Campus Networking Workshop
CIS 399

Introduction to OSPF

UNIVERSITY OF OREGON

Agenda

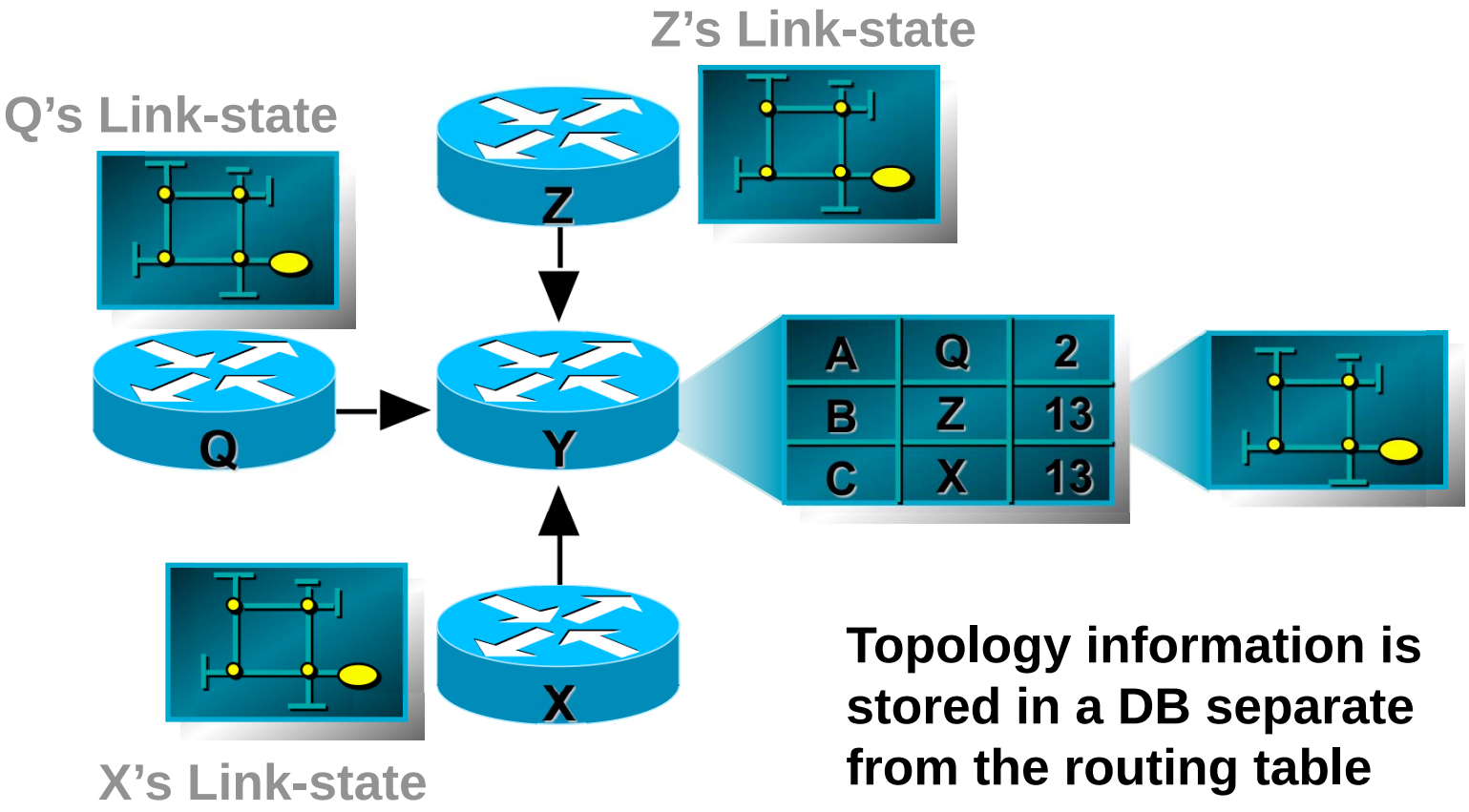
- Basic Elements of OSPF
- OSPF in Service Provider Networks
- Best Common Practices in OSPF – Network Aggregation
- OSPF Command Reference

Basic Elements of OSPF

OSPF

- Open Shortest Path First
- Link State or SPF technology
- Developed by the IETF's OSPF working group (RFC 1247)
- Designed for TCP/IP
- Fast Convergence
- Variable length netmasks
- Non-contiguous subnets
- No need for periodic updates
- Route authentication
- OSPF is defined in RFC2328

Link-State

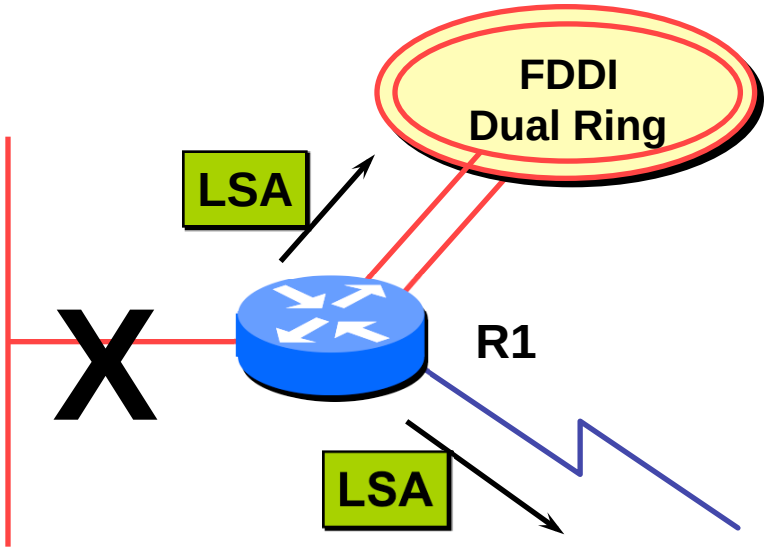


Topology information is stored in a DB separate from the routing table

Link-State Routing

- Neighbor discovery
- Construct a Link State Packet (LSP)
- Distribute the LSP
  - Link State Announcement – LSA
- Route calculation
- If a link fails
  - Flood new LSPs
  - All routers recalculate their routing tables

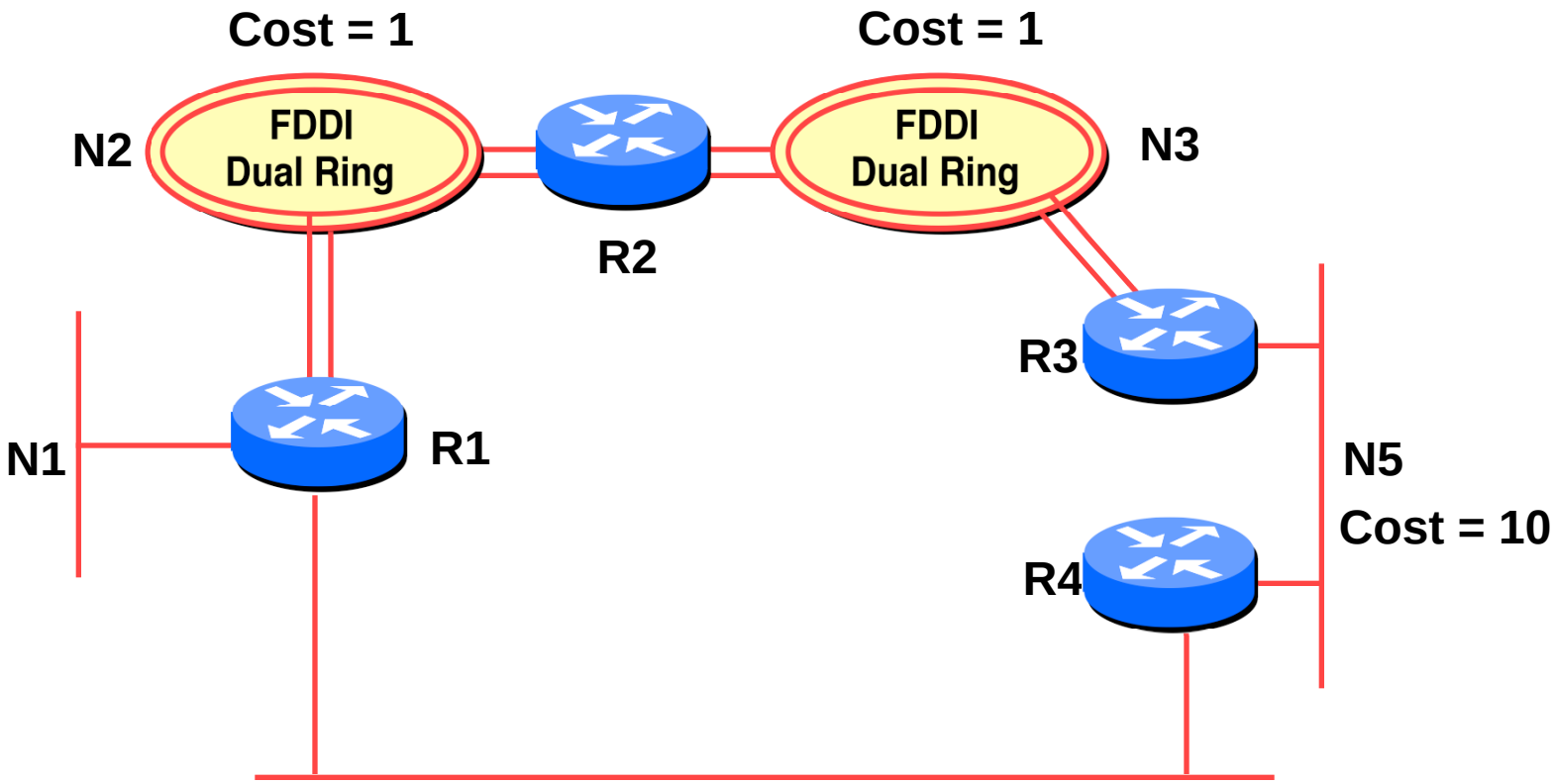
Low Bandwidth Utilization



- Only propagate changes
- Use Multicast in multi-access networks

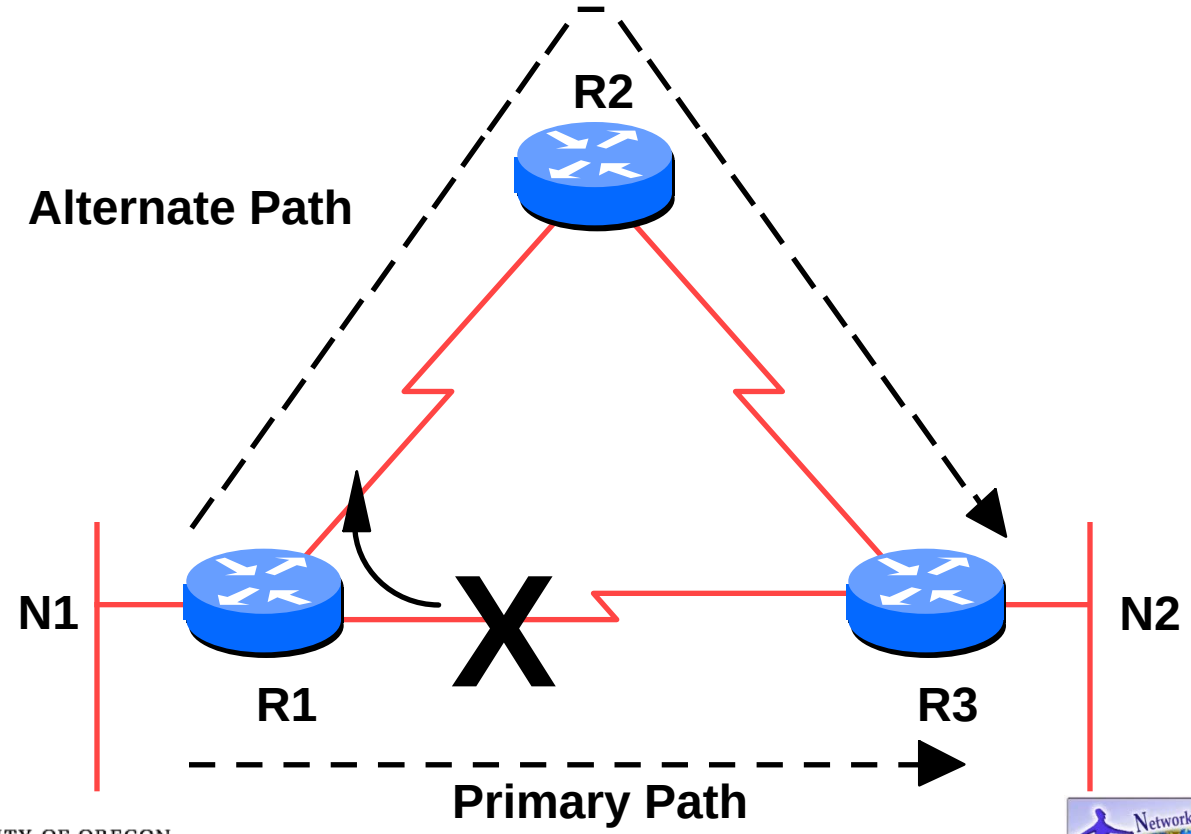
Using the Optimal Path

The optimal path is determined by adding the costs of the interfaces : Cost = 10^8/(Bandwidth)



