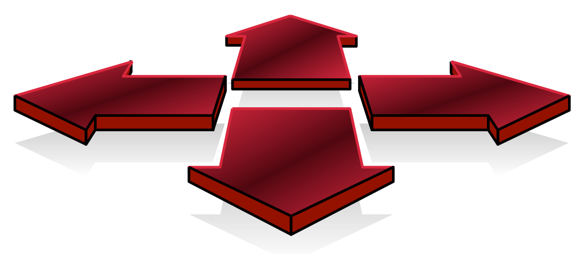
Campus Networking Workshop

Introduction to OSPF

Modified from originals by Philip Smith

Routing versus Forwarding

- Routing = building maps and giving directions
- Forwarding = moving packets between interfaces according to the "directions"



IP Routing – finding the path

- Path derived from information received from a routing protocol
- Several alternative paths may exist
  - best next hop stored in forwarding table
- Decisions are updated periodically or as topology changes (event driven)
- Decisions are based on:
  - topology, policies and metrics (hop count, filtering, delay, bandwidth, etc.)

IP route lookup

Based on destination IP packet

“longest match” routing

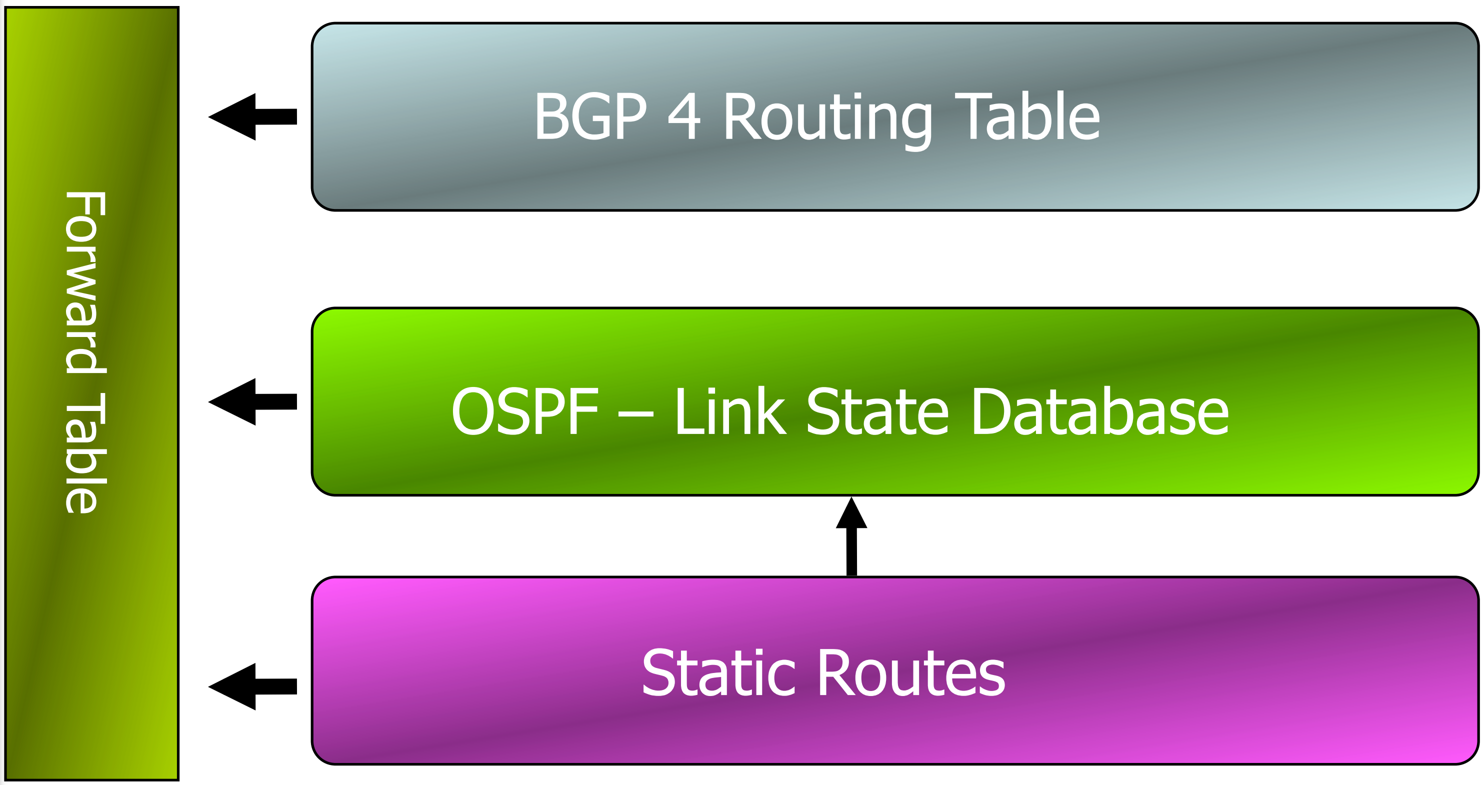
more specific prefix preferred over less specific prefix

–example: packet with destination of 10.1.1.1 is sent to the router announcing 10.1.0.0/16 rather than the router announcing 10.0.0.0/8.

