Introduction to OSPF

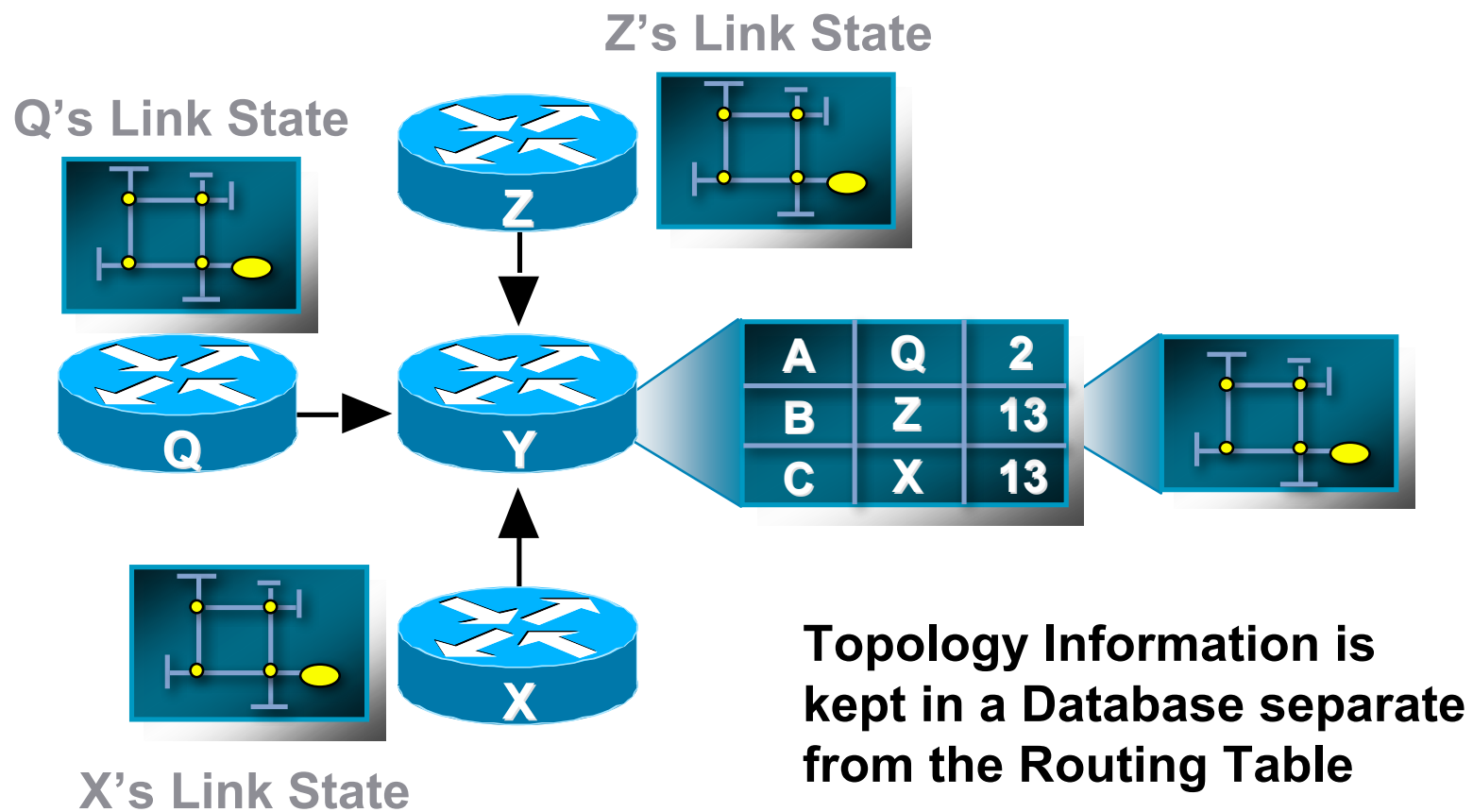**ISP/IXP Workshops**

OSPF

- **O**pen **S**hortest **P**ath **F**irst

- 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
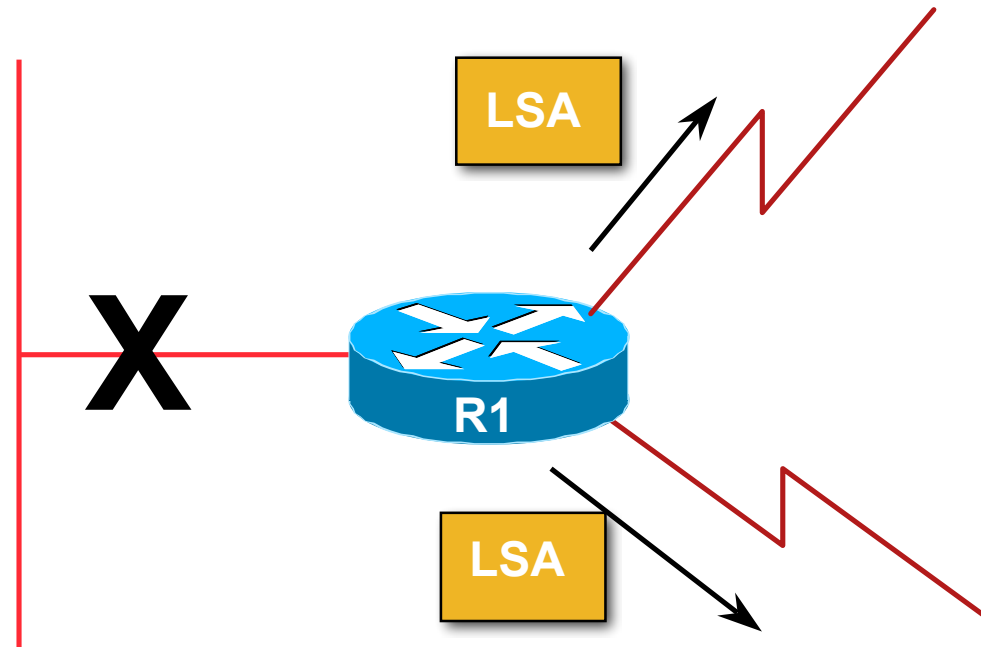
- Runs on IP, Protocol 89

Link State

Z's Link State

Q's Link State

A	Q	2
B	Z	13
C	X	13

X's 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
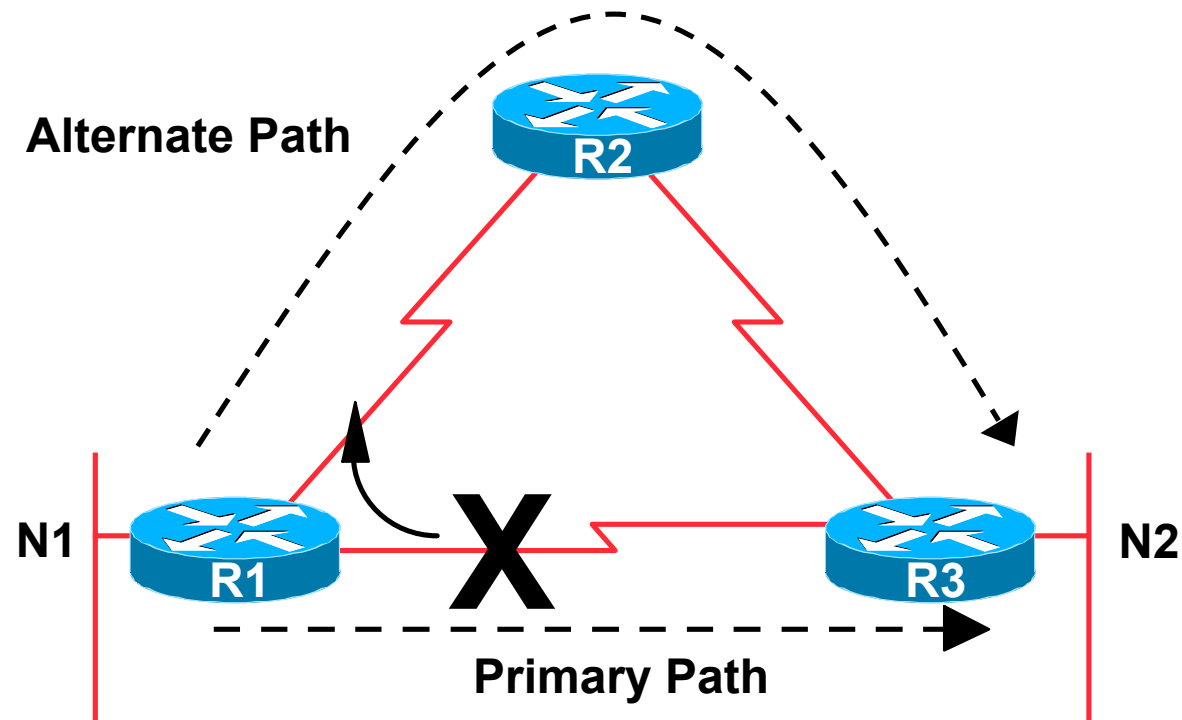
  All routers recompute routing table