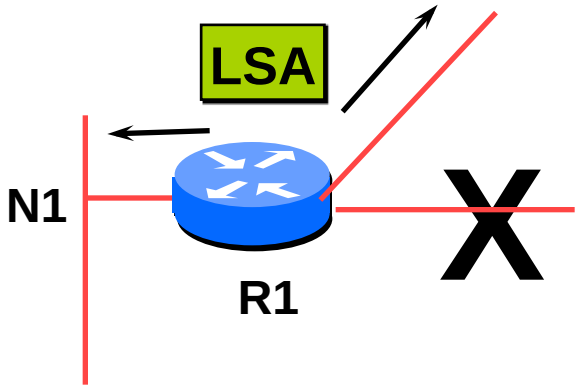
Fast Convergence

- Detection plus LSA/SPF



Fast Convergence

- Finding a new path
  - Flood LSAs in the area
  - Based in acknowledgements (Ack)
  - Synchronized topology DB
  - Each router calculates its routing table for each destination network

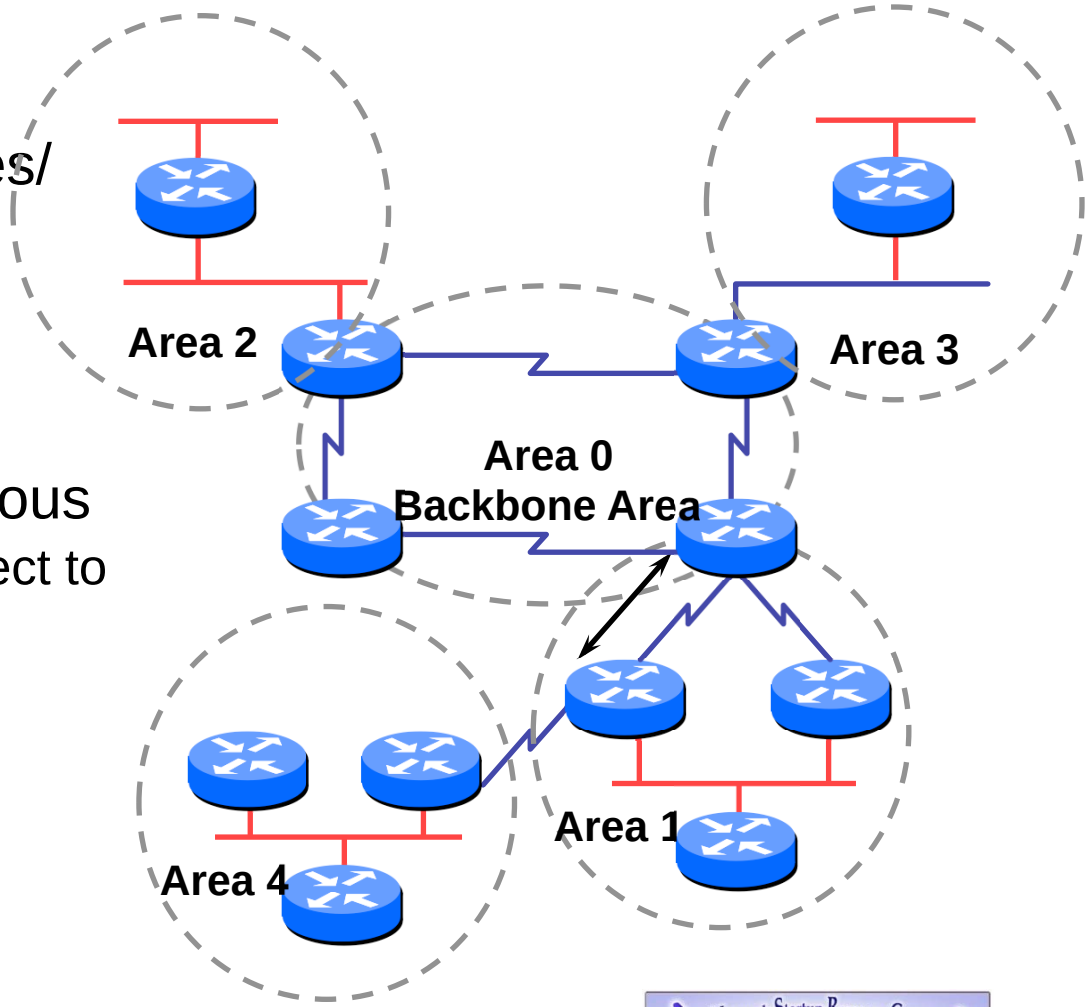


Uses IP Multicast to Send/ Receive changes

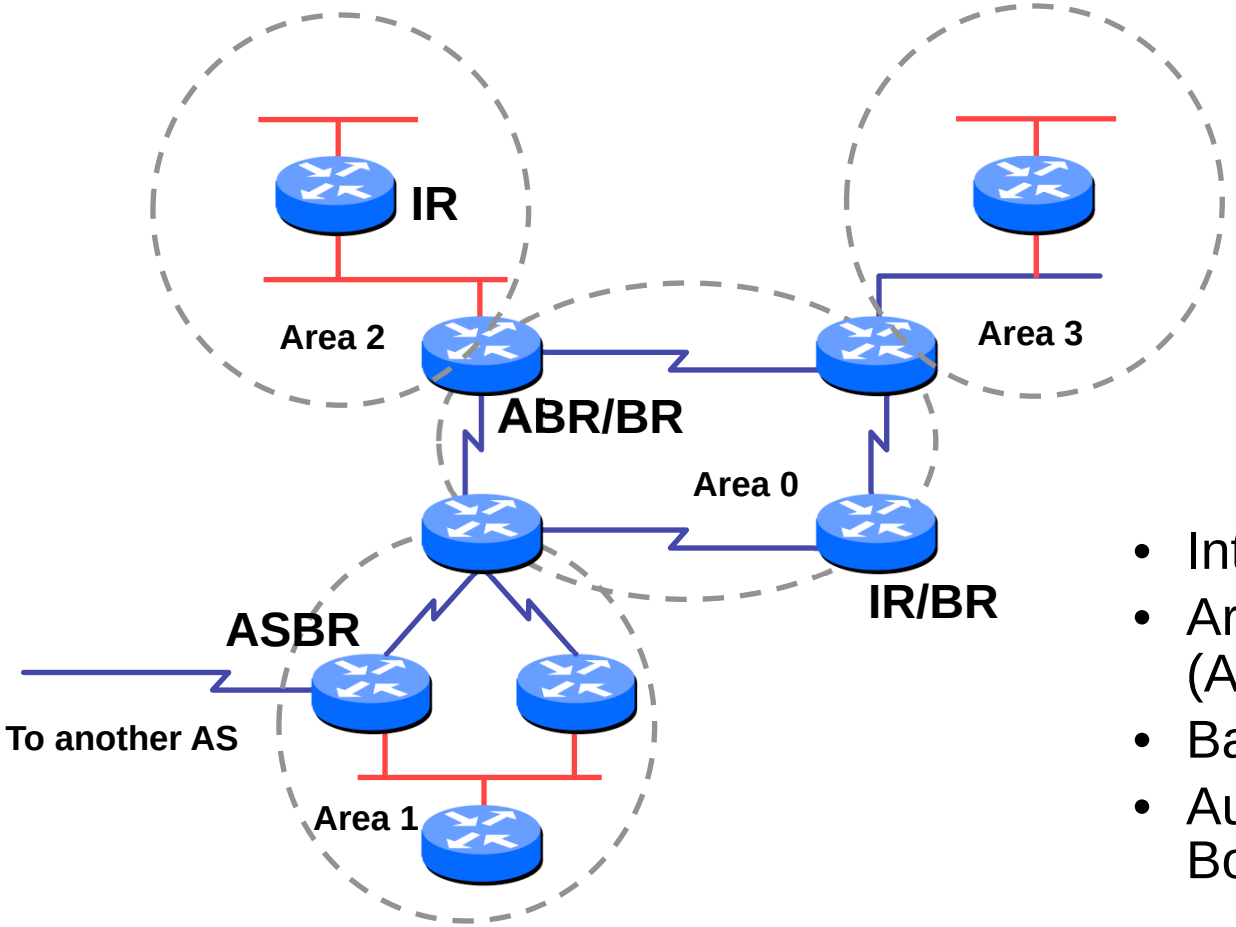
- Multi-Access networks
  - All routers must accept packets sent to the AllSPFRouters (224.0.0.5) address
  - All DR and BDR routers must accept packets sent to the AllDRouters (224.0.0.6) address
- Hello packets are sent to the AllSPFRouters address (Unicast for point-to-point and virtual links)

OSPF Areas

- Group of contiguous nodes/ networks
- Per area topology DB
  - Invisible outside the area
  - Reduces routing traffic
- Backbone Area is contiguous
  - All others areas must connect to the backbone
- Virtual Links