IP Forwarding

- Router makes decision on which interface a packet is sent to
- Forwarding table populated by routing process
- Forwarding decisions:
  – destination address
  – class of service (fair queuing, precedence, others)
  – local requirements (packet filtering)
- Can be aided by special hardware

Routing Tables Feed the Forwarding Table



Routing Protocols

Routing protocols can be classified in

Interior Gateway Protocols (IGP)

- RIP, EIGRP, OSPF, IS-IS

Exterior Gateway Protocols (EGP)

- BGP

OSPF Background

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

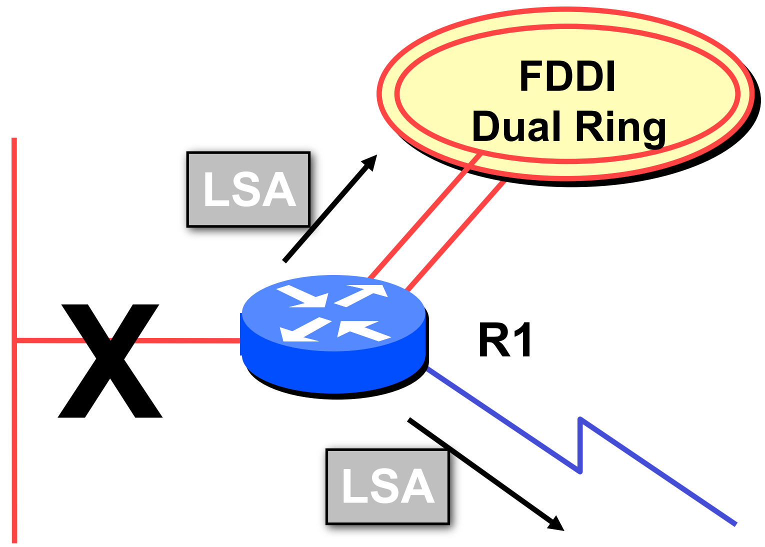
Link State Algorithm

- 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 Advertisement)
- Each router computes its best path to every destination
- On network failure
  - New LSPs are flooded
  - All routers recompute shortest path tree