Low Bandwidth Utilisation

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

Fast Convergence

- Detection Plus LSA/SPF

   Known as the Dijkstra Algorithm

Alternate Path

R2

N1

R1

X
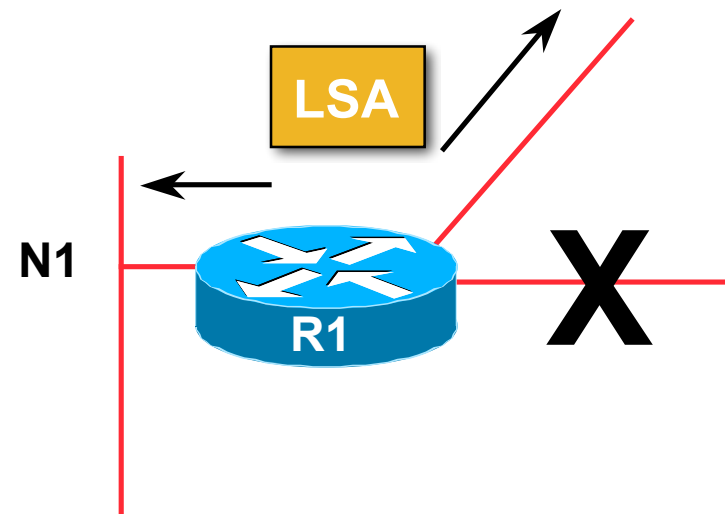
R3

N2

Primary Path

Fast Convergence

- Finding a new route

  LSA flooded throughout area

  Acknowledgement based

  Topology database synchronised

  Each router derives routing table to destination network

LSA

N1

R1

X

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**
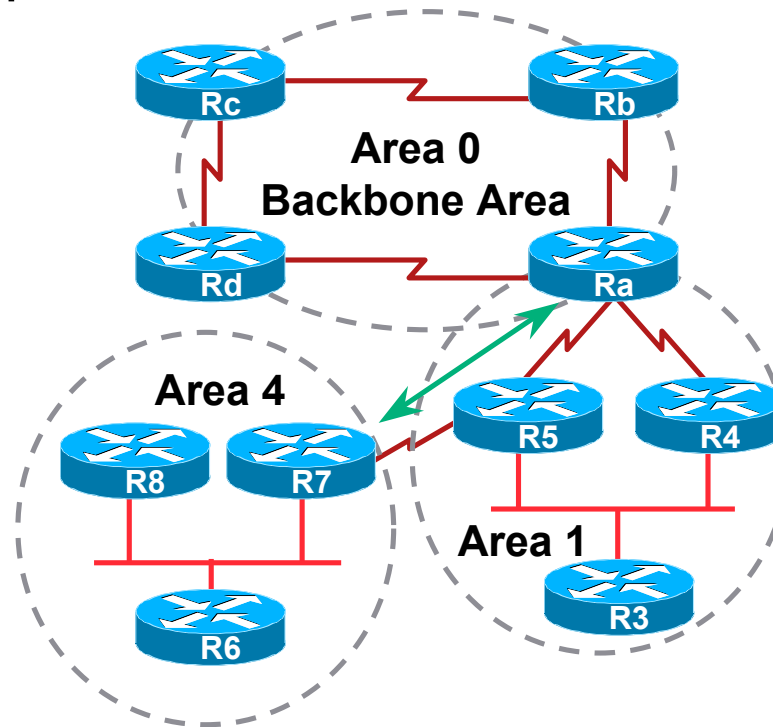 - All other areas must be connected to the backbone

Virtual Links between OSPF Areas

- Virtual Link is used when it is not possible to physically connect the area to the backbone
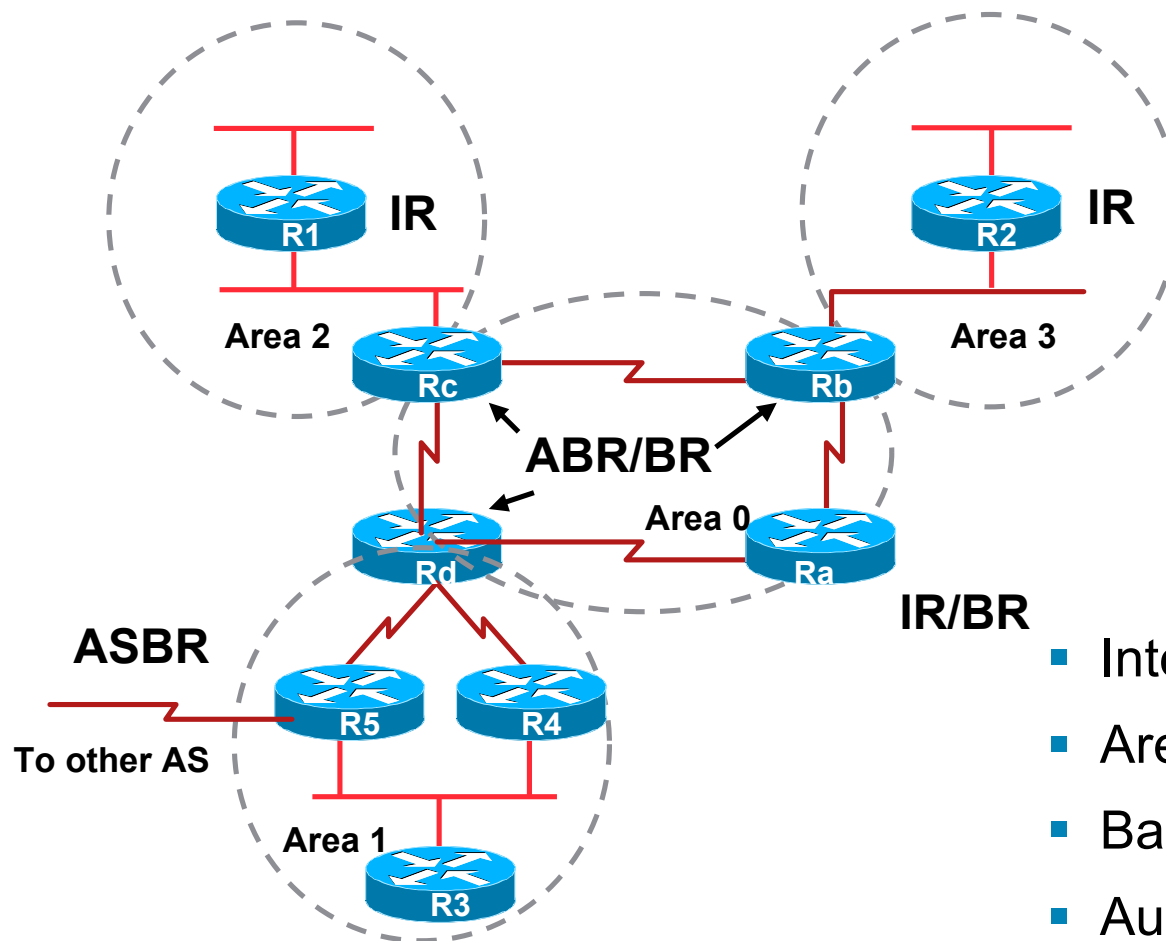
- **ISPs avoid designs which require virtual links**

  Increases complexity
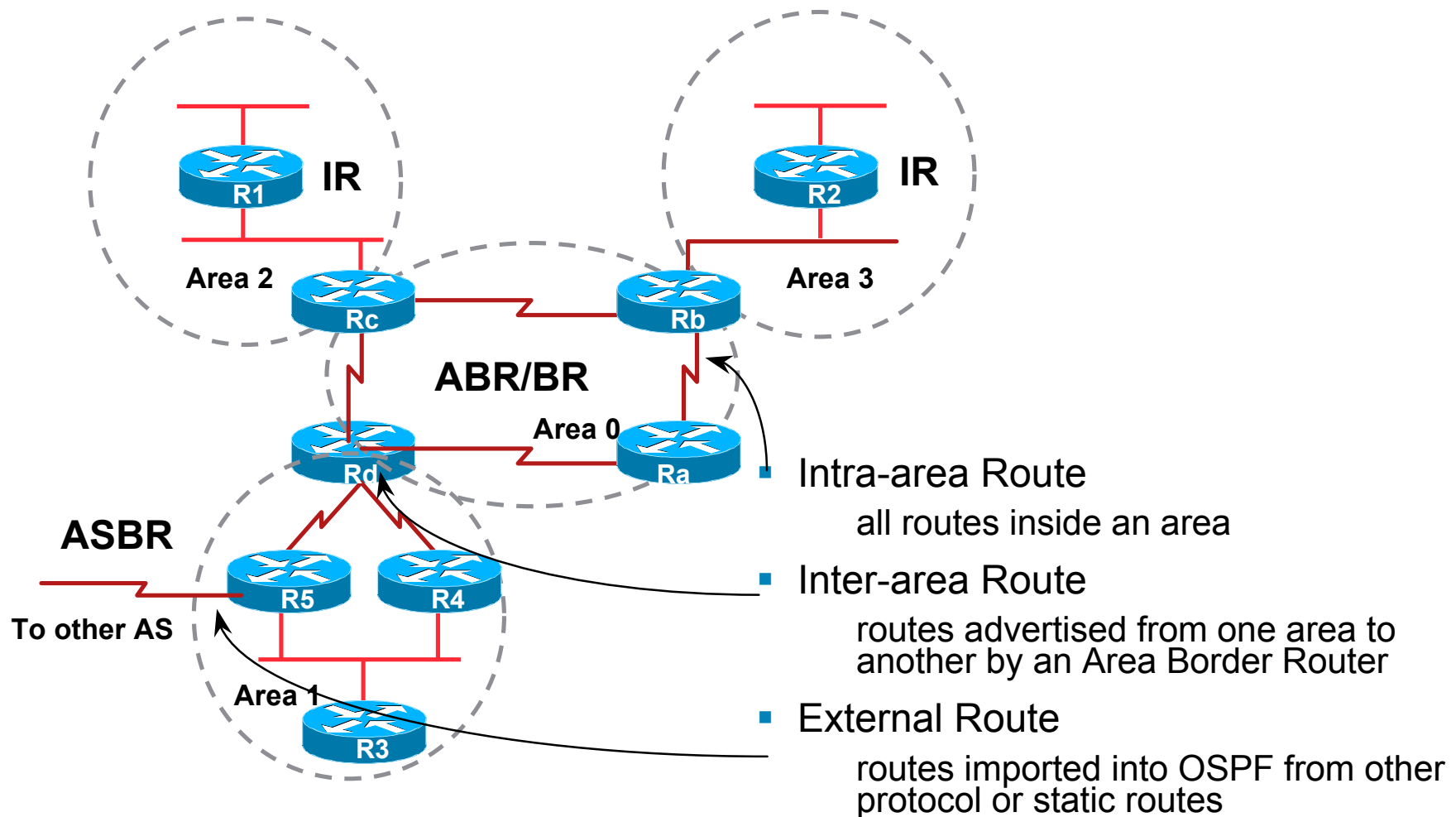
  Decreases reliability and scalability

Classification of Routers

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

OSPF Route Types

IR (R1 — Area 2)
IR (R2 — Area 3)

