OSPF in Detail

ISP Workshops

Agenda

- Detailed Background about OSPF
- OSPF Design in SP Networks
- Adding Networks in OSPF
- OSPF in Cisco's IOS

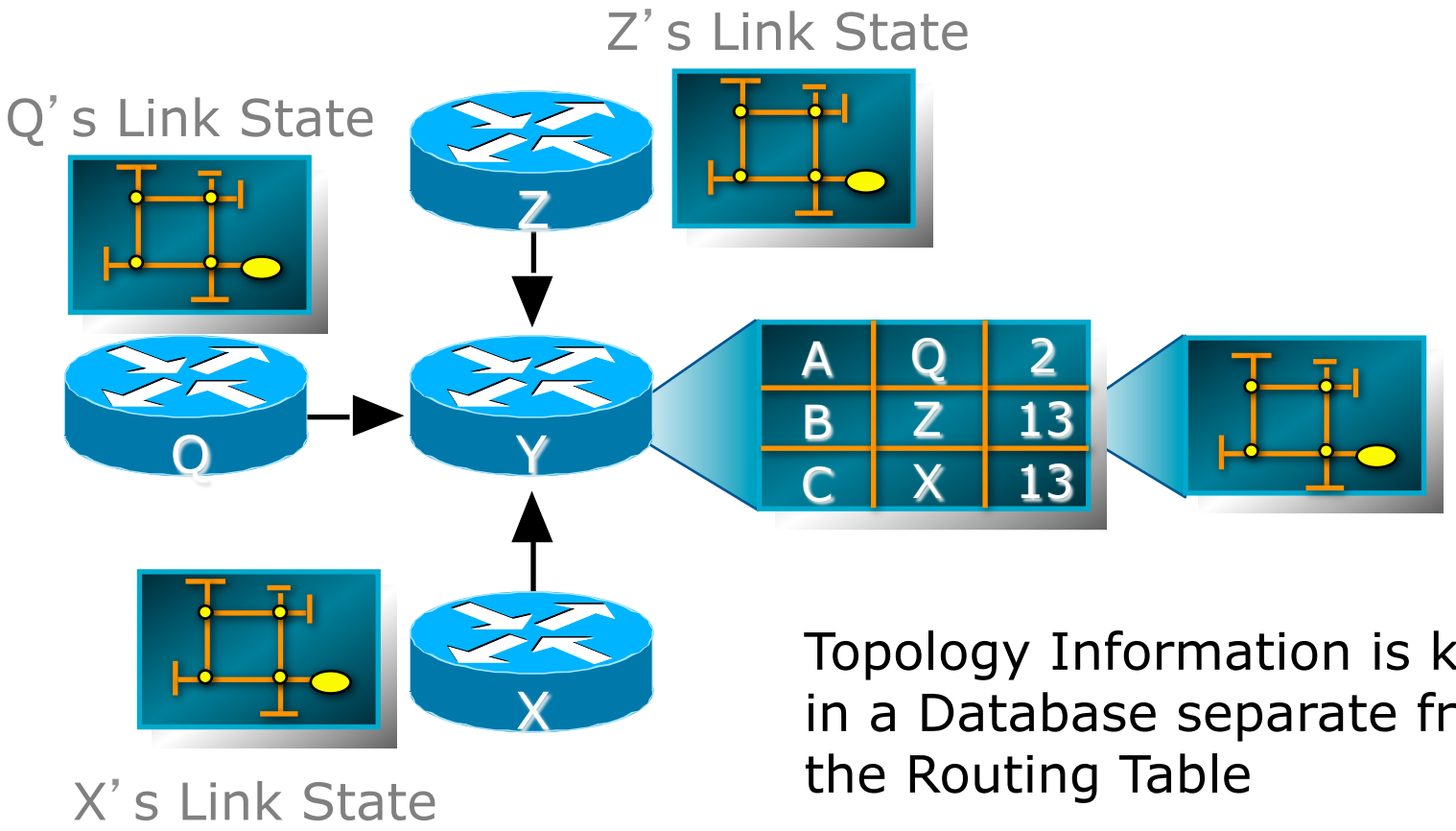
OSPF: The detail

Technical Background

OSPF

- Open Shortest Path First
- Link state or SPF technology
- Developed by OSPF working group of IETF (RFC 1247)
- OSPFv2 standard described in RFC2328
- Designed for:
  - TCP/IP environment
  - Fast convergence
  - Variable-length subnet masks
  - Discontiguous subnets
  - Incremental updates
  - Route authentication
- Runs on IP, Protocol 89

Link State

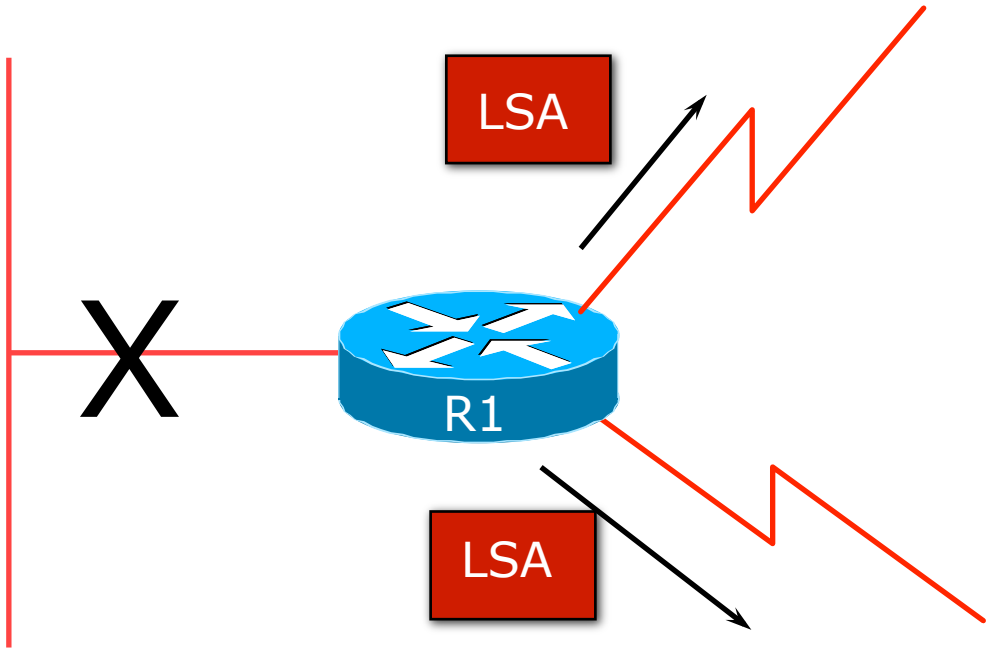


Topology Information is kept in a Database separate from the Routing Table

Link State Routing

- Neighbour discovery
- Constructing a Link State Packet (LSP)
- Distribute the LSP
  - (Link State Announcement – LSA)
- Compute routes
- On network failure
  - New LSPs flooded
  - All routers recompute routing table

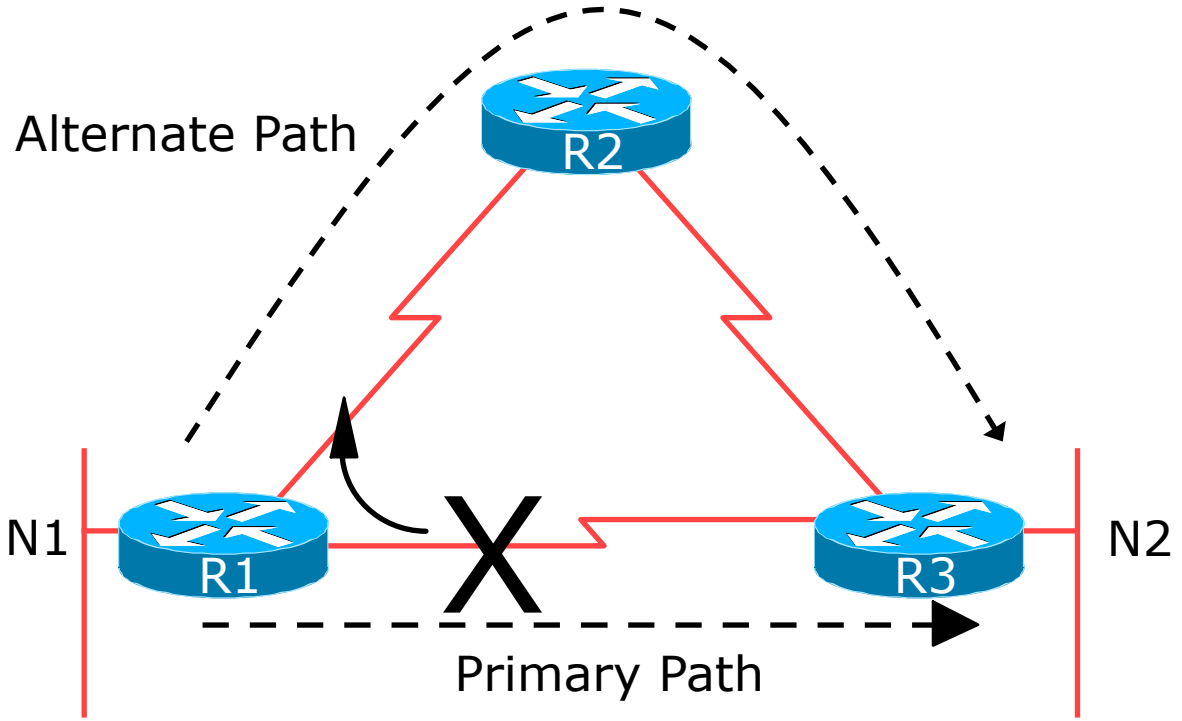
Low Bandwidth Utilisation



- Only changes propagated
- Uses multicast on multi-access broadcast networks

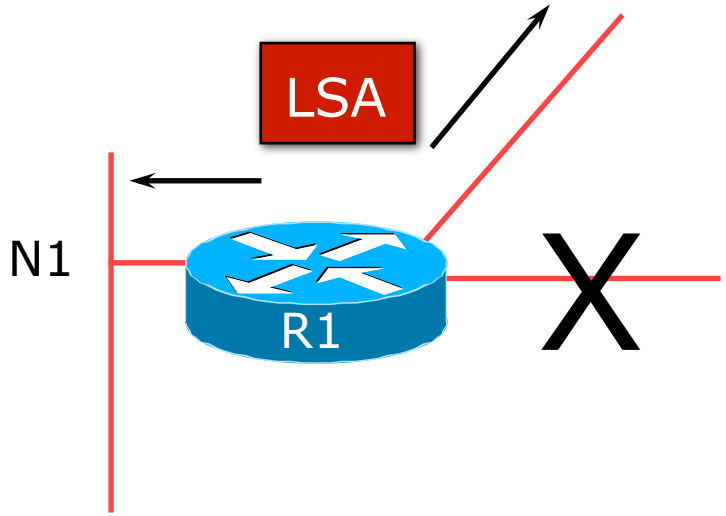
Fast Convergence

- Detection Plus LSA/SPF
  - Known as the Dijkstra Algorithm



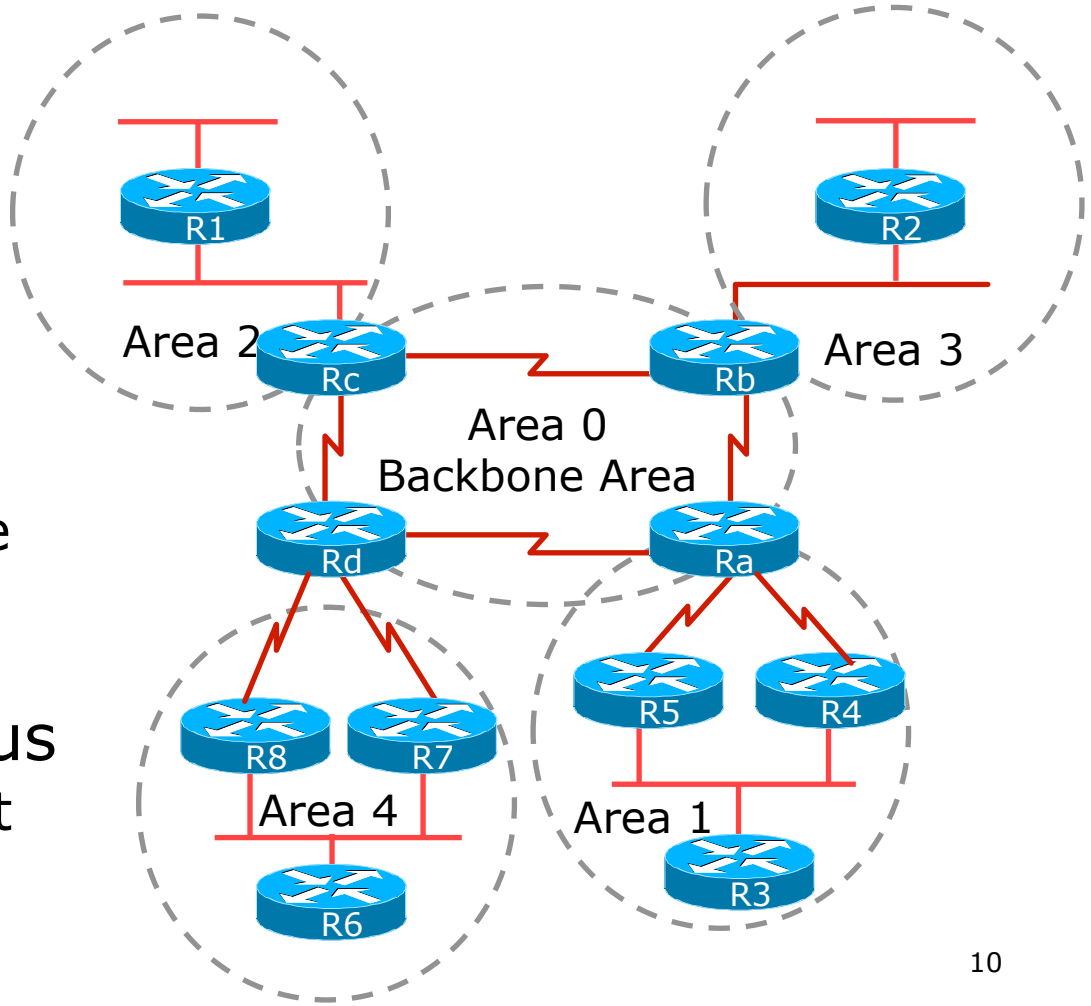
Fast Convergence

- Finding a new route
  - LSA flooded throughout area
  - Acknowledgement based
  - Topology database synchronised
  - Each router derives routing table to destination network



