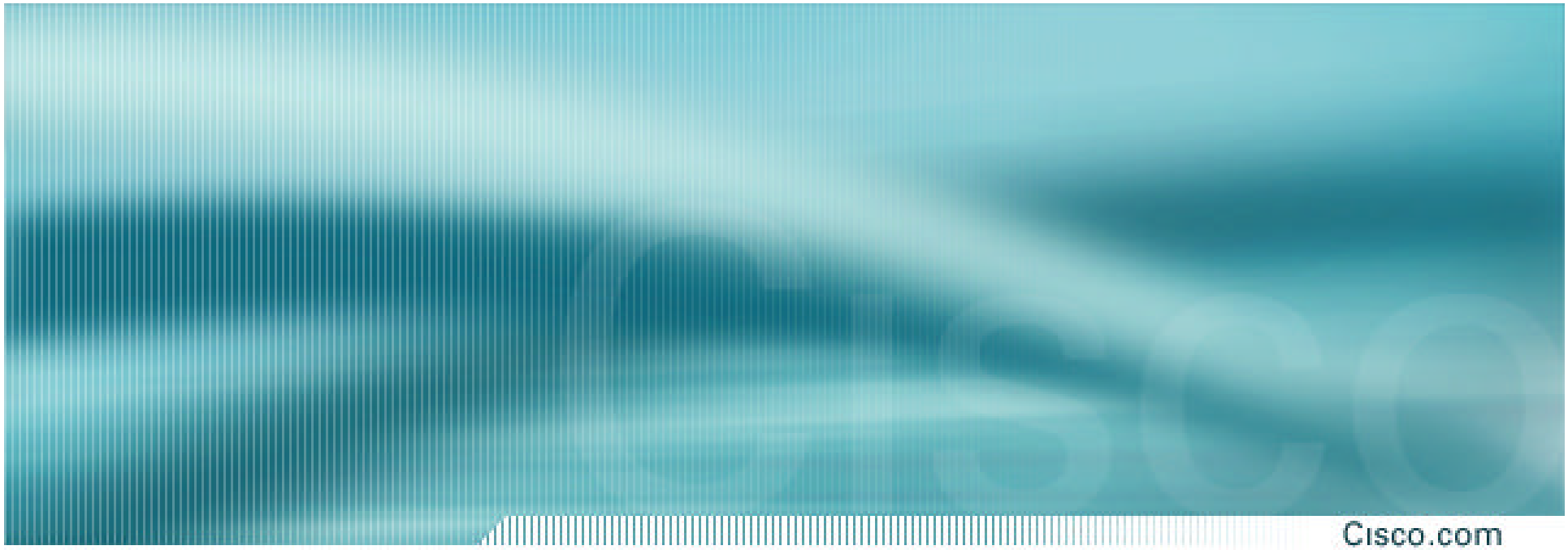


Introduction to OSPF

ISP/IXP Workshops

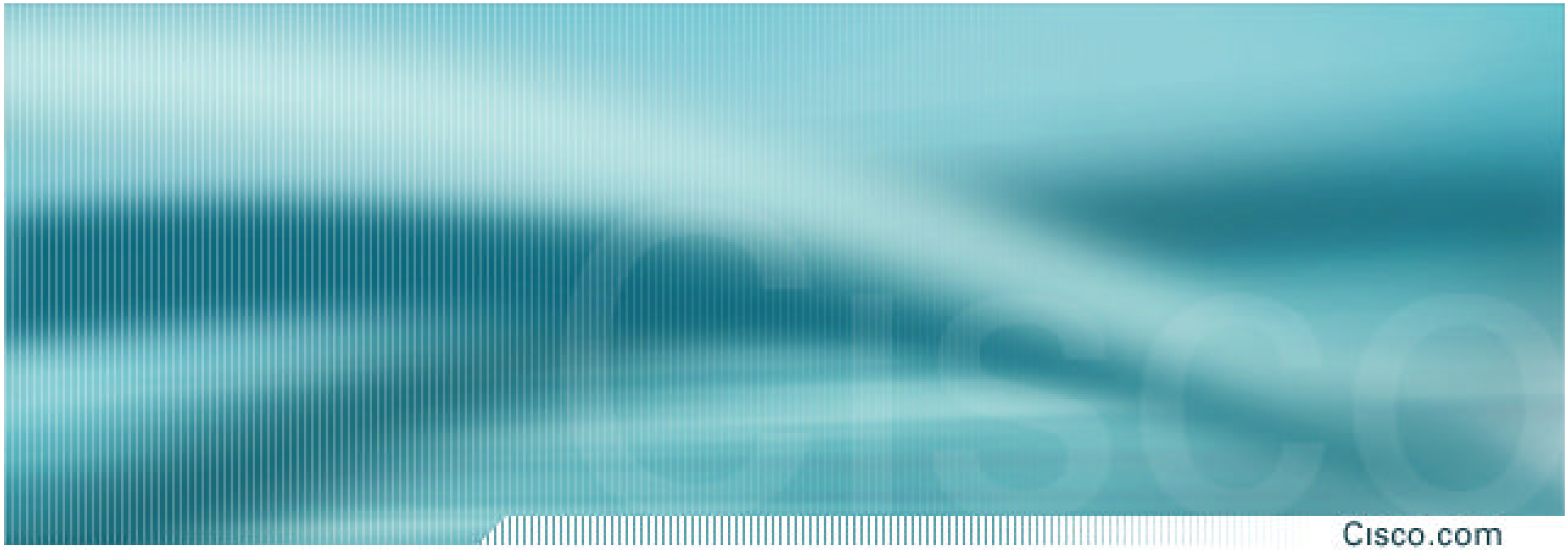
© 2003, Cisco Systems, Inc. All rights reserved.

Agenda

Cisco.com

- OSPF Primer
- OSPF in Service Provider Networks
- OSPF BCP – Adding Networks
- OSPF Command Summary

© 2003, Cisco Systems, Inc. All rights reserved.



OSPF Primer

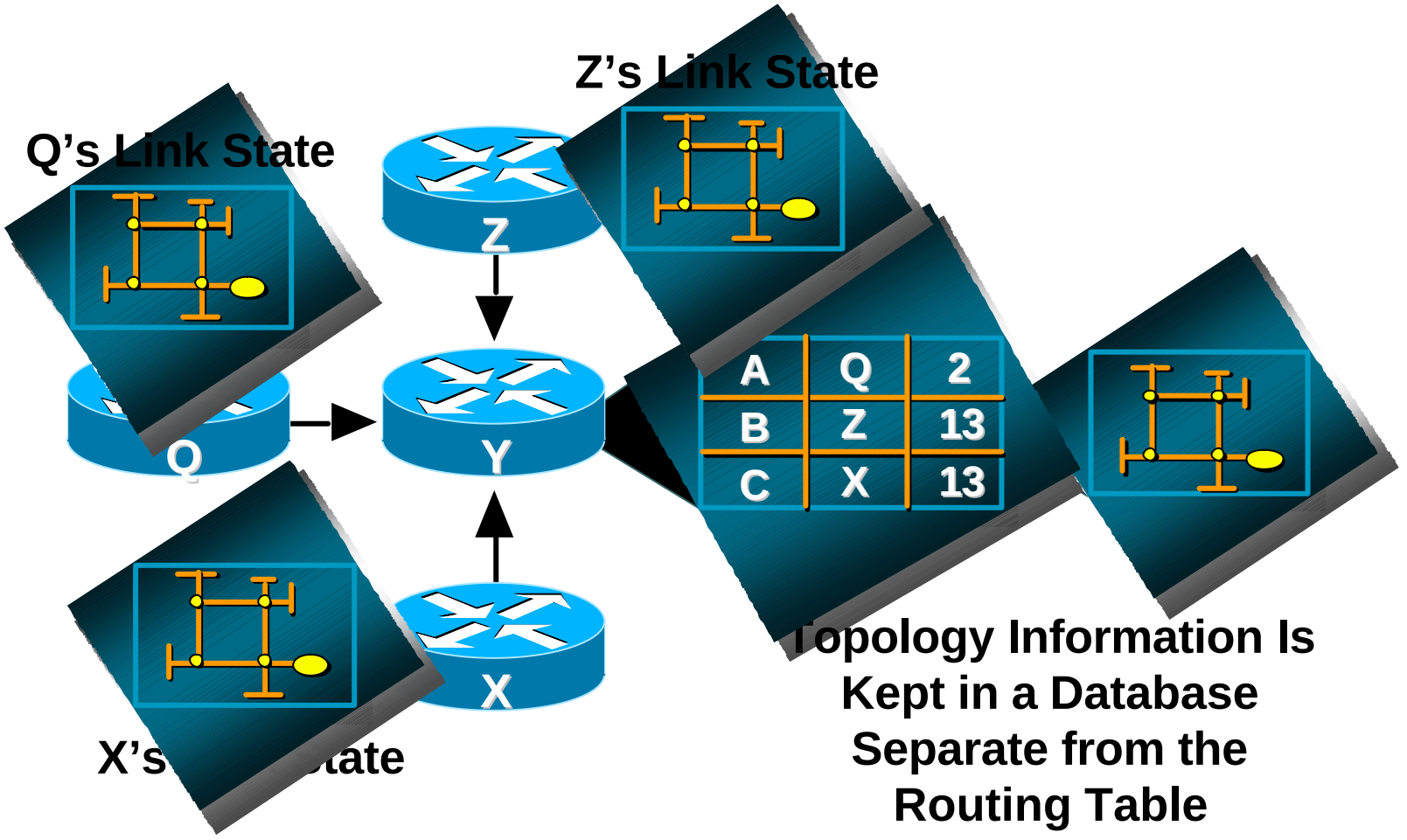
© 2003, Cisco Systems, Inc. All rights reserved.

OSPF

- Open Shortest Path First
- Link state or SPF technology
- Developed by OSPF working group of IETF (RFC 1247)
- Designed for TCP/IP Internet environment
- Fast convergence
- Variable-length subnet masks
- Discontiguous subnets
- No periodic updates
- Route authentication
- Delivered two years after IGRP
- OSPF standard described in RFC2328

© 2003, Cisco Systems, Inc. All rights reserved.

Link State



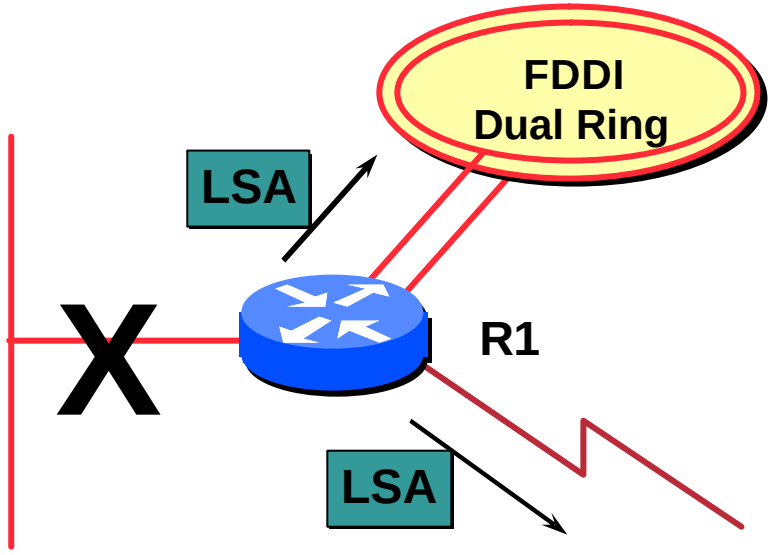
© 2003, Cisco Systems, Inc. All rights reserved.

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 tables

© 2003, Cisco Systems, Inc. All rights reserved.

Low Bandwidth Utilisation

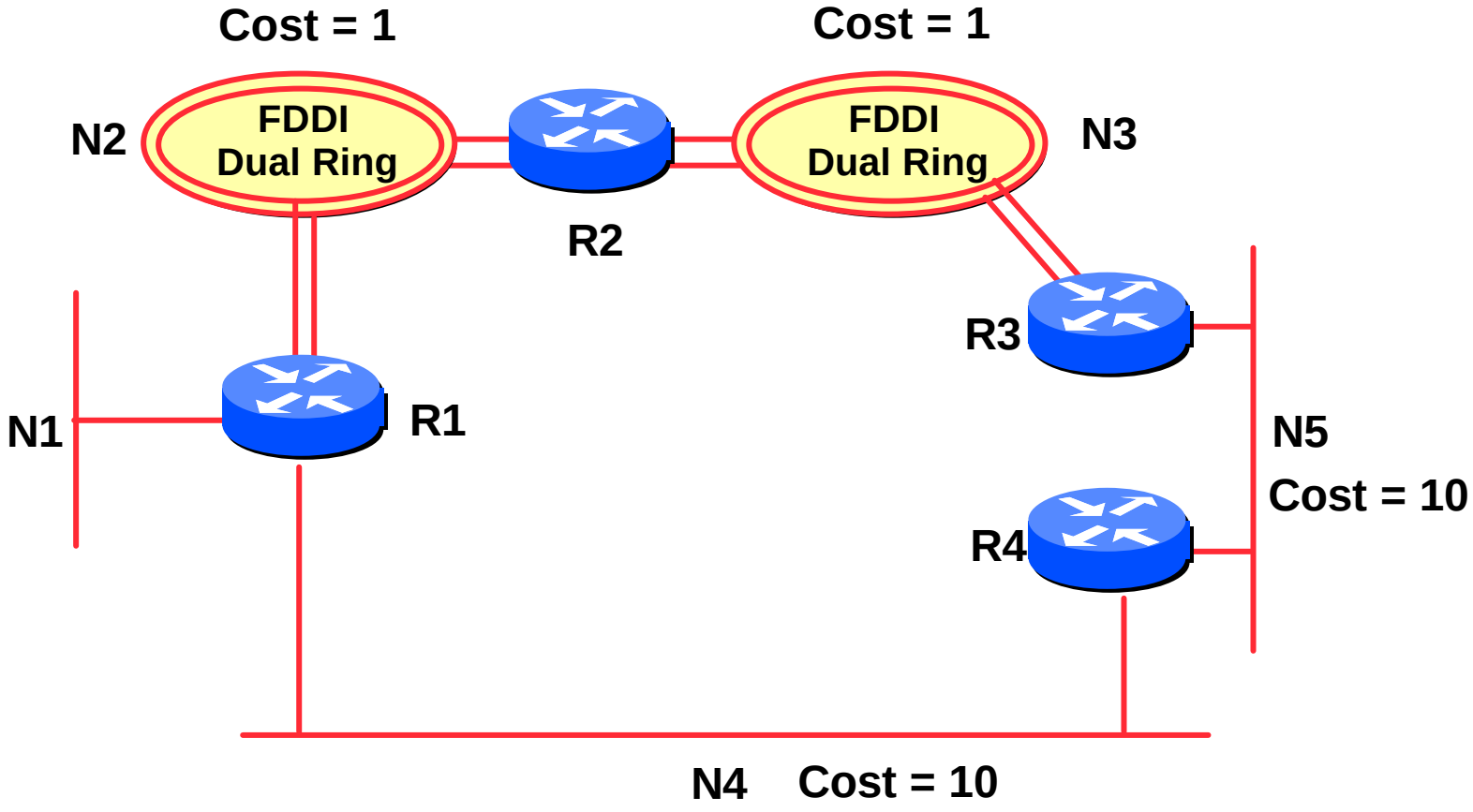


- **Only changes propagated**
- **Multicast on multi-access broadcast networks**

© 2003, Cisco Systems, Inc. All rights reserved.