Rc
Rb
ABR/BR
Area 0
Rd
Ra
ASBR
To other AS
R5
R4
Area 1
R3

- 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
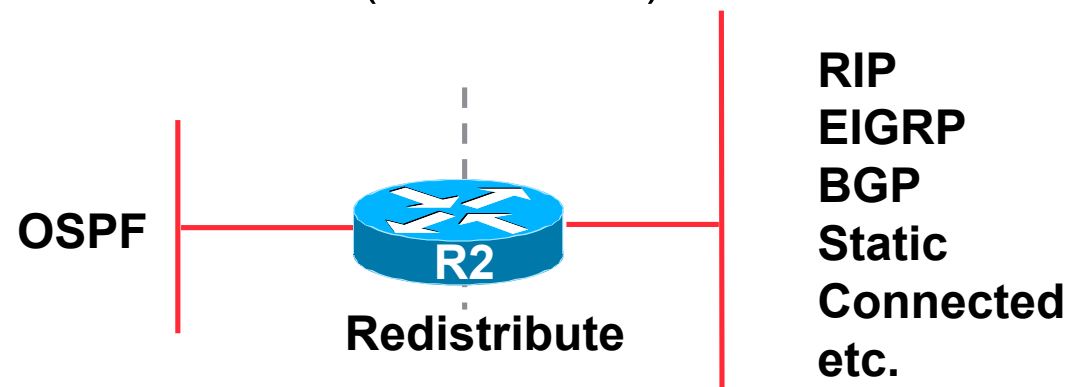
External Routes

- Prefixes which are redistributed into OSPF from other protocols

- Flooded unaltered throughout the AS

  Recommendation: Avoid redistribution!!
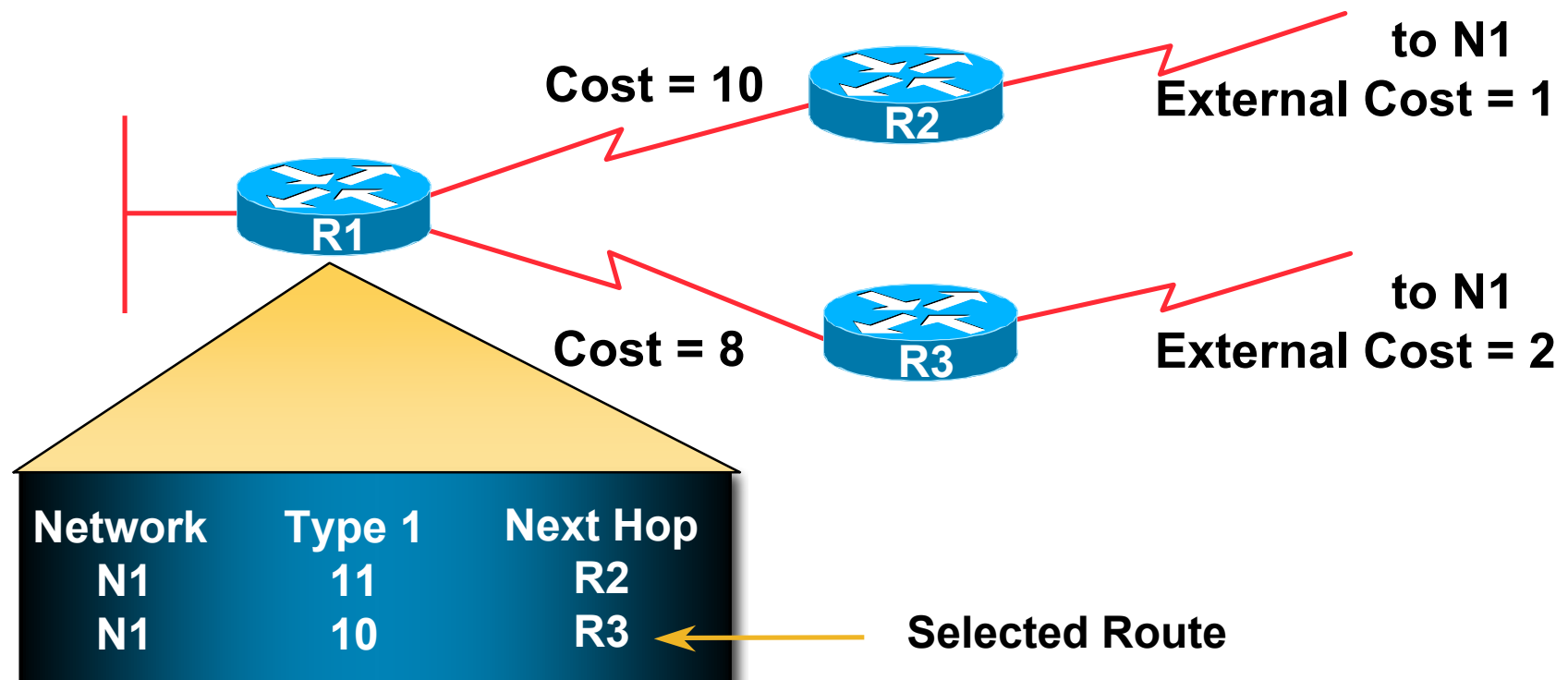
- OSPF supports two types of external metrics

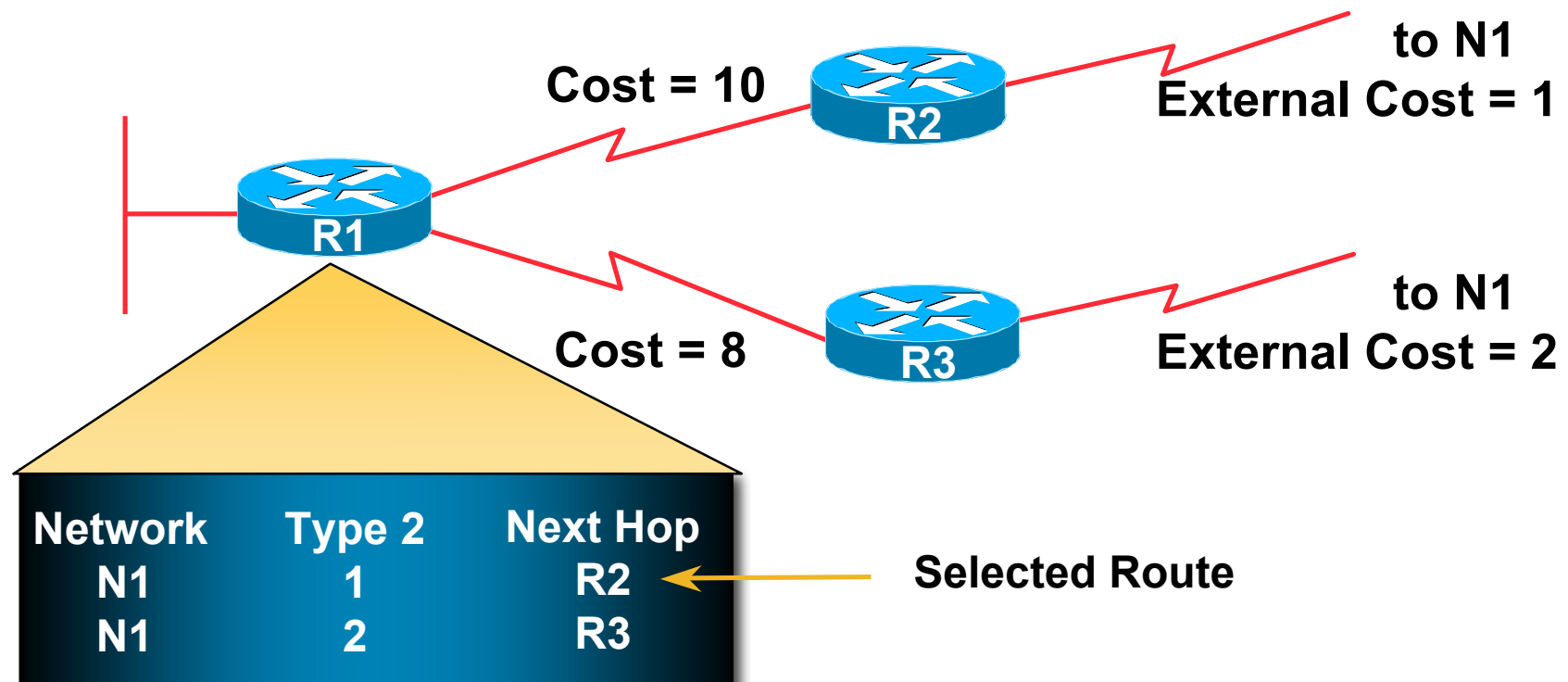 Type 1 external metrics

  Type 2 external metrics (IOS default)

OSPF

R2

Redistribute

**RIP
EIGRP
BGP
Static
Connected
etc.**

External Routes

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

Cost = 10

R2

to N1
External Cost = 1

R1

Cost = 8

R3

to N1
External Cost = 2

Network	Type 1	Next Hop
N1	11	R2
N1	10	R3

Selected Route

External Routes

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

Cost = 10 → **R2** → **to N1 External Cost = 1**

R1

Cost = 8 → **R3** → **to N1 External Cost = 2**

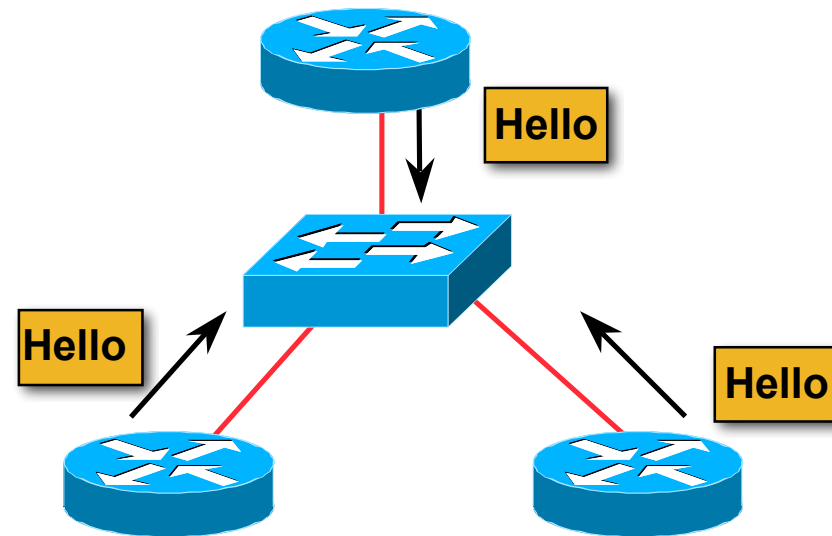| Network	Type 2	Next Hop
N1	1	R2
N1	2	R3