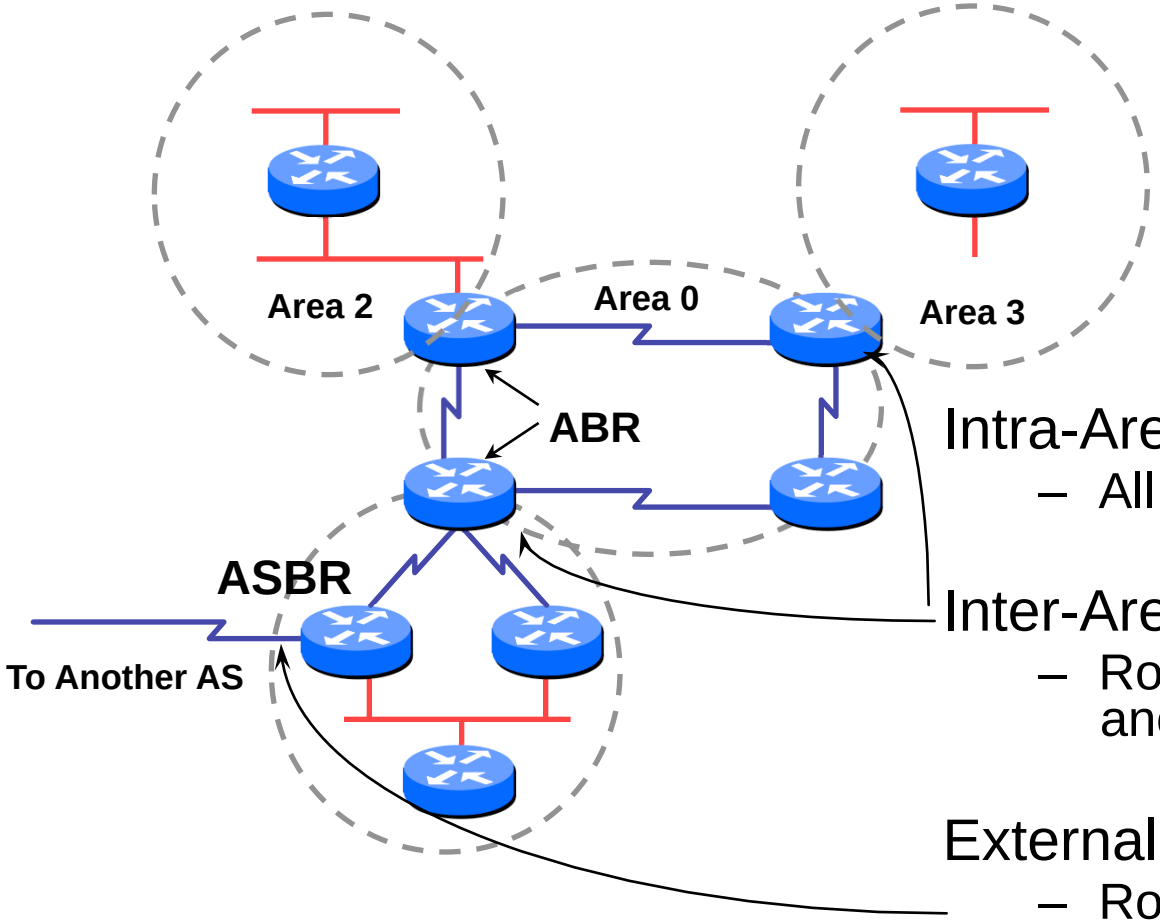


Router Classification



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

OSPF Route Types



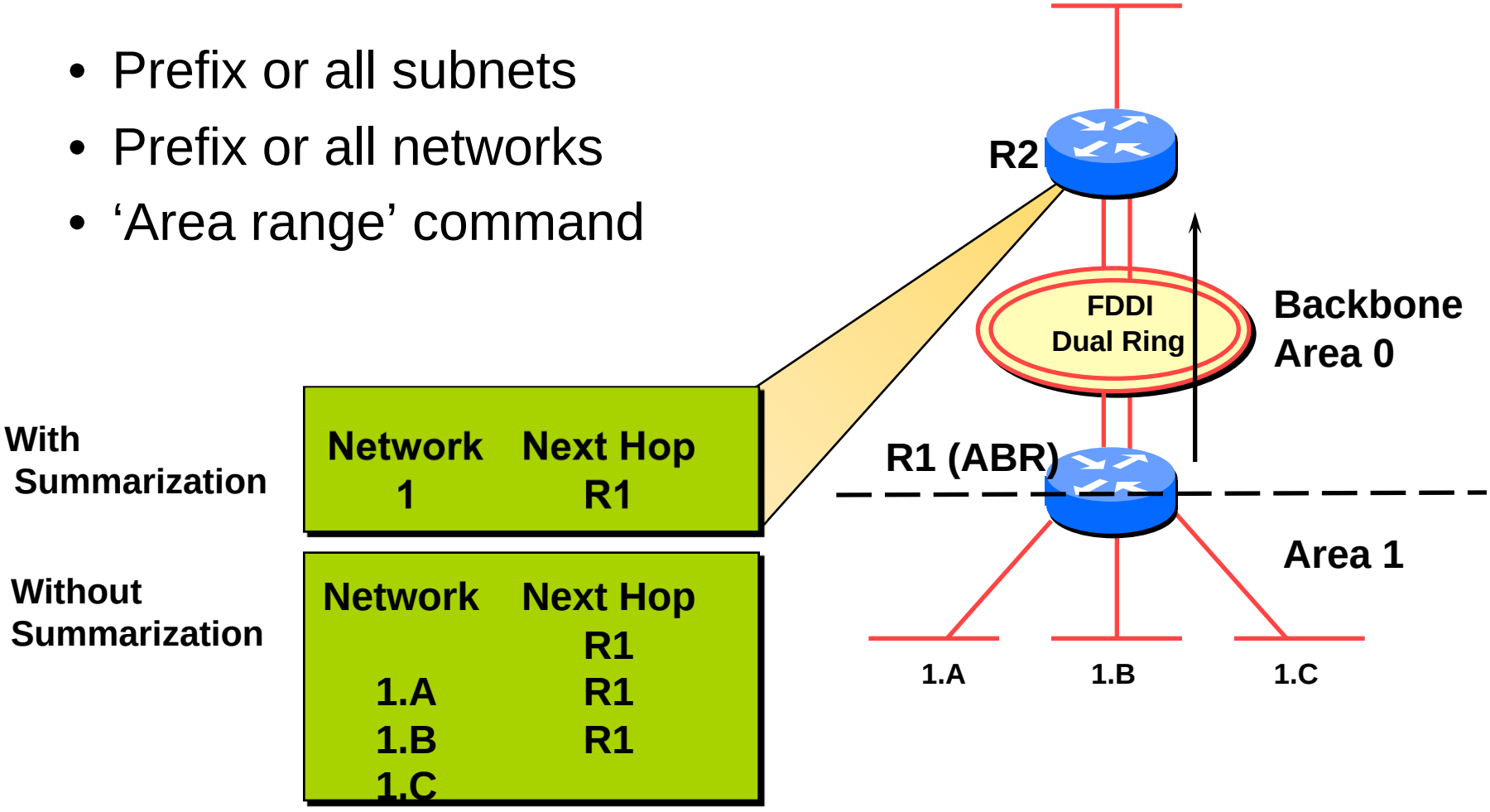
Intra-Area Route
- All routes within an area

Inter-Area Route
- Routes announced from area to another by an ABR

External Route
- Routes imported into OSPF from another protocol or Static routes

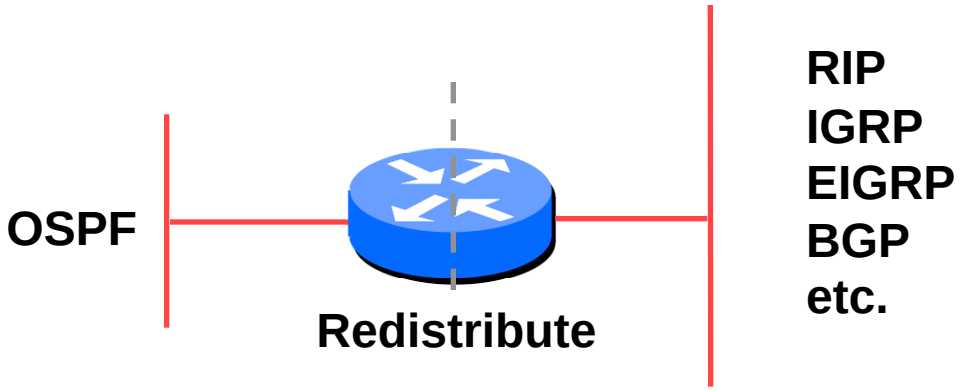
Inter-Area Route Summarization

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



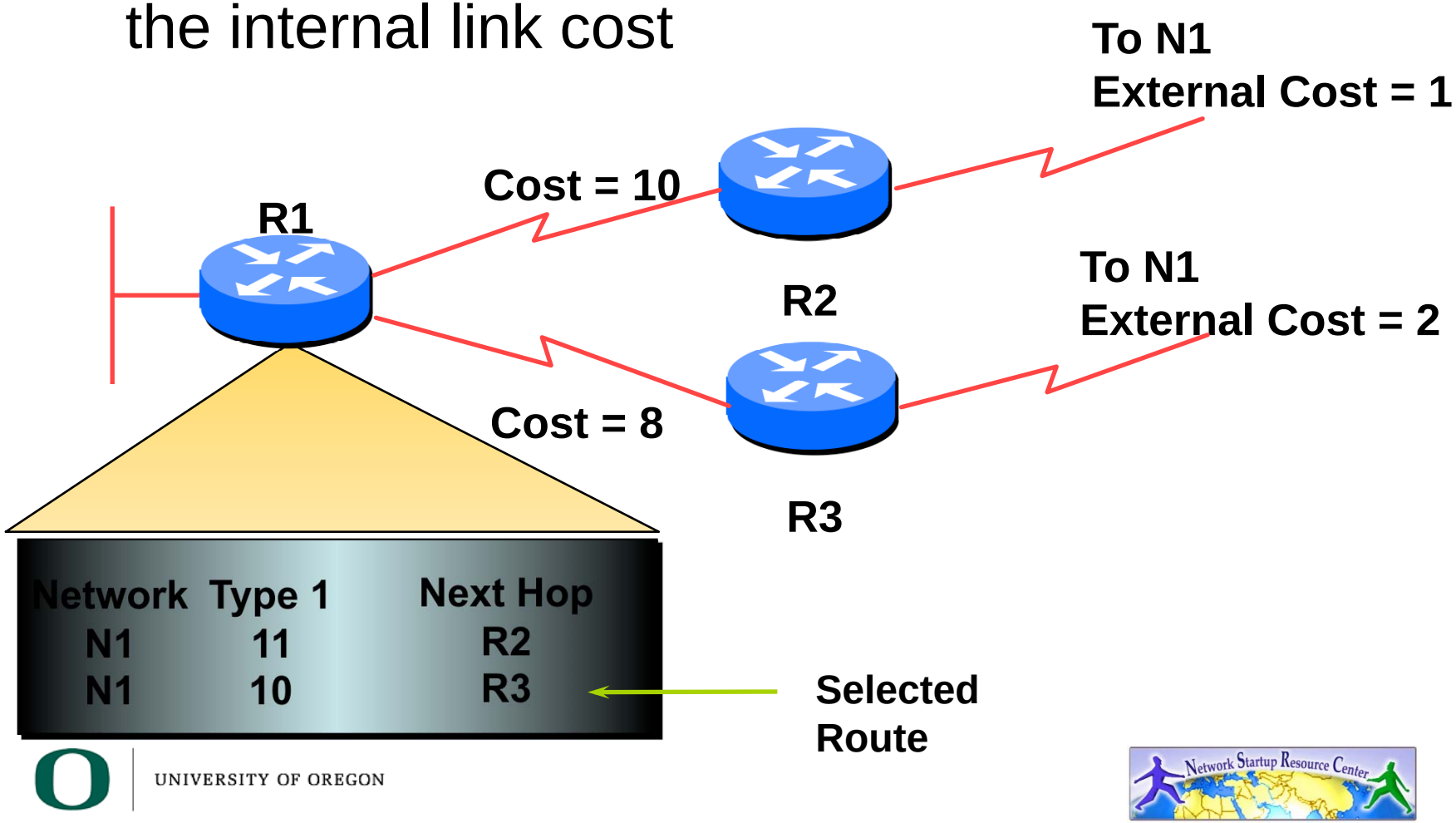
External Routes

- Redistributed into OSPF
- Flooded without changes throughout the AS
- OSPF supports two type of external metrics
  - Type 1
  - Type 2 (Default)