Optimal Path Utilisation

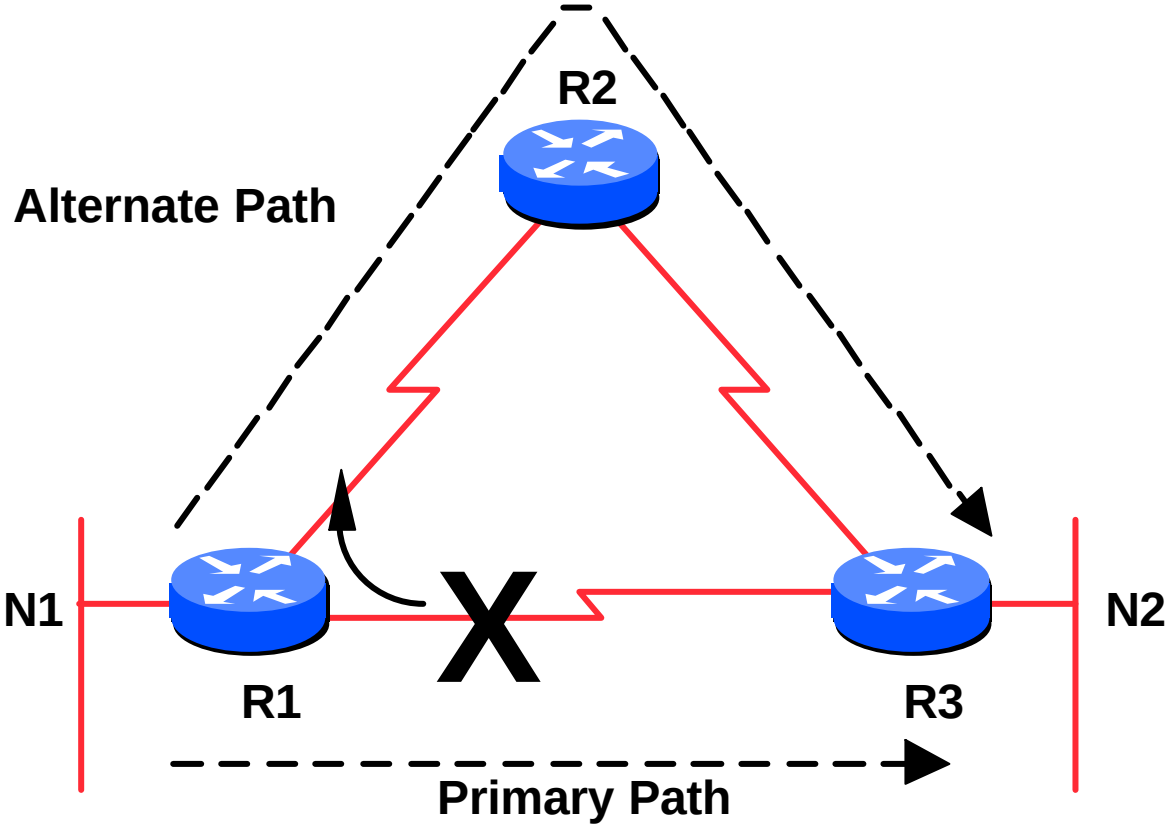
The optimal path is determined by the sum of the interface costs: Cost = 10^8/BW



© 2003, Cisco Systems, Inc. All rights reserved.

Fast Convergence

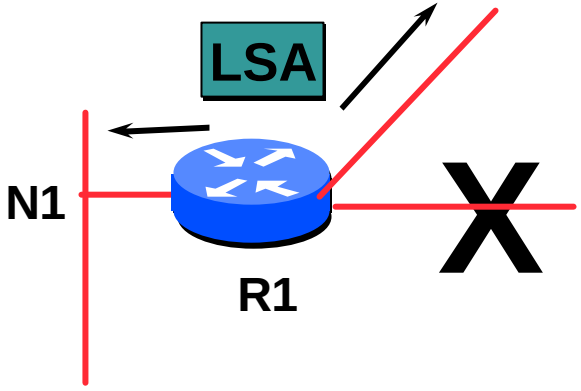
- **Detection Plus LSA/SPF**



© 2003, Cisco Systems, Inc. All rights reserved.

Fast Convergence

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



© 2003, Cisco Systems, Inc. All rights reserved.

Utilises IP Multicast for Sending/Receiving Updates

- **Broadcast networks**

  All routers must accept packets sent to AllSPFRouters (224.0.0.5)

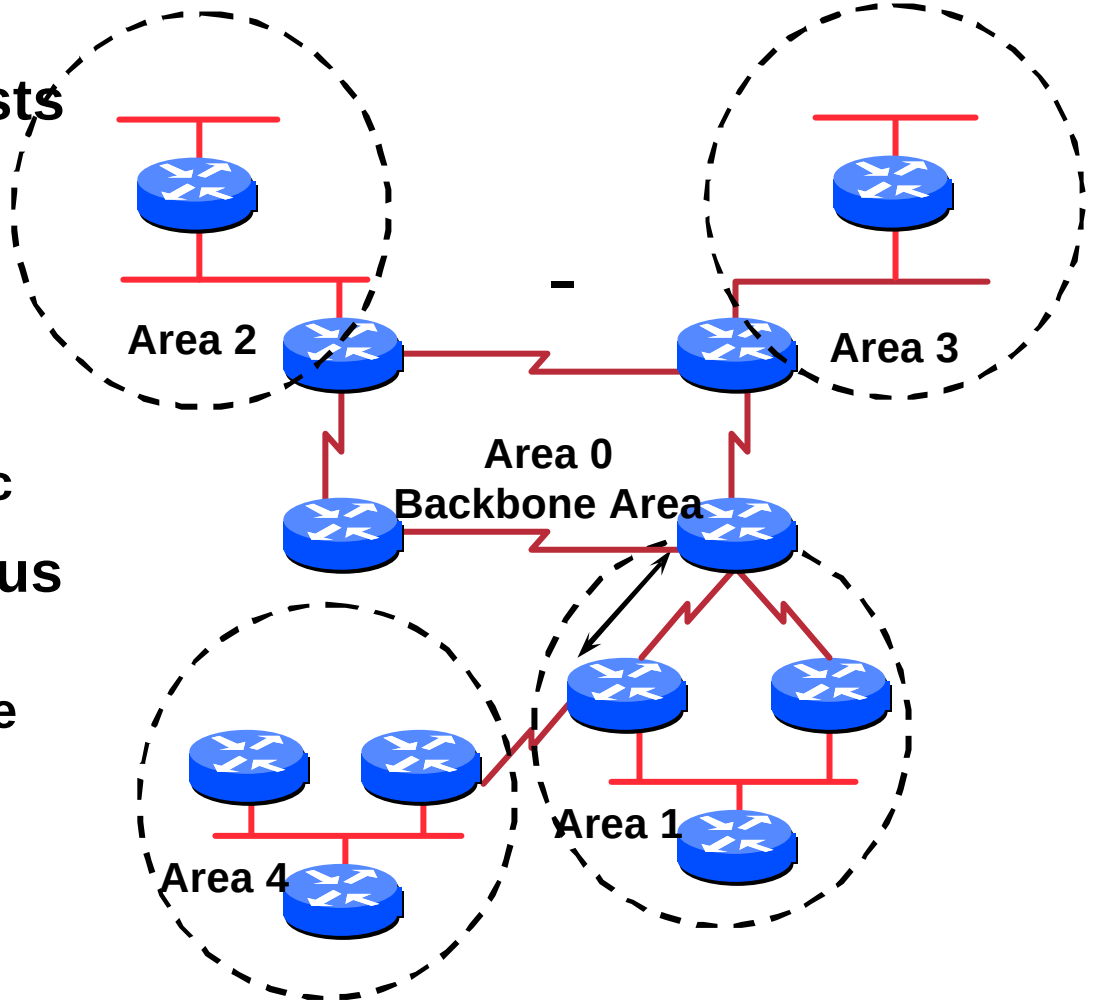
  All DR and BDR routers must accept packets sent to AllDRouters (224.0.0.6)

- **Hello packets sent to AllSPFRouters (Unicast on point-to-point and virtual links)**

© 2003, Cisco Systems, Inc. All rights reserved.

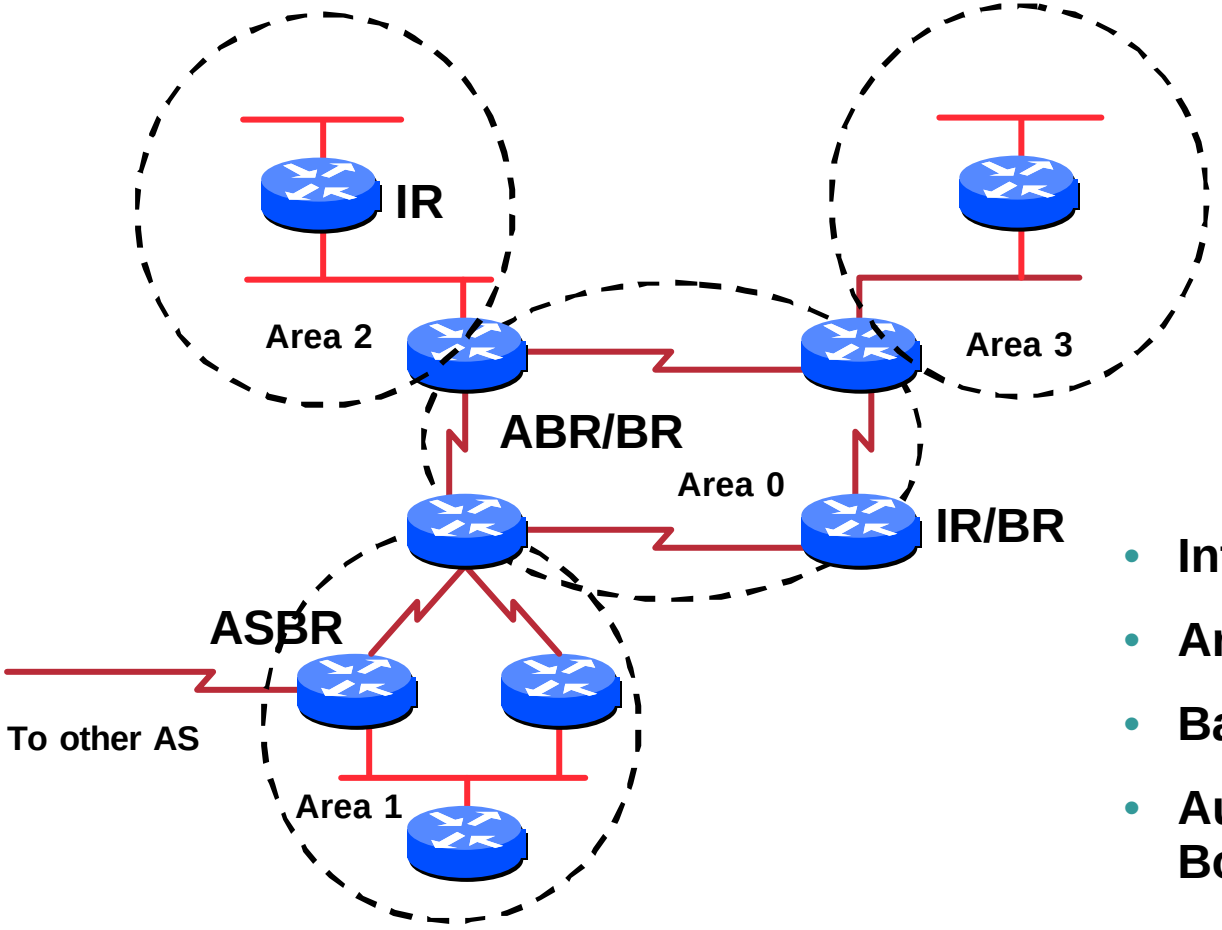
OSPF Areas

- 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



© 2003, Cisco Systems, Inc. All rights reserved.

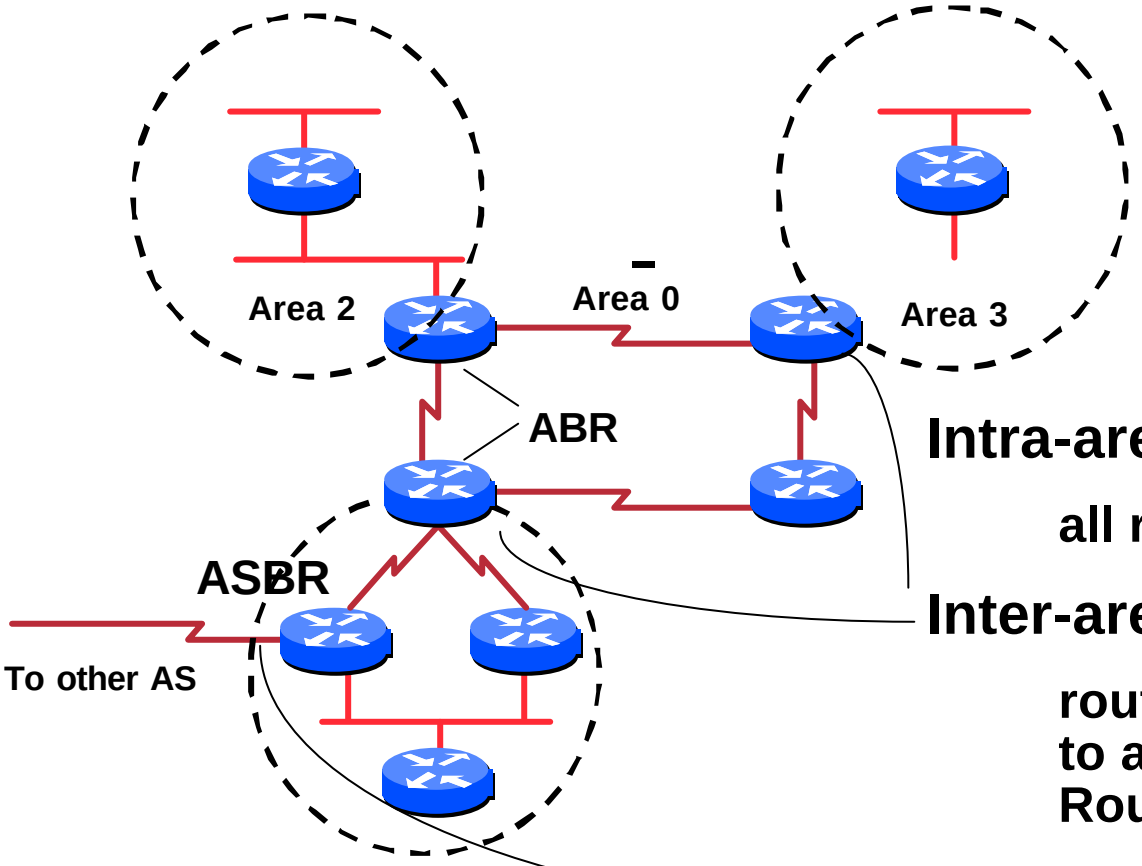
Classification of Routers



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

© 2003, Cisco Systems, Inc. All rights reserved.