Selected Route

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
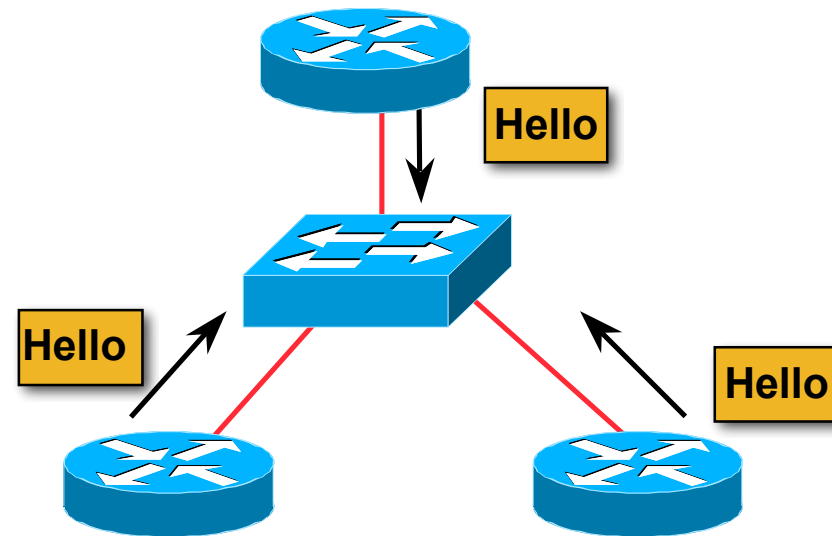
The Hello Protocol

- Responsible for establishing and maintaining neighbour relationships

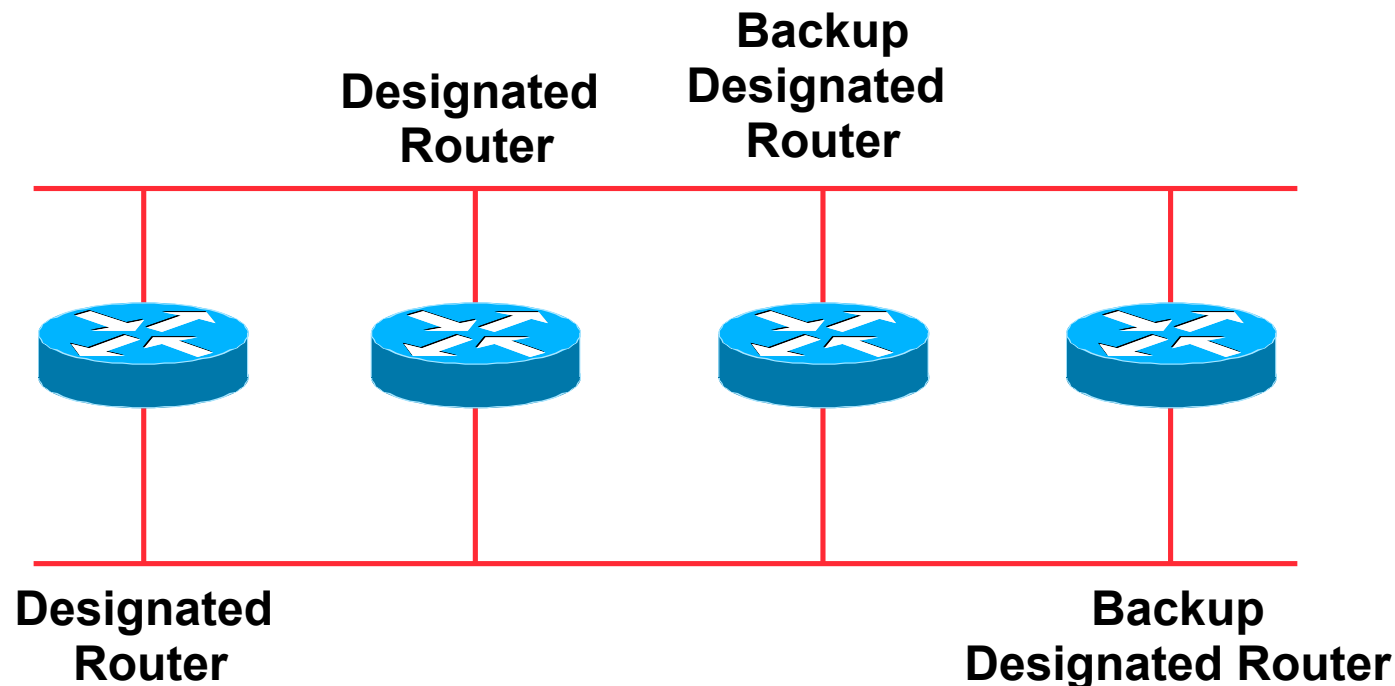- Elects designated router on multi-access networks

The Hello Packet

- Contains:

  Router priority

  Hello interval

  Router dead interval

  Network mask

  List of neighbours

  DR and BDR

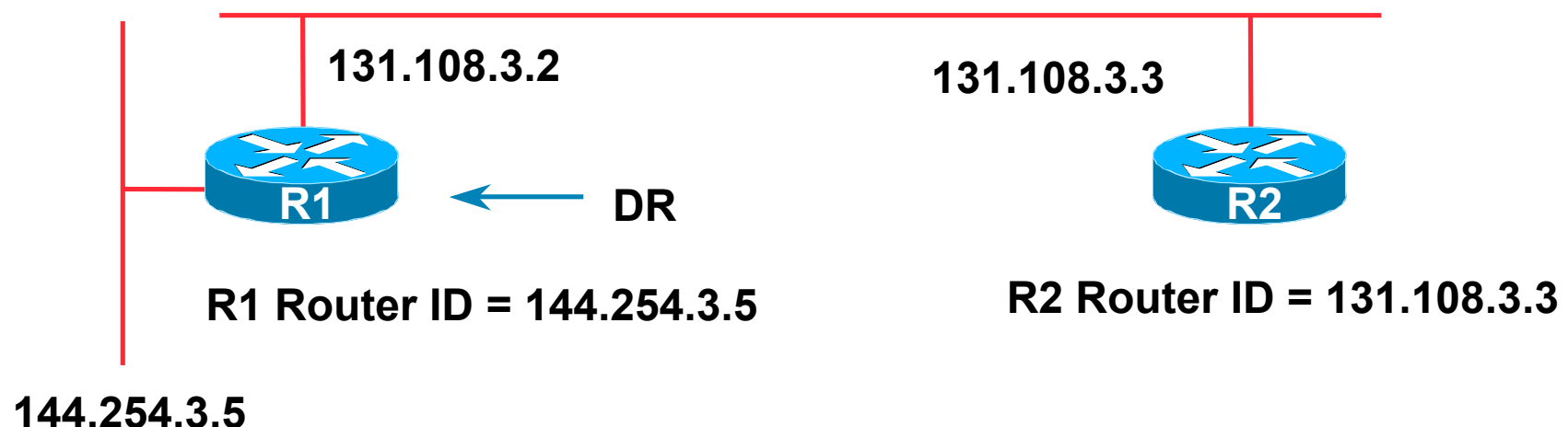 Options: E-bit, MC-bit,…
  (see A.2 of RFC2328)

Designated Router

- There is ONE designated router per multi-access network

    Generates network link advertisements

    Assists in database synchronization

Designated Router

Backup Designated Router

Designated Router

Backup Designated Router

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

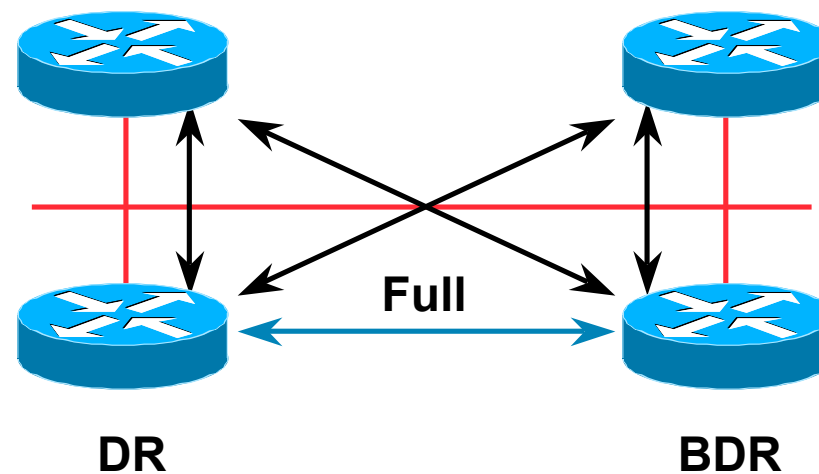 Derived from the loopback interface address, if configured, otherwise the highest IP address