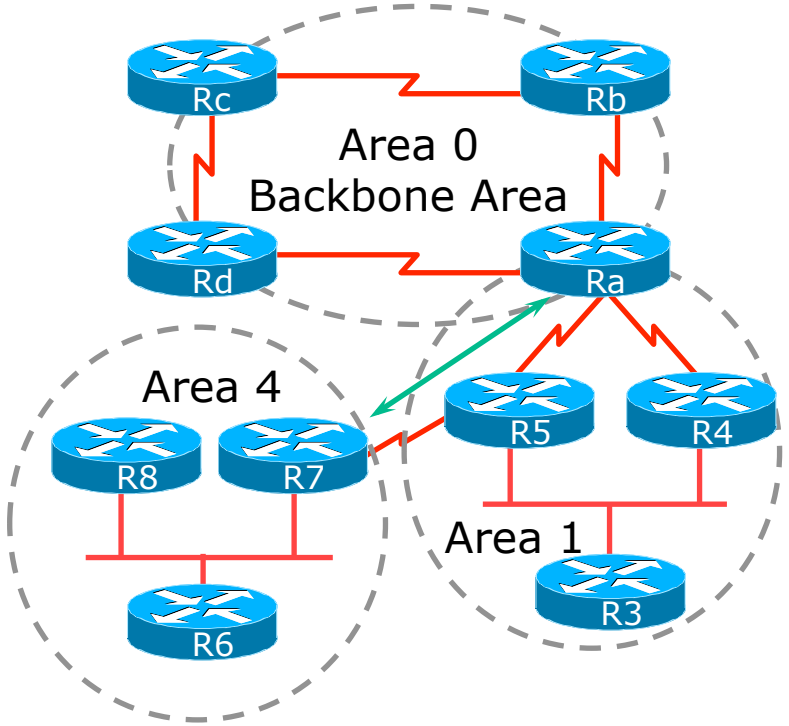
OSPF Areas

- Area is a group of contiguous hosts and networks
  - Reduces routing traffic
- Per area topology database
  - Invisible outside the area
- Backbone area **MUST** be contiguous
  - All other areas must be connected to the backbone

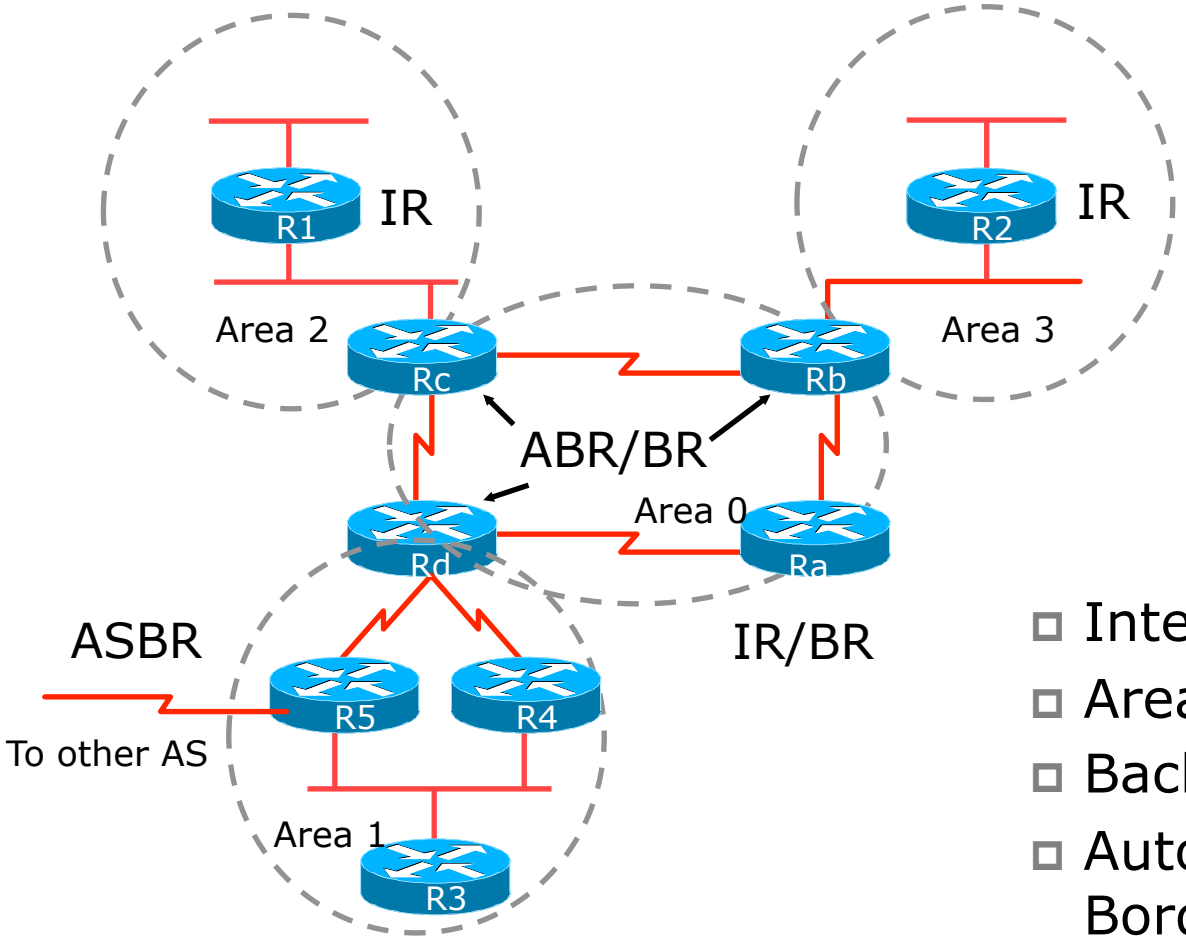


Virtual Links between OSPF Areas

- Virtual Link is used when it is not possible to physically connect the area to the backbone
- **ISPs avoid designs which require virtual links**
  - Increases complexity
  - Decreases reliability and scalability

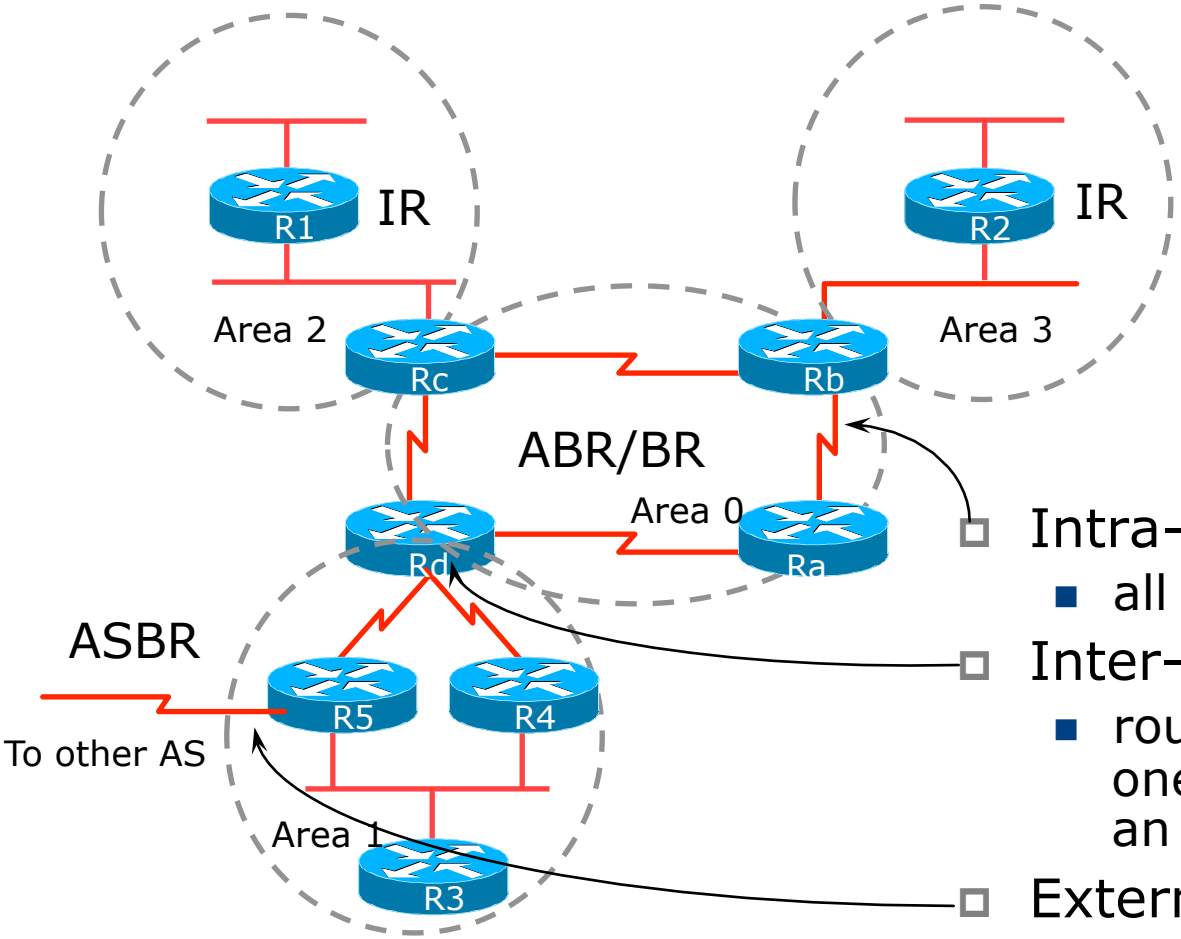


Classification of Routers



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

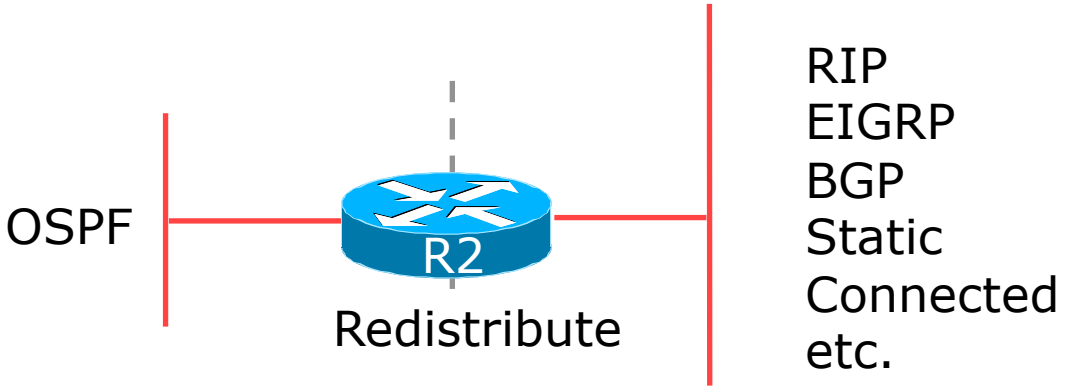
OSPF Route Types



- Intra-area Route
  - all routes inside an area
- Inter-area Route
  - routes advertised from one area to another by an Area Border Router
- External Route
  - routes imported into OSPF from other protocol or static routes

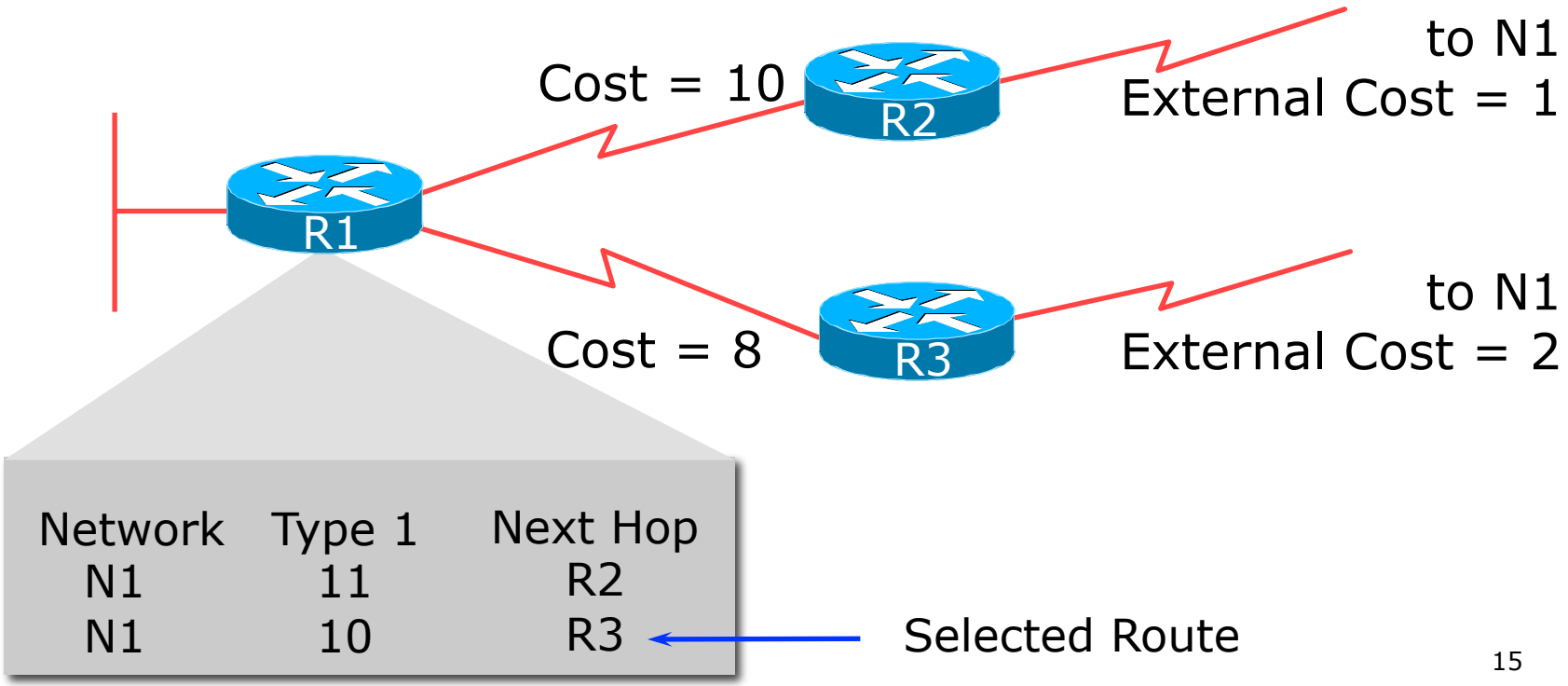
External Routes

- Prefixes which are redistributed into OSPF from other protocols
- Flooded unaltered throughout the AS
  - **Recommendation: Avoid redistribution!!**
- OSPF supports two types of external metrics
  - Type 1 external metrics
  - Type 2 external metrics (Cisco IOS default)