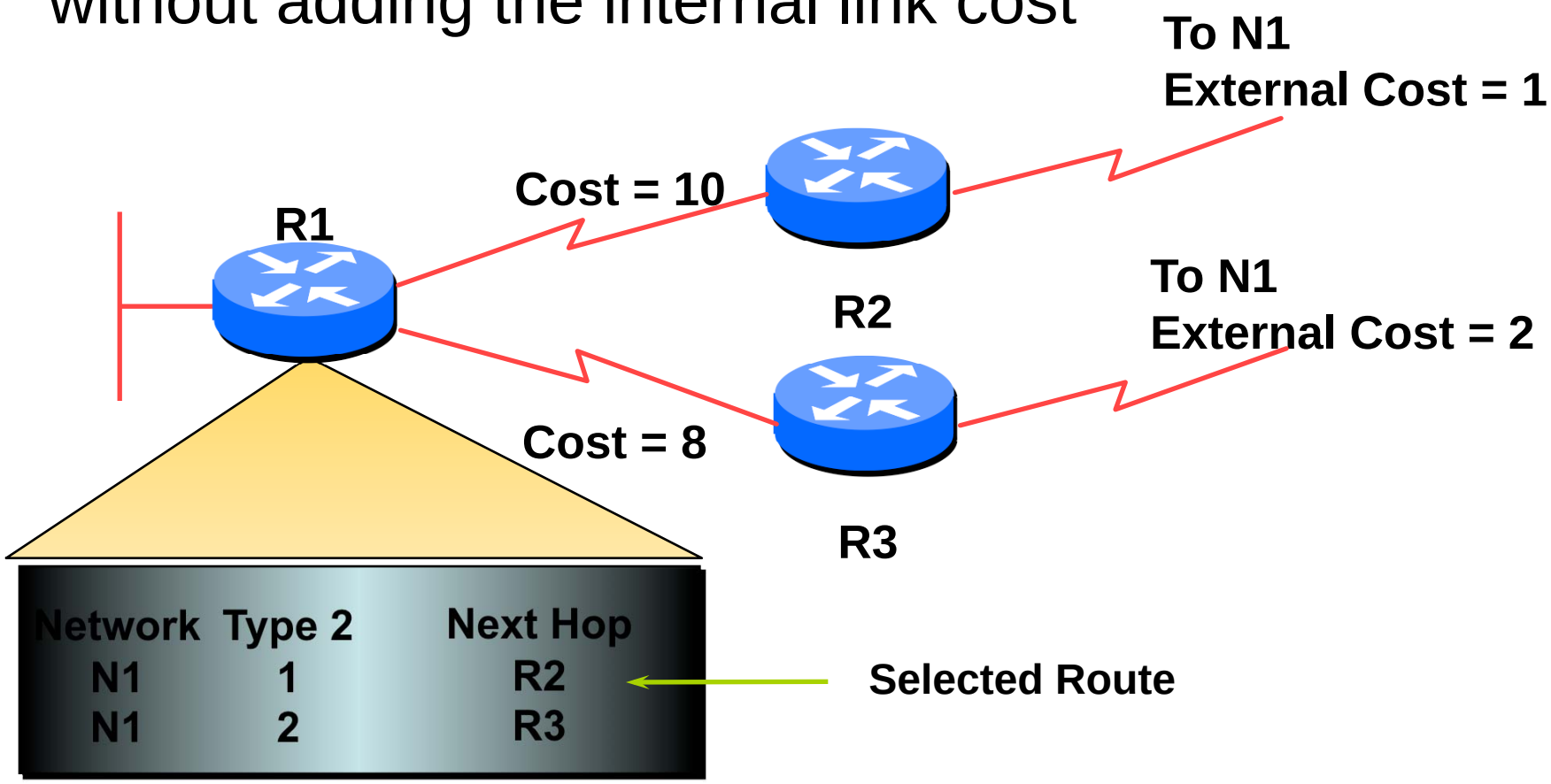
External Routes

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



External Routes

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



Topology/Links-State DB

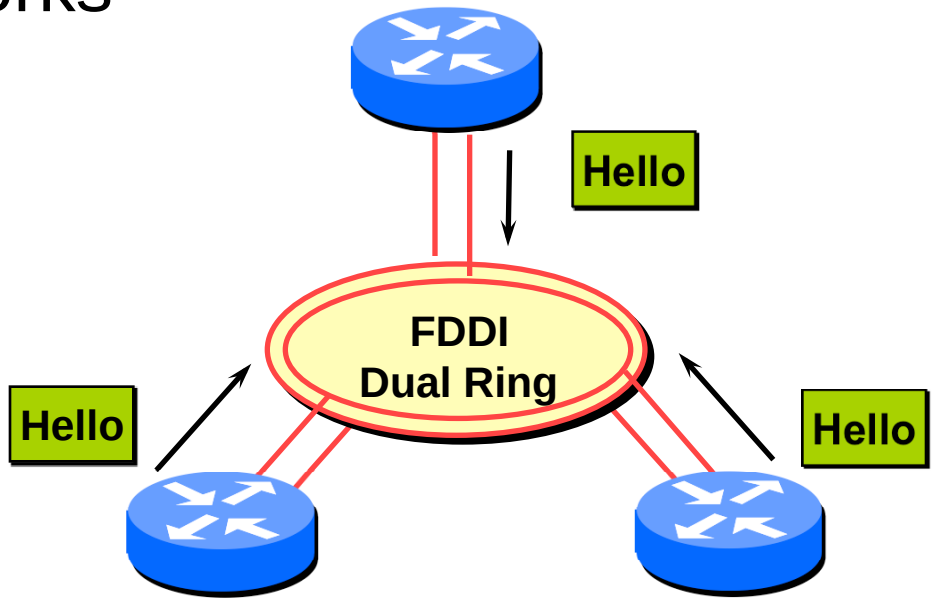
- A router has a separate DB for each area it belongs
- All routers within an area have an identical DB
- SPF calculation is done separately for each area
- LSA flooding is limited to the particular area

Protocol Functionality

- Bringing up adjacencies
- LSA Types
- Area Classification

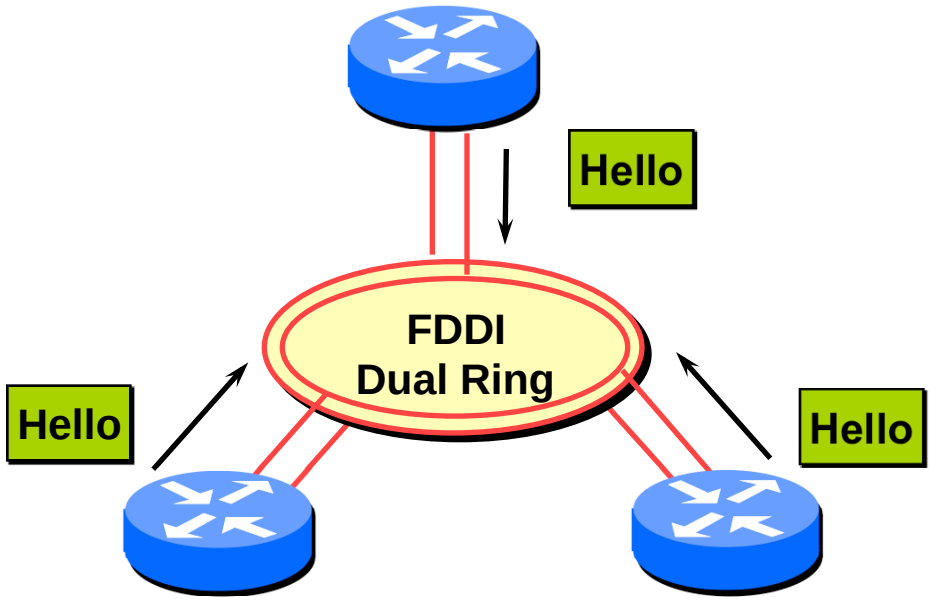
The Hello Protocol

- Responsible to establish and maintain neighbor relationships
- Elects designated router in multi-access networks



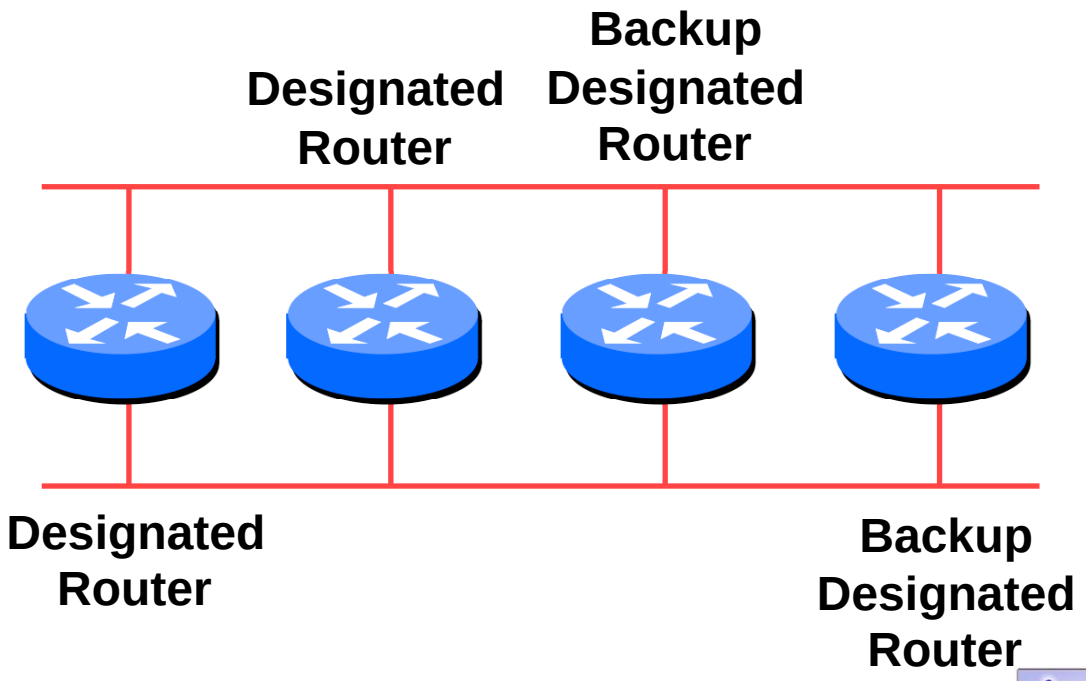
The Hello Packet

- Router Priority
- Hello Interval
- Router dead interval
- Network mask
- Options: T-bit, E-bit
- List of neighbors



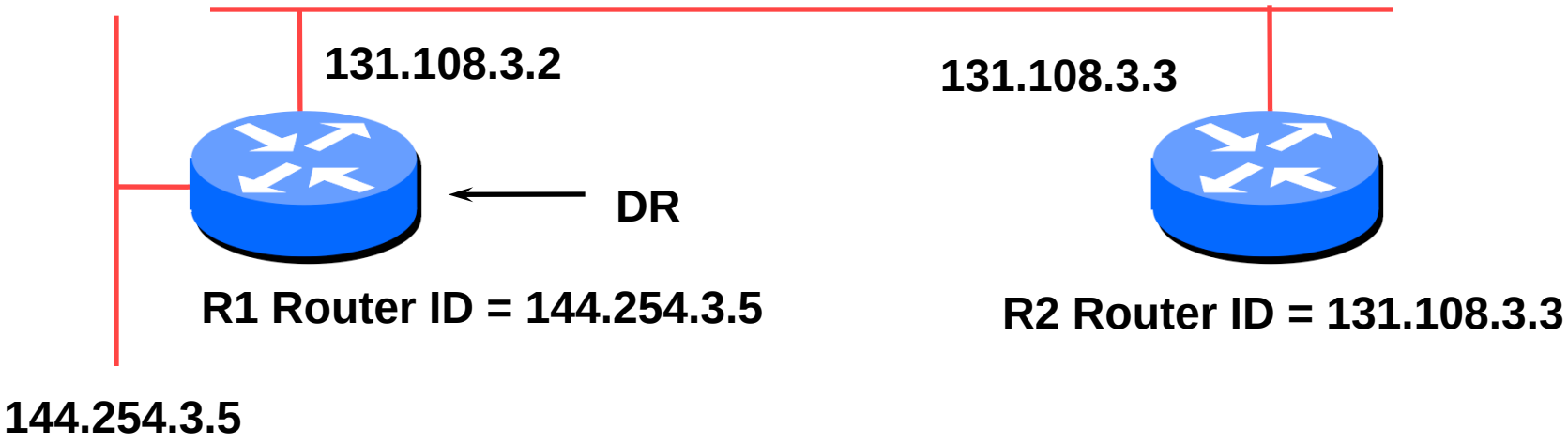
Designated Router (DR)

- **One per multi-access network**
  - **Generates network links advertisements**
  - **Assists in DB synchronization**



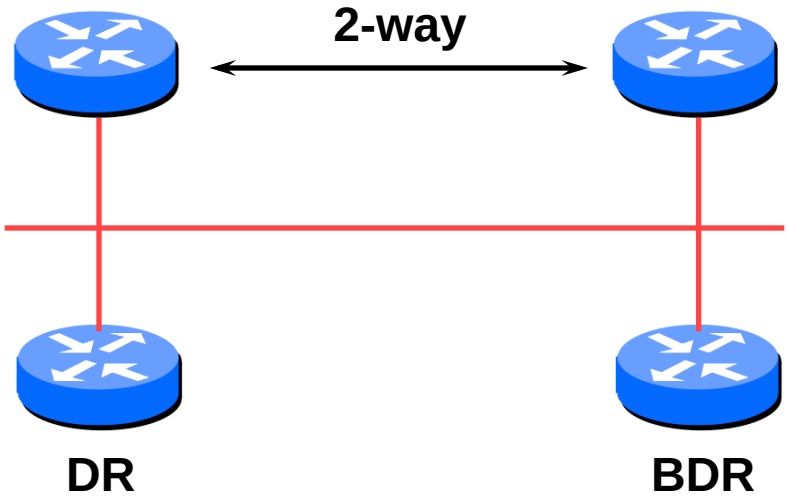
Designated Router by Priority

- Configured priority (per interface)
- Otherwise determined by the highest router ID
  - The router ID is the loopback interface address, in configured otherwise is the highest IP address