131.108.3.2

131.108.3.3

R1

R2

← **DR**

R1 Router ID = 144.254.3.5

R2 Router ID = 131.108.3.3

144.254.3.5

Neighbouring States

- Full

  Routers are fully adjacent

  Databases synchronised

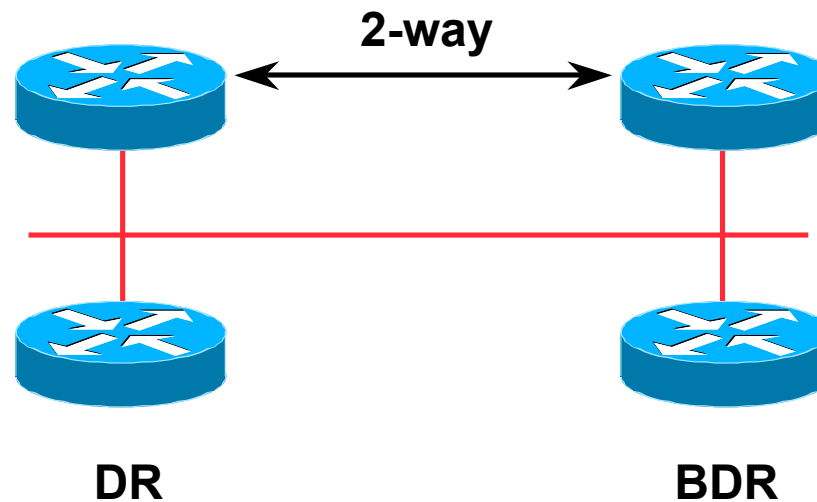 Relationship to DR and BDR

DR   **BDR**

Neighbouring States
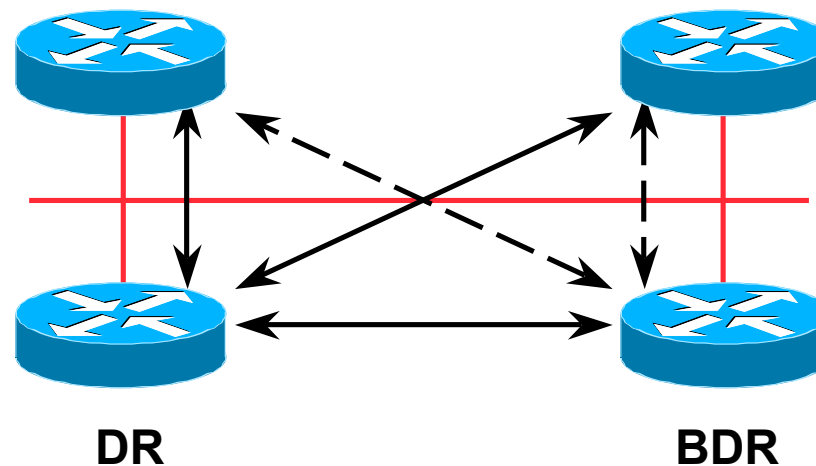
- 2-way

  Router sees itself in other Hello packets

  DR selected from neighbours in state 2-way or greater

2-way

DR   **BDR**

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

DR   **BDR**

- 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

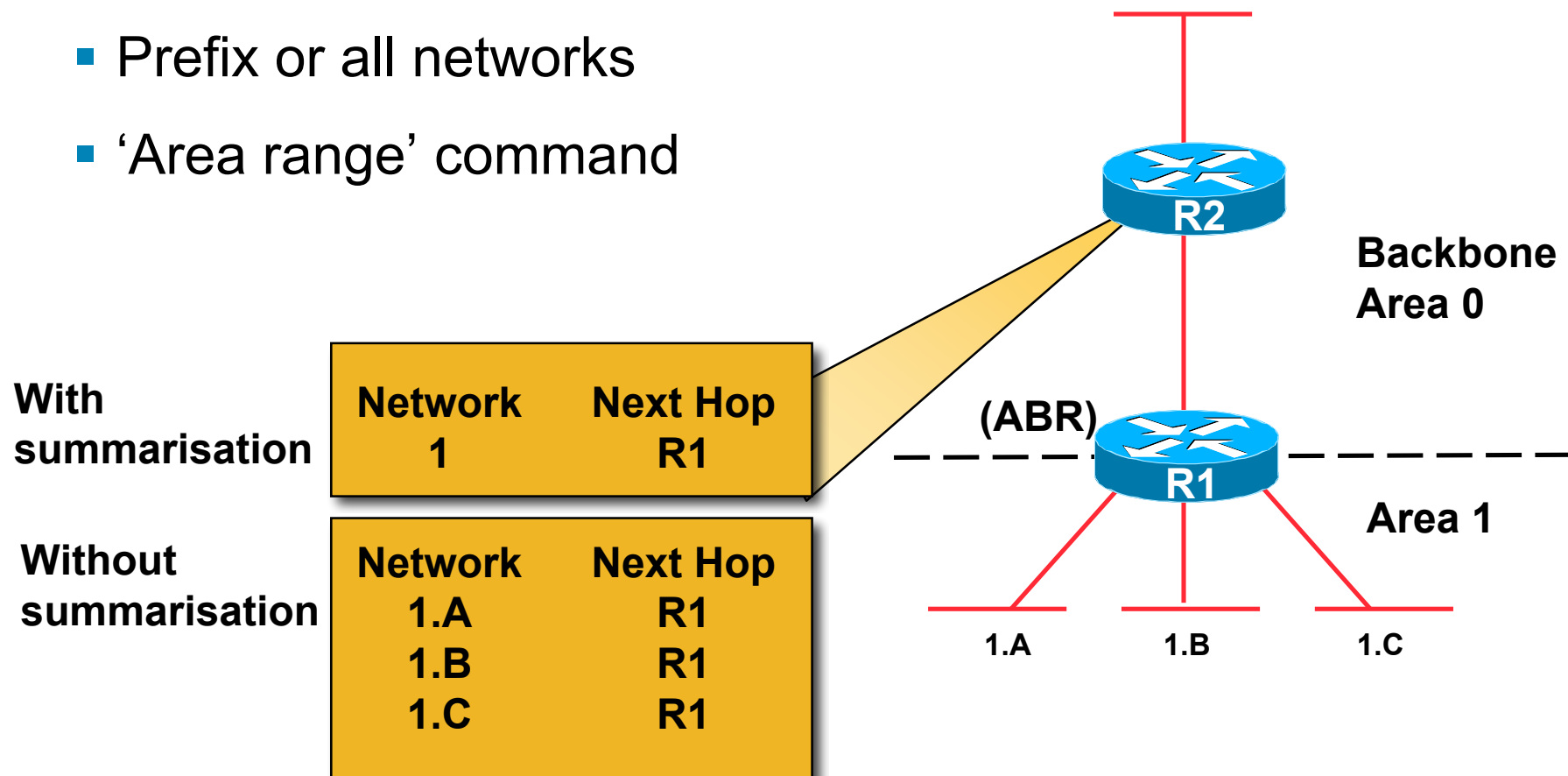# Summary LSA (Type 3 and 4)

- 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

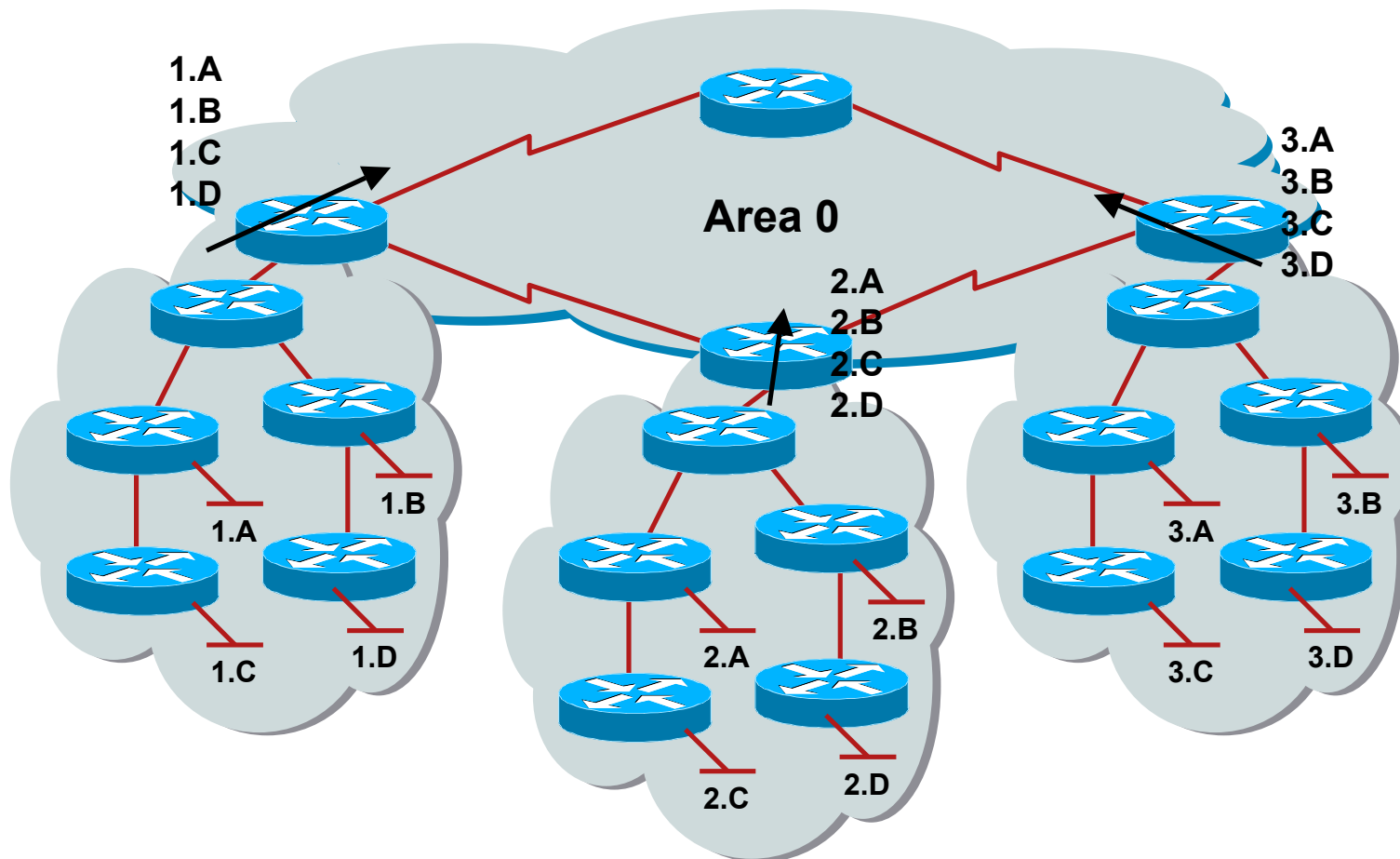- (Type 7 LSAs used to describe external LSA for one specific OSPF area type)

Inter-Area Route Summarisation

- Prefix or all subnets

- Prefix or all networks

- 'Area range' command

With summarisation

Network	Next Hop
1	R1

Without summarisation

Network	Next Hop
1.A	R1
1.B	R1
1.C	R1

R2

Backbone Area 0

(ABR)