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

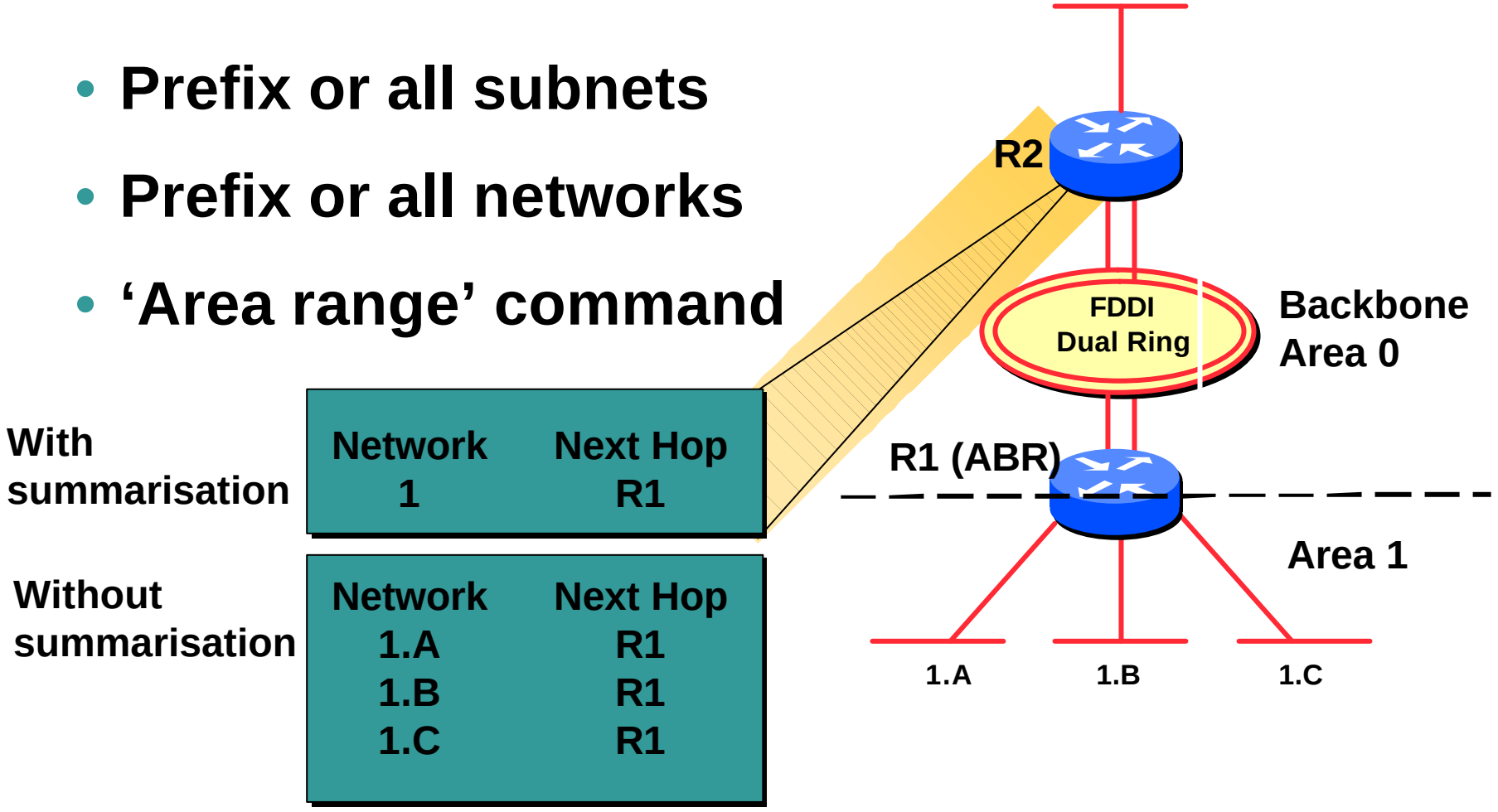
External Route

routes imported into OSPF from other protocol or static routes

© 2003, Cisco Systems, Inc. All rights reserved.

Inter-Area Route Summarisation

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



With summarisation

Network	Next Hop
1	R1

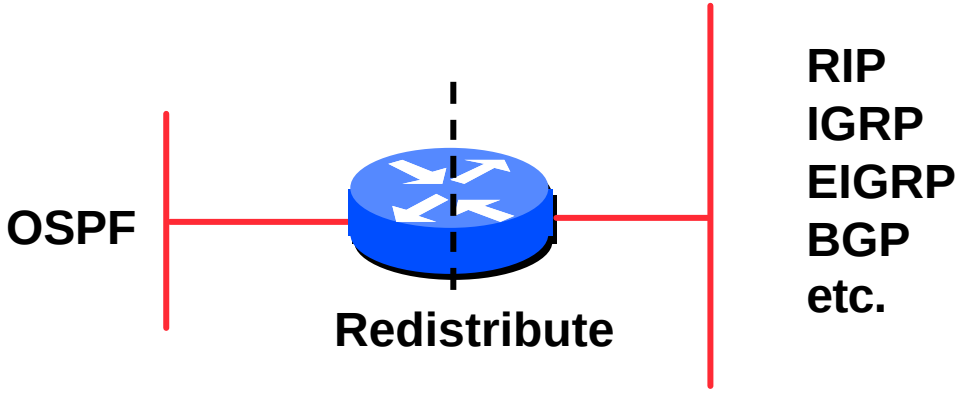
Without summarisation

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

© 2003, Cisco Systems, Inc. All rights reserved.

External Routes

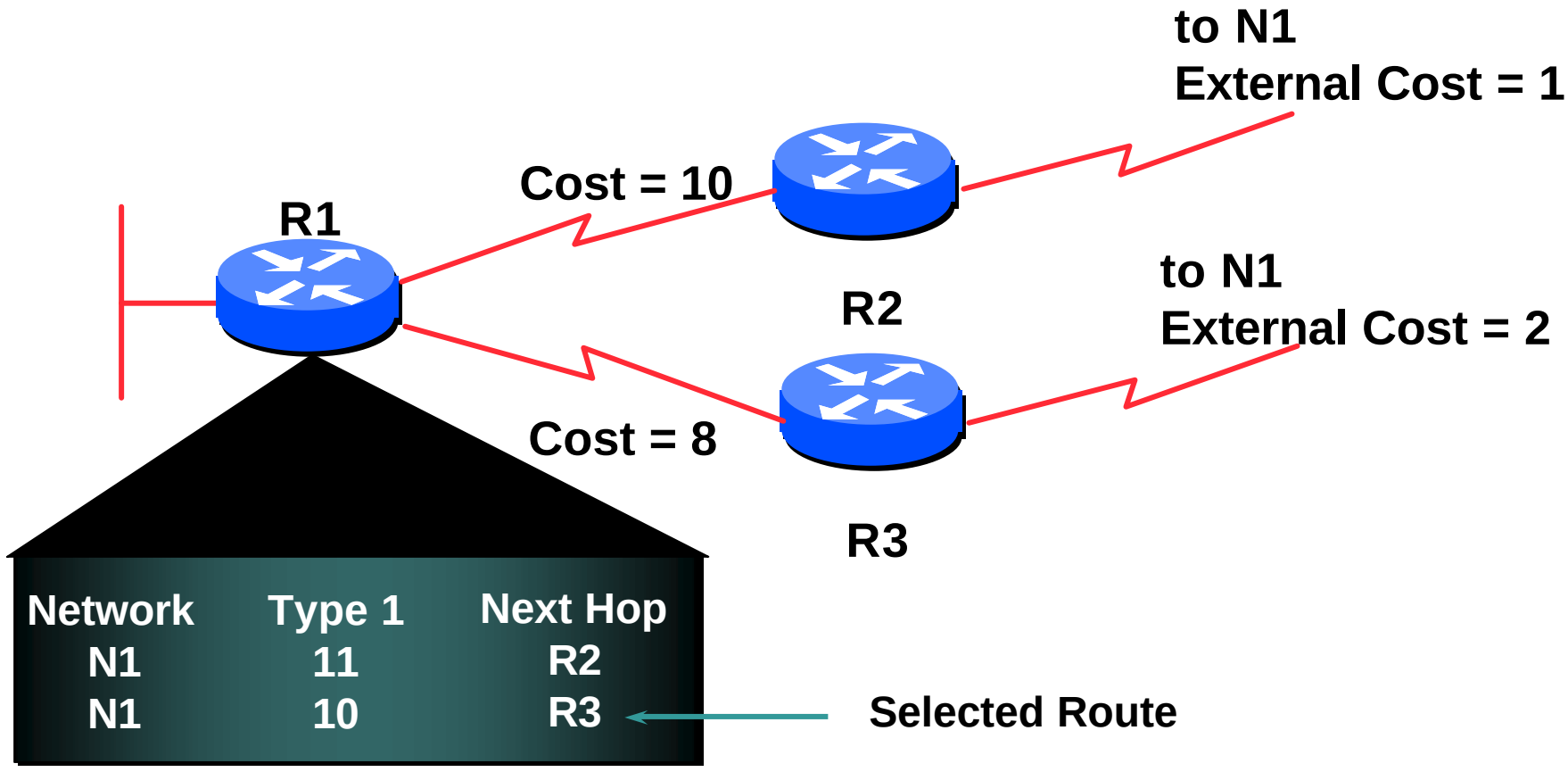
- **Redistributed into OSPF**
- **Flooded unaltered throughout the AS**
- **OSPF supports two types of external metrics**
  - **Type 1 external metrics**
  - **Type 2 external metrics (Default)**



© 2003, Cisco Systems, Inc. All rights reserved.

External Routes

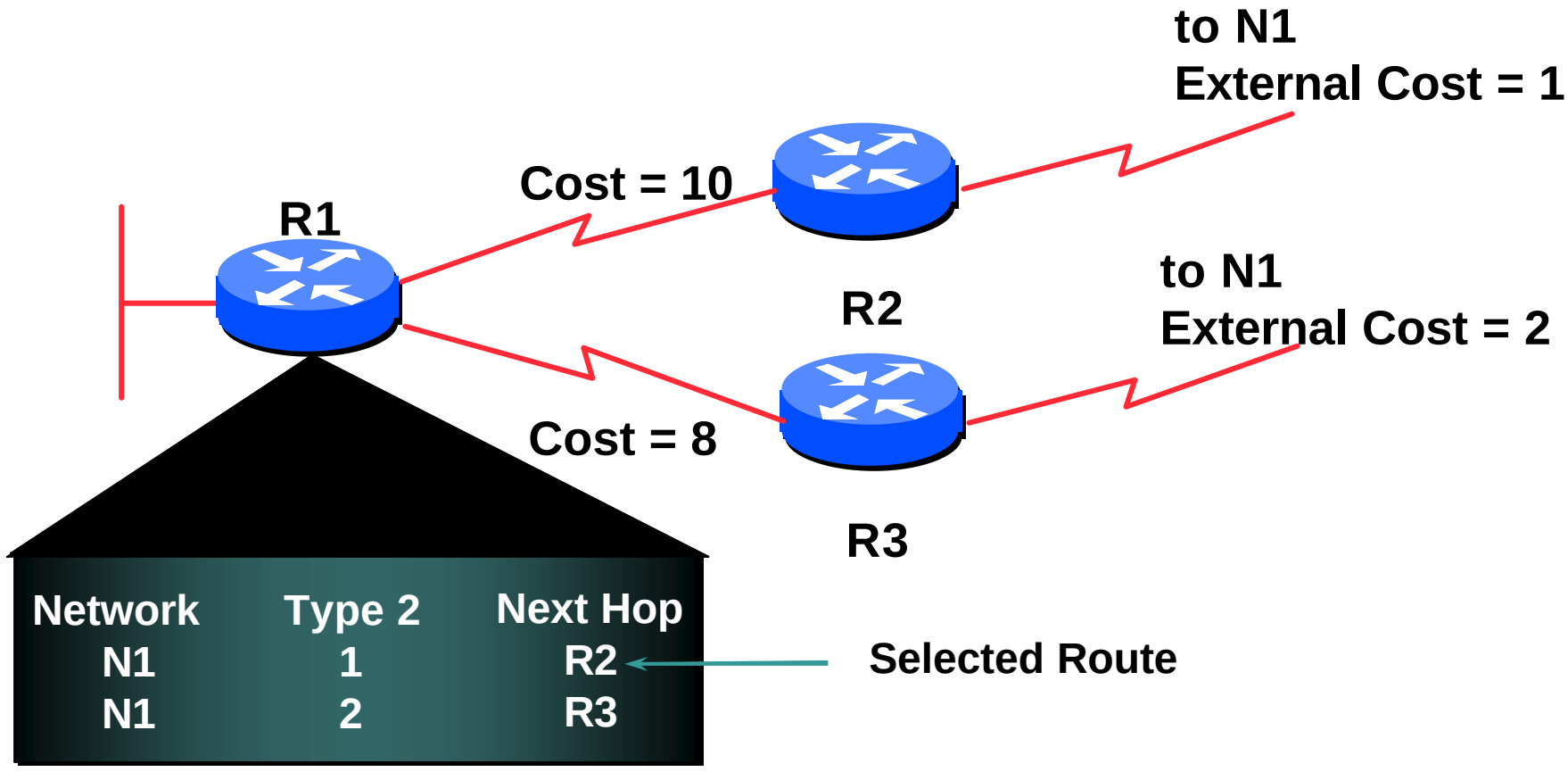
- **Type 1 external metric: metrics are added to the summarised internal link cost**



© 2003, Cisco Systems, Inc. All rights reserved.

External Routes

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



© 2003, Cisco Systems, Inc. All rights reserved.

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

© 2003, Cisco Systems, Inc. All rights reserved.

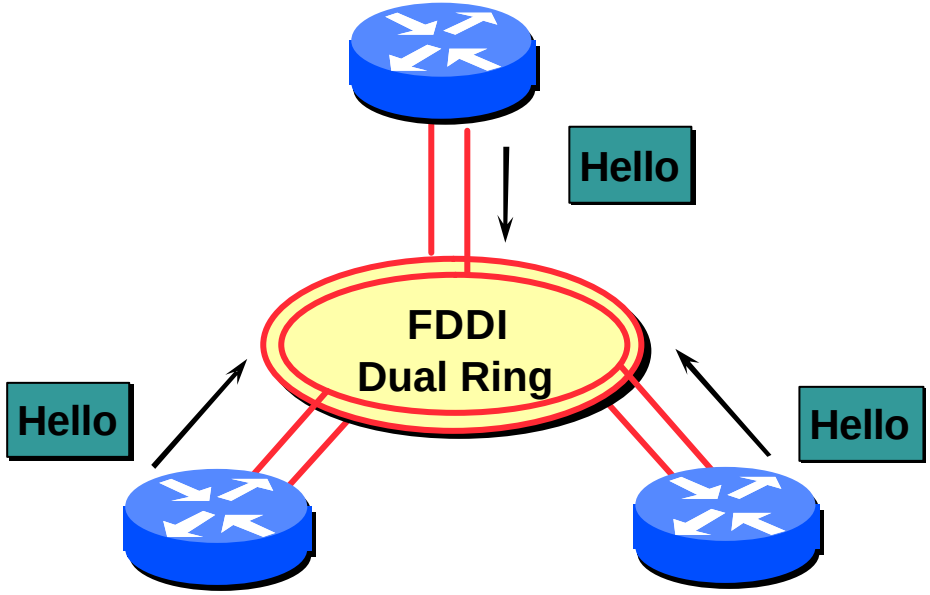
Protocol Functionality

- **Bringing up adjacencies**
- **LSA types**
- **Area classification**

© 2003, Cisco Systems, Inc. All rights reserved.