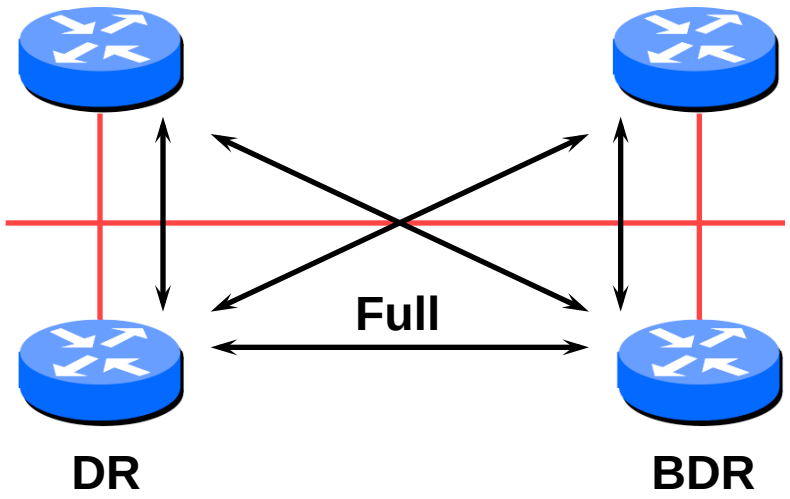
Neighbor States

- 2-way
  - The router sees itself in other Hello packets
  - DR is selected from neighbors in state 2-way or greater



Neighbor States

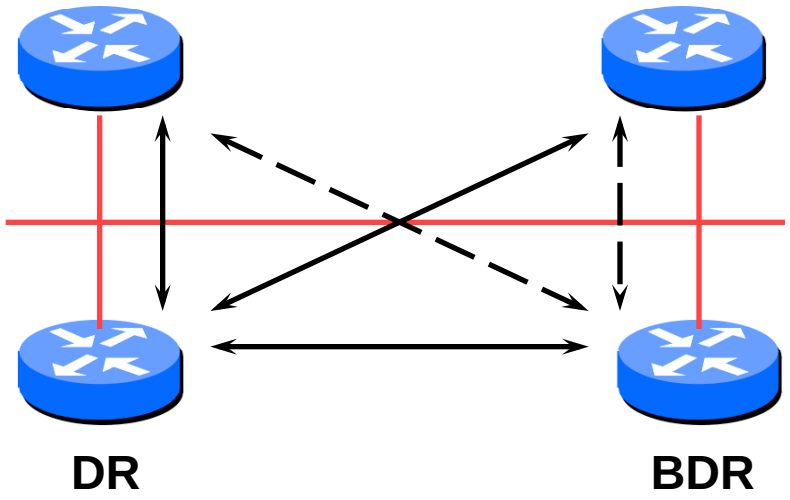
- Full
  - Routers are fully adjacent
  - DB is synchronized
  - Relationship to the DR and BDR



When to Become Adjacent

- Underlying network is point-to-point
- Underlying network type is virtual link
- The router itself is the DR
- The router itself is the BDR
- The neighboring router is the DR
- The neighboring router is the BDR

LSAs Propagate Along Adjacencies



- LSAs acknowledged along adjacencies

Routing Protocol Packets

- Share a common protocol header
- Routing protocol packets are sent with a TOS of 0
- Five types of OSPF routing protocol packets
  - Hello – packet type 1
  - DB Description – packet type 2
  - Link-state request – packet type 3
  - Link-state update – packet type 4
  - Link-state Acknowledgment – packet type 5

Different Types of LSAs

- Five LSA types
  - Type 1 : Router LSA
  - Type 2 : Network LSA
  - Type 3 y 4: Summary LSA
  - Type 5 y 7: External LSA

Router LSA (Type 1)

- Describes the state and cost of the router's link to the area
- All the router's links in an area must be described in a single LSA
- Flooded throughout the particular area and not beyond
- Router indicates whether it is an ASBR, ABR, or the end point of a virtual link

Network LSA (Type 2)

- Generated for every transit broadcast or NBMA network
- Describes all the routers attached to the network
- Only the DR originates this type of LSA
- Flooded throughout the area and not beyond

Summary LSA (Type 3 y 4)

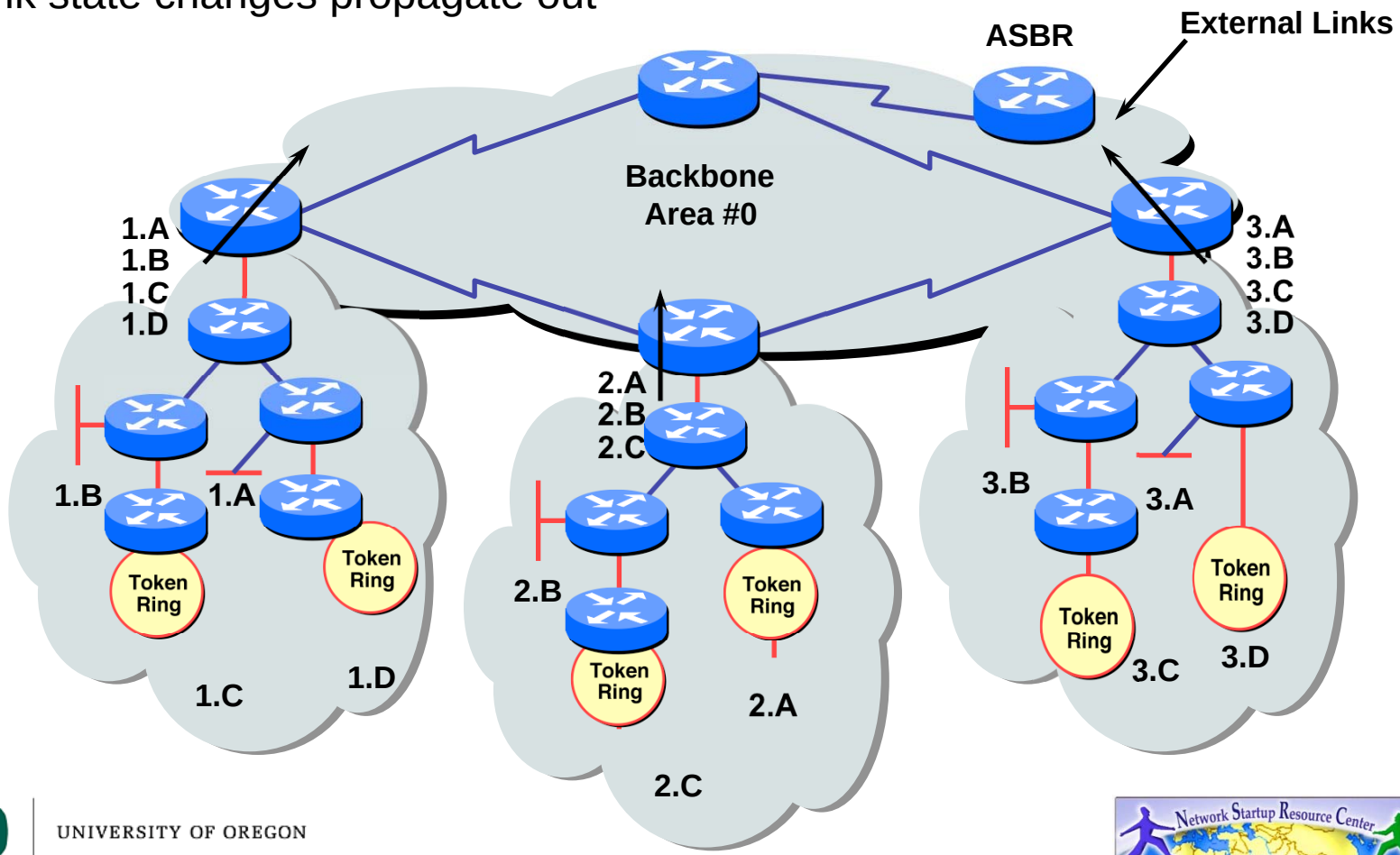
- Describes a destination outside the area but still within the AS
- Flooded throughout a single area
- Originated by an ABR
- Only intra-area routes are advertised into the backbone (Area 0)
- Type 4 is the information about the ASBR

External LSA (Type 5)

- Defines routes to destinations outside the AS
- Default route is also sent as external
- Two Types of external LSA:
  - E1: Considers the total cost of to the external destination
  - E2: Considers only the cost of the outgoing interface to the external destination