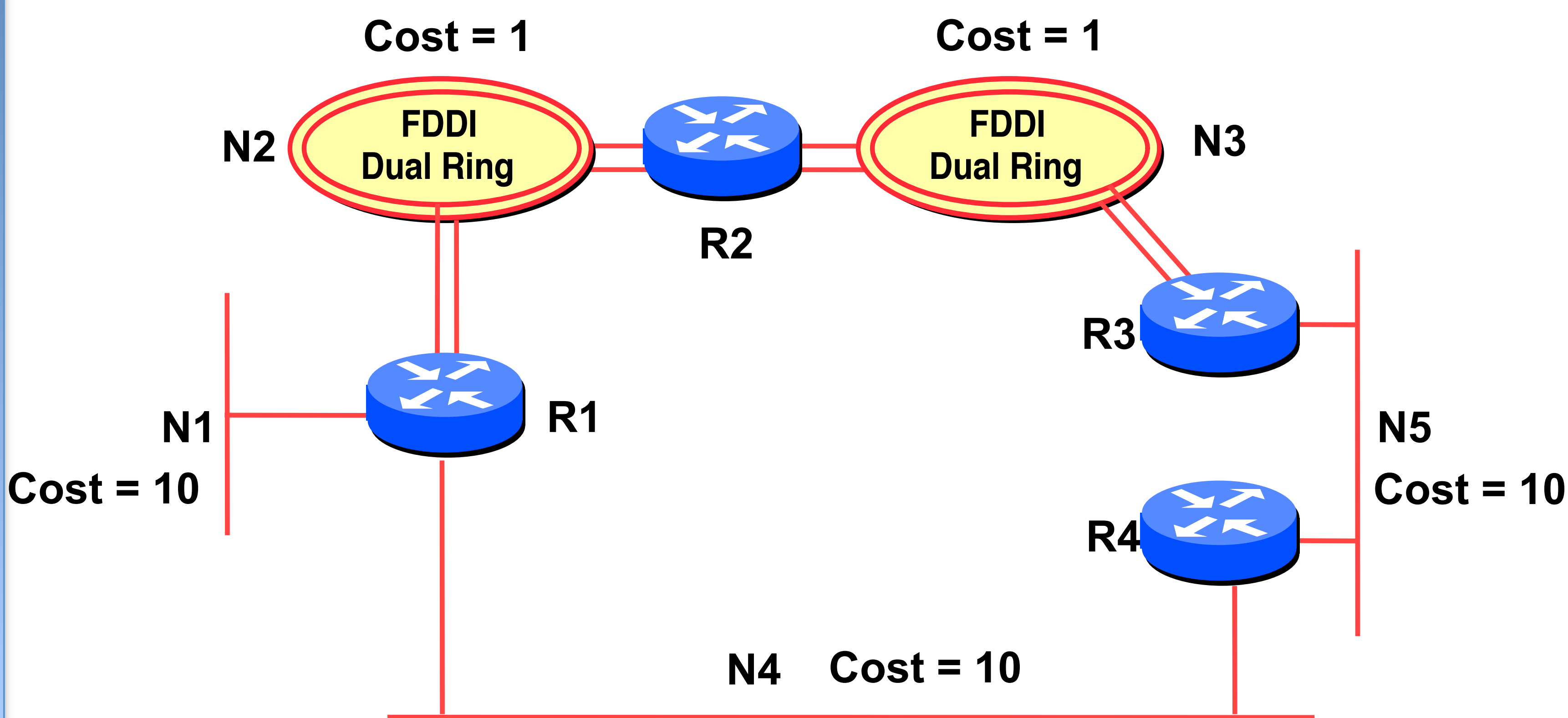
Low Bandwidth Requirements



- 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”

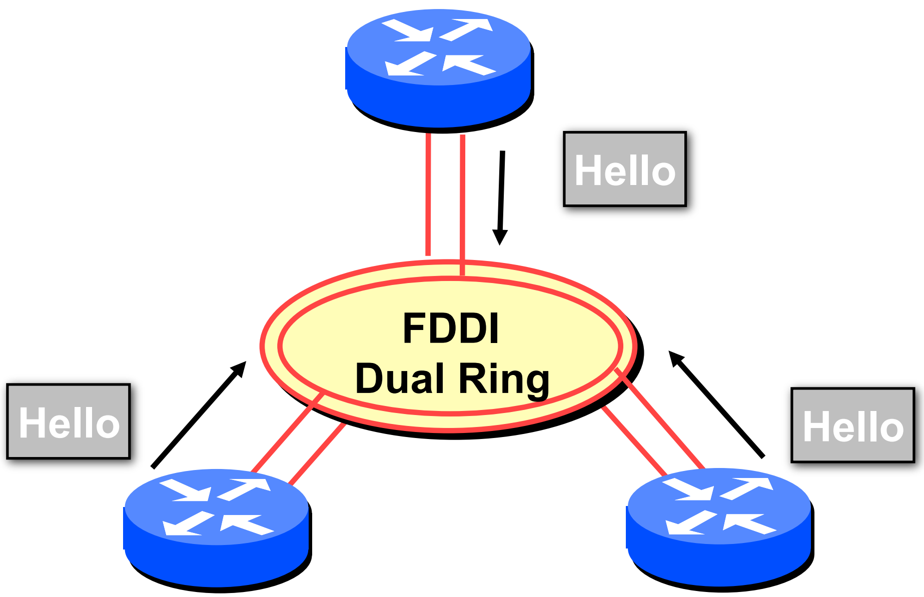
The optimal path is determined by the sum of the interface costs: Cost = 10^8/bandwidth



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
  - All pairs of devices which can see each others hellos are **neighbours**
  - Adjacencies (exchange of routing information) 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