The Hello Protocol

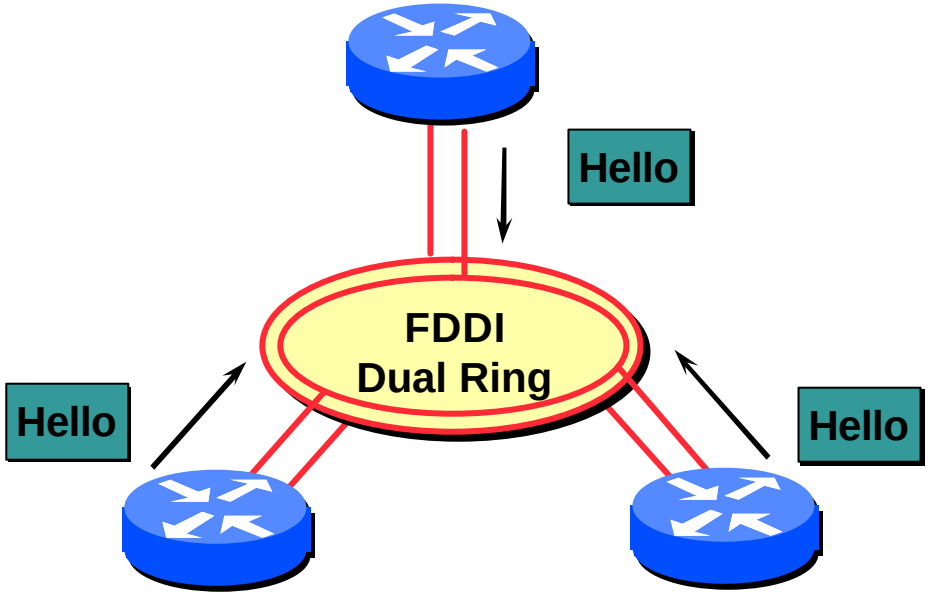
- **Responsible for establishing and maintaining neighbour relationships**
- **Elects designated router on multi-access networks**



© 2003, Cisco Systems, Inc. All rights reserved.

The Hello Packet

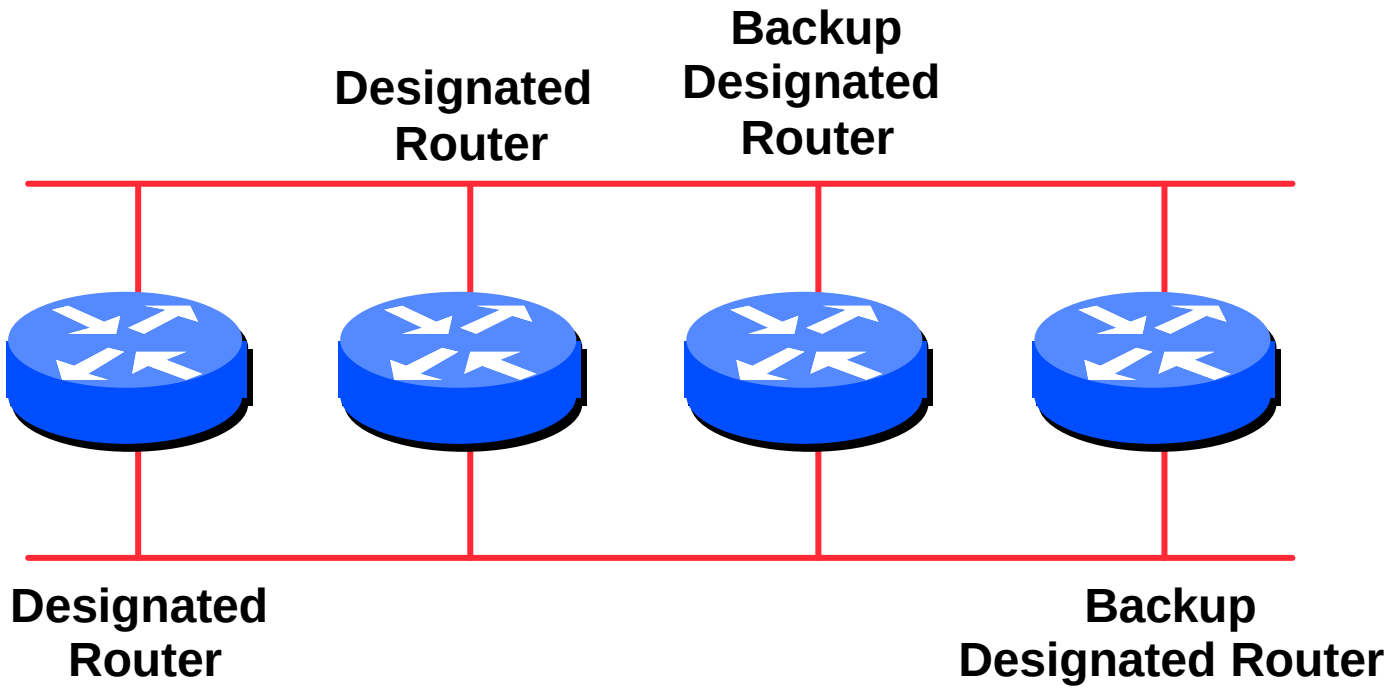
- Router priority
- Hello interval
- Router dead interval
- Network mask
- Options: T-bit, E-bit
- List of neighbours



© 2003, Cisco Systems, Inc. All rights reserved.

Designated Router

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

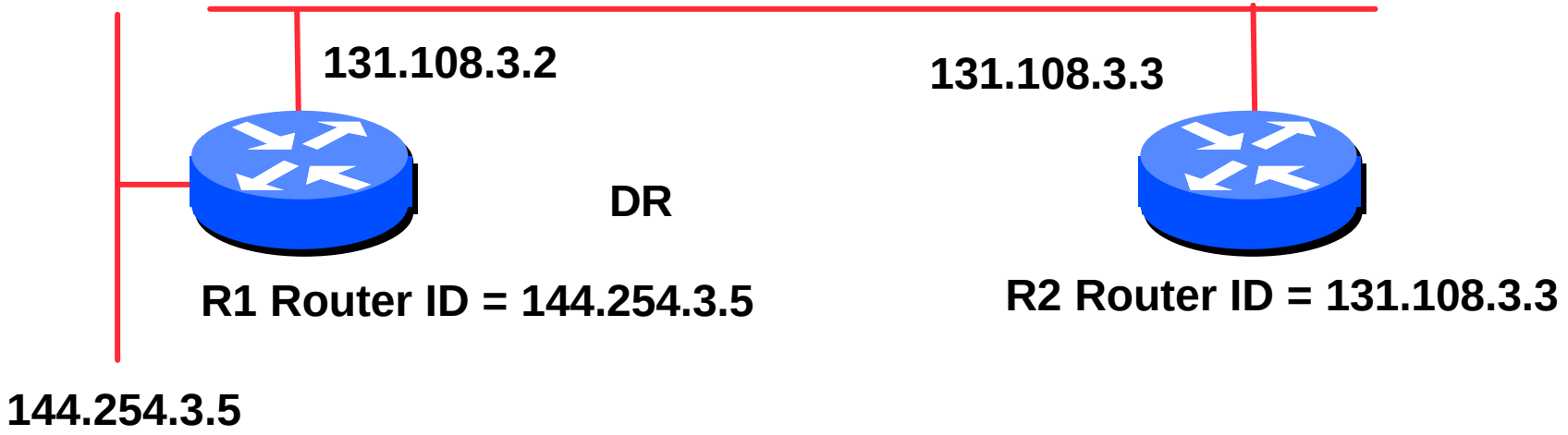


© 2003, Cisco Systems, Inc. All rights reserved.

Designated Router by Priority

- Configured priority (per interface)
- Else determined by highest router ID

  Router ID is the loopback interface address, if configured, otherwise the highest IP address



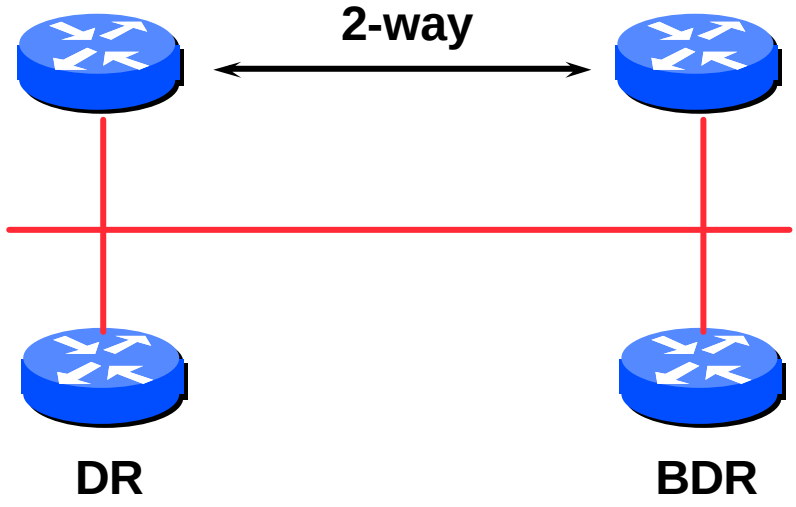
© 2003, Cisco Systems, Inc. All rights reserved.

Neighbouring States

- **2-way**

  Router sees itself in other Hello packets

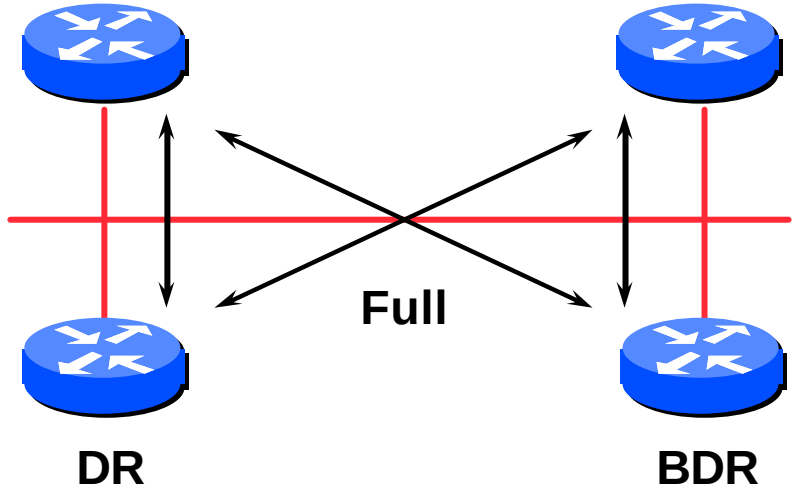
  DR selected from neighbours in state 2-way or greater



© 2003, Cisco Systems, Inc. All rights reserved.

Neighbouring States

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



© 2003, Cisco Systems, Inc. All rights reserved.

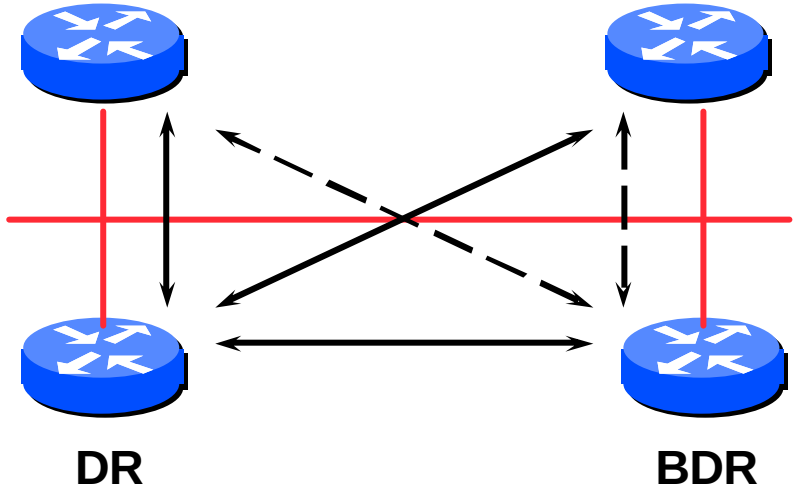
When to Become Adjacent

Cisco.com

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

© 2003, Cisco Systems, Inc. All rights reserved.

LSAs Propagate Along Adjacencies



- **LSAs acknowledged along adjacencies**

© 2003, Cisco Systems, Inc. All rights reserved.

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

© 2003, Cisco Systems, Inc. All rights reserved.

Different Types of LSAs

- **Five distinct type of LSAs**
  - **Type 1 : Router LSA**
  - **Type 2 : Network LSA**
  - **Type 3 and 4: Summary LSA**
  - **Type 5 and 7: External LSA**

© 2003, Cisco Systems, Inc. All rights reserved.

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

© 2003, Cisco Systems, Inc. All rights reserved.

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

© 2003, Cisco Systems, Inc. All rights reserved.

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 intra-area routes are advertised into the backbone
- Type 4 is the information about the ASBR

© 2003, Cisco Systems, Inc. All rights reserved.