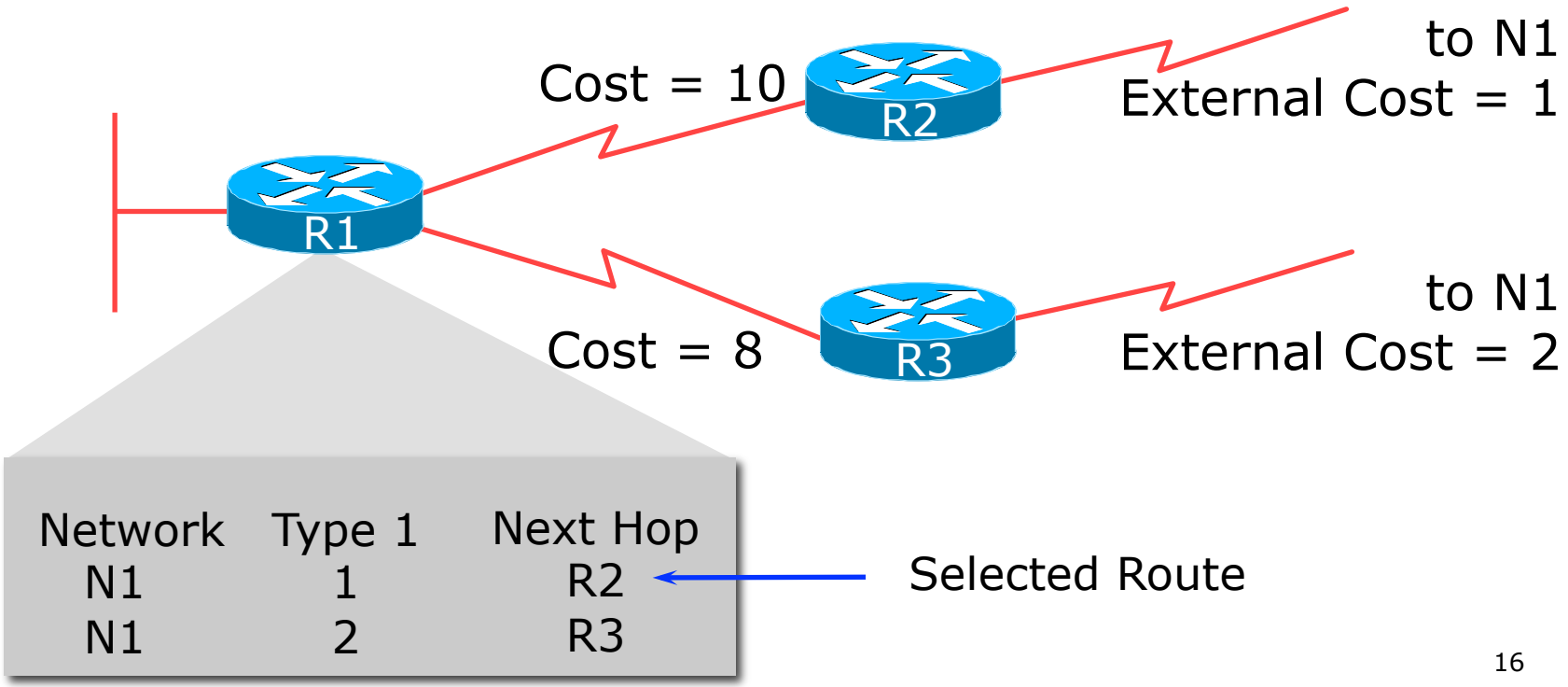
External Routes

- 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

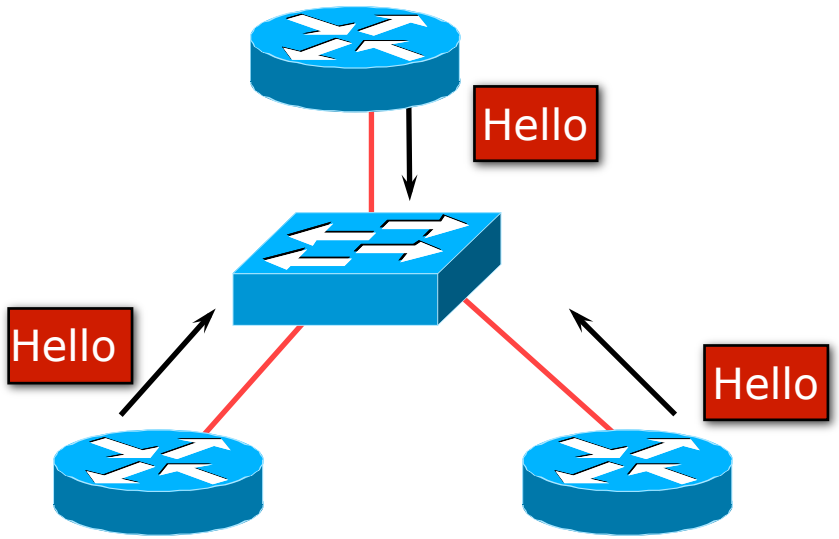


Topology/Link State Database

- A router has a separate LS database for each area to which it belongs
- All routers belonging to the same area have identical database
- SPF calculation is performed separately for each area
- LSA flooding is bounded by area
- Recommendation:
  - Limit the number of areas a router participates in!!
  - 1 to 3 is fine (typical ISP design)
  - >3 can overload the CPU depending on the area topology complexity

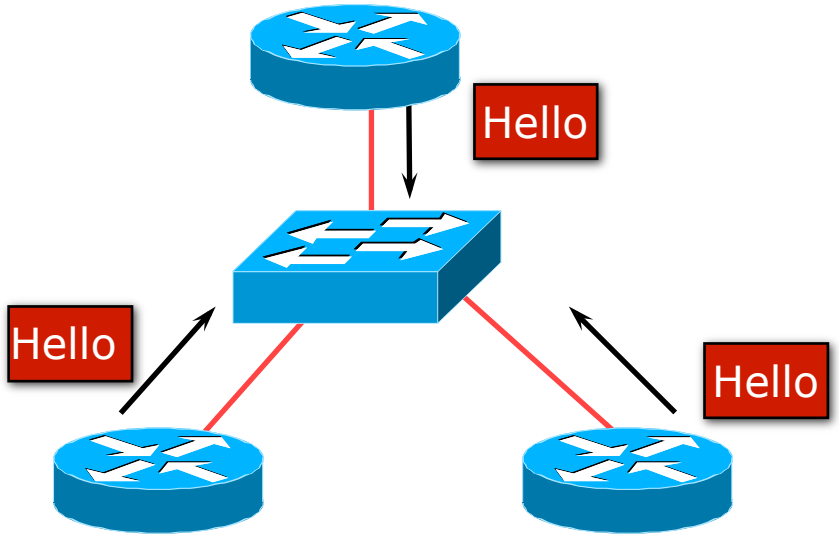
The Hello Protocol

- Responsible for establishing and maintaining neighbour relationships
- Elects designated router on multi-access networks



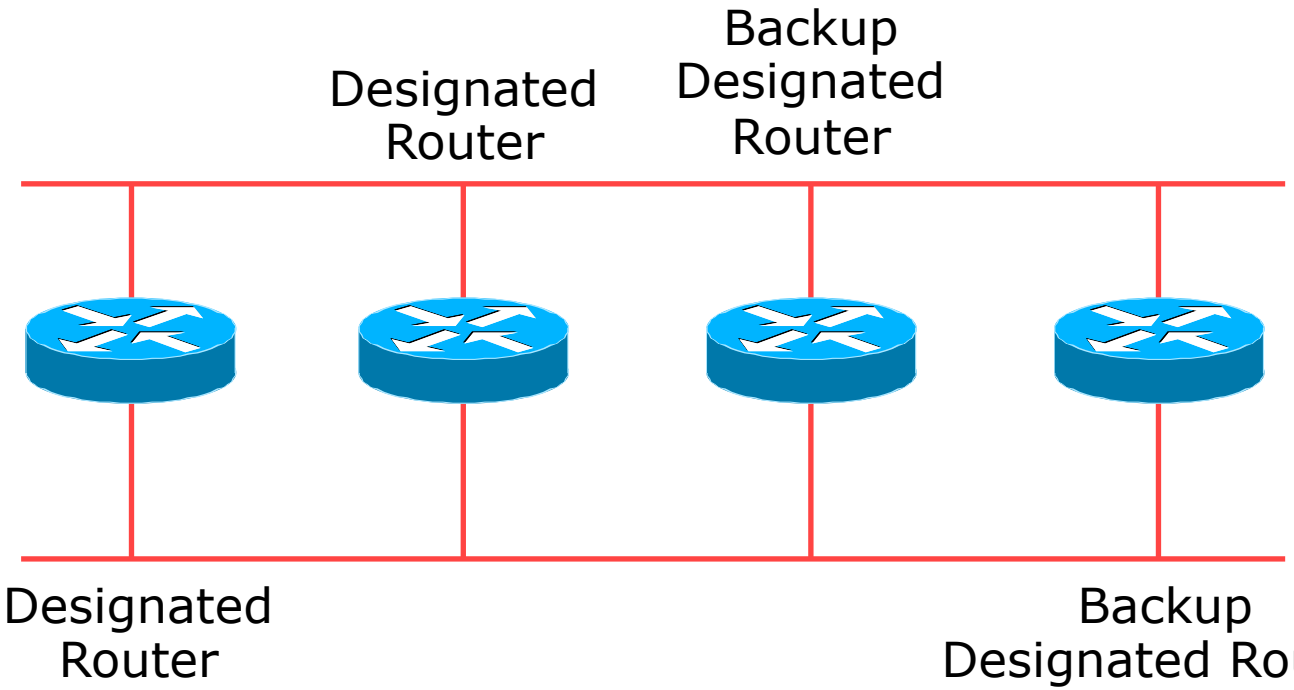
The Hello Packet

- Contains:
  - Router priority
  - Hello interval
  - Router dead interval
  - Network mask
  - List of neighbours
  - DR and BDR
  - Options: E-bit, MC-bit,… (see A.2 of RFC2328)



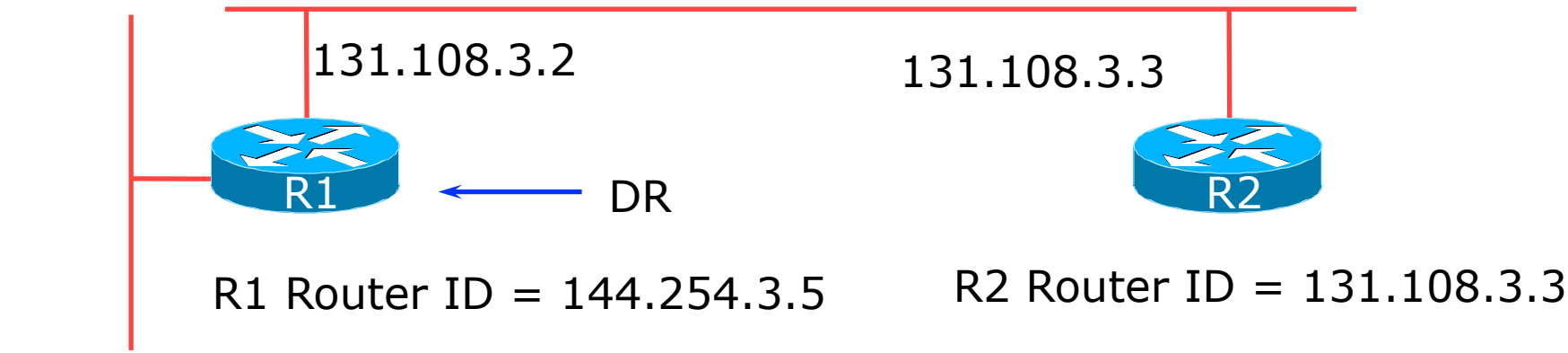
Designated Router

- There is ONE designated router per multi-access network
  - Generates network link advertisements
  - Assists in database synchronization



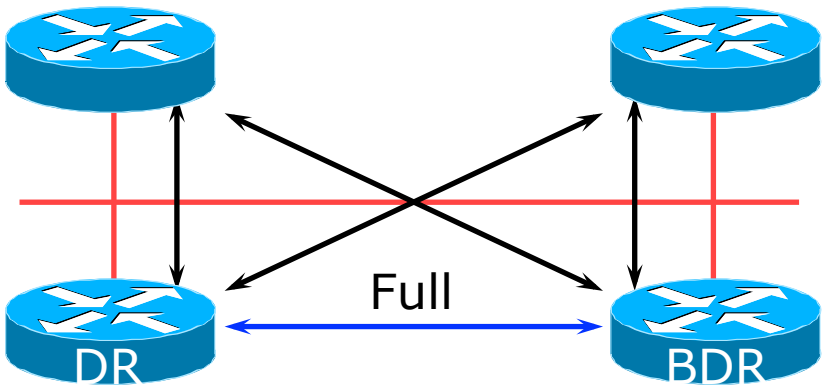
Designated Router by Priority

- Configured priority (per interface)
  - ISPs configure high priority on the routers they want as DR/BDR
- Else determined by highest router ID
  - Router ID is 32 bit integer
  - Derived from the loopback interface address, if configured, otherwise the highest IP address



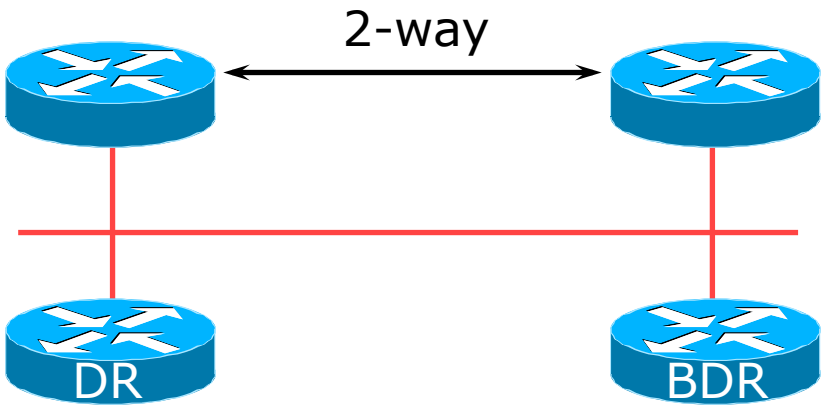
Neighbouring States

- Full
  - Routers are fully adjacent
  - Databases synchronised
  - Relationship to DR and BDR