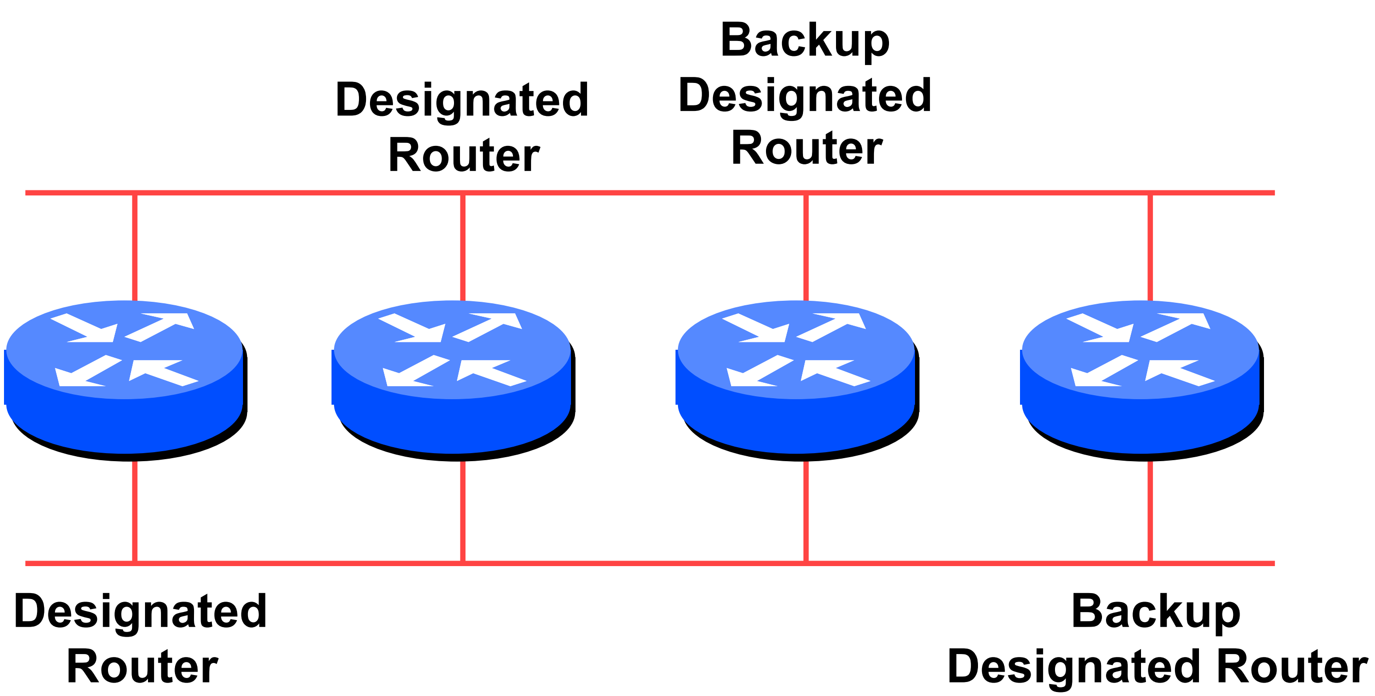
Broadcast Networks

- These are network technologies such as Ethernet
- 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

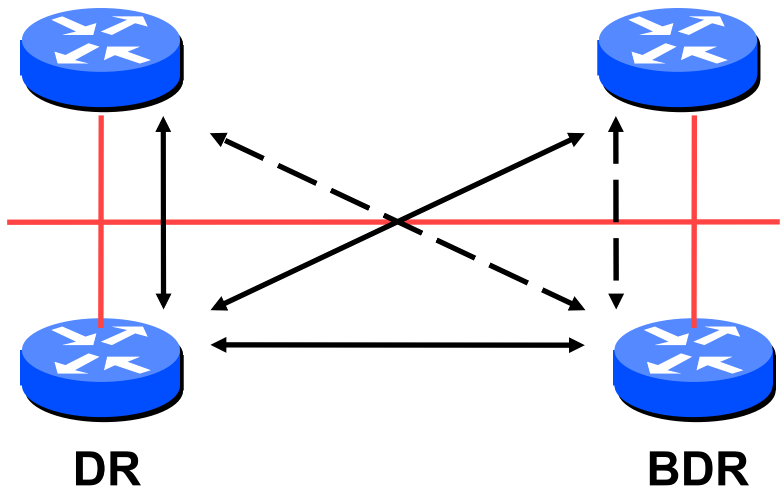
- Generates network link advertisements for the multi-access network
- Speeds database synchronisation



Designated Router

- All routers are adjacent to the DR
  - All routers are adjacent to the BDR also
- All routers exchange routing information with DR
  - BDR also stays synchronized with the DR
- DR updates the database of all its neighbours
  - BDR waits silently and only takes over if DR dies
- This scales!
  - *2n* problem rather than having an *n-squared* problem.

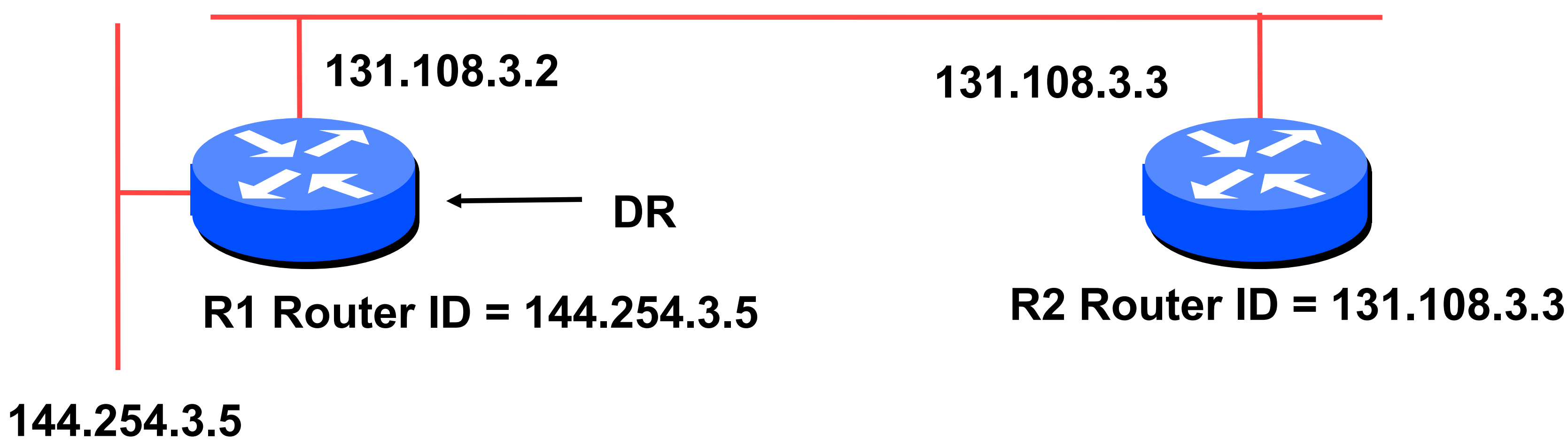
Designated Router



- 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)