External LSA (Type 5)

- Defines routes to destination external to the AS
- Default route is also sent as external
- Two types of external LSA:

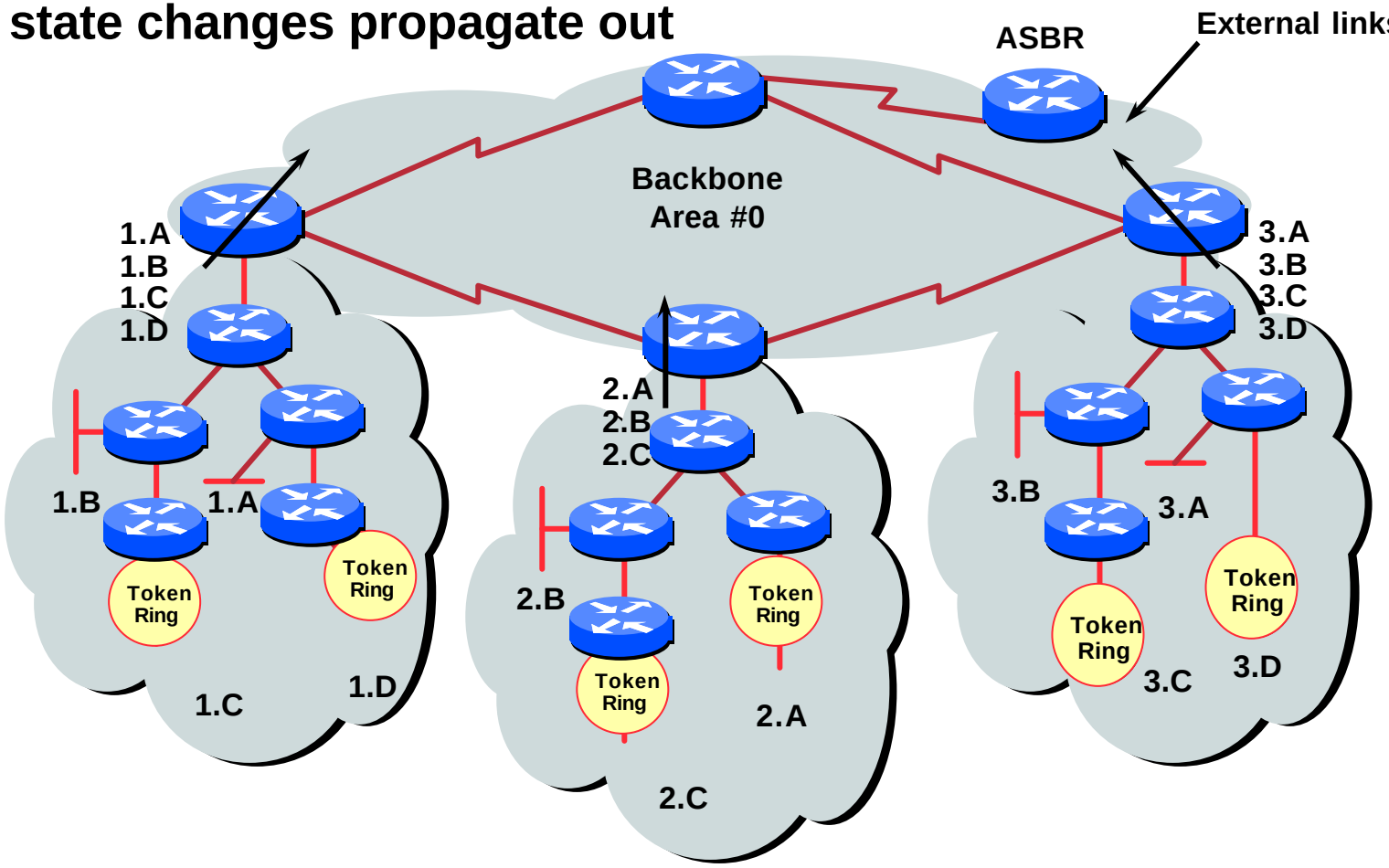
  E1: Consider the total cost up to the external destination

  E2: Considers only the cost of the outgoing interface to the external destination

© 2003, Cisco Systems, Inc. All rights reserved.

Not Summarised: Specific Links

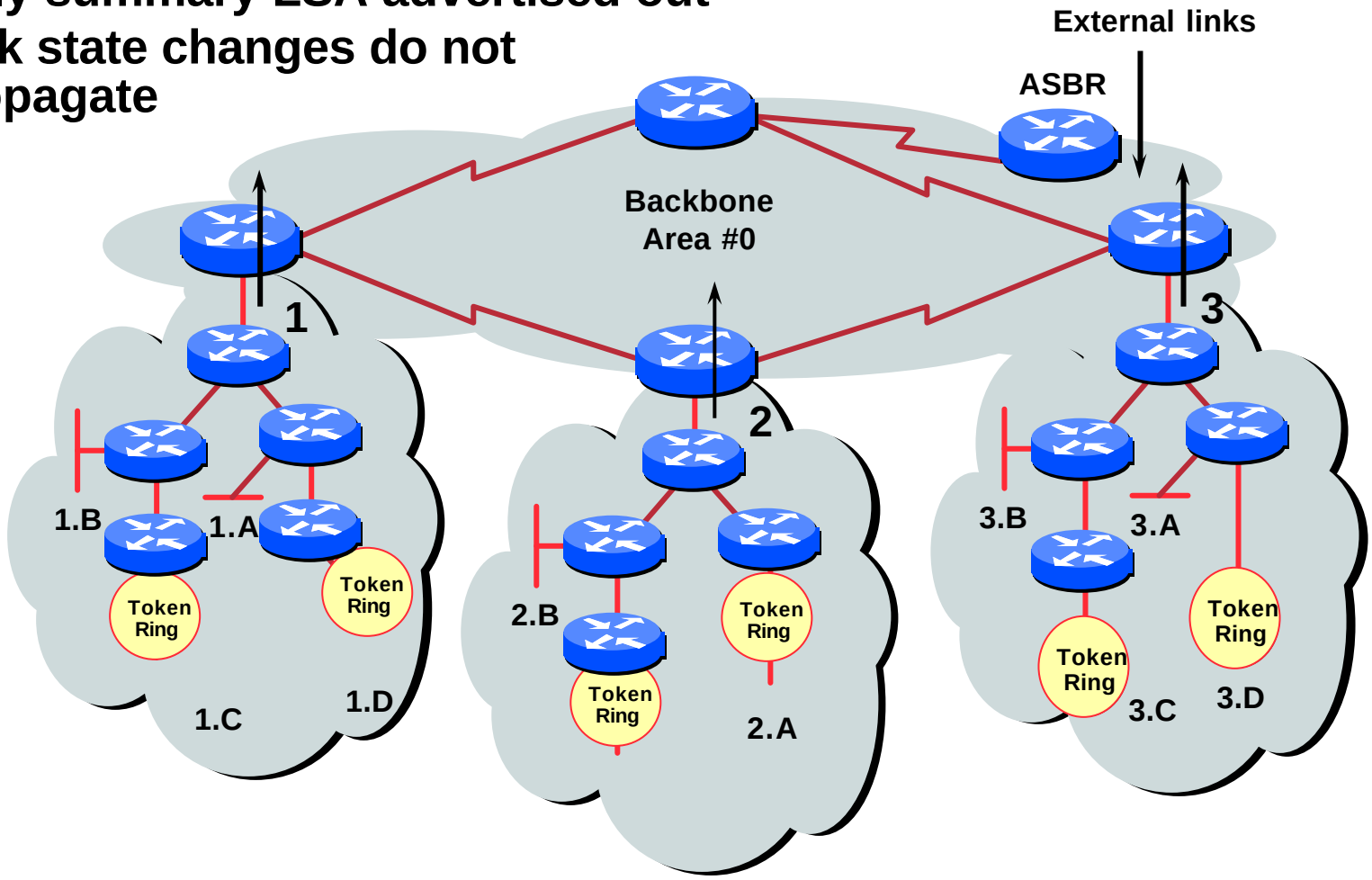
- Specific link LSA advertised out
- Link state changes propagate out



© 2003, Cisco Systems, Inc. All rights reserved.

Summarised: Summary Links

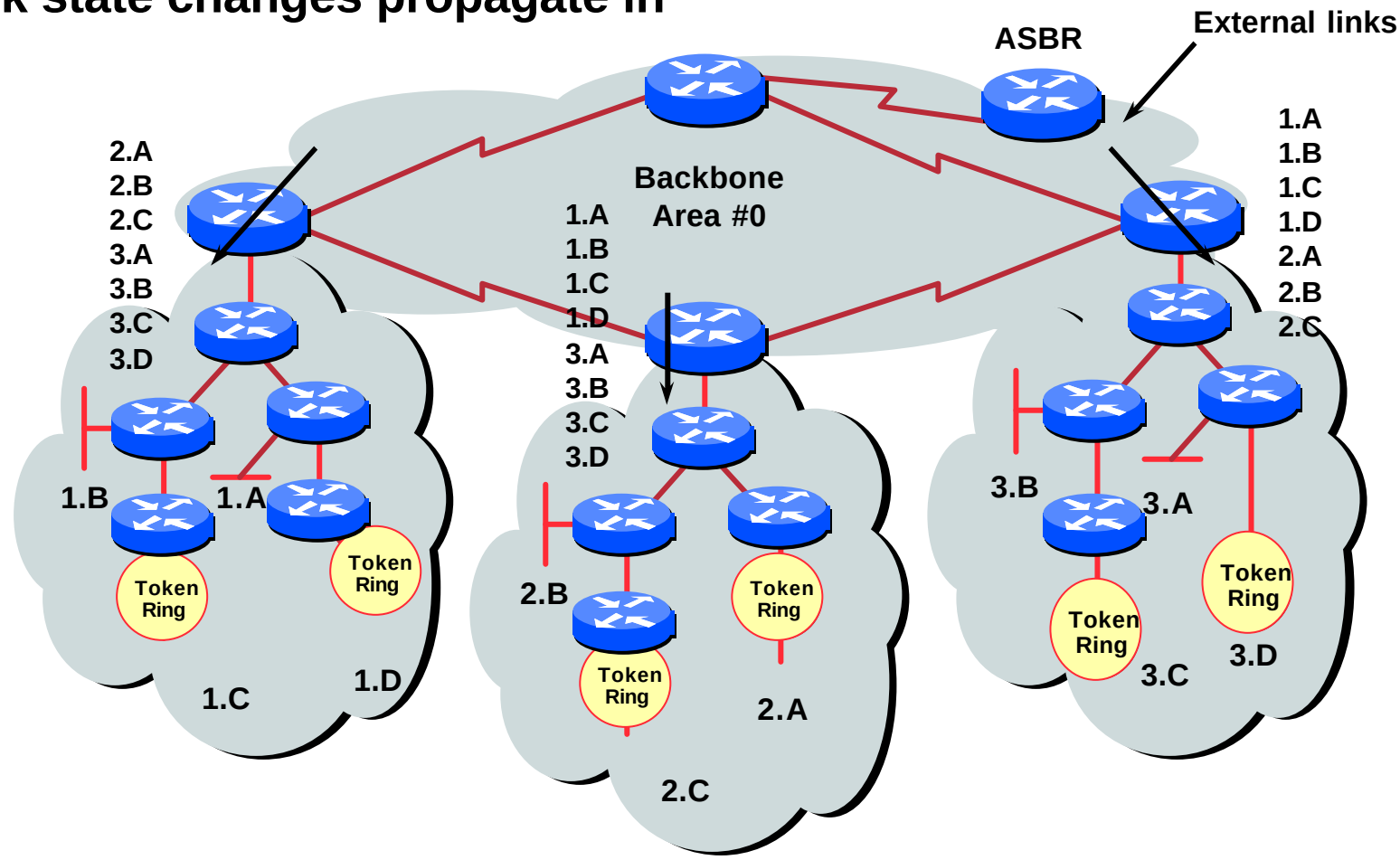
- Only summary LSA advertised out
- Link state changes do not propagate



© 2003, Cisco Systems, Inc. All rights reserved.

Not Summarised: Specific Links

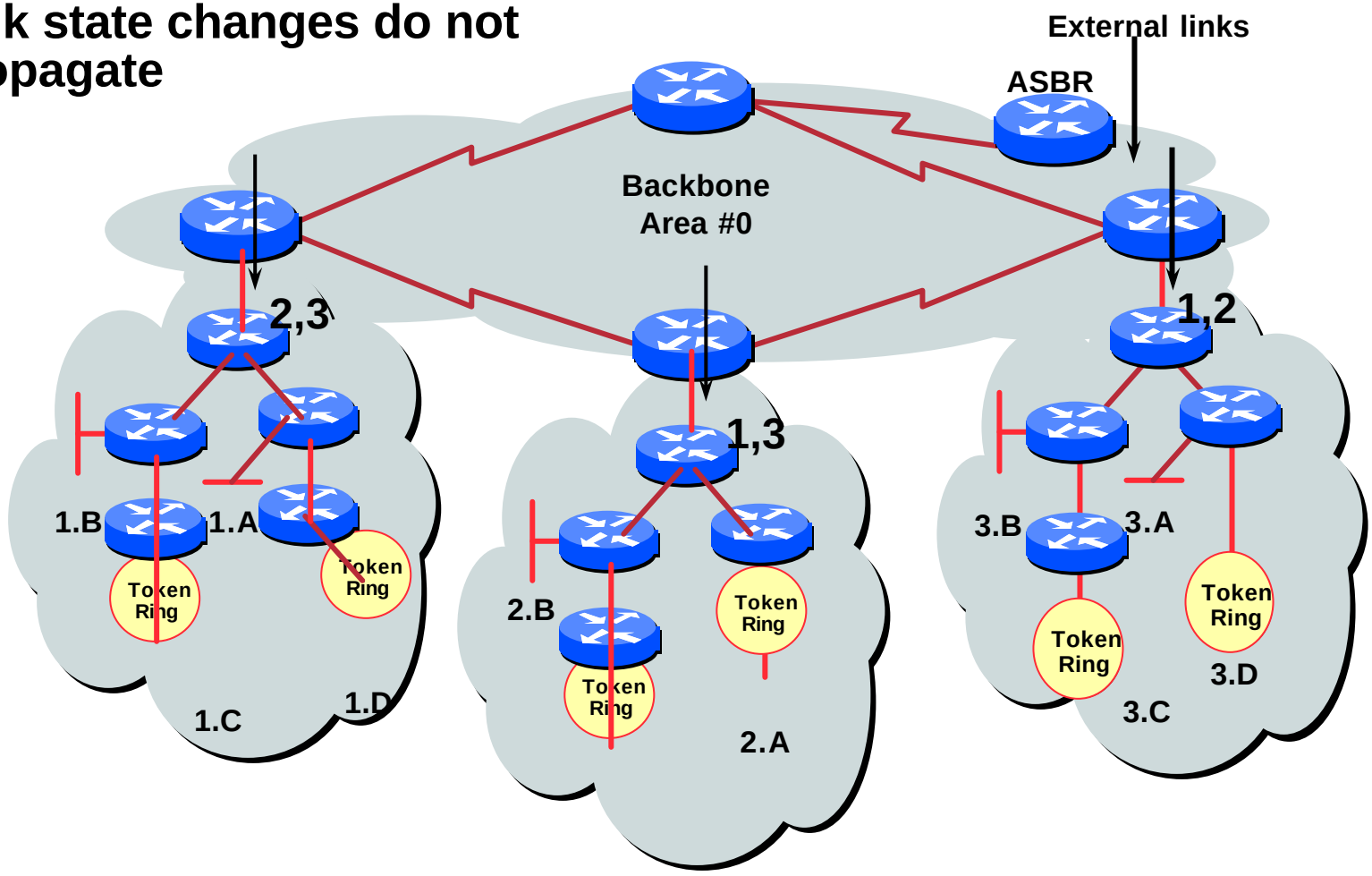
- Specific link LSA advertised in
- Link state changes propagate in



© 2003, Cisco Systems, Inc. All rights reserved.