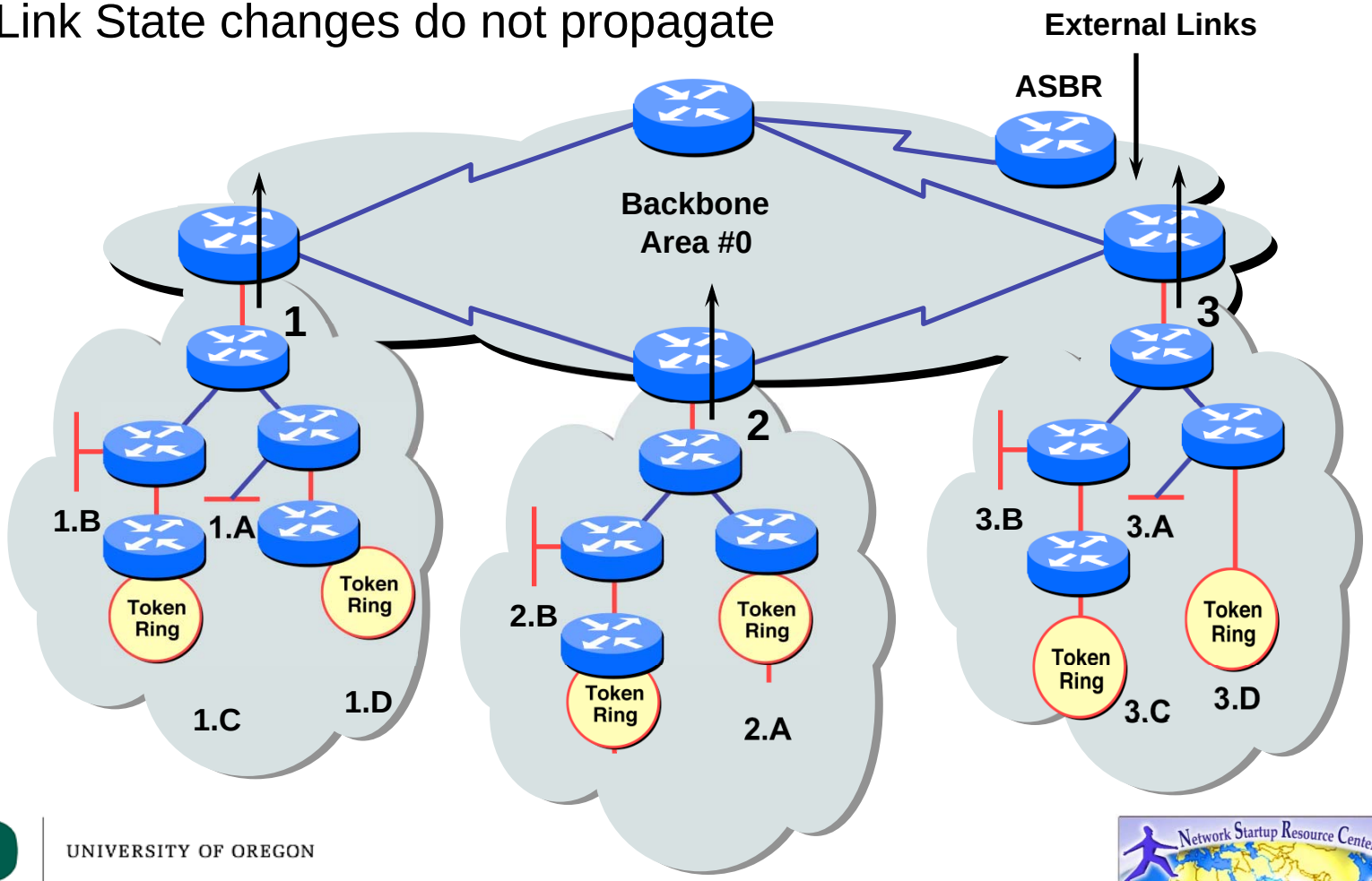
Not Summarized: Specific Link

- Specific link LSA advertised out
- Link state changes propagate out



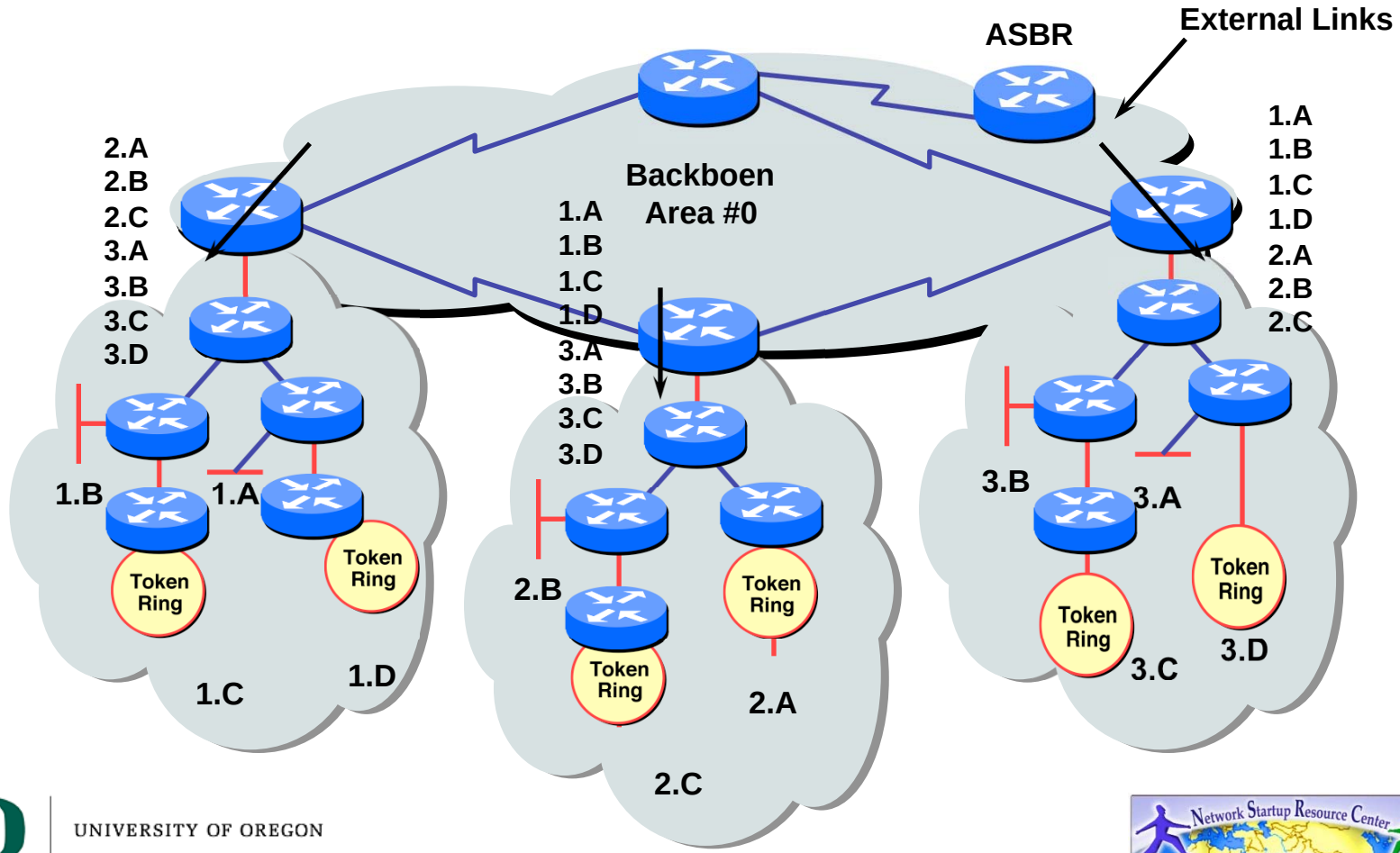
Summarized: Summary Links

- Only Summary LSA advertised out
- Link State changes do not propagate



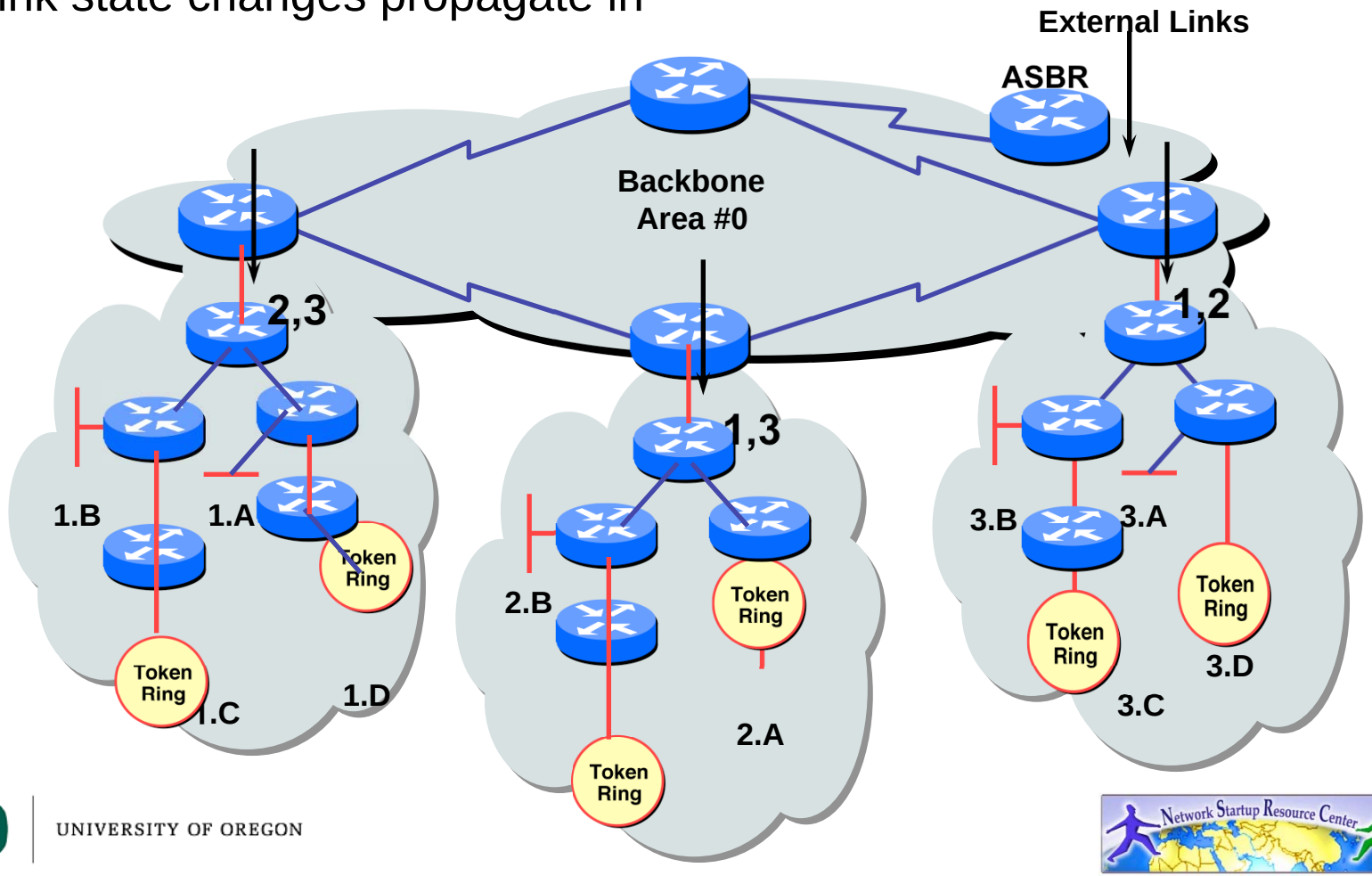
Not Summarized: Specific Links

- Specific Link LSA advertised in
- Links state changes propagate in



Summarized: Summary Links

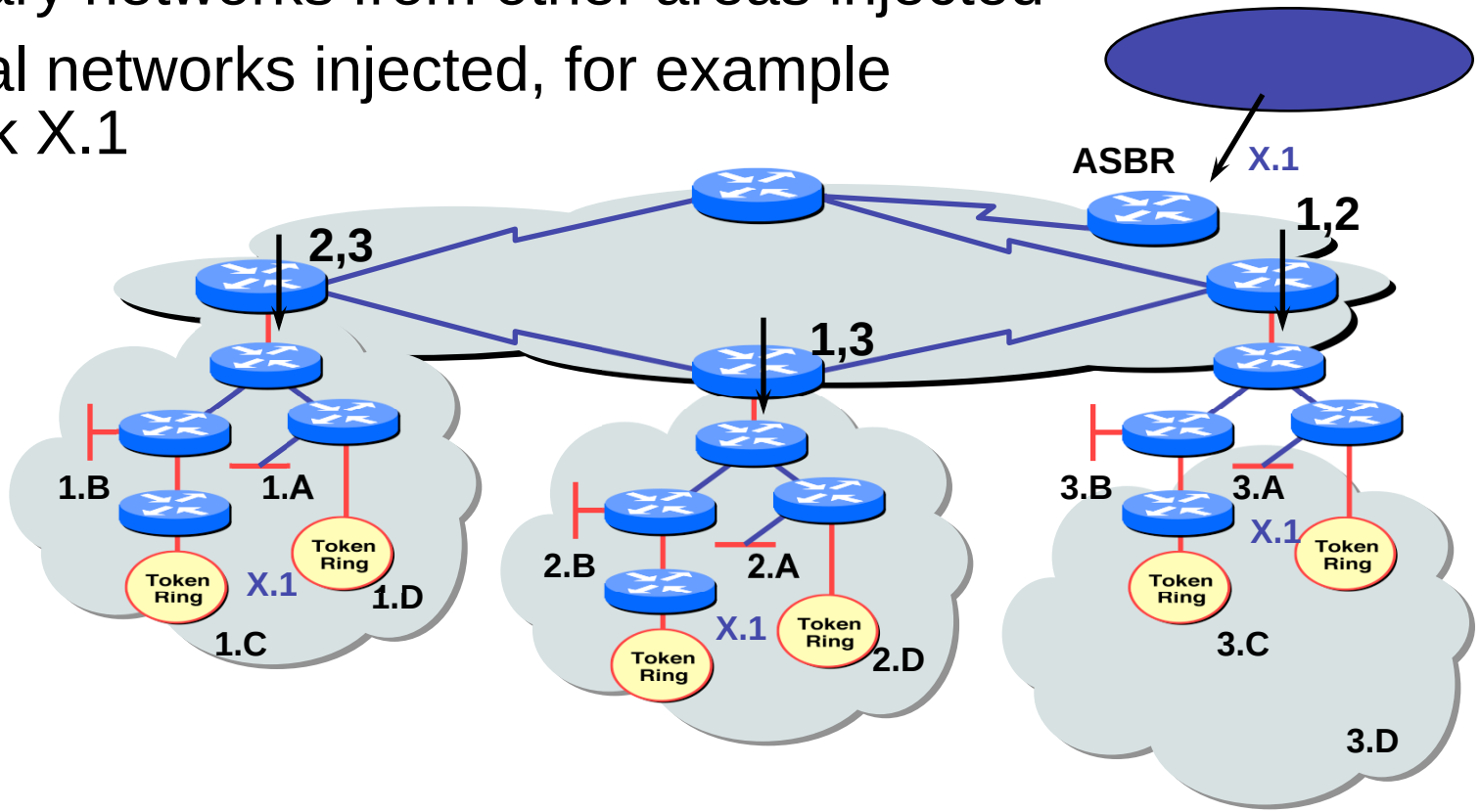
- Specific Link LSA advertised in
- Link state changes propagate in



Regular Area (Not a stub)