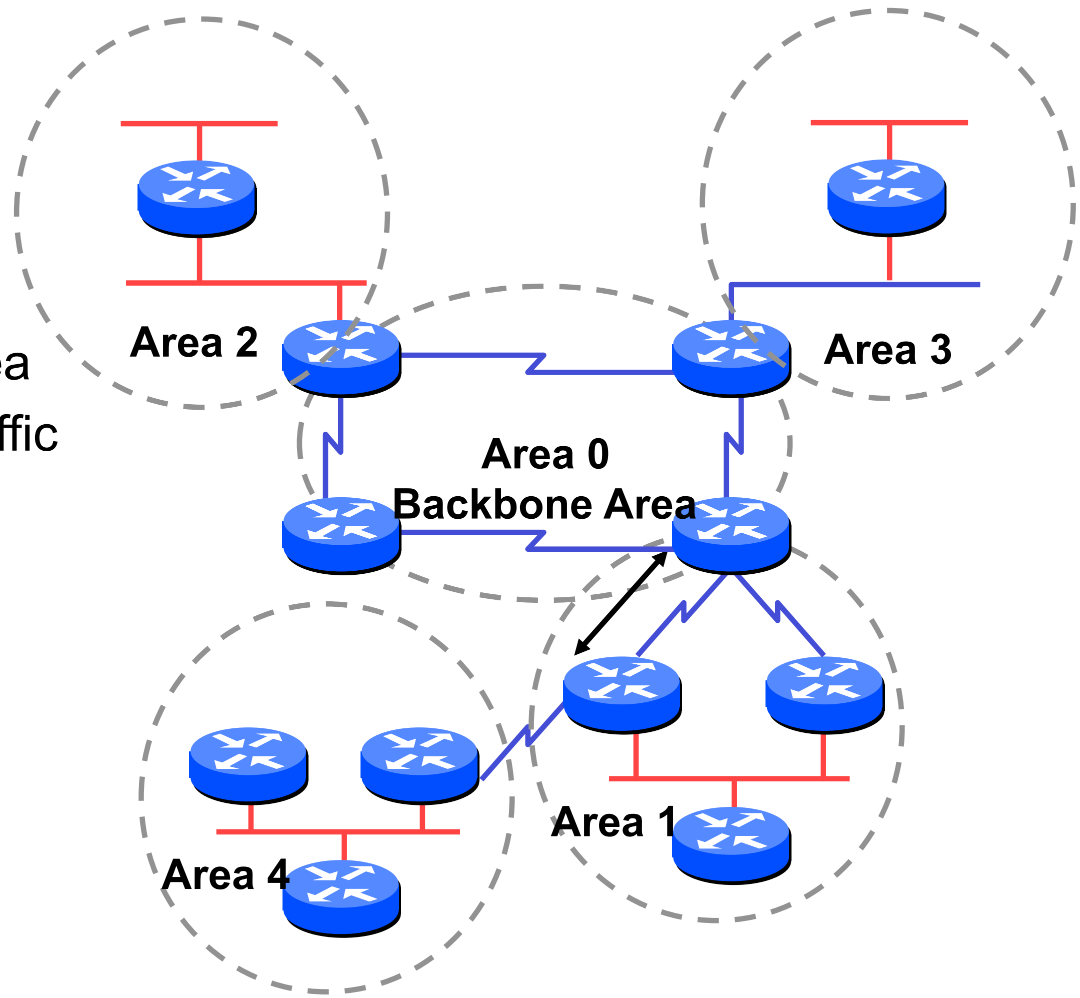


More Advanced OSPF

- 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



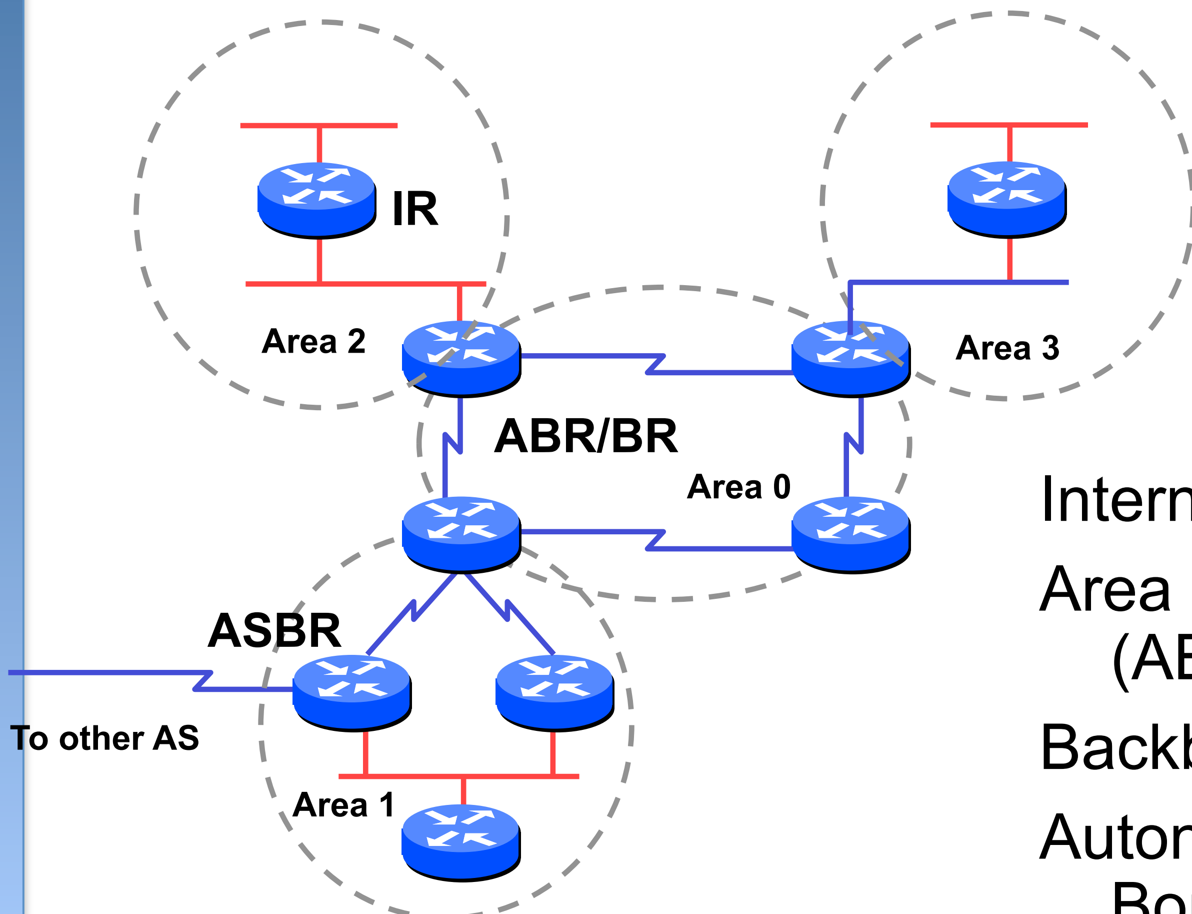