Summarised: Summary Links

- Only summary LSA advertised in
- Link state changes do not propagate

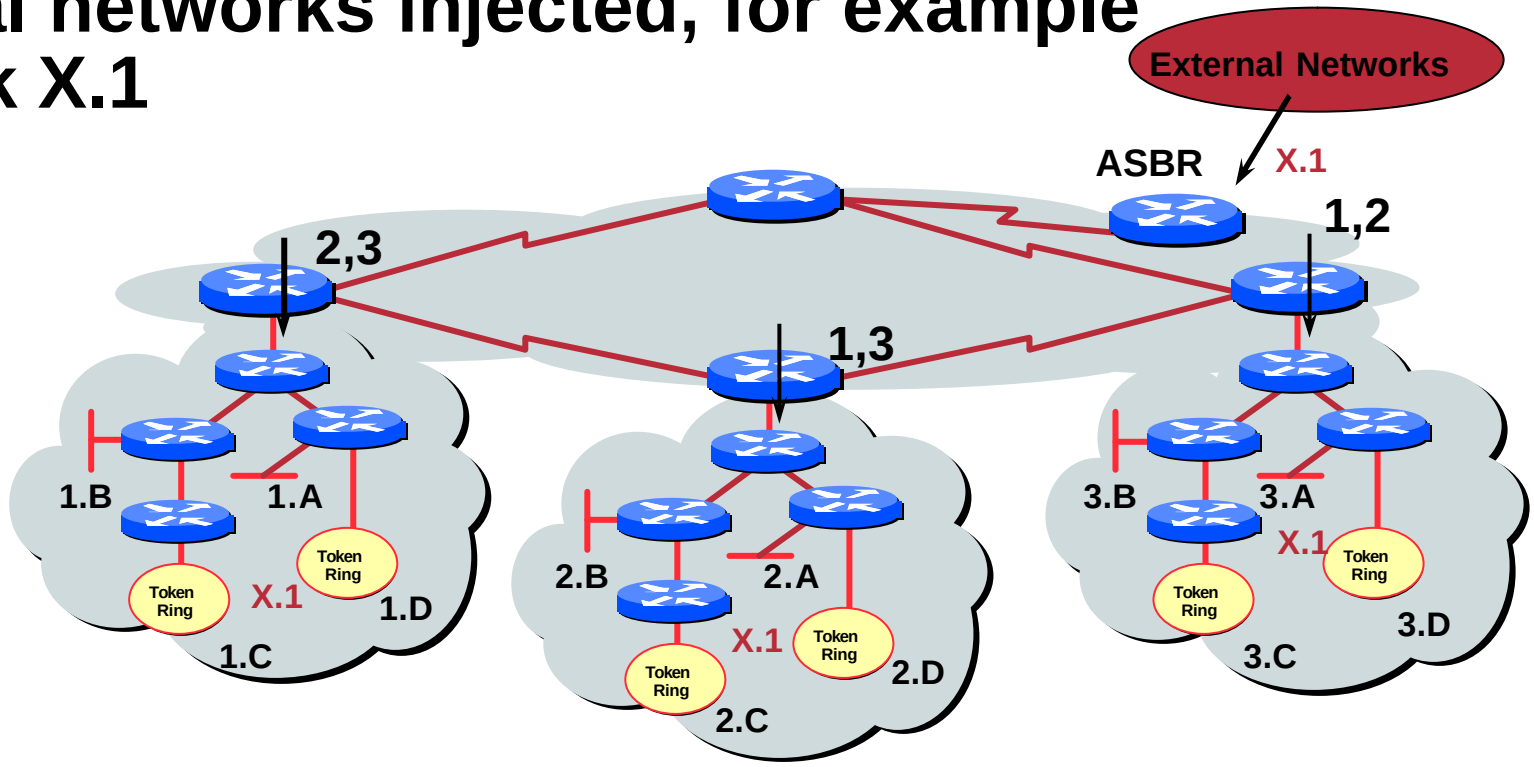


© 2003, Cisco Systems, Inc. All rights reserved.

Regular Area (Not a Stub)

From area 1's viewpoint

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

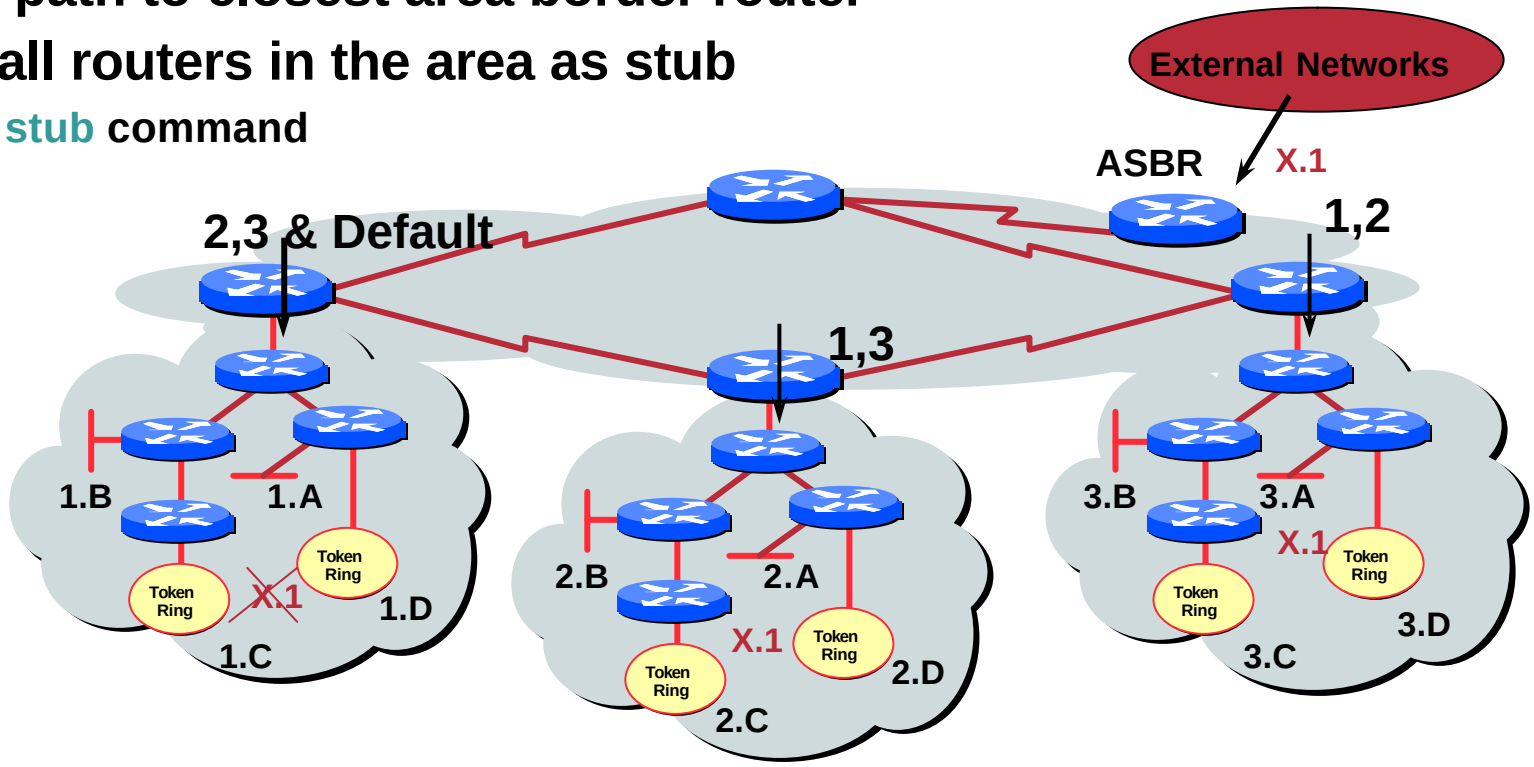


© 2003, Cisco Systems, Inc. All rights reserved.

Normal Stub Area

From area 1's viewpoint

- **Summary networks from other areas injected**
- **Default network injected into the area - represents external links**
- **Default path to closest area border router**
- **Define all routers in the area as stub**
  - **area x stub command**

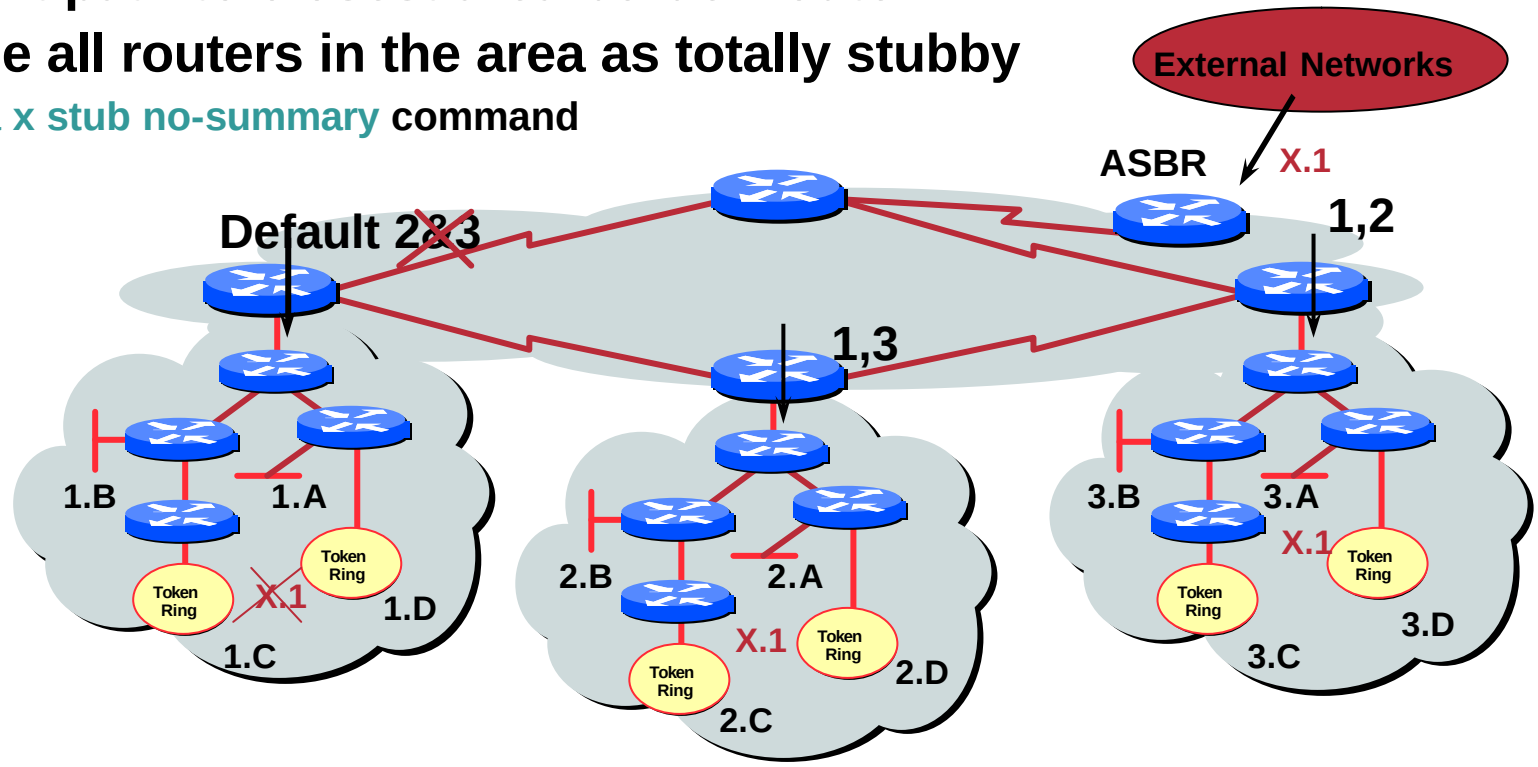


© 2003, Cisco Systems, Inc. All rights reserved.

Totally Stubby Area

From area 1's viewpoint

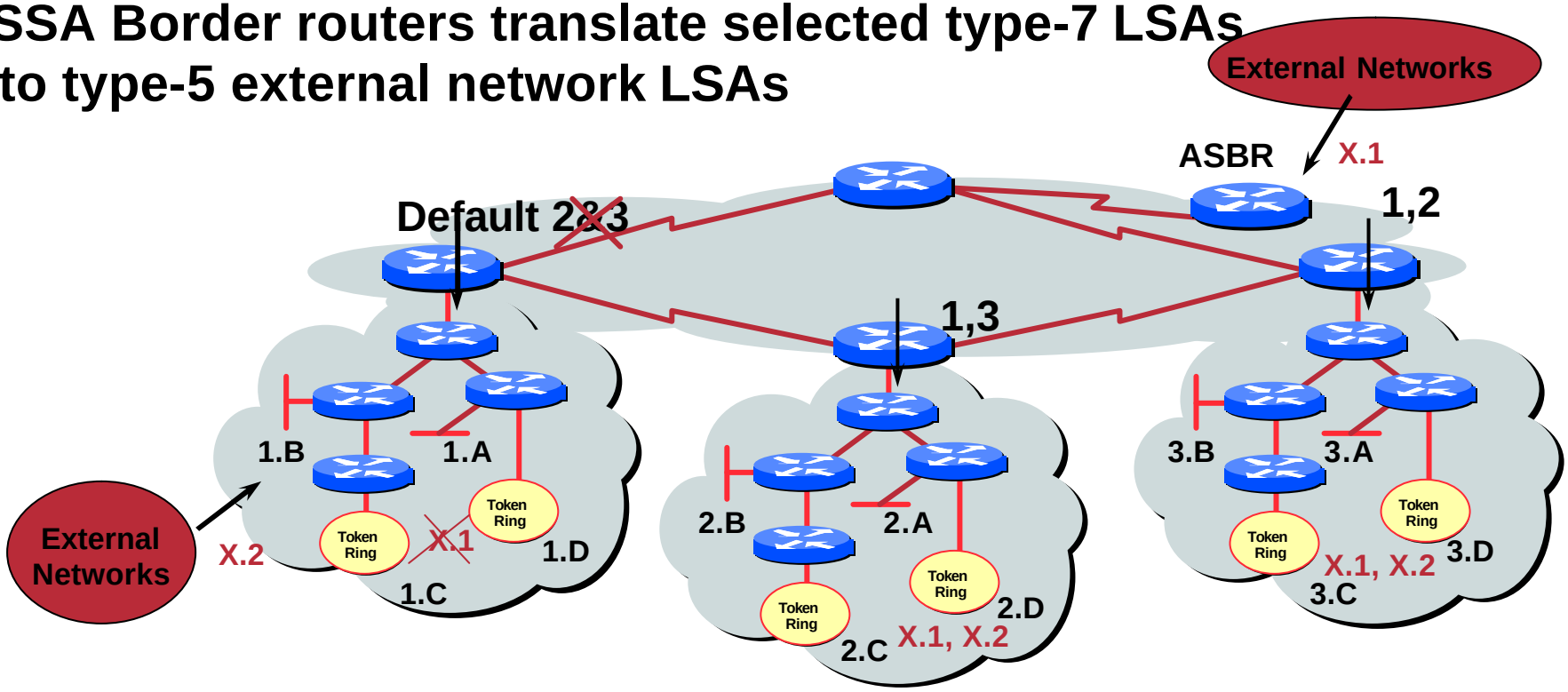
- **Only a default network is injected into the area**
  - **Represents external networks and all inter-area routes**
- **Default path to closest area border router**
- **Define all routers in the area as totally stubby**
  - **area x stub no-summary command**



© 2003, Cisco Systems, Inc. All rights reserved.