Neighbouring States

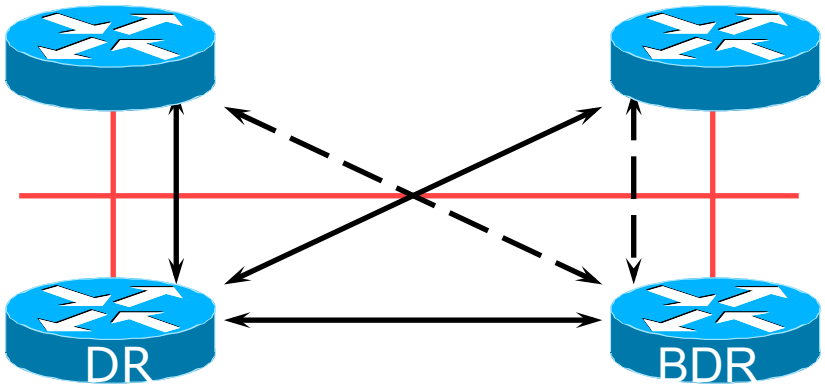
- 2-way
  - Router sees itself in other Hello packets
  - DR selected from neighbours in state 2-way or greater



When to Become Adjacent

- Underlying network is point to point
- Underlying network type is virtual link
- The router itself is the designated router or the backup designated router
- The neighbouring router is the designated router or the backup designated router

LSAs Propagate Along Adjacencies



- LSAs acknowledged along adjacencies

Broadcast Networks

- IP Multicast used for Sending and Receiving Updates
  - All routers must accept packets sent to AllSPFRouters (224.0.0.5)
  - All DR and BDR routers must accept packets sent to AllDRouters (224.0.0.6)
- Hello packets sent to AllSPFRouters (Unicast on point-to-point and virtual links)

Routing Protocol Packets

- Share a common protocol header
- Routing protocol packets are sent with type of service (TOS) of 0
- Five types of OSPF routing protocol packets
  - Hello – packet type 1
  - Database description – packet type 2
  - Link-state request – packet type 3
  - Link-state update – packet type 4
  - Link-state acknowledgement – packet type 5

Different Types of LSAs

- Six distinct type of LSAs
  - Type 1 : Router LSA
  - Type 2 : Network LSA
  - Type 3 & 4: Summary LSA
  - Type 5 & 7: External LSA (Type 7 is for NSSA)
  - Type 6: Group membership LSA
  - Type 9, 10 & 11: Opaque LSA (9: Link-Local, 10: Area)

Router LSA (Type 1)

- Describes the state and cost of the router's links to the area
- All of the router's links in an area must be described in a single LSA
- Flooded throughout the particular area and no more
- Router indicates whether it is an ASBR, ABR, or end point of virtual link

Network LSA (Type 2)

- Generated for every transit broadcast and NBMA network
- Describes all the routers attached to the network
- Only the designated router originates this LSA
- Flooded throughout the area and no more

Summary LSA (Type 3 and 4)

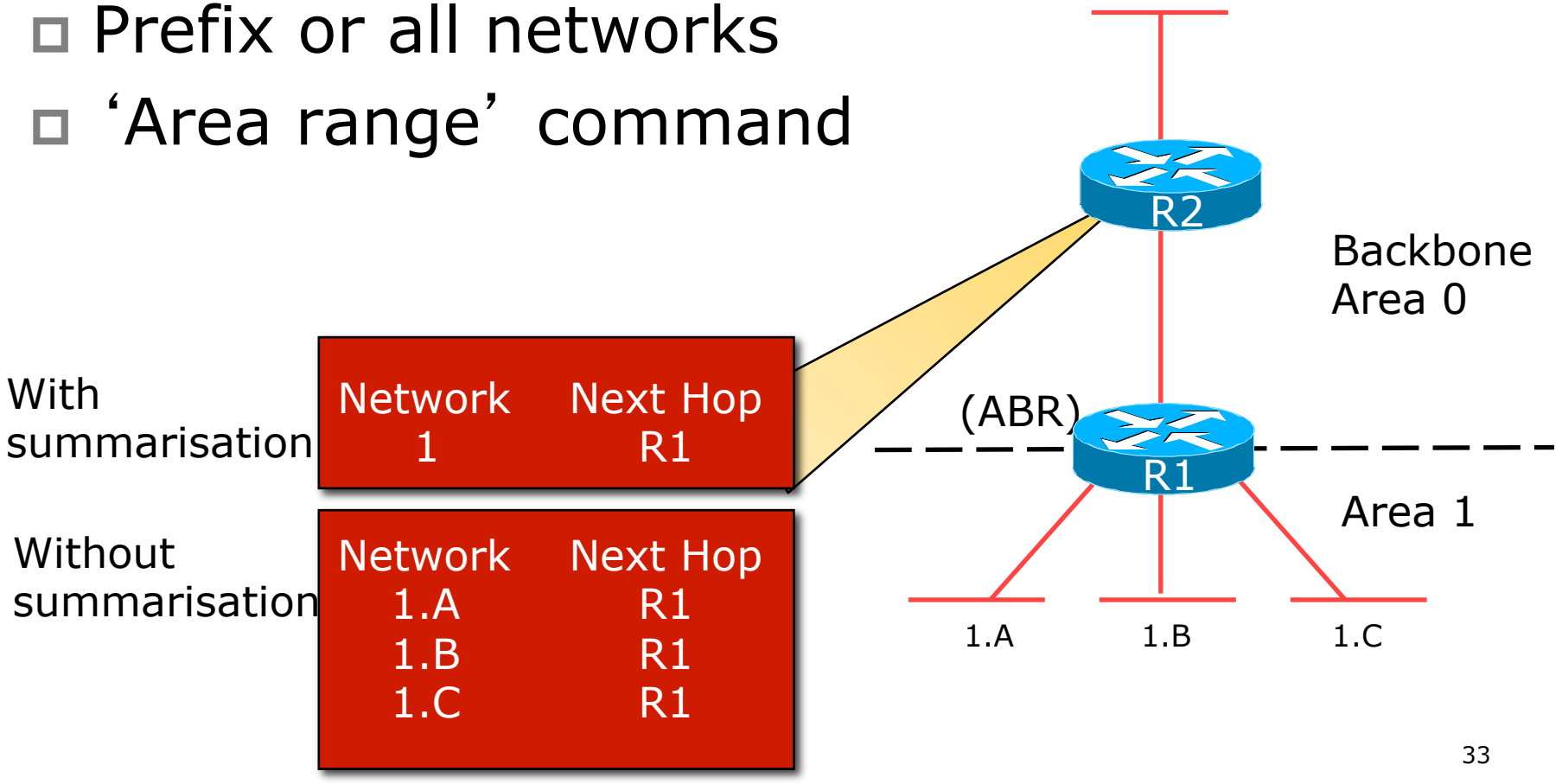
- Describes the destination outside the area but still in the AS
- Flooded throughout a single area
- Originated by an ABR
- Only inter-area routes are advertised into the backbone
- Type 4 is the information about the ASBR

External LSA (Type 5 and 7)

- Defines routes to destination external to the AS
- Default route is also sent as external
- Two types of external LSA:
  - E1: Consider the total cost up to the external destination
  - E2: Considers only the cost of the outgoing interface to the external destination
- (Type 7 LSAs used to describe external LSA for one specific OSPF area type)

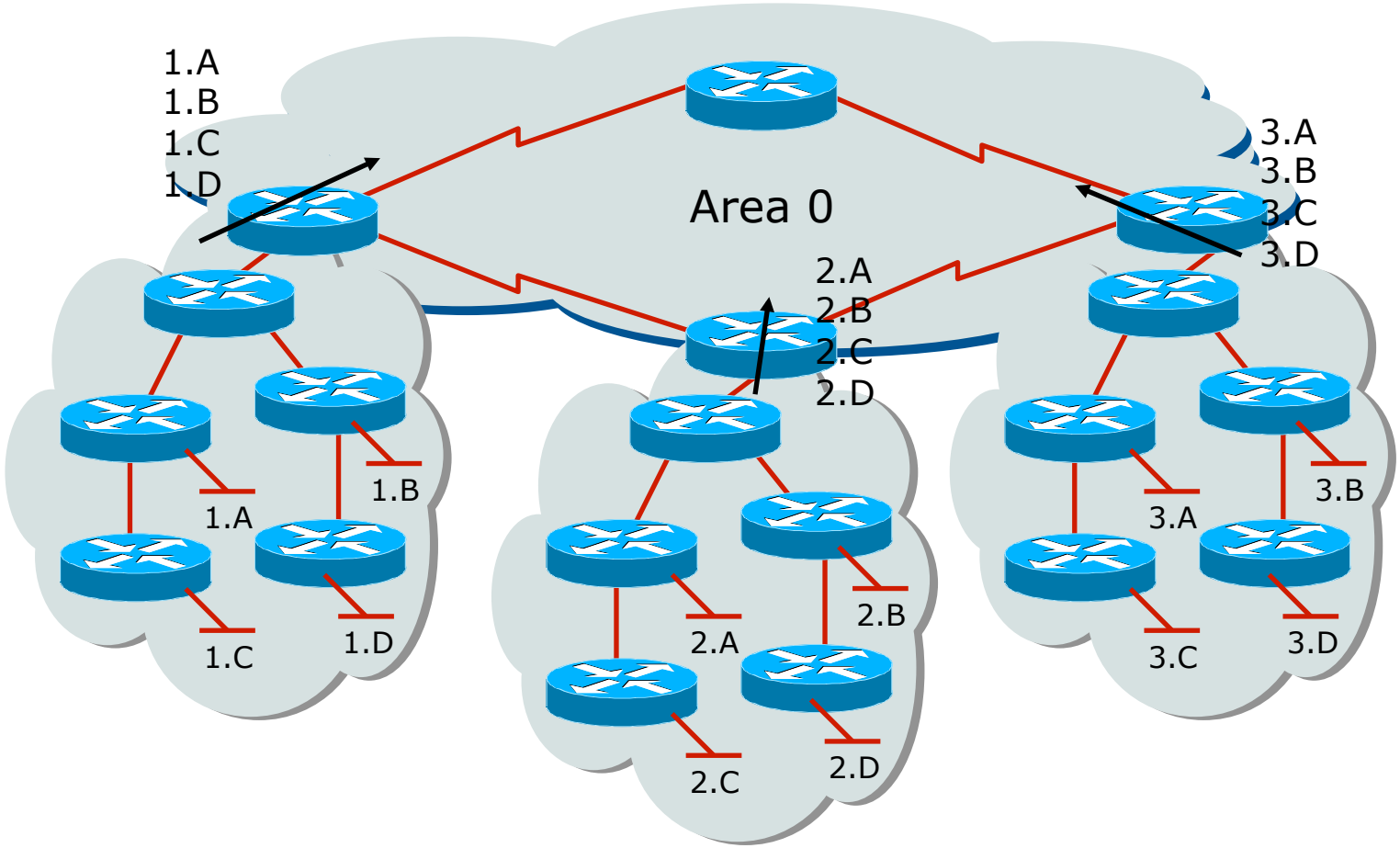
Inter-Area Route Summarisation

- Prefix or all subnets
- Prefix or all networks
- ‘Area range’ command



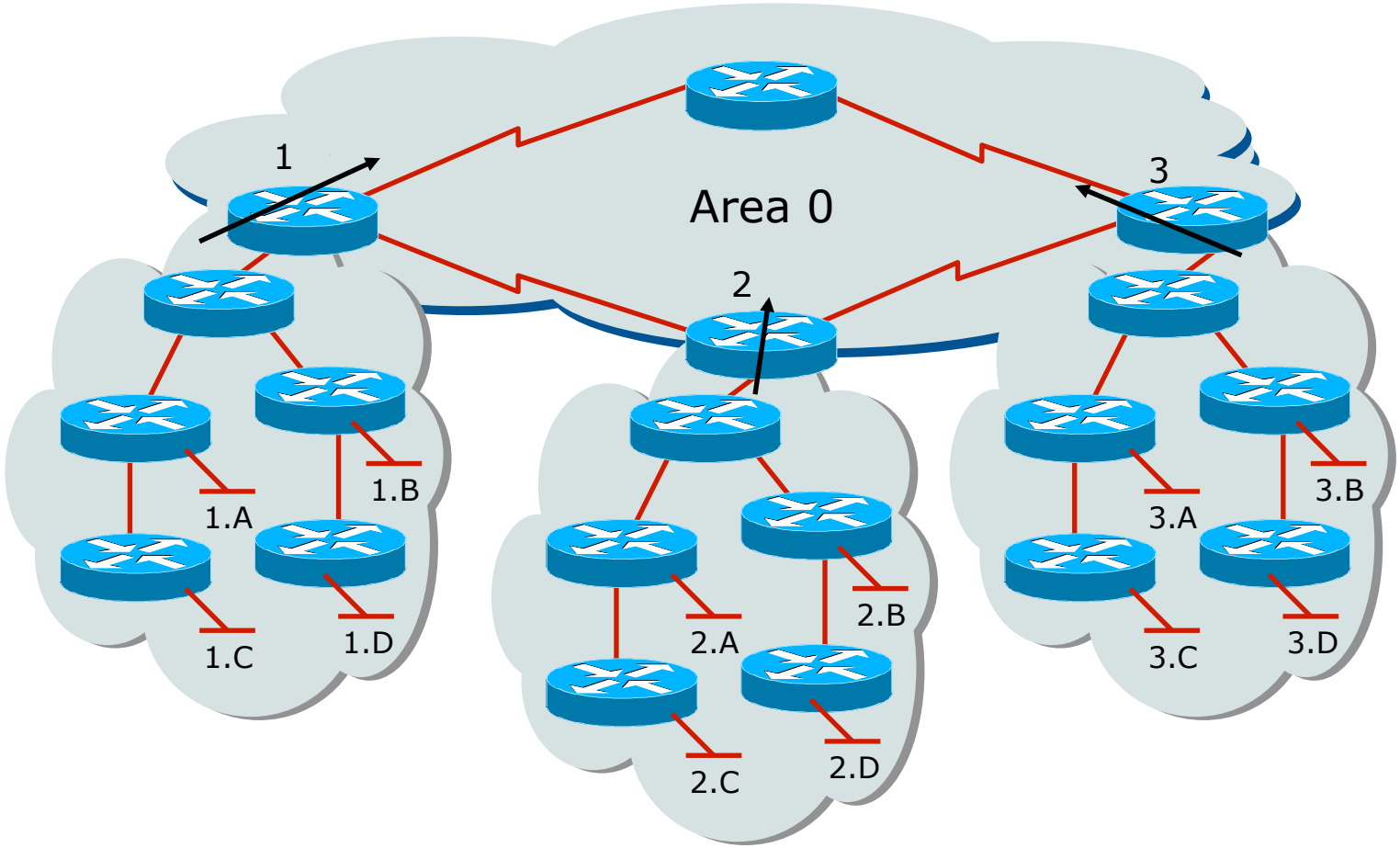
No Summarisation

- Specific Link LSA advertised out of each area
- Link state changes propagated out of each area