OSPF Areas

- 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



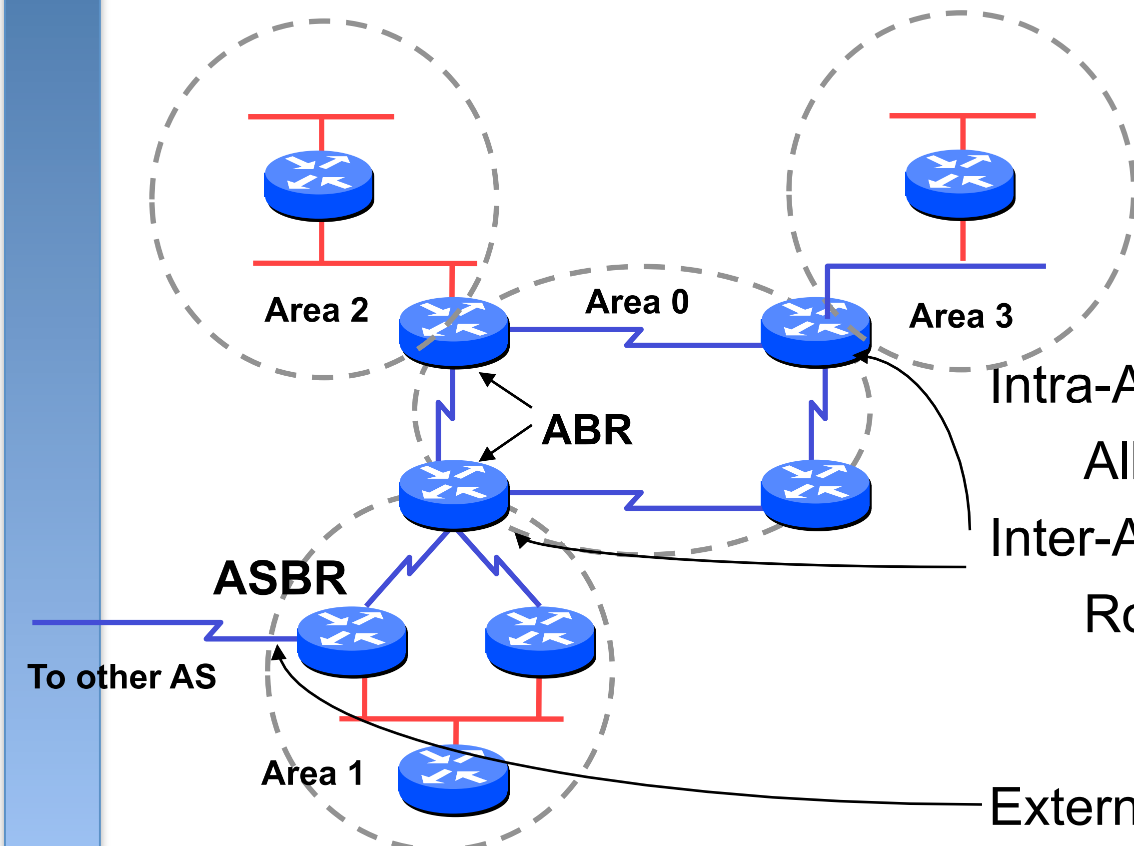
Internal Router (IR)