R1
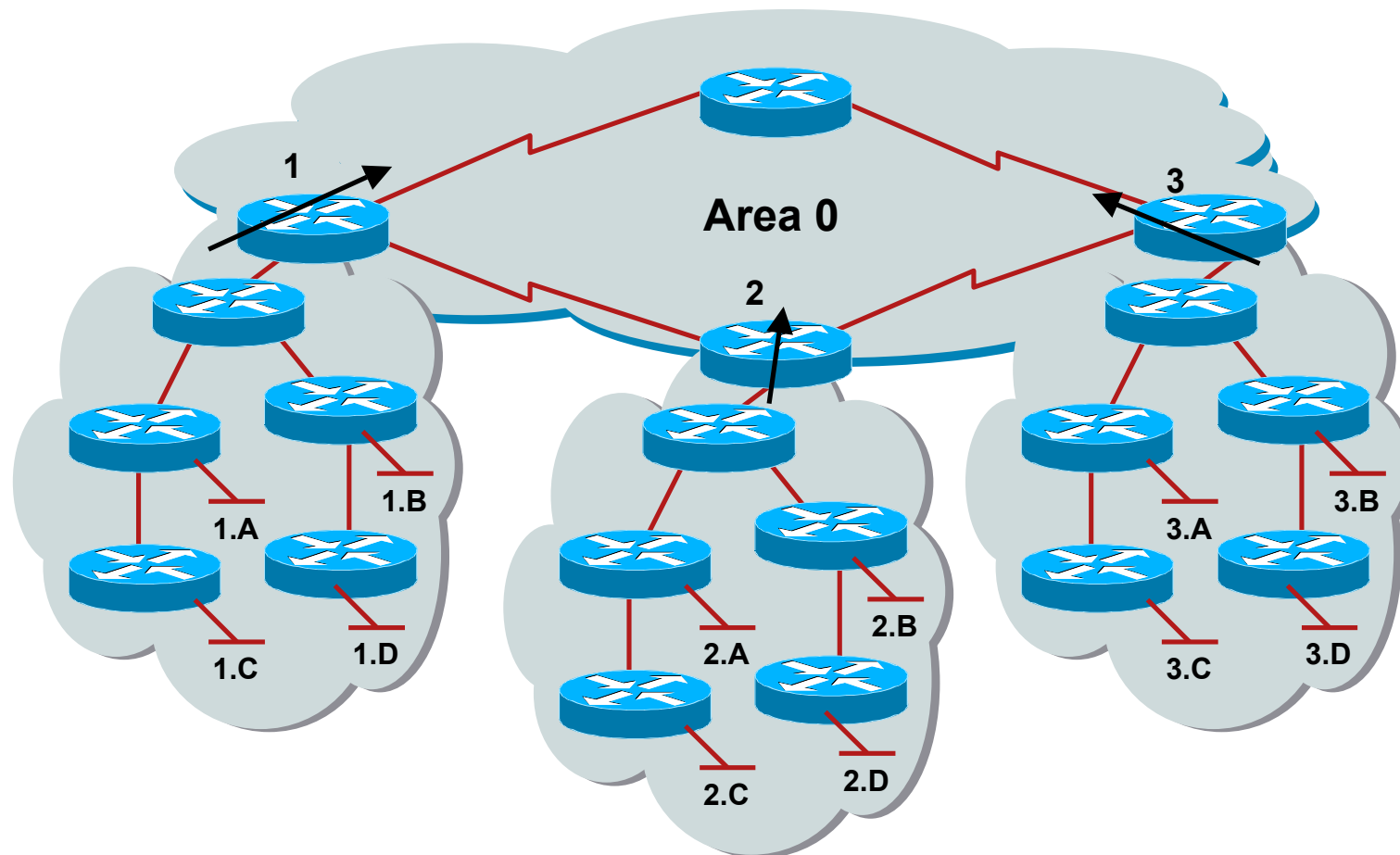
Area 1

1.A   1.B   1.C

No Summarisation

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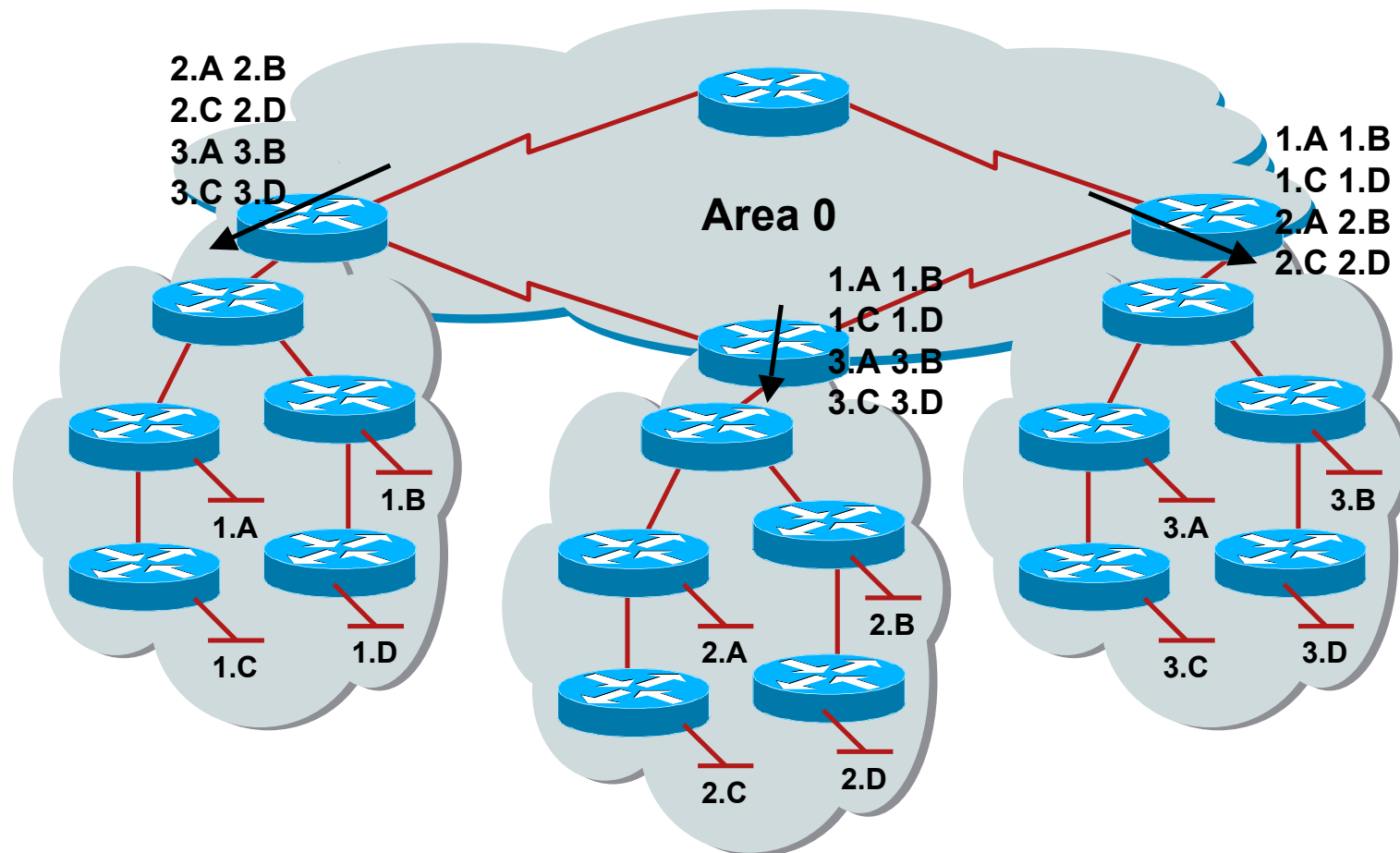- Link state changes propagated out of each area

With Summarisation

- Only summary LSA advertised out of each area

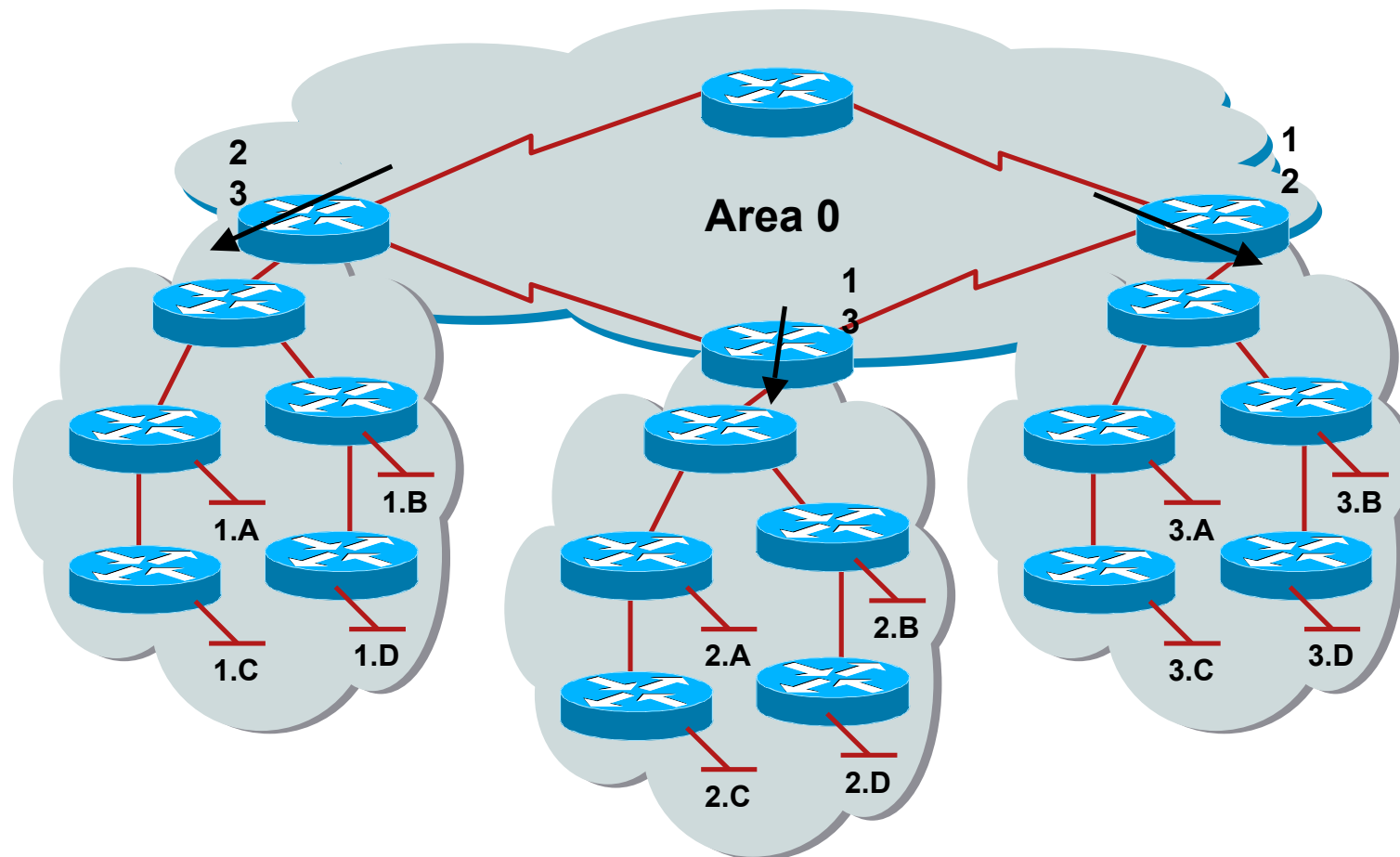- Link state changes do not propagate out of the area