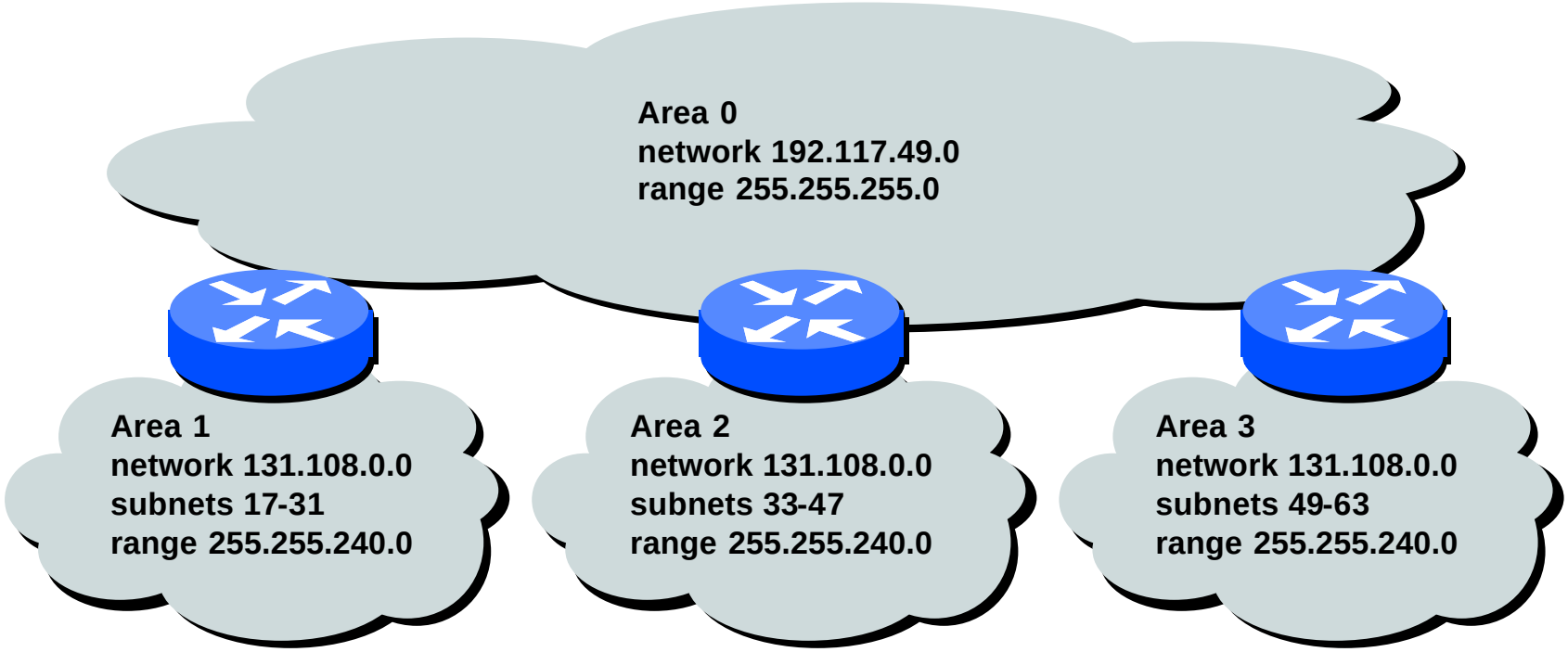
Not-So-Stubby Area

- Capable of importing external 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



© 2003, Cisco Systems, Inc. All rights reserved.

Addressing



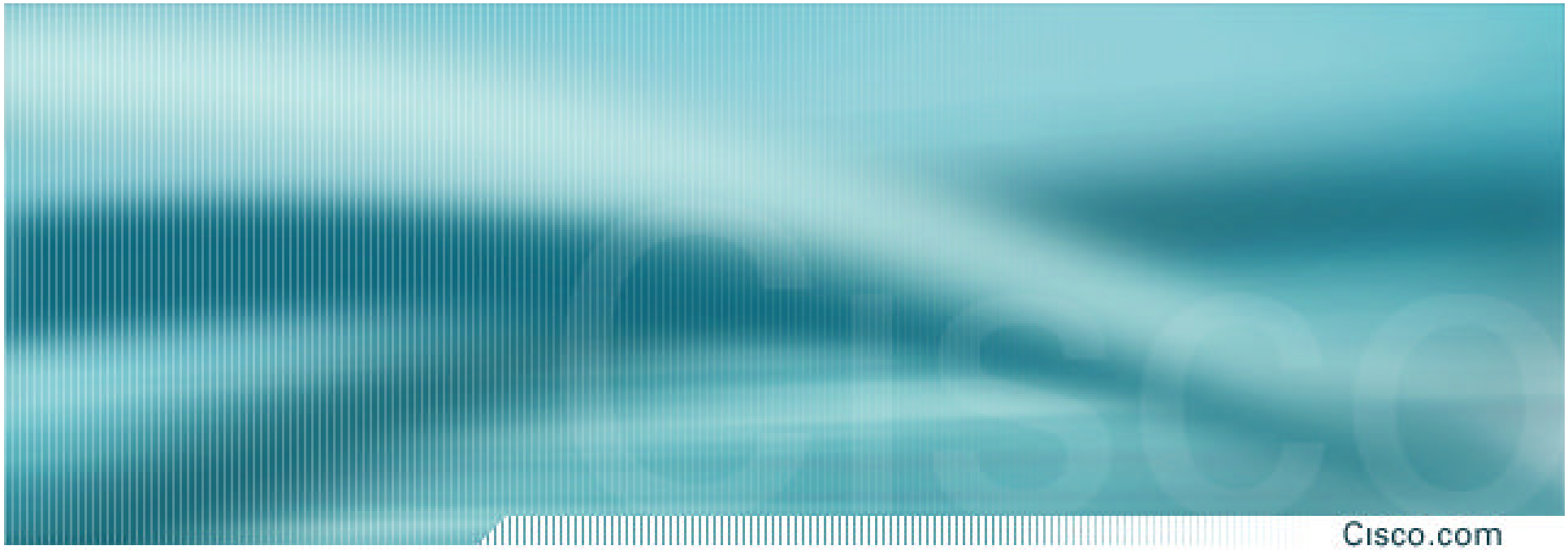
Assign contiguous ranges of subnets per area to facilitate summarisation

© 2003, Cisco Systems, Inc. All rights reserved.

Summary

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

© 2003, Cisco Systems, Inc. All rights reserved.

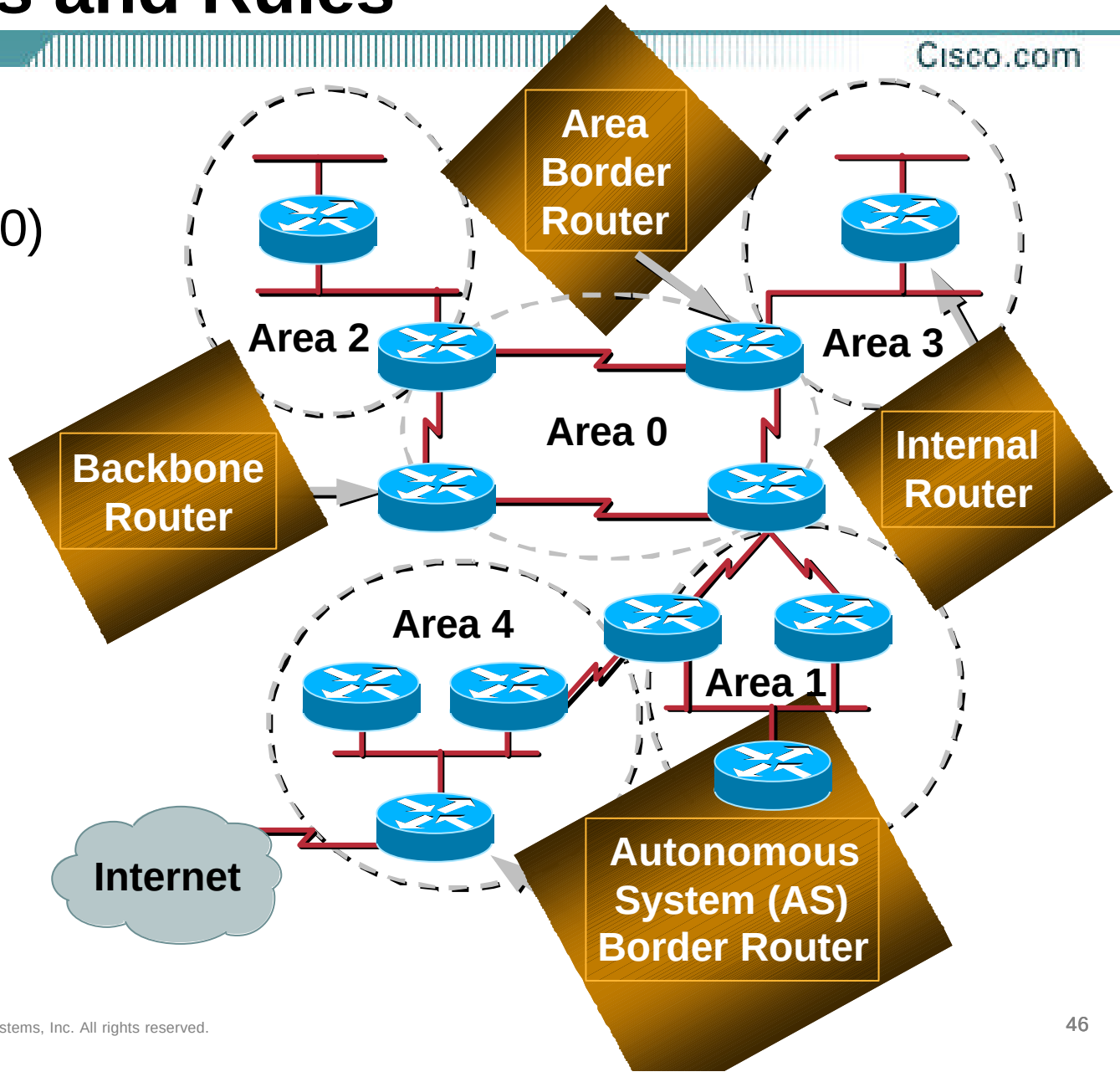


OSPF Design In Service Provider Networks

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Areas and Rules

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



© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Design

- **OSPF design and Addressing go together.**
  - **Objective is to keep the Link State Data Base *lean.***
  - **Create address hierarchy to match topology**
  - **Separate Blocks for infrastructure, customer interfaces, customers, etc.**

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Design

- **Examine physical topology**
  - **Is it meshed or hub-and-spoke?**
- **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**

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Design

- One SPF per area, flooding done per area
  - Watch out for overloading ABRs
- Different types of areas do different flooding
  - Normal areas
  - Stub areas
  - Totally stubby (stub no-summary)
  - Not so stubby areas (NSSA)

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Design

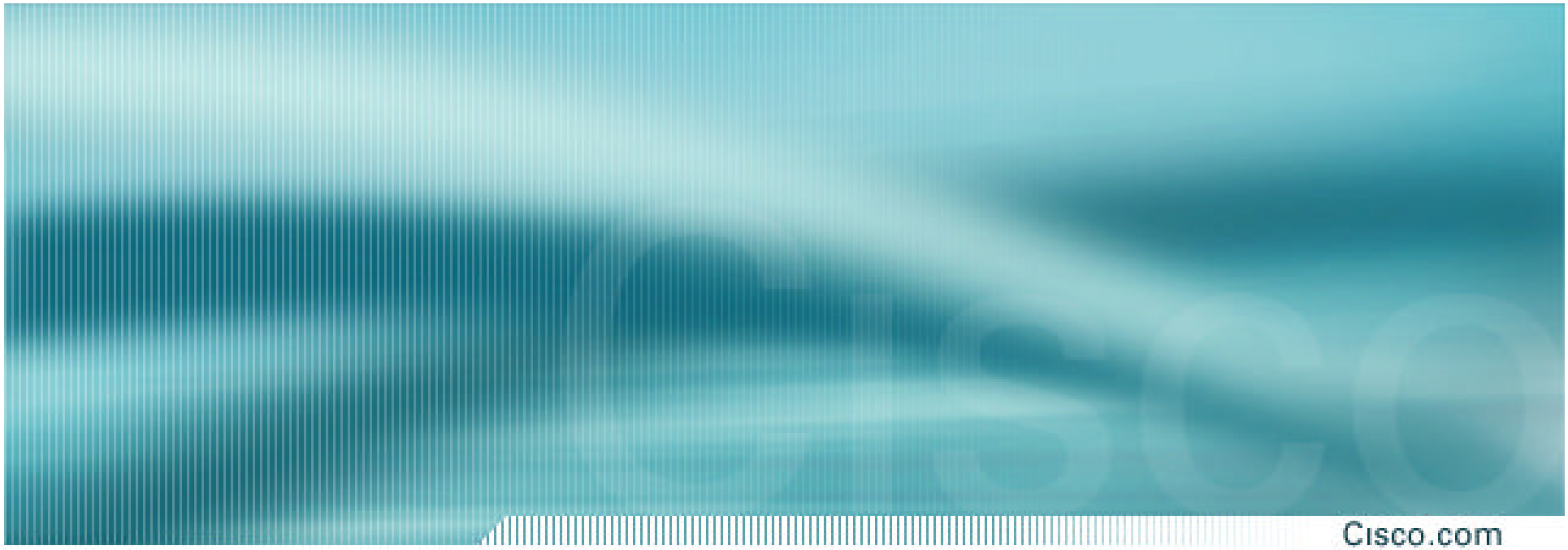
- **Redundancy**
  - **Dual Links out of each area – using metrics (cost) for traffic engineering**
  - **Too much redundancy…**
    - **Dual links to backbone in stub areas must be the same – other wise sub-optimal routing will result**
    - **Too Much Redundancy in the backbone area without good summarization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

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF for ISPs

- **OSPF features which should be considered:**
  - **OSPF logging neighbour changes**
  - **OSPF reference cost**
  - **OSPF Router ID Command**
  - **OSPF Process Clear/Restart**

© 2003, Cisco Systems, Inc. All rights reserved.