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

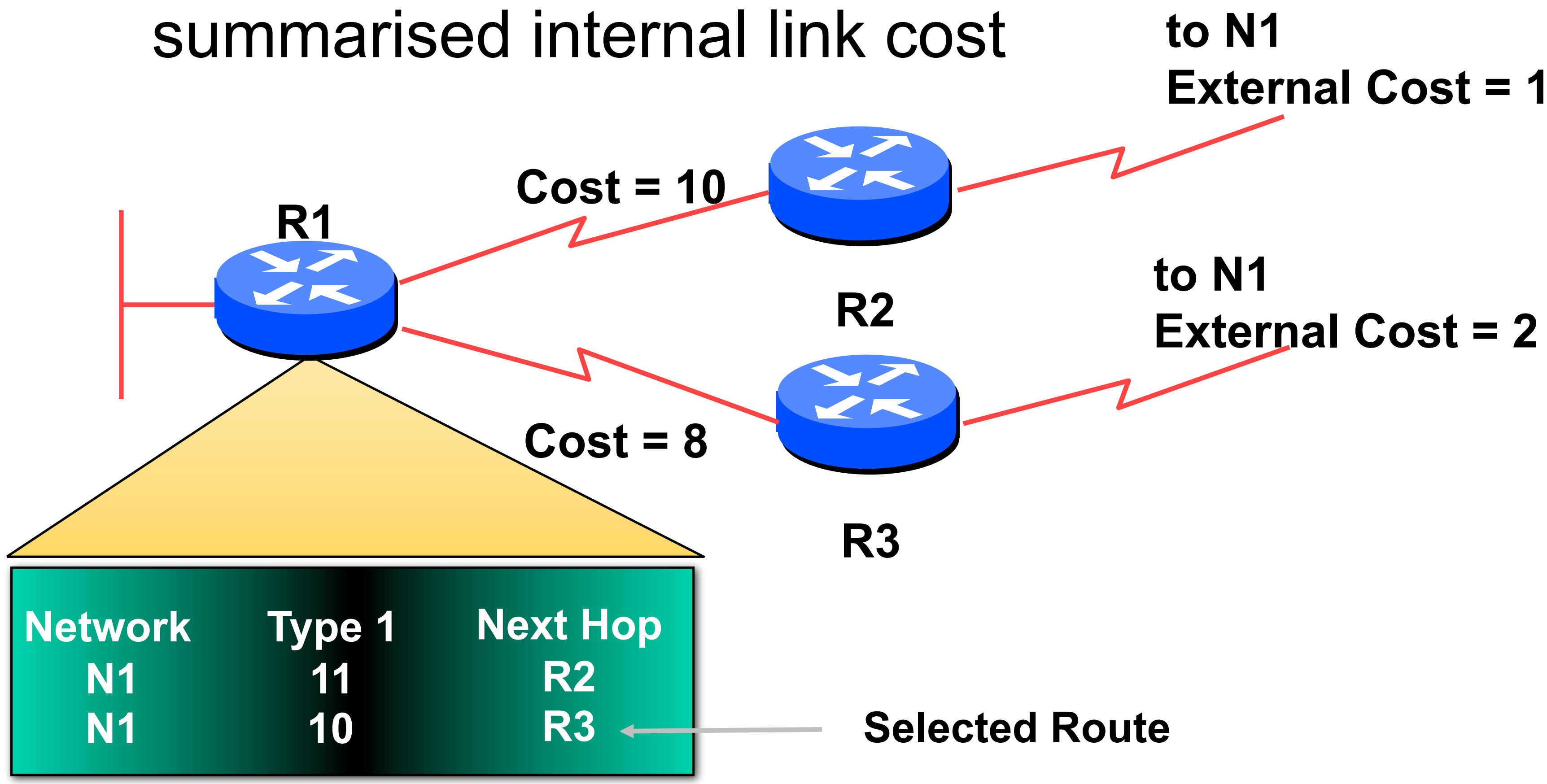
- Routes advertised from one area to another area by an ABR