No Summarisation

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

2.A 2.B
2.C 2.D
3.A 3.B
3.C 3.D

Area 0

1.A 1.B
1.C 1.D
2.A 2.B
2.C 2.D

1.A 1.B
1.C 1.D
3.A 3.B
3.C 3.D

1.A
1.B
1.C
1.D

2.A
2.B
2.C
2.D

3.A
3.B
3.C
3.D

With Summarisation

- Only summary link LSA advertised in to each area

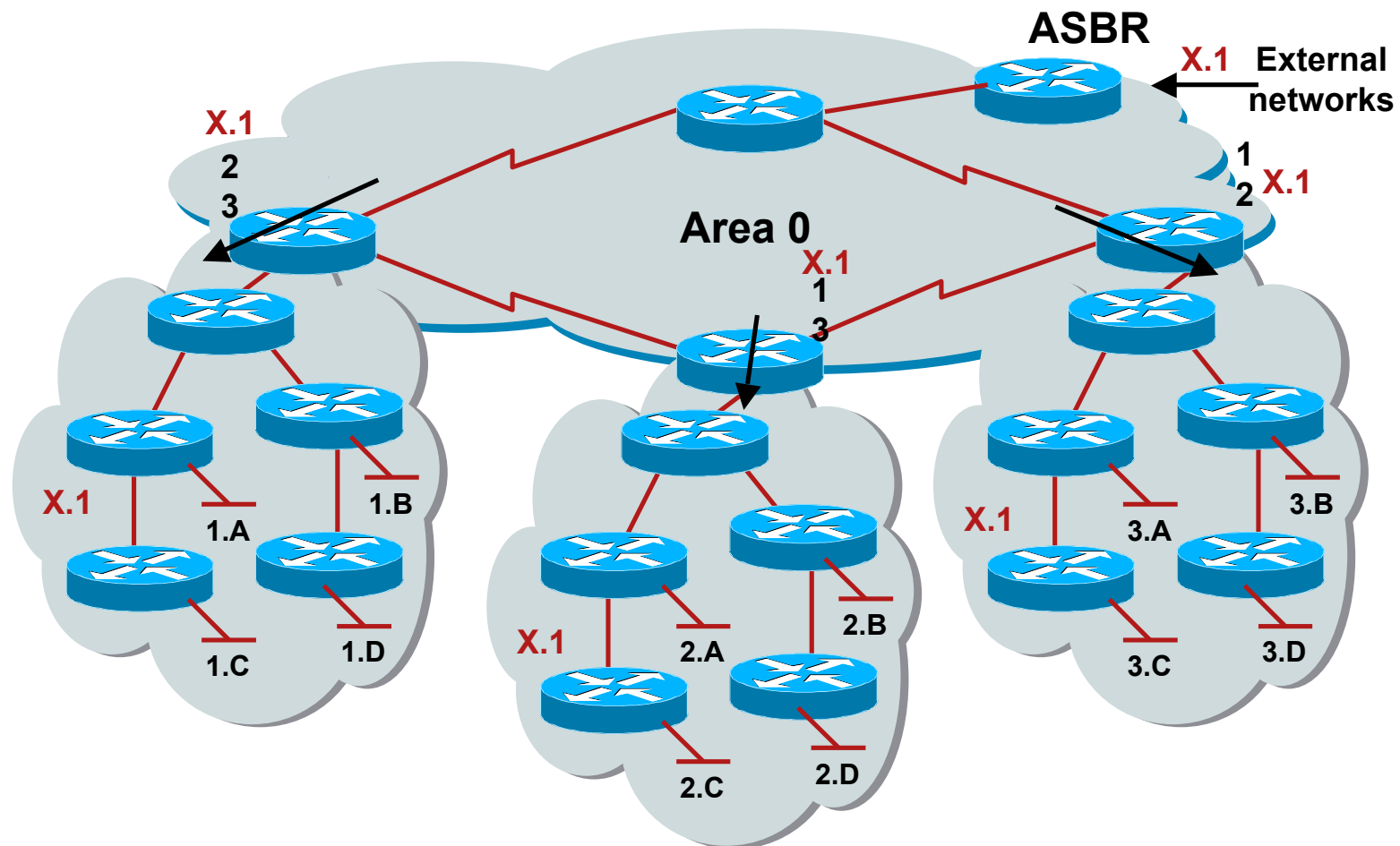- Link state changes do not propagate in to each area

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
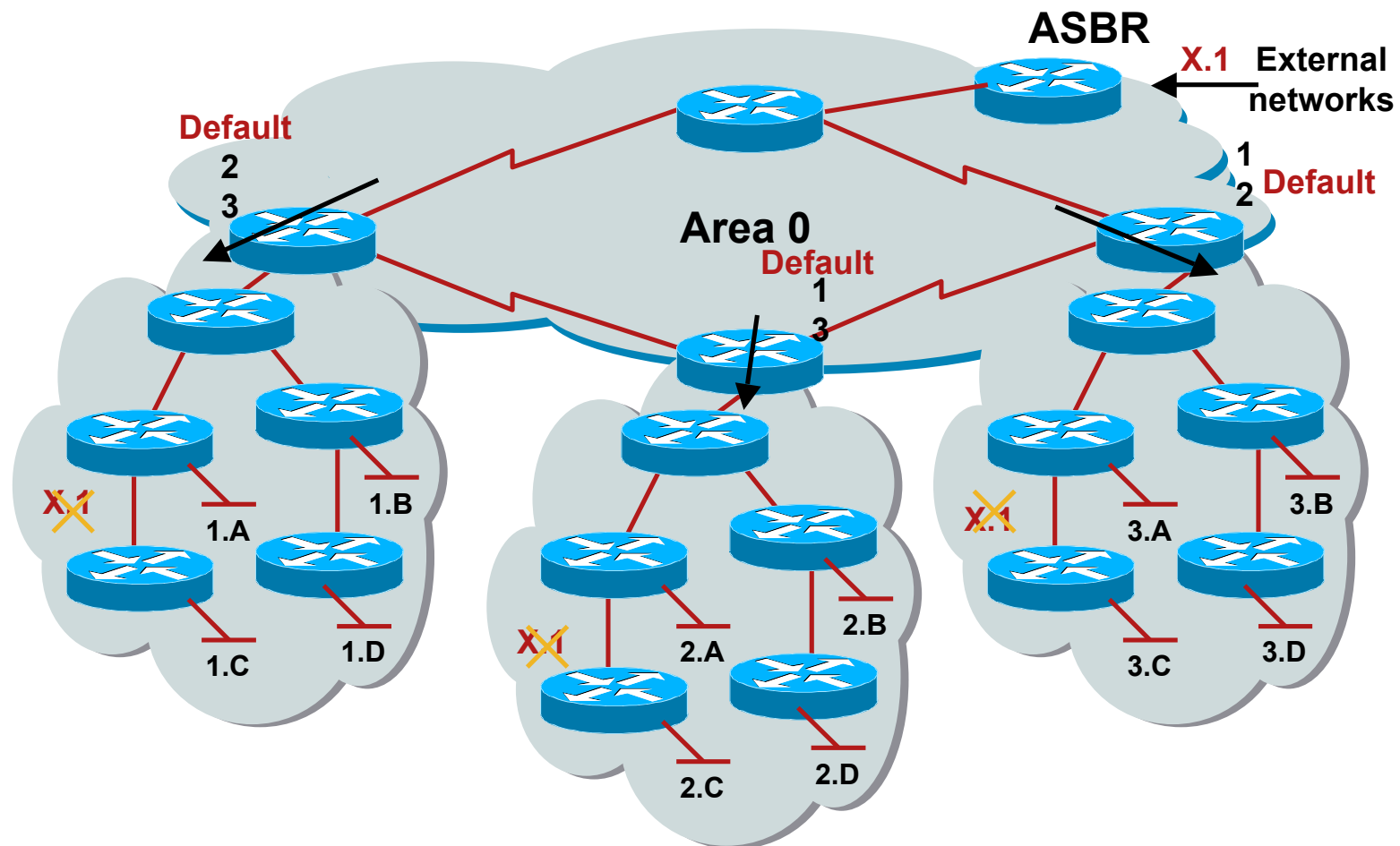
Regular Area (Not a Stub)