From area 1's point of view

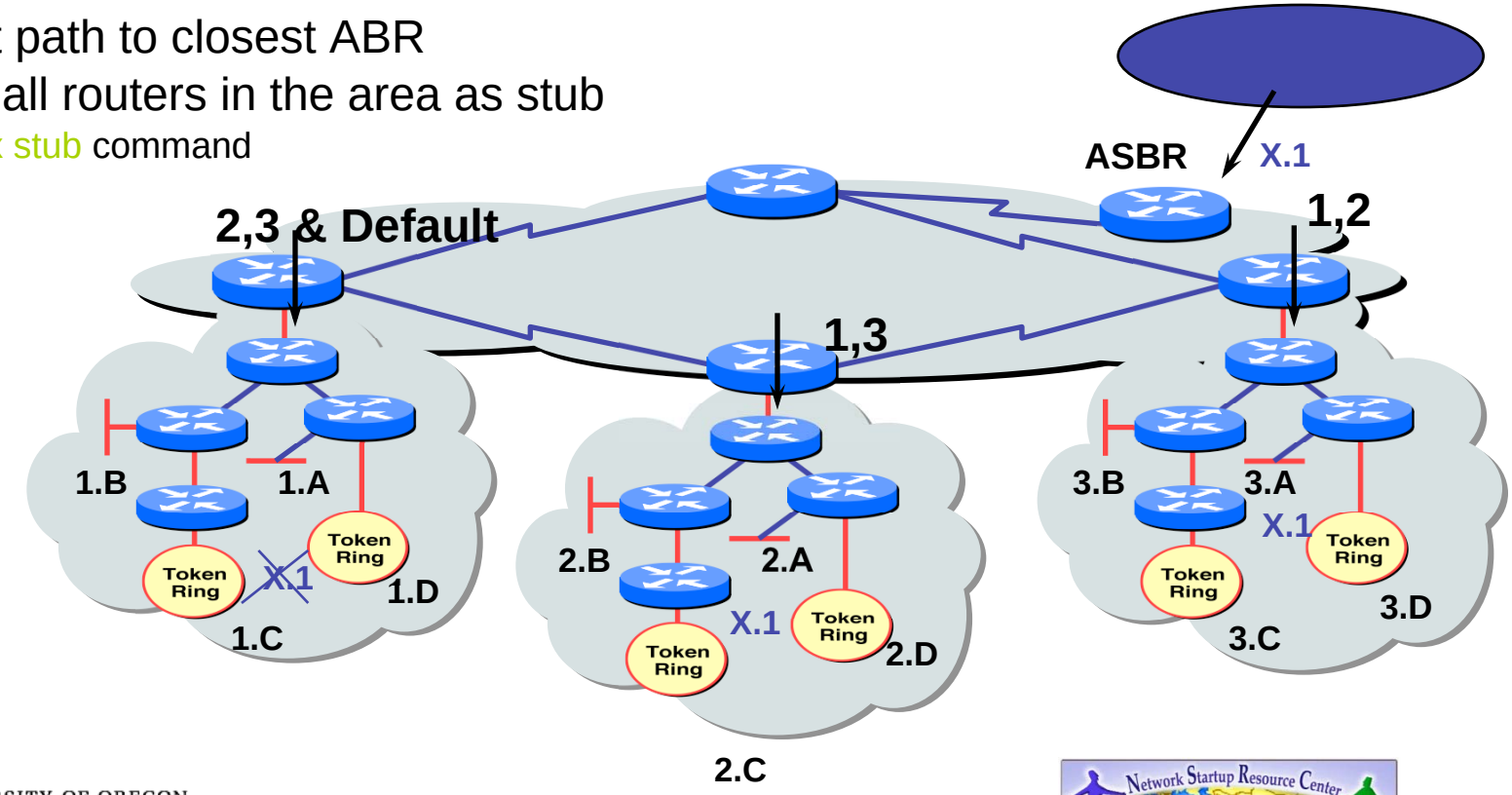
- Summary networks from other areas injected
- External networks injected, for example network X.1



Normal Stub Area

From area 1's point of view

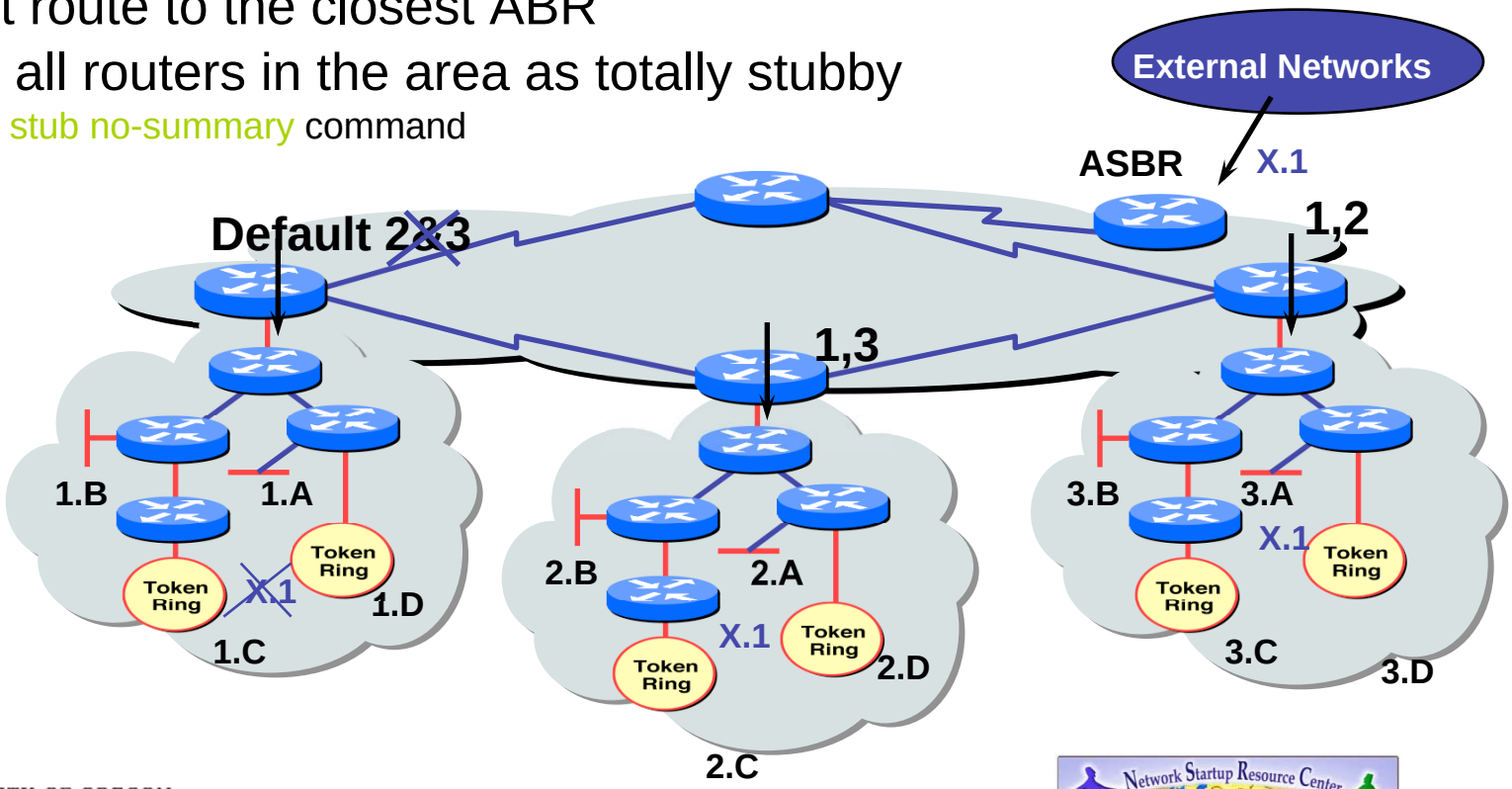
- Summary networks from other areas injected
- Default route injected into the area – represent external links
- Default path to closest ABR
- Define all routers in the area as stub
  - area x stub command



Totally Stubby Area

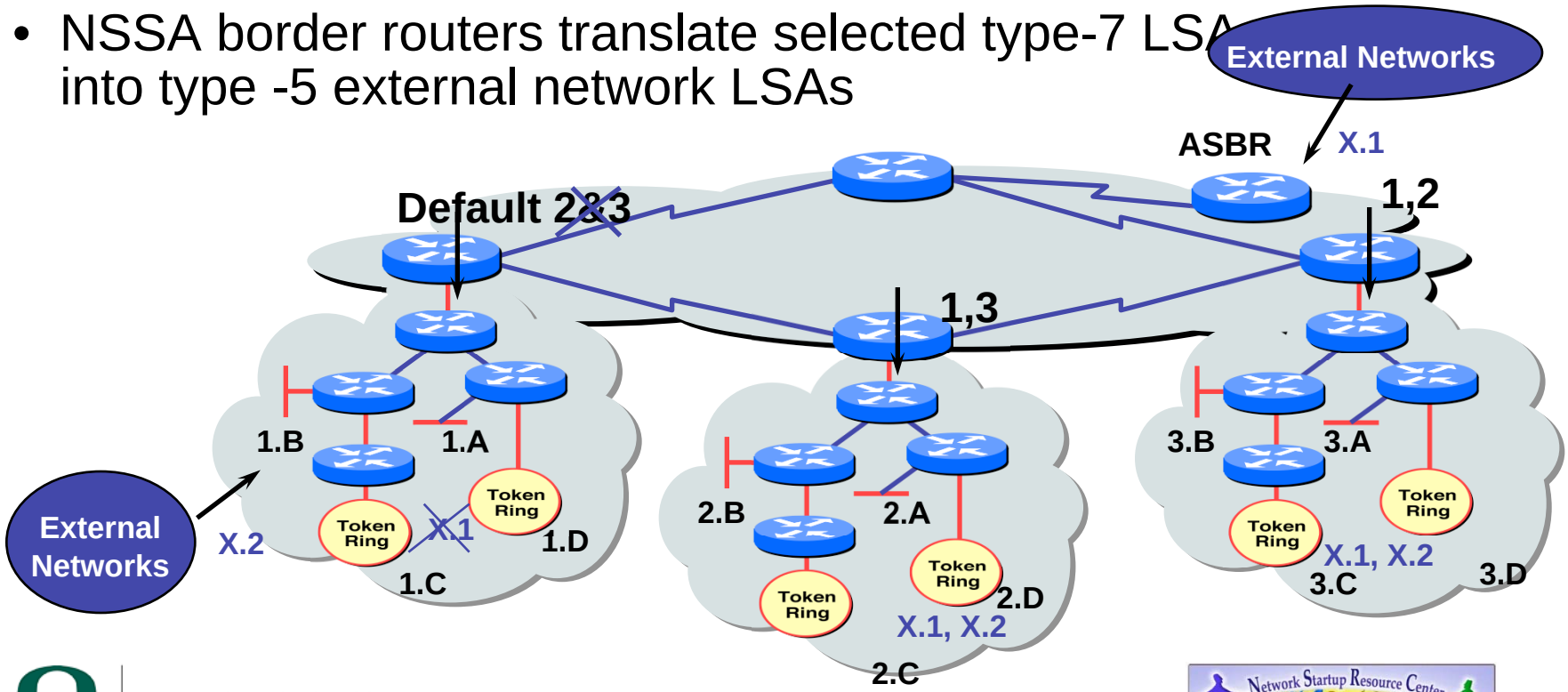
From area 1's point of view

- Only a default network is injected into the area
  - Represents external networks and all inter-area routes
- Default route to the closest ABR
- Define all routers in the area as totally stubby
  - area x stub no-summary command