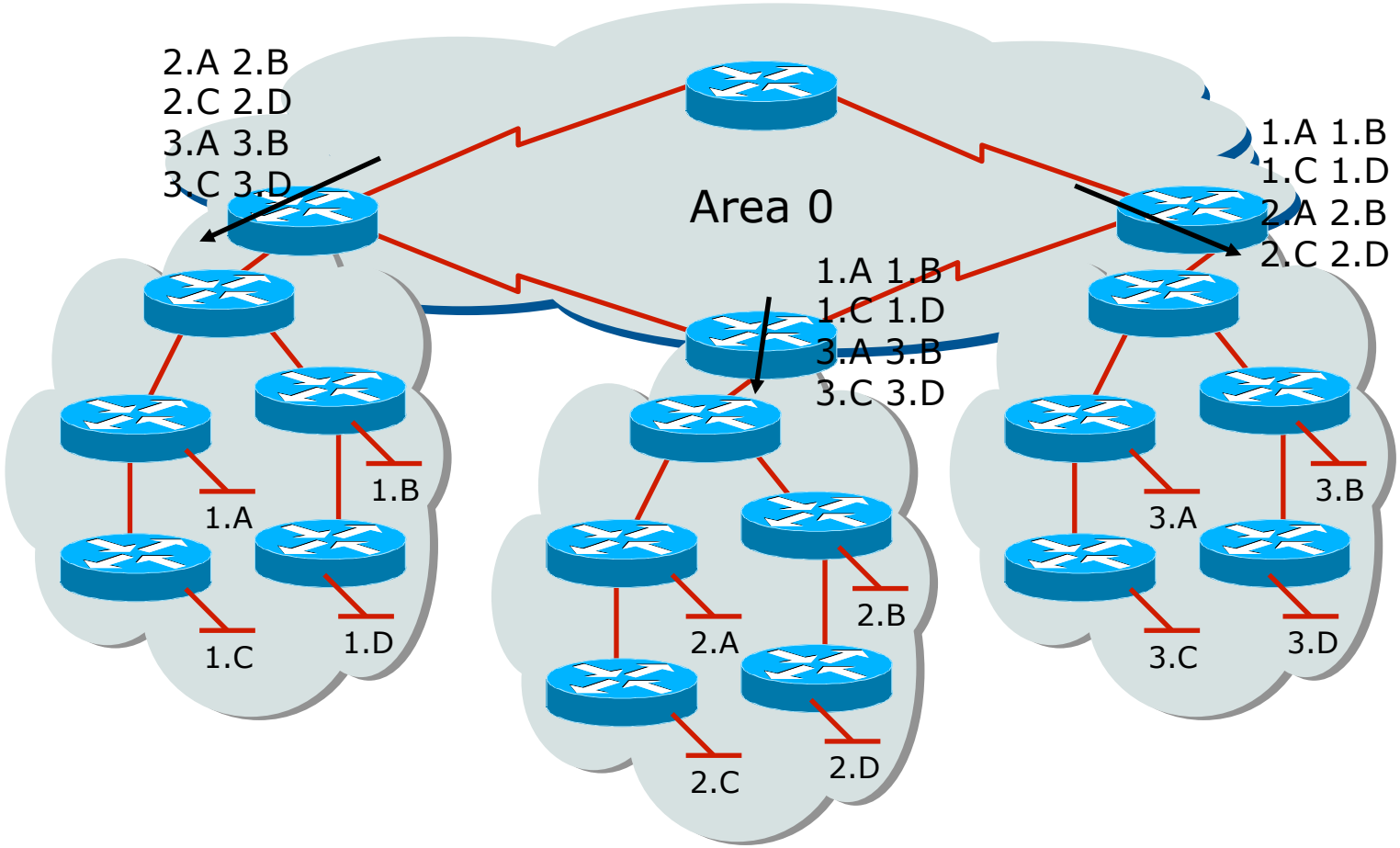
With Summarisation

- Only summary LSA advertised out of each area
- Link state changes do not propagate out of the area



No Summarisation

- Specific Link LSA advertised in to each area
- Link state changes propagated in to each area



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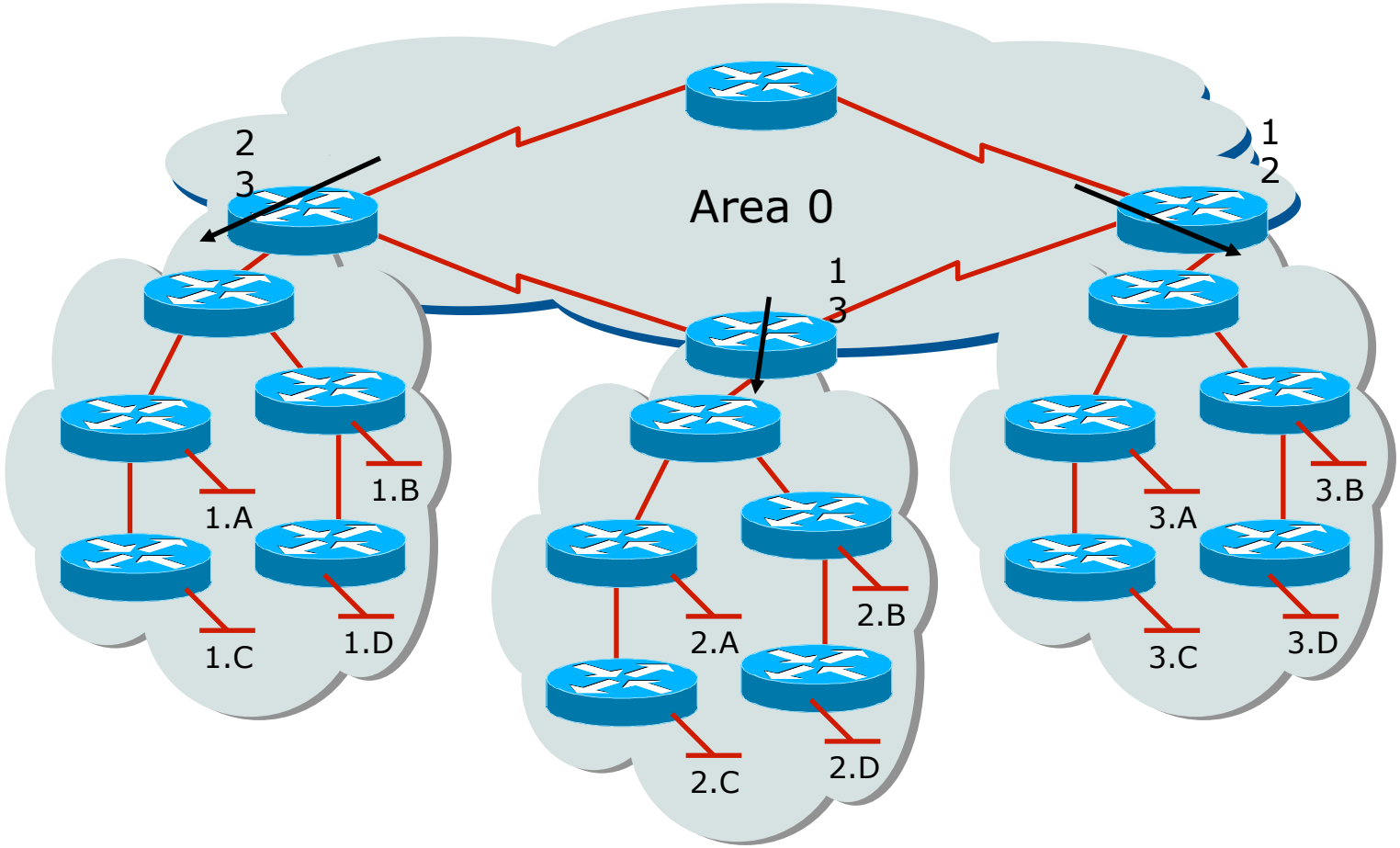
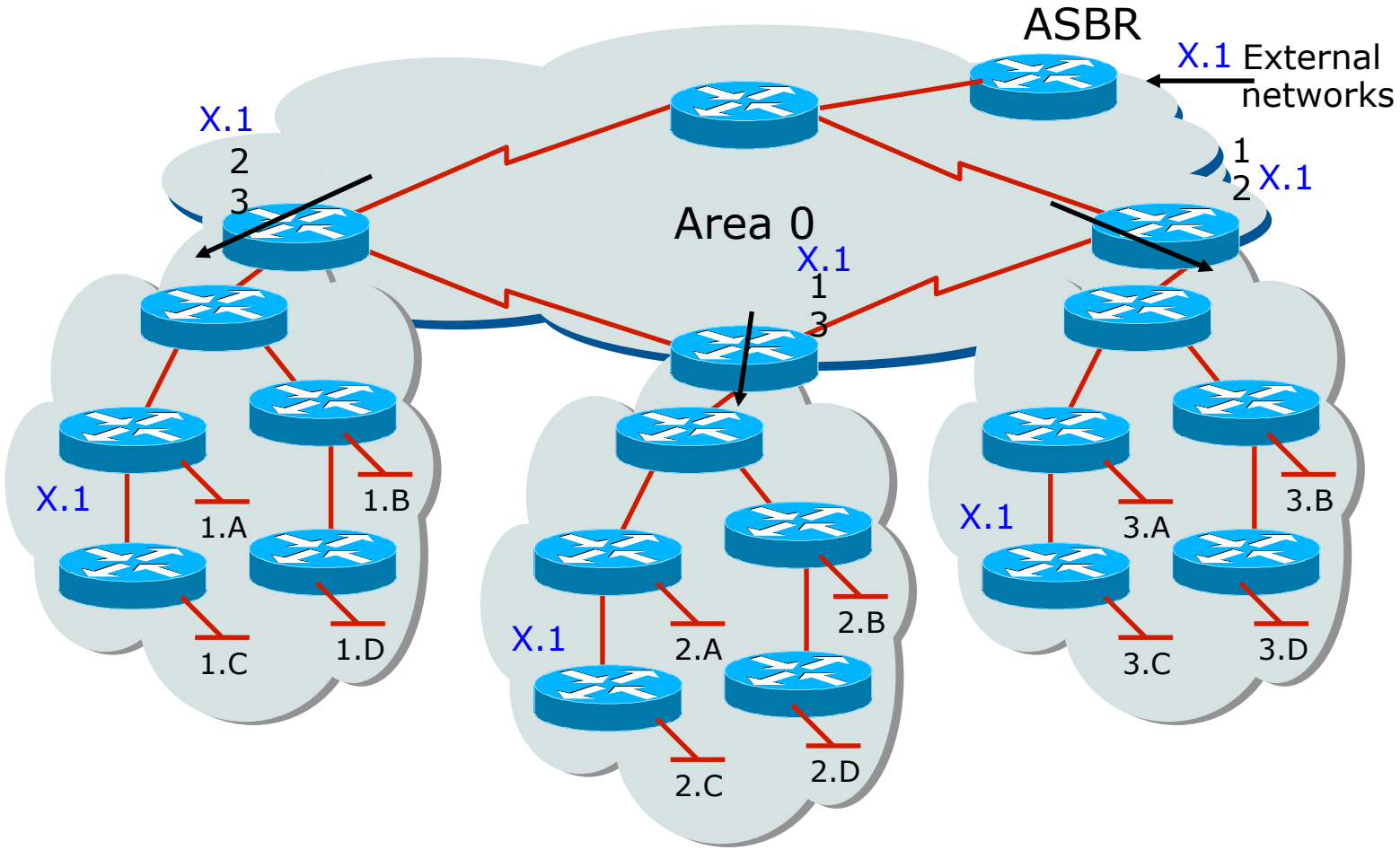


Types of Areas

- Regular
- Stub
- Totally Stubby
- Not-So-Stubby
- **Only "regular" areas are useful for ISPs**
  - Other area types handle redistribution of other routing protocols into OSPF – ISPs don't redistribute anything into OSPF
- The next slides describing the different area types are provided for information only

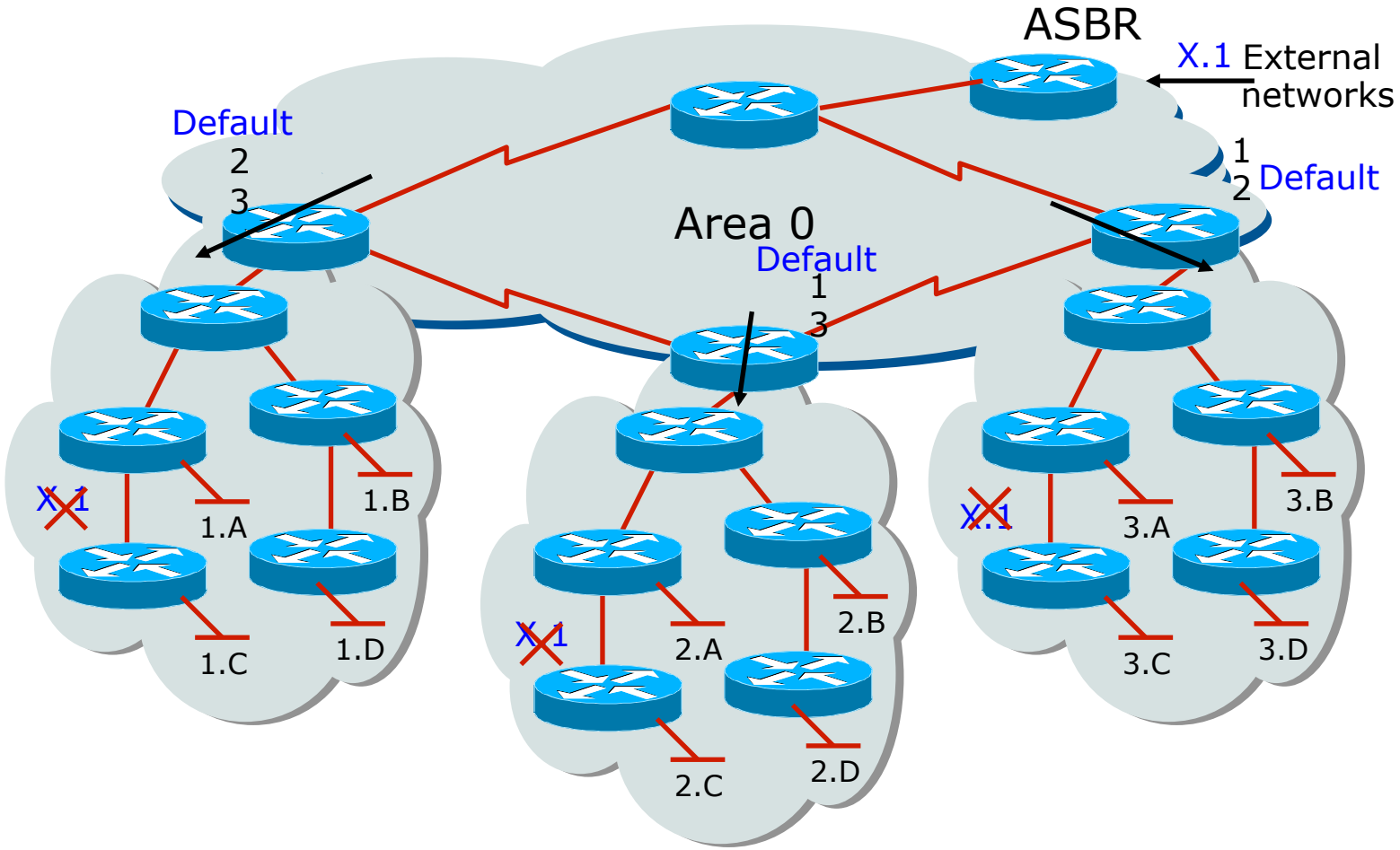
Regular Area (Not a Stub)