External route

- Routes imported into OSPF from another routing protocol by an ASBR

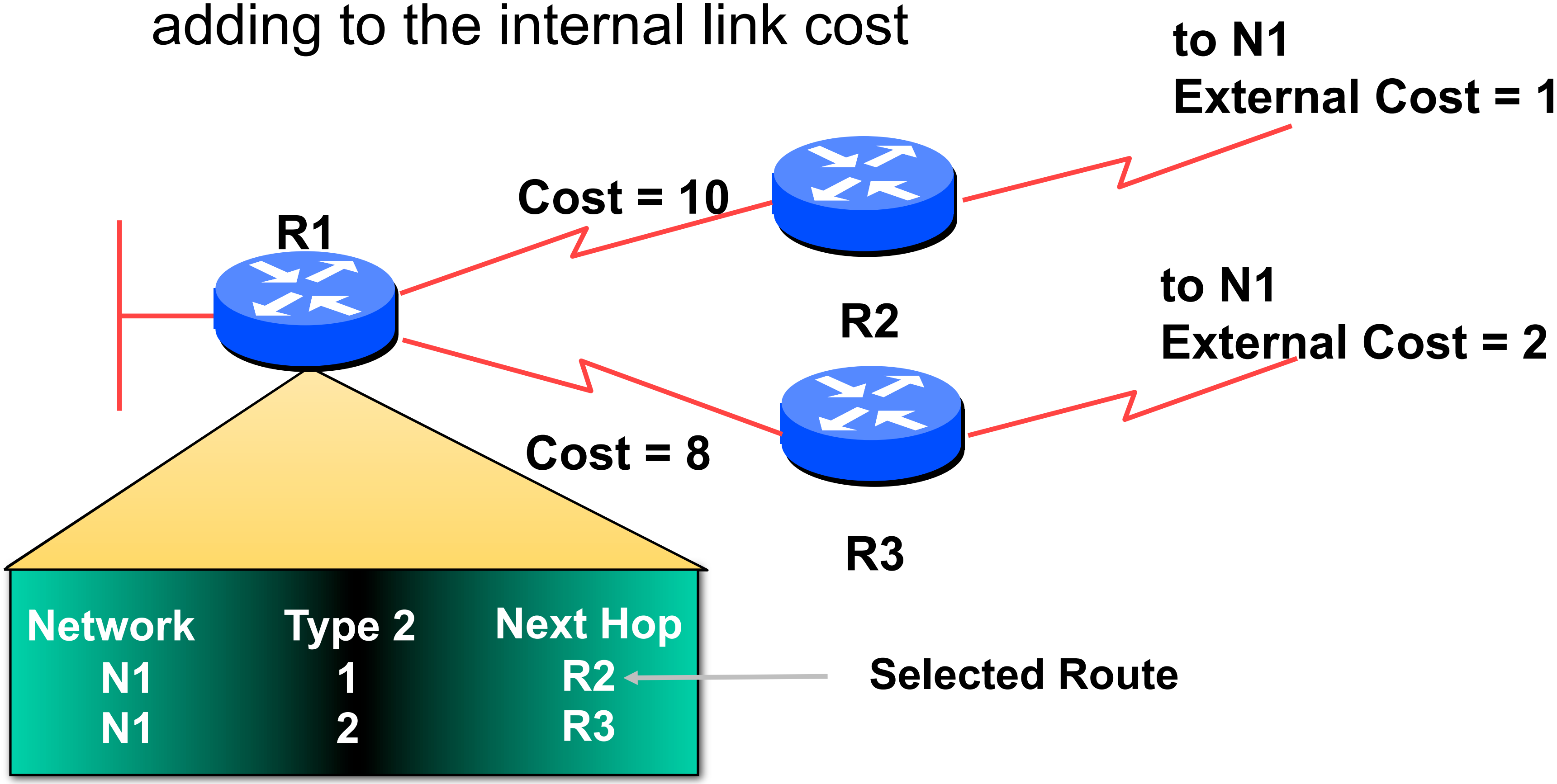
External Routes

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 muliplexors
  - Don’t need to use static routing

OSPFv3

- OSPFv2 only supports IPv4
- OSPFv3 developed for IPv6 only
  - Dual stack networks need to run both protocols
  - They run independently of each other

OSPFv2 vs. OSPFv3

- Very similar, with a few differences
  - New LSA types to separate links from their prefixes
    - Avoids SPF recalculations when only the link prefix changes
  - Removes OSPF-specific authentication
    - Relies on underlying IPv6 security headers
  - Supports multiple instances

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

Redistributing routes

- Allows routes not learned from OSPF to be learned by other routers via OSPF
- **Connected** routes: links I am connected to (but which may not be talking OSPF)
- **Static** routes: next hop points along a connected route
- Routes imported from other protocols (e.g. RIP, BGP) - not always a good idea
- **Loopback** interfaces

Loopback interfaces

- A software interface, internal to the router
- Normally allocate a single IP address (/32)
- (keep an address range for loopbacks)
- The loopback address is a "connected" route, and you redistribute it into your IGP

Loopback interfaces (contd)

- As long as there's at least one working link to the router, it's reachable on this address
- As links go up and down, it's still reachable - whereas, if you talk on one of the "real" interface IPs, that interface may go down
- Sessions are uninterrupted even when topology changes
- Uses: management (ssh, snmp)
- Uses: iBGP peering