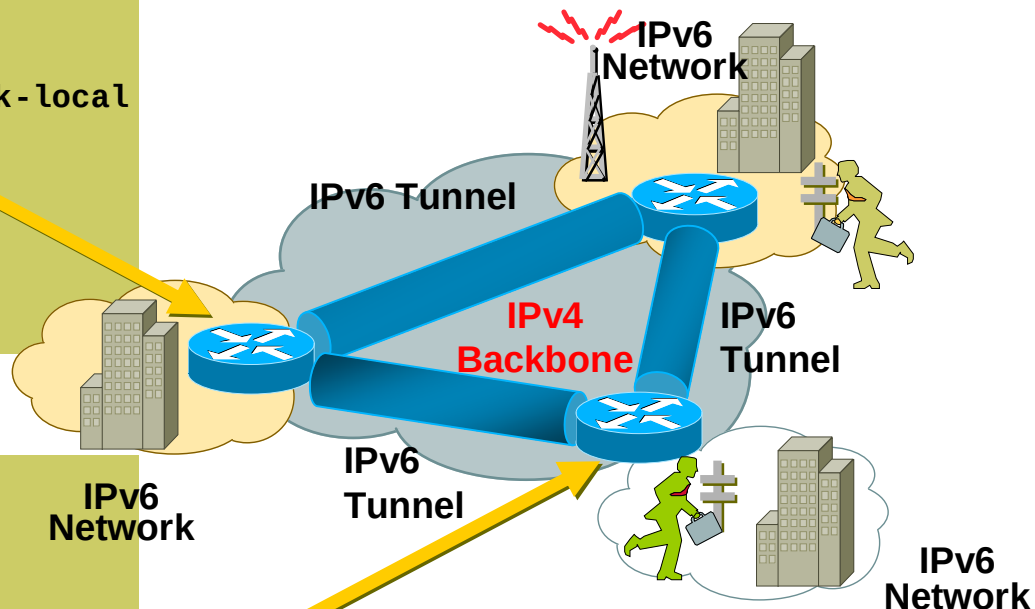
OSPFv3 entries in Routing Table

```
Router2#sh ipv6 route
IPv6 Routing Table - 5 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
OI  2001:db8:FFFF:1::/64 [110/2]
     via FE80::2D0:FFFF:FE60:DFFF, POS3/0
C   2001:db8:1:1::/64 [0/0]
     via ::, POS3/0
L   2001:db8:1:1::1/128 [0/0]
     via ::, POS3/0
L   FE80::/10 [0/0]
     via ::, Null0
L   FF00::/8 [0/0]
     via ::, Null0
```

OSPFv3 on IPv6 Tunnels over IPv4

```
On Router1:
interface Tunnel0
 no ip address
 ipv6 address 2001:db8:1::1/64
 ipv6 address FE80::10:7BC2:ACC9:10 link-local
 ipv6 router ospf 1 area 0
 tunnel source 10.42.1.1
 tunnel destination 10.42.2.1
 tunnel mode ipv6ip
!
ipv6 router ospf 1
```

```
On Router2:
interface Tunnel0
 no ip address
 ipv6 address 2001:db8:1::2/64
 ipv6 address FE80::10:7BC2:B280:11 link-local
 ipv6 router ospf 1 area 0
 tunnel source 10.42.2.1
 tunnel destination 10.42.1.1
 tunnel mode ipv6ip
!
ipv6 router ospf 1
```



Introduction to OSPF

Questions?