- From Area 1's point of view, summary networks from other areas are injected, as are external networks such as X.1



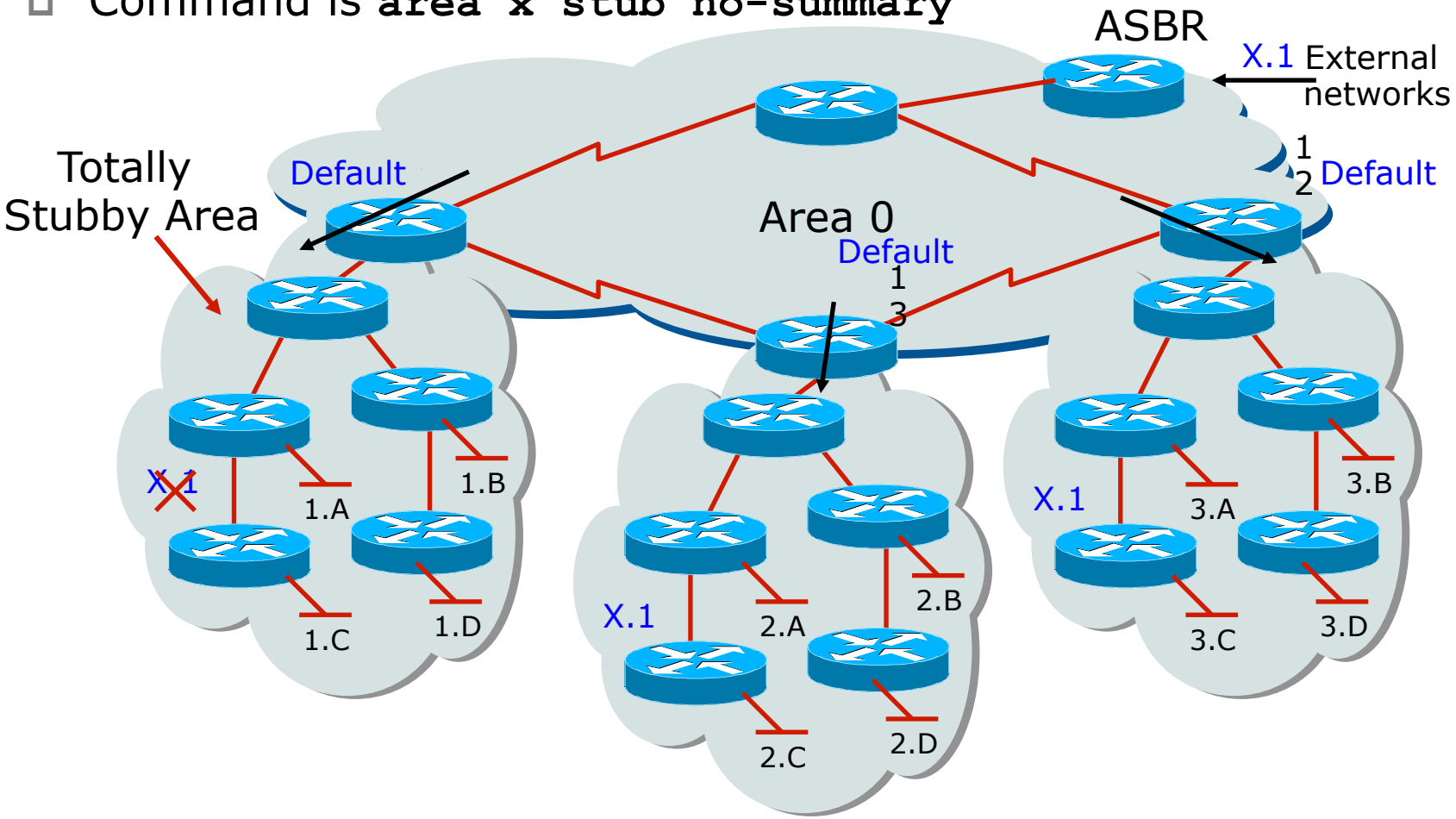
Normal Stub Area

- Summary networks, default route injected
- Command is **`area x stub`**



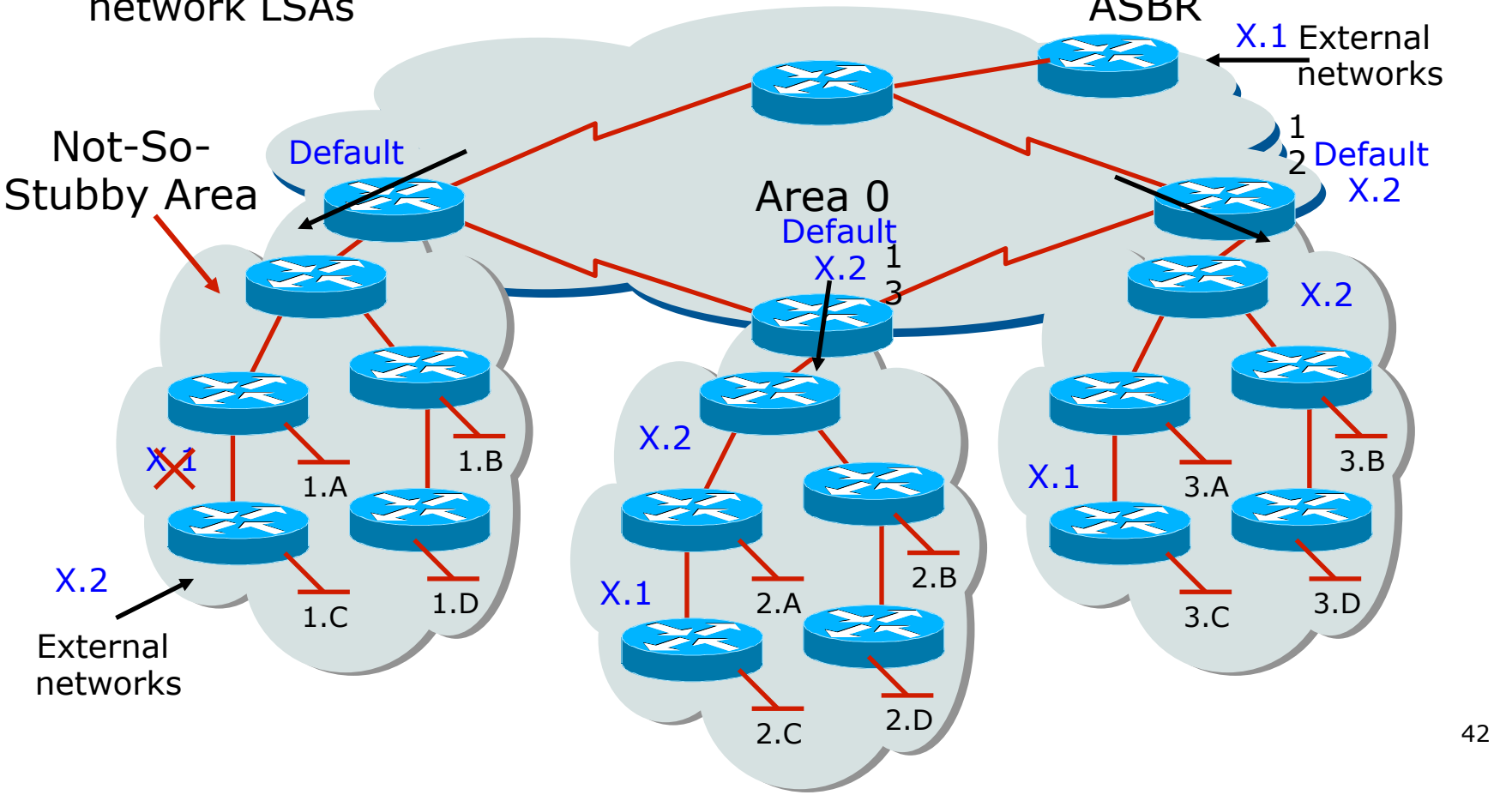
Totally Stubby Area

- Only a default route injected
  - Default path to closest area border router
- Command is **`area x stub no-summary`**



Not-So-Stubby Area

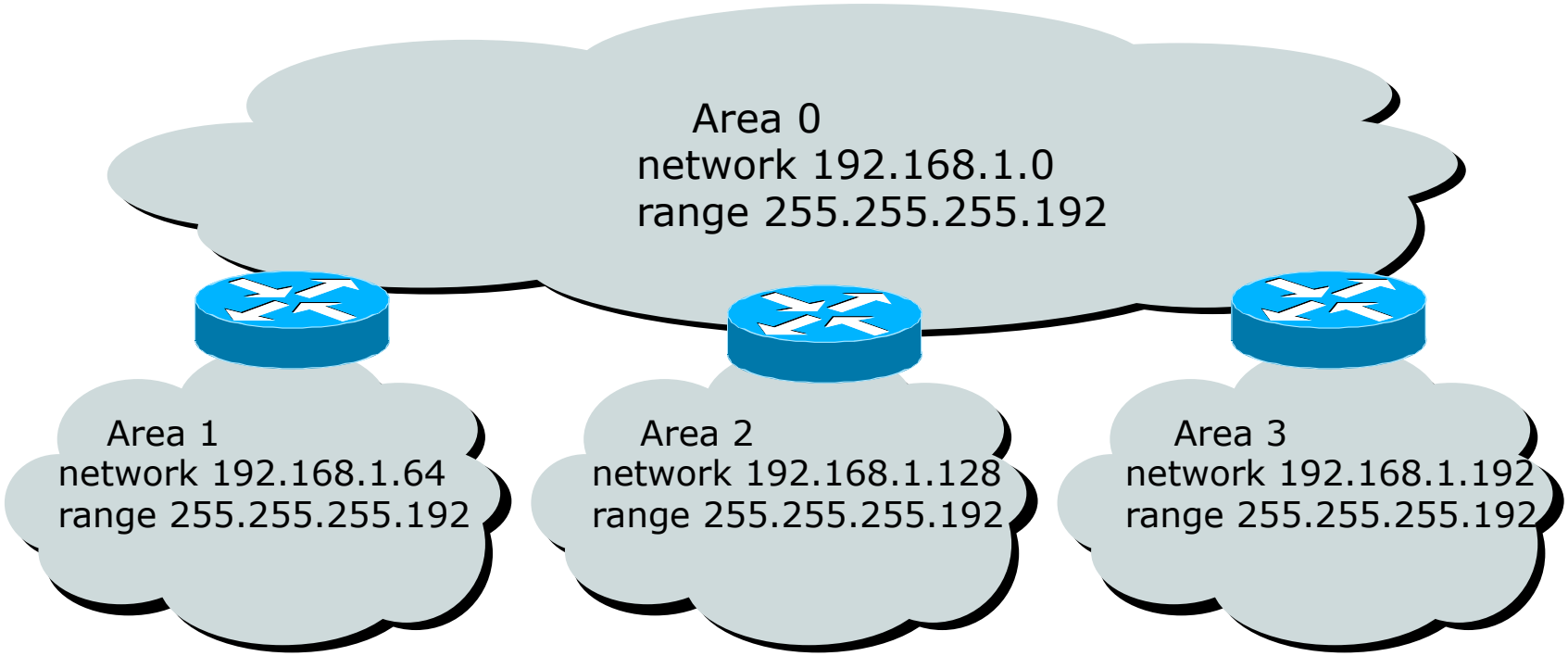
- Capable of importing routes in a limited fashion
- Type-7 LSA's carry external information within an NSSA
- NSSA Border routers translate selected type-7 LSAs into type-5 external network LSAs



ISP Use of Areas

- ISP networks use:
  - Backbone area
  - Regular area
- Backbone area
  - No partitioning
- Regular area
  - Summarisation of point to point link addresses used within areas
  - Loopback addresses allowed out of regular areas without summarisation (otherwise iBGP won't work)