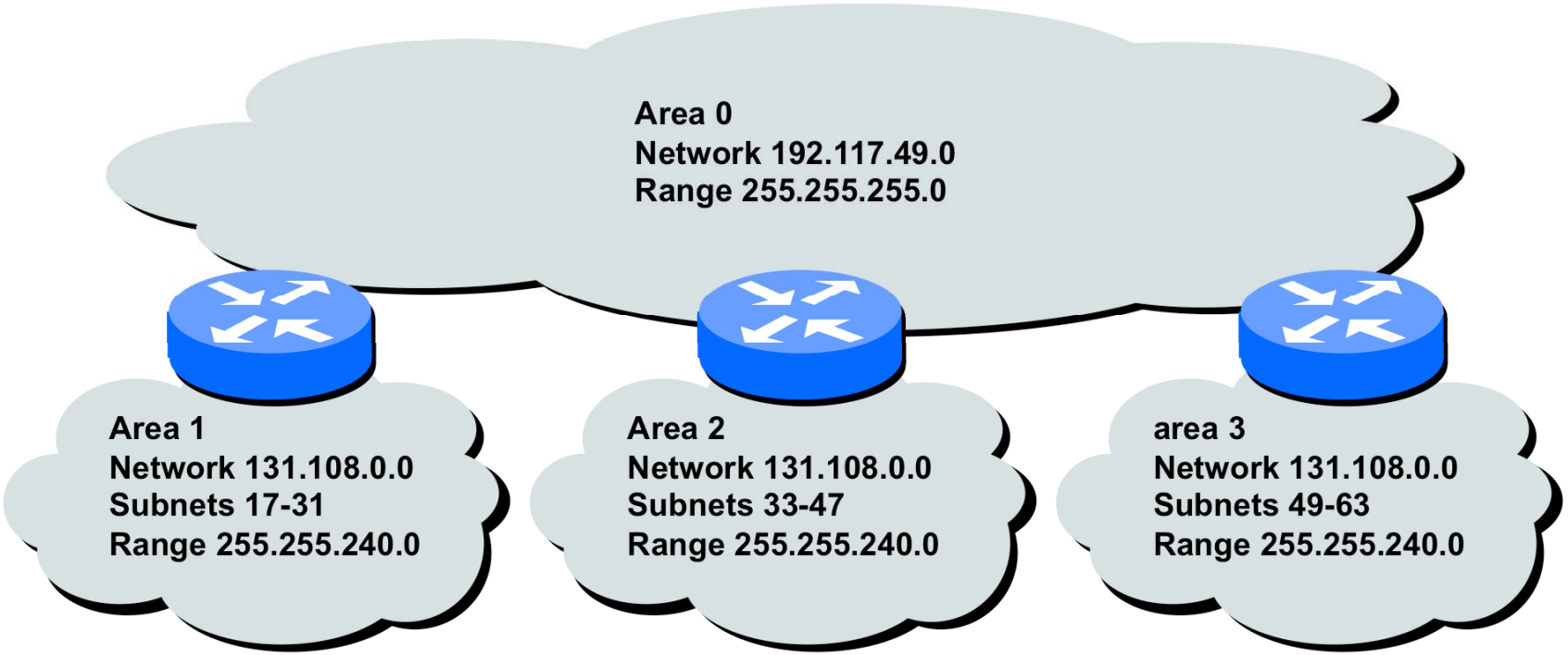


Not-So-Stubby Area

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



Addressing



Try to assign contiguous subnet ranges to facilitate summarization

Summary

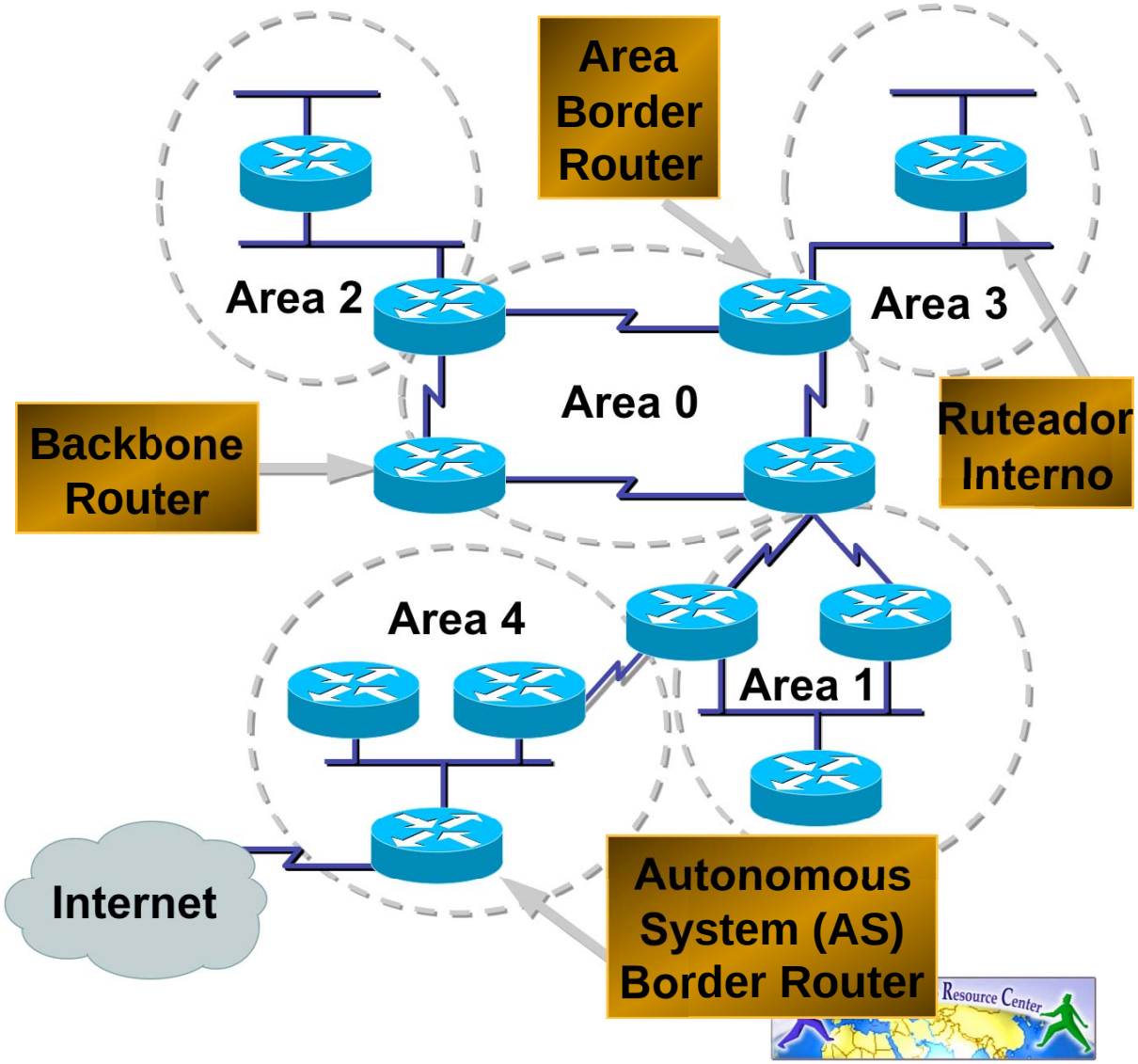
- Scalable OSPF Network Design
  - Area hierarchy
  - Stub areas
  - Contiguous addressing
  - Route summarization

OSPF Design Service Provider Networks

UNIVERSITY OF OREGON

OSPF Areas and Rules

- Backbone area (0) must exist
- All other areas must have connection to backbone
- Backbone must be contiguous
- Do not partition area (0)



OSPF Design

- Figure out your addressing first – OSPF and addressing go together
  - The objective is to maintain a small link-state DB
  - Create address hierarchy to match the network topology
  - Separate blocks for infrastructure, customer interfaces, customers, etc.

OSPF Design

- Examine the physical topology
  - Is it meshed or hub-and-spoke (star)
- Try to use as Stubby an area as possible
  - It reduces overhead and LSA counts
- Push the creation of a backbone
  - Reduces mesh and promotes hierarchy

OSPF Design

- One SPF per area, flooding done per area
  - Try not to overload the ABRs
- Different types of areas do different flooding
  - Normal areas
  - Stub areas
  - Totally stubby (stub no-summary)
  - Not so stubby areas (NSSA)

OSPF Design

- 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 – otherwise sub-optimal routing will result
    - Too much redundancy in the backbone area without good summarization will affect convergence in the area 0

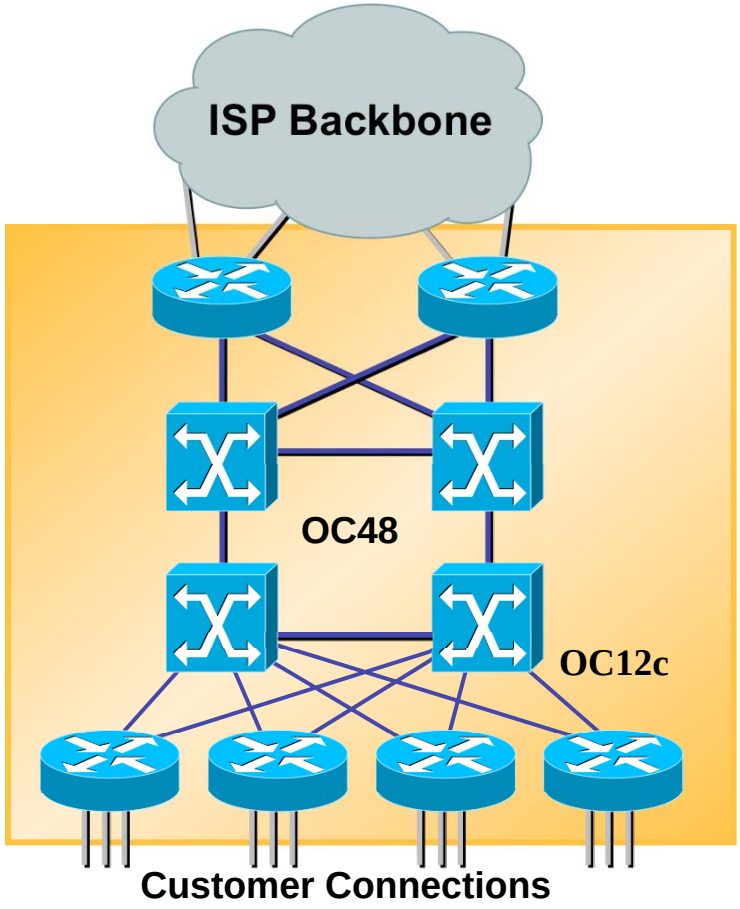
OSPF for ISPs

- OSPF features you should consider:
  - OSPF logging neighbor changes
  - OSPF reference cost
  - OSPF router ID command
  - OSPF Process Clear/Restart

OSPF Best Common Practices – Adding Networks

OSPF – Network Aggregation

- BCP – Individual OSPF network statement for each infrastructure link
  - Have separate IP address blocks for infrastructure and customer links
  - Use IP unnumbered interfaces or BGP to carry /30 to customers
  - OSPF should only carry infrastructure routes in an ISP's network



OSPF – Adding Networks

- Redistribute connected subnet
  - Works for all connected interfaces on the router but sends networks as external types-2s – which are not summarized
    - `router ospf 100`
    - `redistribute connected subnets`
- Not recommended

OSPF – Adding Networks

- Specific network statements
  - Each interface requires an OSPF network statement. Interfaces that should not bet broadcasting Hello packets need a passive-interface statement
    - `router ospf 100`
    - `network 192.168.1.1 0.0.0.3 area 51`
    - `network 192.168.1.5 0.0.0.3 area 51`
    - `passive interface Serial 1/0`

OSPF – Adding Networks

- Network statements - wildcard mask
  - Every interface covered by a wildcard mask used in the OSPF network statement. Interfaces that should not be broadcasting Hello packets need a *passive-interface* statement or *default passive-interface* should be used
    - `router ospf 100`
    - `network 192.168.1.0 0.0.0.255 area 51`
    - `default passive-interface default`
    - `no passive interface POS 4/0`

OSPF – Adding Networks

- The key theme when selecting which method to use is to keep the links-state DB as small as possible
  - Increases stability
  - Reduces the amount of information in the LSAs
  - Speeds up convergence time

OSPF – New and Useful Features

OSPF Logging Neighbor Changes

- The router will generate a log message whenever an OSPF neighbor changes state
- Syntax:
  - [no] ospf log-adjacency-changes
- 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 neighbors given in detail (list all neighbors). When specified, neighbor state transition counters are displayed per interface or neighbor ID

State Changes (Cont.)

- To reset OSPF related statistics, use the clear ip ospf counters EXEC command.
  - clear ip ospf counters [neighbor [<type number>] [neighbor-id]]

OSPF Cost: Reference Bandwidth

- Bandwidth used in metric calculation
  - Cost = 10^8/BW
  - Not useful for BW > 100 Mbps but can be changed
- Syntax:
  - ospf auto-cost reference-bandwidth <reference-bandwidth>
- Default reference bandwidth is still100Mbps for backward compatibility

OSPF 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!
- Subcommand to manually set the OSPF router ID :
  - `router-id <ip address>`

OSPF Clear/Restart

- clear ip ospf [pid] redistribution
  - –This command can clear redistribution based on OSPF routing process ID. If no PID is given, it assumes all OSPF processes
- clear ip ospf [pid] counters
  - –This command clear counters based on OPSF routing process ID. If no PID is given, it assumes all OSPF processes
- clear ip ospf [pid] process
  - –This command will restart the specified OSPF process. If no PID is given, it assumes all OSPF processes. 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. It requires user confirmation because it will cause network churn.

OSPF Command Summary

Redistributing Routes into OSPF

- ROUTER OSPF <pid#x>
- REDISTRIBUTE {protocol} <as#y>
- <metric>
- <metric-type (1 or 2)
- <tag>
- <subnets>
-

OSPF Router Sub-Commands

- NETWORK <n.n.n.n> <mask> AREA <area-id>
- AREA <area-id> STUB {no-summary}
- AREA <area-id> AUTHENTICATION
- AREA <area-id> DEFAULT_COST <cost>
- AREA <area-id> VIRTUAL-LINK <router-id>...
- AREA <area-id> RANGE <address mask>

Interface Sub-Commands

- IP OSPF COST <cost>
- IP OSPF PRIORITY <8-bit-number>
- IP OSPF HELLO-INTERVAL <number-of-seconds>
- IP OSPF DEAD-INTERVAL <number-of-seconds>
- IP OSPF AUTHENTICATION-KEY <8-bytes-of-password>