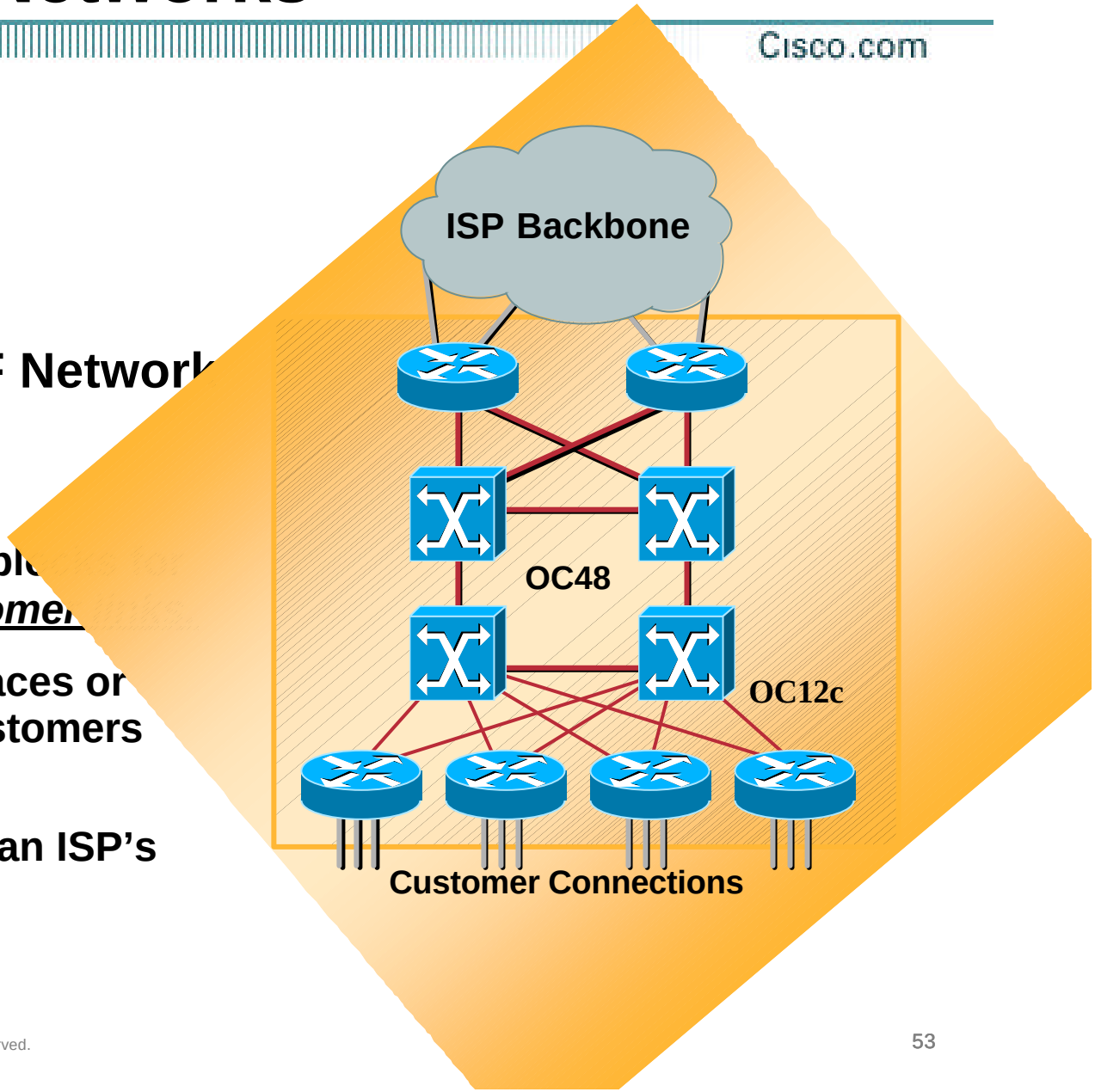


OSPF BCP
Adding Networks

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF – Adding Networks

- **BCP – Individual OSPF Network statement for each infrastructure link.**
  - **Have separate IP address bl*** ***infrastructure*** **and** ***customer***
  - **Use *IP Unnumbered* Interfaces or BGP to carry /30s to customers**
  - **OSPF should only carry infrastructure routes in an ISP's network.**



© 2003, Cisco Systems, Inc. All rights reserved.

OSPF – Adding Networks (Method One)

- **redistribute connected subnets**

  Works for all connected interfaces on the router but sends networks as external type-2s – which are not summarized

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

- **Not recommended**

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF – Adding Networks

- **Specific network statements**

  Every interface needs a OSPF network statement. Interface that should not be broadcasting OSPF Hello packets needs *passive-interface.*

```
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
```


© 2003, Cisco Systems, Inc. All rights reserved.

OSPF – Adding Networks

- **Network statements – wildcard mask**

  Every interface covered by wildcard mask used in OSPF network statement. Interfaces that should not be broadcasting OSPF Hello packets need *passive-interface* or *default passive-interface.*

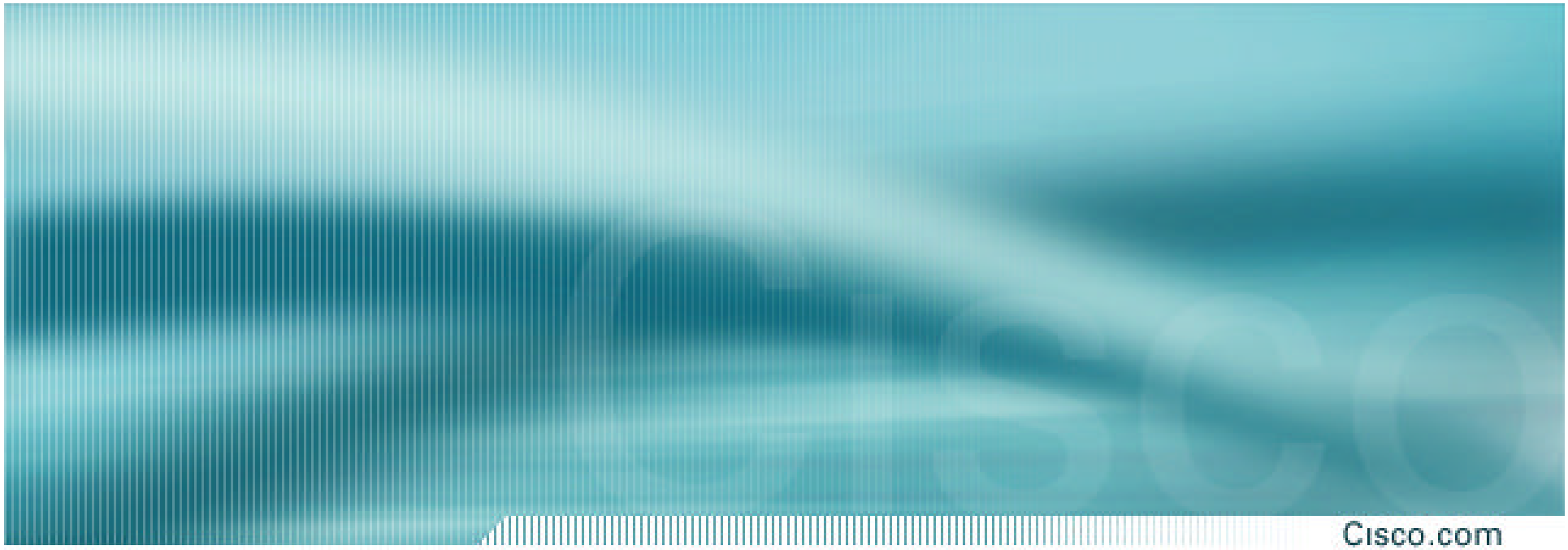
```
router ospf 100
 network 192.168.1.0 0.0.0.255 area 51
 default passive-interface default
 no passive interface POS 4/0
```


© 2003, Cisco Systems, Inc. All rights reserved.

OSPF – Adding Networks

- **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**

© 2003, Cisco Systems, Inc. All rights reserved.



OSPF – New and Useful Features

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Logging Neighbour Changes

- The router will generate a log message whenever an OSPF neighbour changes state
- Syntax:

  [no] ospf log-adjacency-changes

- Example of a typical log message:

  %OSPF-5-ADJCHG: Process 1, Nbr 223.127.255.223 on Ethernet0 from LOADING to FULL, Loading Done

© 2003, Cisco Systems, Inc. All rights reserved.

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

© 2003, Cisco Systems, Inc. All rights reserved.

State Changes (Continued)

- To reset OSPF-related statistics, use the **clear ip ospf counters** EXEC command. At this point **neighbor** is the only available option; it will reset neighbour state transition counters per interface or neighbour id

  clear ip ospf counters [neighbor [<type number>] [neighbor-id]]

© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Cost: Reference Bandwidth

- **Bandwidth used in Metric calculation**

  Cost = 10^8/BW

  Not useful for BW > 100 Mbps

- **Syntax:**

  ospf auto-cost reference-bandwidth <reference-bandwidth>

- **Default reference bandwidth still 100 Mbps for backward compatibility**

© 2003, Cisco Systems, Inc. All rights reserved.

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!
- New sub command to manually set the OSPF Router ID:

```
router-id <ip address>
```


© 2003, Cisco Systems, Inc. All rights reserved.

OSPF Clear/Restart

- **clear ip ospf [pid] redistribution**

  This command can now clear redistribution based on OSPF routing process ID. If no pid is given, it assumes all OSPF processes.

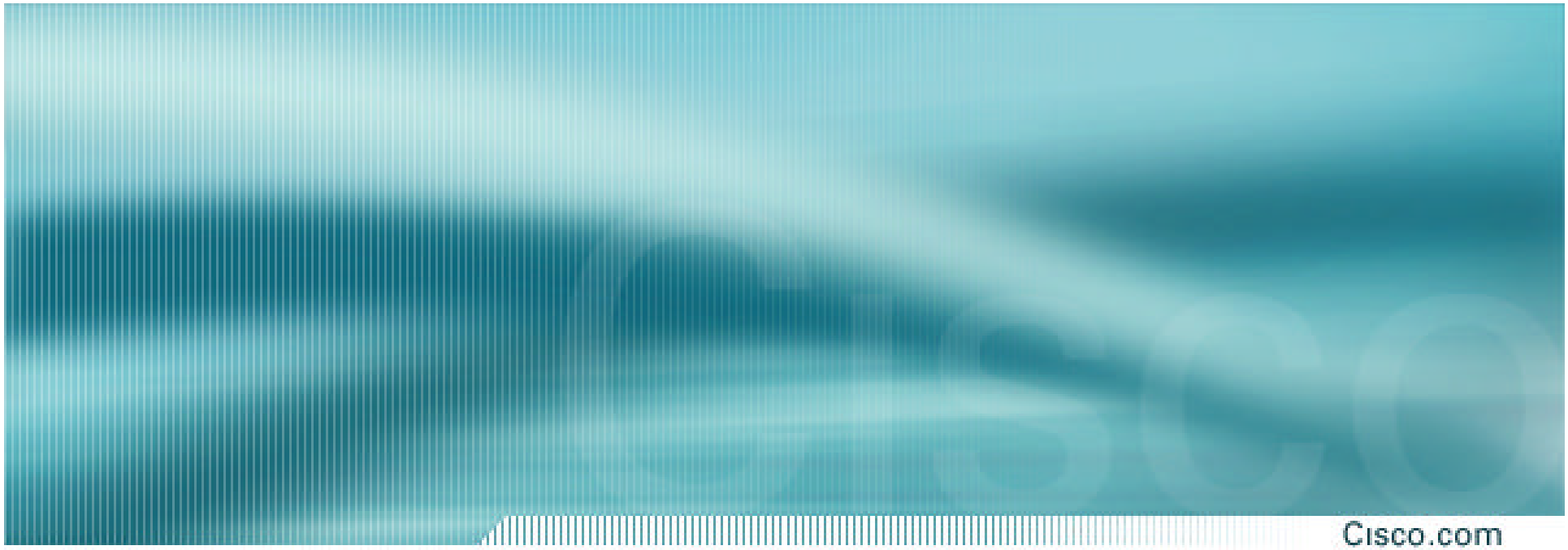
- **clear ip ospf [pid] counters**

  This command can now clear counters based on OSPF 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. Since this command can potentially cause a network churn, a user confirmation is required before performing any action.

© 2003, Cisco Systems, Inc. All rights reserved.



OSPF Command Summary

© 2003, Cisco Systems, Inc. All rights reserved.

Redistributing Routes into OSPF

ROUTER OSPF <pid#x>

REDISTRIBUTE {protocol} <as#y>

<metric>

<metric-type (1 or 2)

<tag>

<subnets>

© 2003, Cisco Systems, Inc. All rights reserved.

Router Sub-commands

Cisco.com

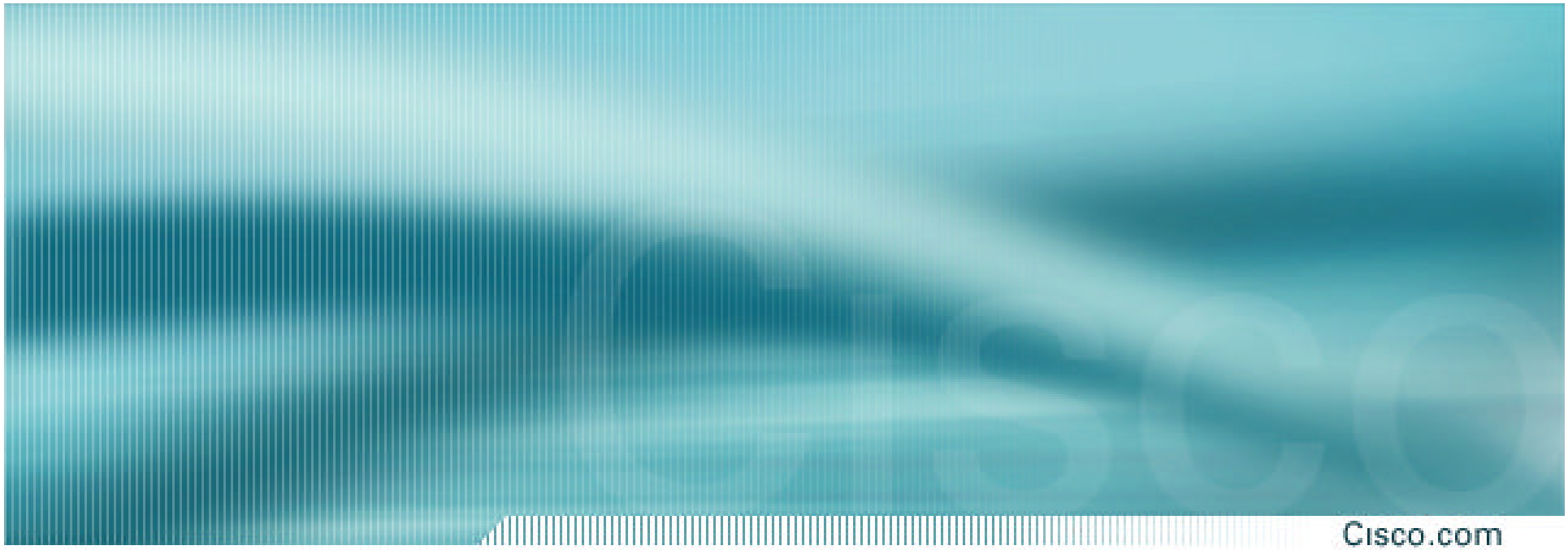
- NETWORK <n.n.n.n> <mask> AREA <area-id>
- AREA <area-id> STUB {no-summary}
- AREA <area-id> AUTHENTICATION
- AREA <area-id> DEFAULT_COST <cost>
- AREA <area-id> VIRTUAL-LINK <router-id>...
- AREA <area-id> RANGE <address mask>

© 2003, Cisco Systems, Inc. All rights reserved.

Interface Subcommands

- 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>

© 2003, Cisco Systems, Inc. All rights reserved.



Introduction to OSPF

ISP/IXP Workshops

© 2003, Cisco Systems, Inc. All rights reserved.