Addressing for Areas



- Assign contiguous ranges of subnets per area to facilitate summarisation

Summary

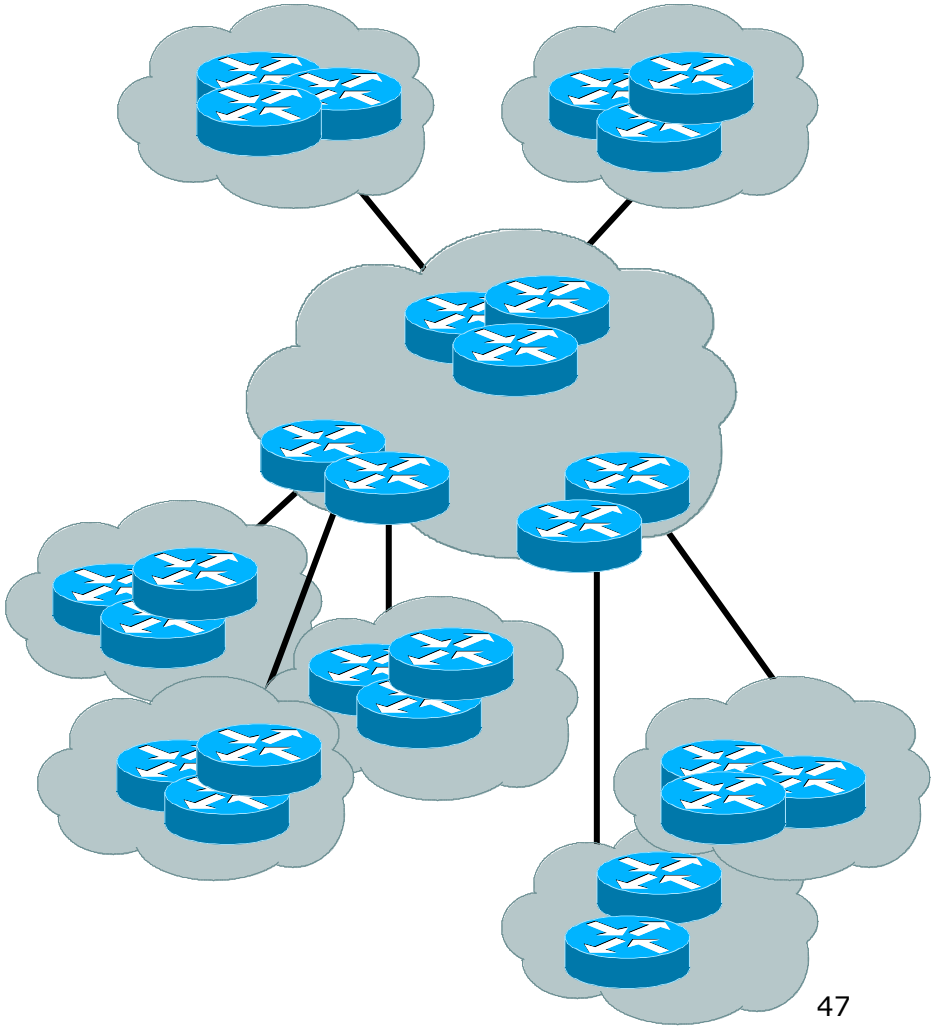
- Fundamentals of Scalable OSPF Network Design
  - Area hierarchy
  - DR/BDR selection
  - Contiguous intra-area addressing
  - Route summarisation
  - Infrastructure prefixes only

OSPF Design

As applicable to Service Provider Networks

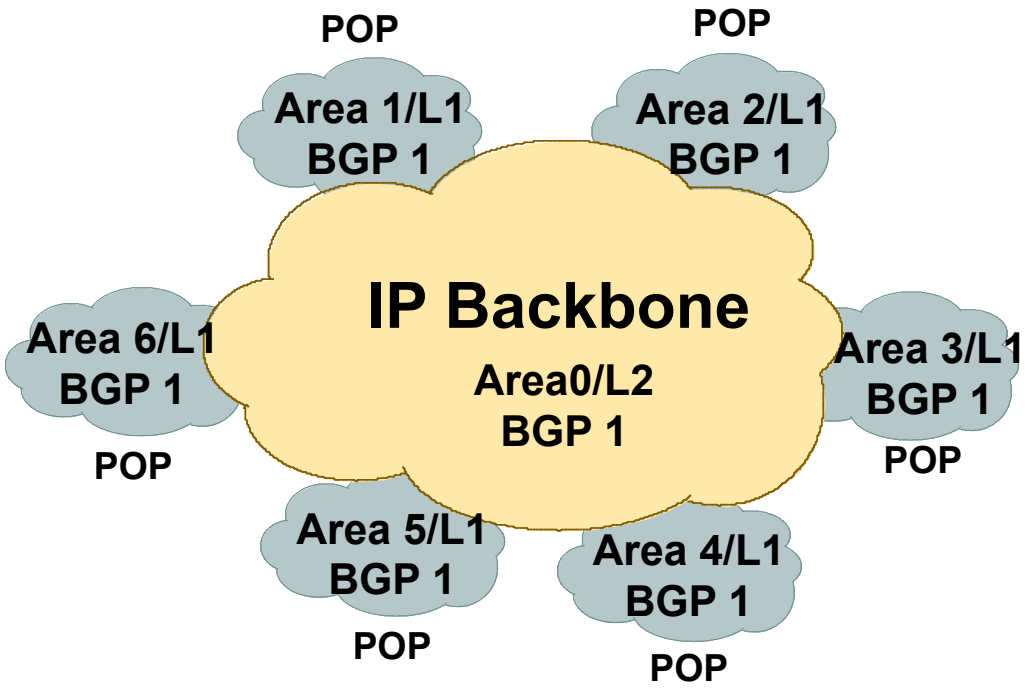
Service Providers

- SP networks are divided into PoPs
- PoPs are linked by the backbone
- Transit routing information is carried via iBGP
- IGP is only used to carry the next hop for BGP
- Optimal path to the next hop is critical



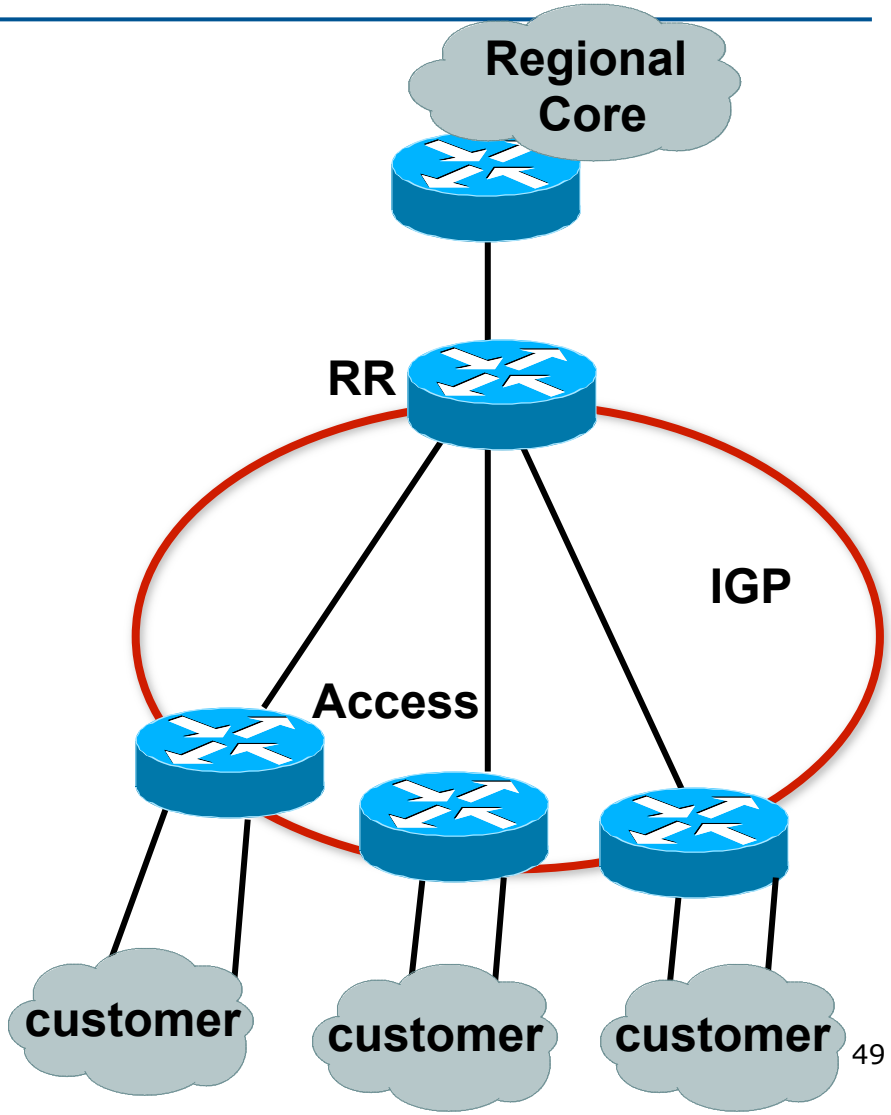
SP Architecture

- Major routing information is ~450K prefixes via BGP
- Largest known IGP routing table is ~9–10K
- Total of 460K
- 10K/460K is 2½% of IGP routes in an ISP network
- A very small factor but has a huge impact on network convergence!



SP Architecture

- You can reduce the IGP size from 10K to approx the number of routers in your network
- This will bring really fast convergence
- Optimise where you must and summarise where you can
- Stops unnecessary flapping



OSPF Design: Addressing

- OSPF Design and Addressing go together
  - Objective is to keep the Link State Database lean
  - Create an address hierarchy to match the topology
  - Use separate Address Blocks for loopbacks, network infrastructure, customer interfaces & customers

OSPF Design: Addressing

- Minimising the number of prefixes in OSPF:
  - **Number loopbacks out of a contiguous address block**
    - But do not summarise these across area boundaries: iBGP peer addresses need to be in the IGP
  - Use contiguous address blocks per area for infrastructure point-to-point links
    - Use **`area range`** command on ABR to summarise
- With these guidelines:
  - Number of prefixes in area 0 will then be very close to the number of routers in the network
  - It is critically important that the number of prefixes and LSAs in area 0 is kept to the absolute minimum

OSPF Design: Areas

- Examine physical topology
  - Is it meshed or hub-and-spoke?
- Use areas and summarisation
  - This reduces overhead and LSA counts
  - (but watch next-hop for iBGP when summarising)
- Don’t bother with the various stub areas
  - No benefits for ISPs, causes problems for iBGP
- Push the creation of a backbone
  - Reduces mesh and promotes hierarchy

OSPF Design: Areas

- One SPF per area, flooding done per area
  - Watch out for overloading ABRs
- Avoid externals in OSPF
  - **DO NOT REDISTRIBUTE** into OSPF
  - External LSAs flood through entire network
- Different types of areas do different flooding
  - Normal areas
  - Stub areas
  - Totally stubby (stub no-summary)
  - Not so stubby areas (NSSA)

OSPF Design: Areas

- Area 0 **must** be contiguous
  - Do NOT use virtual links to join two Area 0 islands
- Traffic between two non-zero areas always goes via Area 0
  - **There is no benefit in joining two non-zero areas together**
  - Avoid designs which have two non-zero areas touching each other
  - (Typical design is an area per PoP, with core routers being ABR to the backbone area 0)

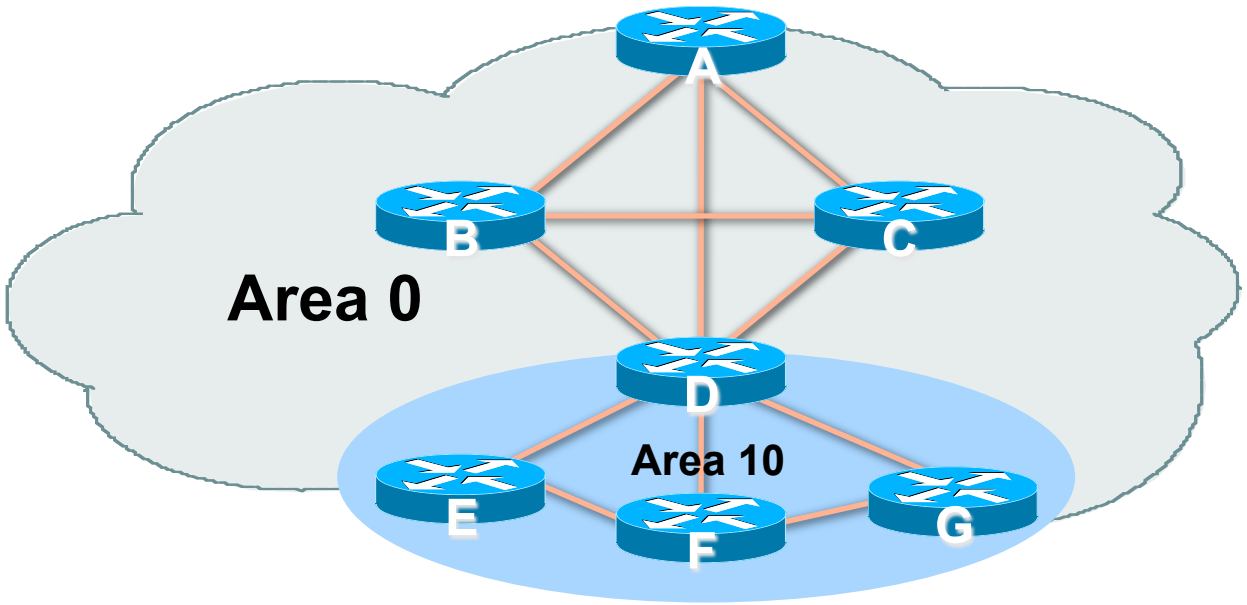
OSPF Design: Summary

- Think Redundancy
  - Dual Links out of each area – using metrics (cost) for traffic engineering
- Too much redundancy…
  - Dual links to backbone in stub areas must be the same cost – other wise sub-optimal routing will result
  - Too Much Redundancy in the backbone area without good summarisation will effect convergence in the Area 0

OSPF Areas: Migration

- Where to place OSPF Areas?
  - **Follow the physical topology!**
  - Remember the earlier design advice
- Configure area at a time!
  - Start at the outermost edge of the network
  - Log into routers at either end of a link and change the link from Area 0 to the chosen Area
  - Wait for OSPF to re-establish adjacencies
  - And then move onto the next link, etc
  - Important to ensure that there is never an Area 0 island anywhere in the migrating network

OSPF Areas: Migration



- Migrate small parts of the network, one area at a time
  - Remember to introduce summarisation where feasible
- With careful planning, the migration can be done with minimal network downtime

OSPF for Service Providers

Configuring OSPF & Adding Networks

OSPF: Configuration

- Starting OSPF in Cisco's IOS

  ```
  router ospf 100
  ```

  - Where "100" is the process ID
- OSPF process ID is unique to the router
  - Gives possibility of running multiple instances of OSPF on one router
  - Process ID is not passed between routers in an AS
  - Many ISPs configure the process ID to be the same as their BGP Autonomous System Number

OSPF: Establishing Adjacencies

- Cisco IOS OSPFv2 automatically tries to establish adjacencies on all defined interfaces (or subnets)
- Best practice is to disable this
  - Potential security risk: sending OSPF Hellos outside of the autonomous system, and risking forming adjacencies with external networks
  - Example: Only POS4/0 interface will attempt to form an OSPF adjacency

```
router ospf 100
 passive-interface default
 no passive-interface POS4/0
```