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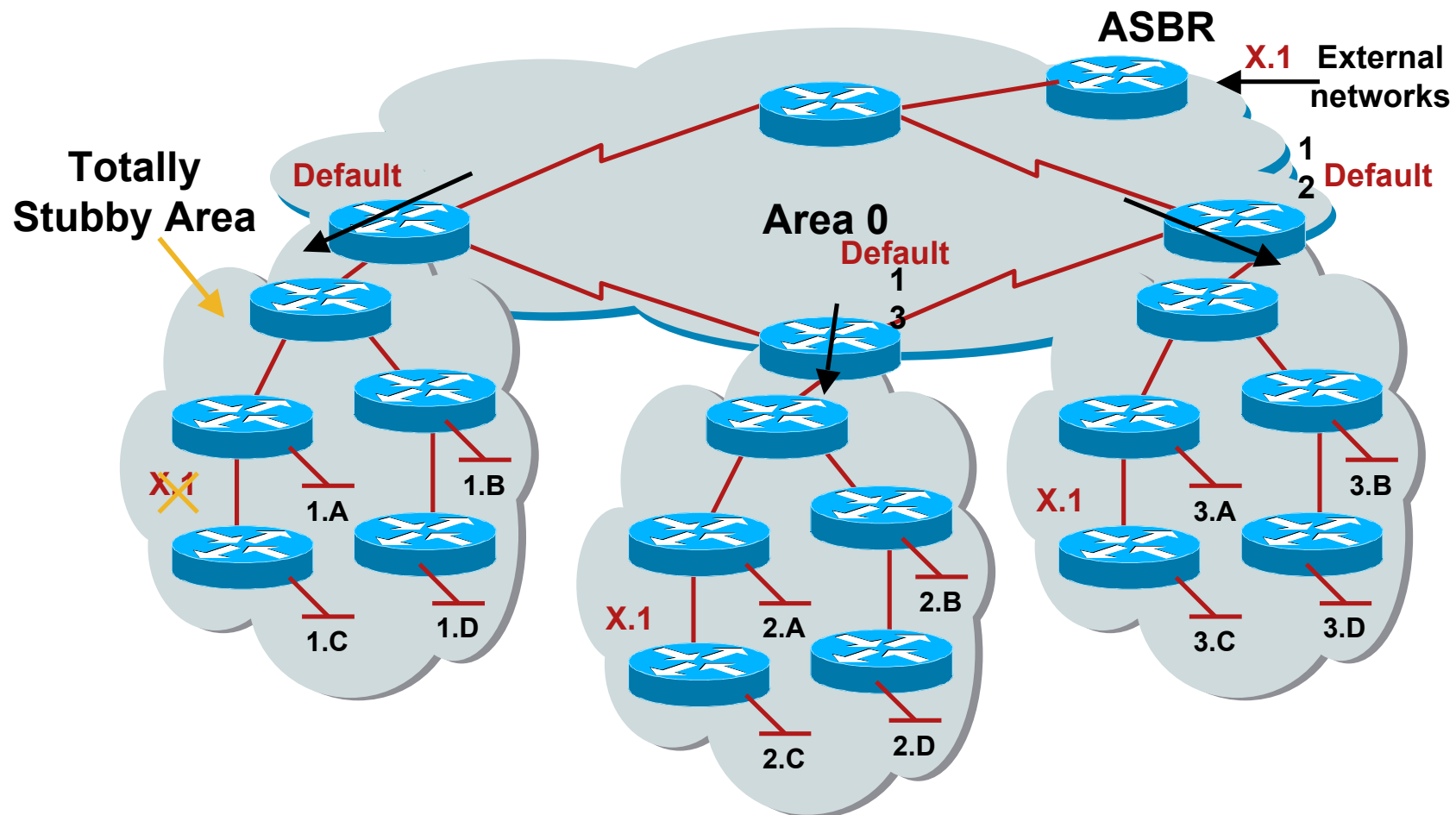
Normal Stub Area

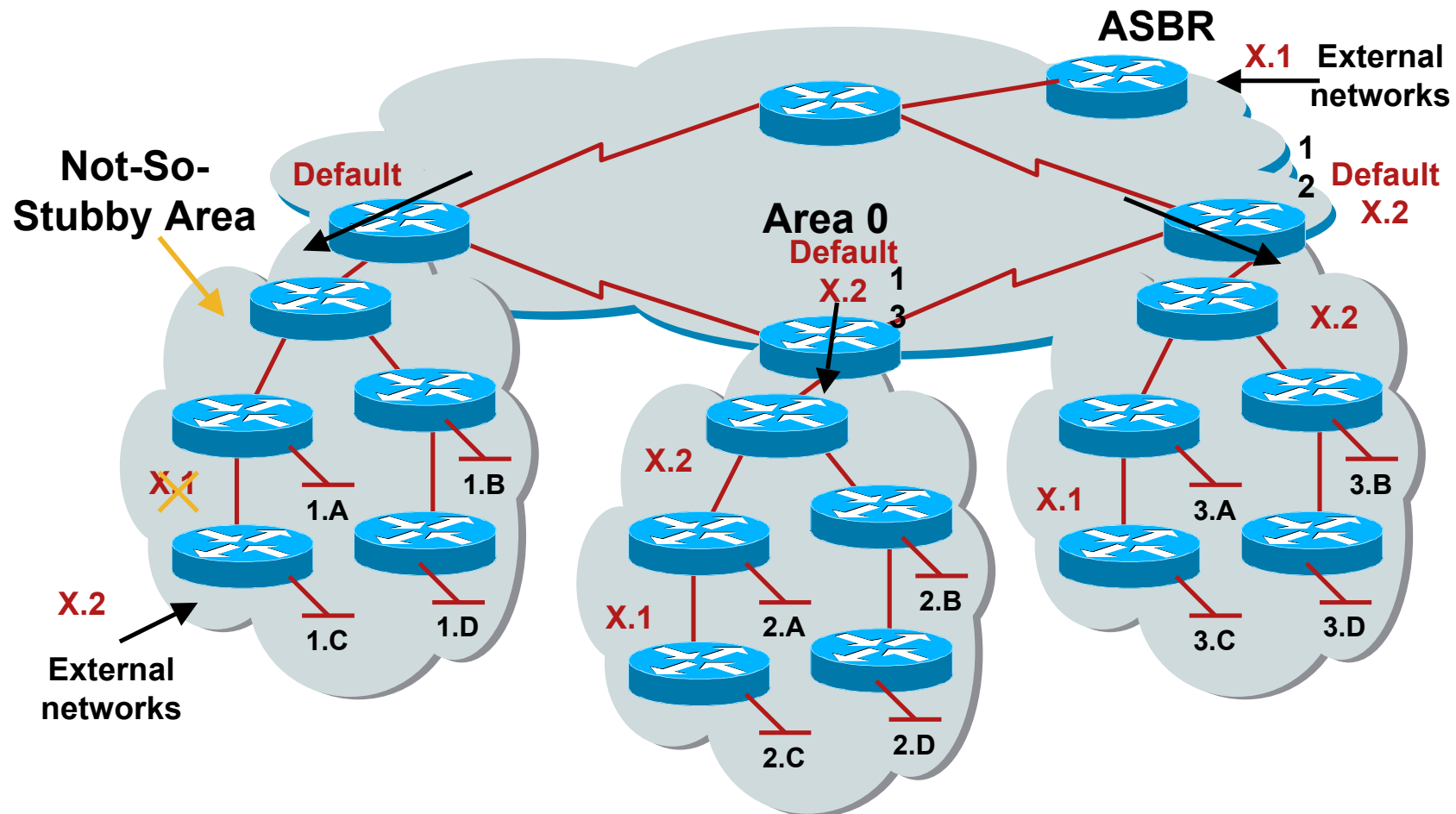- Summary networks, default route injected
- Command is area x stub

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:
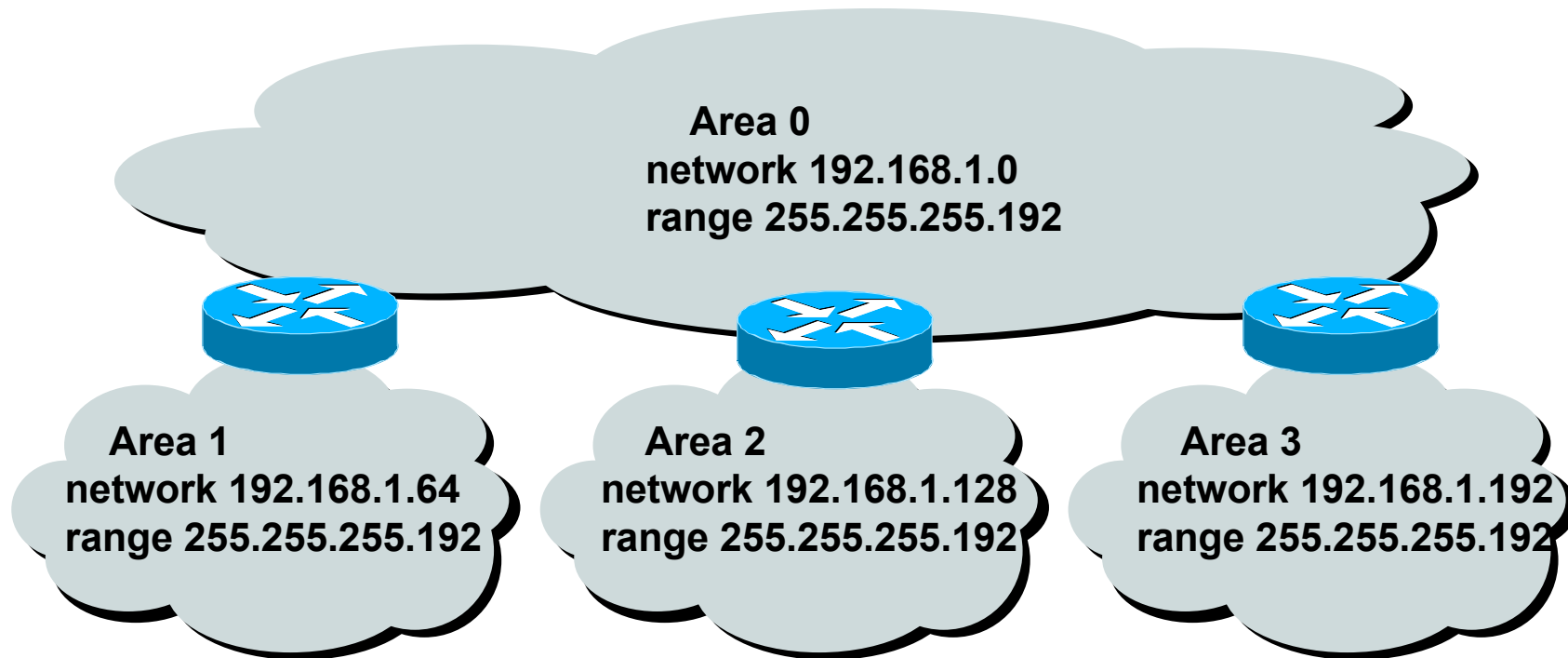
  Backbone area

  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

Area 0
network 192.168.1.0
range 255.255.255.192

Area 1
network 192.168.1.64
range 255.255.255.192

Area 2
network 192.168.1.128
range 255.255.255.192

Area 3
network 192.168.1.192
range 255.255.255.192

- 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

Introduction to OSPF

ISP/IXP Workshops