OSPF: Adding Networks Option One

- Redistribution:
  - Applies to all connected interfaces on the router but sends networks as external type-2s – which are not summarised

```
router ospf 100
 redistribute connected subnets
```

- **Do NOT do this!** Because:
  - Type-2 LSAs flood through entire network
  - These LSAs are not all useful for determining paths through backbone; they simply take up valuable space

OSPF: Adding Networks Option Two

- Per link configuration – from IOS 12.4 onwards
  - OSPF is configured on each interface (same as ISIS)
  - Useful for multiple subnets per interface

```
interface POS 4/0
 ip address 192.168.1.1 255.255.255.0
 ip address 172.16.1.1 255.255.255.224 secondary
 ip ospf 100 area 0
!
router ospf 100
 passive-interface default
 no passive-interface POS 4/0
```

OSPF: Adding Networks Option Three

- Specific network statements
  - Every active interface with a configured IP address needs an OSPF network statement
  - Interfaces that will have no OSPF neighbours need passive-interface to disable OSPF Hello's
    - That is: all interfaces connecting to devices outside the ISP backbone (i.e. customers, peers, etc)

```
router ospf 100
 network 192.168.1.0 0.0.0.3 area 51
 network 192.168.1.4 0.0.0.3 area 51
 passive-interface Serial 1/0
```

OSPF: Adding Networks Option Four

- Network statements – wildcard mask
  - Every active interface with configured IP address covered by wildcard mask used in OSPF network statement
  - Interfaces covered by wildcard mask but having no OSPF neighbours need passive-interface (or use passive-interface default and then activate the interfaces which will have OSPF neighbours)

```
router ospf 100
 network 192.168.1.0 0.0.0.255 area 51
 passive-interface default
 no passive interface POS 4/0
```

OSPF: Adding Networks Recommendations

- Don't ever use Option 1
- Use Option 2 if supported; otherwise:
- Option 3 is fine for core/infrastructure routers
  - Doesn't scale too well when router has a large number of interfaces but only a few with OSPF neighbours
  - → solution is to use Option 3 with "no passive" on interfaces with OSPF neighbours
- Option 4 is preferred for aggregation routers
  - Or use iBGP next-hop-self
  - Or even ip unnumbered on external point-to-point links

OSPF: Adding Networks Example One (Cisco IOS ≥ 12.4)

- Aggregation router with large number of leased line customers and just two links to the core network:

```
interface loopback 0
 ip address 192.168.255.1 255.255.255.255
 ip ospf 100 area 0
interface POS 0/0
 ip address 192.168.10.1 255.255.255.252
 ip ospf 100 area 0
interface POS 1/0
 ip address 192.168.10.5 255.255.255.252
 ip ospf 100 area 0
interface serial 2/0:0 ...
 ip unnumbered loopback 0
! Customers connect here ^^^^^^^
router ospf 100
 passive-interface default
 no passive interface POS 0/0
 no passive interface POS 1/0
```

OSPF: Adding Networks Example One (Cisco IOS < 12.4)

- Aggregation router with large number of leased line customers and just two links to the core network:

```
interface loopback 0
 ip address 192.168.255.1 255.255.255.255
interface POS 0/0
 ip address 192.168.10.1 255.255.255.252
interface POS 1/0
 ip address 192.168.10.5 255.255.255.252
interface serial 2/0:0 ...
 ip unnumbered loopback 0
! Customers connect here ^^^^^^^
router ospf 100
 network 192.168.255.1 0.0.0.0 area 51
 network 192.168.10.0 0.0.0.3 area 51
 network 192.168.10.4 0.0.0.3 area 51
 passive-interface default
 no passive interface POS 0/0
 no passive interface POS 1/0
```

OSPF: Adding Networks Example Two (Cisco IOS ≥ 12.4)

- Core router with only links to other core routers:

```
interface loopback 0
 ip address 192.168.255.1 255.255.255.255
 ip ospf 100 area 0
interface POS 0/0
 ip address 192.168.10.129 255.255.255.252
 ip ospf 100 area 0
interface POS 1/0
 ip address 192.168.10.133 255.255.255.252
 ip ospf 100 area 0
interface POS 2/0
 ip address 192.168.10.137 255.255.255.252
 ip ospf 100 area 0
interface POS 2/1
 ip address 192.168.10.141 255.255.255.252
 ip ospf 100 area 0
router ospf 100
 passive interface loopback 0
```

OSPF: Adding Networks Example Two (Cisco IOS < 12.4)

- Core router with only links to other core routers:

```
interface loopback 0
 ip address 192.168.255.1 255.255.255.255
interface POS 0/0
 ip address 192.168.10.129 255.255.255.252
interface POS 1/0
 ip address 192.168.10.133 255.255.255.252
interface POS 2/0
 ip address 192.168.10.137 255.255.255.252
interface POS 2/1
 ip address 192.168.10.141 255.255.255.252
router ospf 100
 network 192.168.255.1 0.0.0.0 area 0
 network 192.168.10.128 0.0.0.3 area 0
 network 192.168.10.132 0.0.0.3 area 0
 network 192.168.10.136 0.0.0.3 area 0
 network 192.168.10.140 0.0.0.3 area 0
 passive interface loopback 0
```

OSPF: Adding Networks Summary

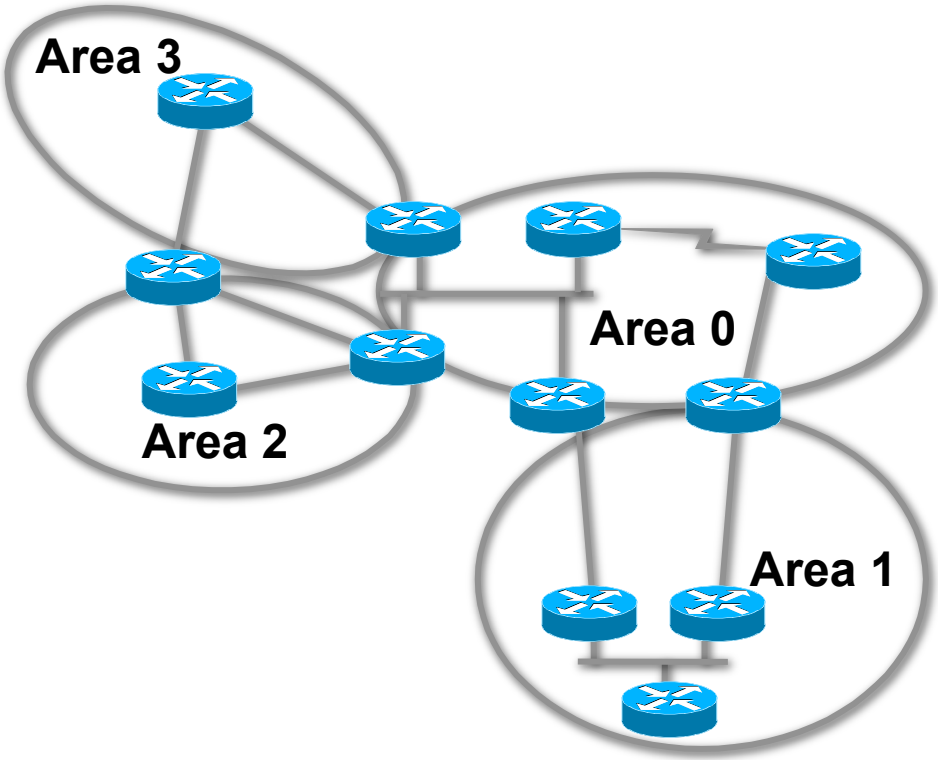
- Key Theme when selecting a technique: Keep the Link State Database Lean
  - Increases Stability
  - Reduces the amount of information in the Link State Advertisements (LSAs)
  - Speeds Convergence Time

OSPF in Cisco IOS

Useful features for ISPs

Areas

- An area is stored as a 32-bit field:
  - Defined in IPv4 address format (i.e. Area 0.0.0.0)
  - Can also be defined using single decimal value (i.e. Area 0)
- 0.0.0.0 reserved for the backbone area



Logging Adjacency Changes

- The router will generate a log message whenever an OSPF neighbour changes state
- Syntax:
  - **`[no] [ospf] log-adjacency-changes`**
  - (OSPF keyword is optional, depending on IOS version)
- Example of a typical log message:
  - `%OSPF-5-ADJCHG: Process 1, Nbr 223.127.255.223 on Ethernet0 from LOADING to FULL, Loading Done`

Number of State Changes

- The number of state transitions is available via SNMP (ospfNbrEvents) and the CLI:
  - **`show ip ospf neighbor [`*`type number`*`] [`*`neighbor-id`*`] [detail]`**
  - Detail—(Optional) Displays all neighbours given in detail (list all neighbours). When specified, neighbour state transition counters are displayed per interface or neighbour ID

State Changes (Continued)

- To reset OSPF-related statistics, use the `clear ip ospf counters` command
  - This will reset neighbour state transition counters per interface or neighbour id
  - **`clear ip ospf counters [neighbor [<`*`type number`*`>] [`*`neighbor-id`*`]]`**

Router ID

- If the loopback interface exists and has an IP address, that is used as the router ID in routing protocols – **stability**!
- If the loopback interface does not exist, or has no IP address, the router ID is the highest IP address configured – **danger**!
- OSPF sub command to manually set the Router ID:
  - **`router-id <ip address>`**

Cost & Reference Bandwidth

- Bandwidth used in Metric calculation
  - Cost = 10^8/bandwidth
  - Not useful for interface bandwidths > 100 Mbps
- Syntax:
  - **`ospf auto-cost reference-bandwidth <`*`reference-bw`*`>`**
- Default reference bandwidth still 100 Mbps for backward compatibility
- Most ISPs simply choose to develop their own cost strategy and apply to each interface type

Cost: Example Strategy

100GE	100Gbps	cost = 1
40GE/OC768	40Gbps	cost = 2
10GE/OC192	10Gbps	cost = 5
OC48	2.5Gbps	cost = 10
GigEthernet	1Gbps	cost = 20
OC12	622Mbps	cost = 50
OC3	155Mbps	cost = 100
FastEthernet	100Mbps	cost = 200
Ethernet	10Mbps	cost = 500
E1	2Mbps	cost = 1000

Default routes

- Originating a default route into OSPF
  - **`default-information originate metric <n>`**
  - Will originate a default route into OSPF if there is a matching default route in the Routing Table (RIB)
  - The optional **`always`** keyword will always originate a default route, even if there is no existing entry in the RIB

Clear/Restart

- OSPF **`clear`** commands
  - If no process ID is given, all OSPF processes on the router are assumed
- **`clear ip ospf [pid] redistribution`**
  - This command clears redistribution based on OSPF routing process ID
- **`clear ip ospf [pid] counters`**
  - This command clears counters based on OSPF routing process ID
- **`clear ip ospf [pid] process`**
  - This command will restart the specified OSPF process. It attempts to keep the old router-id, except in cases where a new router-id was configured or an old user configured router-id was removed. Since this command can potentially cause a network churn, a user confirmation is required before performing any action

Use OSPF Authentication

- Use authentication
  - Too many operators overlook this basic requirement
- When using authentication, use the MD5 feature
  - Under the global OSPF configuration, specify:

    `area <area-id> authentication message-digest`
  - Under the interface configuration, specify:

    `ip ospf message-digest-key 1 md5 <key>`
- Authentication can be selectively disabled per interface with:

  `ip ospf authentication null`

Point to Point Ethernet Links

- For any broadcast media (like Ethernet), OSPF will attempt to elect a designated and backup designated router when it forms an adjacency
  - If the interface is running as a point-to-point WAN link, with only 2 routers on the wire, configuring OSPF to operate in "point-to-point mode" scales the protocol by reducing the link failure detection times
  - Point-to-point mode improves convergence times on Ethernet networks because it:
    - Prevents the election of a DR/BDR on the link,
    - Simplifies the SPF computations and reduces the router's memory footprint due to a smaller topology database.

```
interface fastethernet0/2
 ip ospf network point-to-point
```

Tuning OSPF (1)

- DR/BDR Selection
  - **`ip ospf priority 100`** (default 1)
  - This feature should be in use in your OSPF network
  - Forcibly set your DR and BDR per segment so that they are known
  - Choose your most powerful, or most idle routers, so that OSPF converges as fast as possible under maximum network load conditions
  - Try to keep the DR/BDR limited to one segment each

Tuning OSPF (2)

- OSPF startup
  - **`max-metric router-lsa on-startup wait-for-bgp`**
  - Avoids blackholing traffic on router restart
  - Causes OSPF to announce its prefixes with highest possible metric until iBGP is up and running
  - When iBGP is running, OSPF metrics return to normal, make the path valid
- ISIS equivalent:
  - **`set-overload-bit on-startup wait-for-bgp`**

Tuning OSPF (3)

- Hello/Dead Timers
  - **`ip ospf hello-interval 3`** (default 10)
  - **`ip ospf dead-interval 15`** (default is 4x hello)
  - This allows for faster network awareness of a failure, and can result in faster reconvergence, but requires more router CPU and generates more overhead
- LSA Pacing
  - **`timers lsa-group-pacing 300`** (default 240)
  - Allows grouping and pacing of LSA updates at configured interval
  - Reduces overall network and router impact

Tuning OSPF (4)

- OSPF Internal Timers
  - **`timers spf 2 8`** (default is 5 and 10)
  - Allows you to adjust SPF characteristics
  - The first number sets wait time from topology change to SPF run
  - The second is hold-down between SPF runs
  - BE CAREFUL WITH THIS COMMAND; if you're not sure when to use it, it means you don't need it; default is sufficient 95% of the time

Tuning OSPF (5)

- LSA filtering/interface blocking
  - Per interface:
    - **`ip ospf database-filter all out`** (no options)
  - Per neighbor:
    - **`neighbor 1.1.1.1 database-filter all out`** (no options)
  - OSPFs router will flood an LSA out all interfaces except the receiving one; LSA filtering can be useful in cases where such flooding unnecessary (i.e., NBMA networks), where the DR/BDR can handle flooding chores
  - **`area <area-id> filter-list <acl>`**
  - Filters out specific Type 3 LSAs at ABRs
- Improper use can result in routing loops and black-holes that can be very difficult to troubleshoot

Summary

- OSPF has a bewildering number of features and options
- Observe ISP best practices
- Keep design and configuration simple
- Investigate tuning options and suitability for your own network
  - Don’t just turn them on!

OSPF in Detail

ISP Workshops