

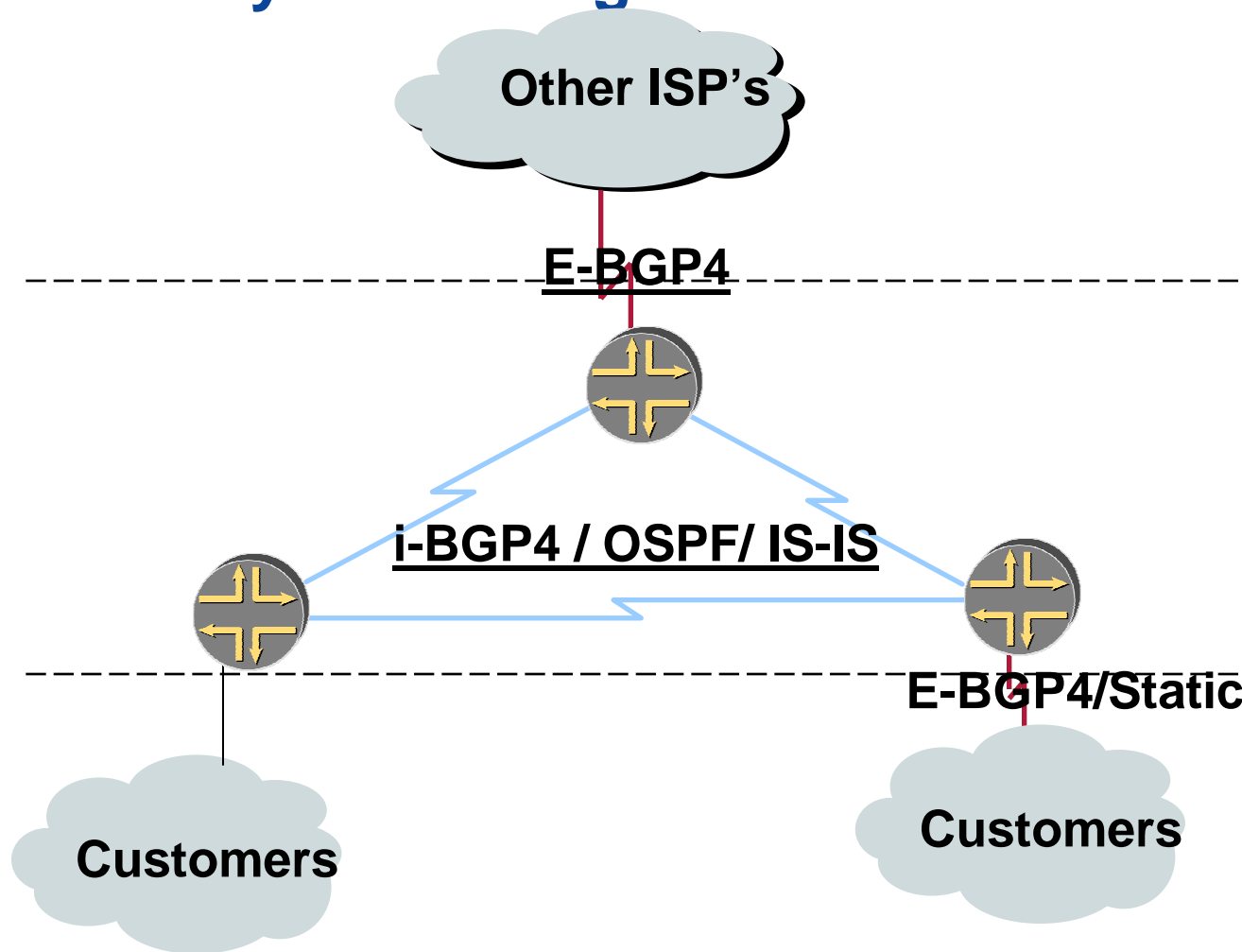


Introduction to OSPF

Module Objectives

- **After completing this module, you should be able to describe**
 - OSPF protocol basics
 - Each LSA type
 - Helpful CLI commands

Hierarchy of Routing Protocols within an AS



Interior vs. Exterior – Routing Protocols

■ Interior

- Automatic discovery
- Generally trust your neighbour routers
- Within same admin boundary
- Routes go to all IGP routers

■ Exterior

- Specifically configured peers
- Connecting with outside networks
- Set administrative boundaries
- Route filtering

Fundamental Link-state Concepts

- **Adjacency**
- **Information flooding**
- **Link-state database**
- **SPF calculation**

Open Shortest Path First (OSPF) Routing Protocol: Background

- **Runs directly over IP**
- **Each router maintains an identical database (within areas)**
- **Each router constructs a tree of shortest paths by running SPF algorithm on the database**
- **Tree provides route to each known destination**

OSPF Protocol Overview

- **OSPF is a link-state IGP that routes packets within a single AS**
- **OSPF floods LSAs to distribute link-state information**
- **Each router uses these LSAs to create a complete routing table for the network**
- **OSPF uses the SPF algorithm to calculate the best route**
- **OSPF is defined in**
 - RFC 2328, *OSPF Version 2*

OSPF Terminology

- **Areas**
 - Single AS can be divided into smaller groups called areas
- **ABRs**
 - Routers that belong to more than one area are called area border routers
- **Backbone area**
 - Backbone area (0.0.0.0) distributes routing information between areas
- **ASBRs**
 - Routers that exchange routing information with routers in other ASs are called AS border routers

OSPF Terminology

■ Stub areas

- Areas through or into which AS external advertisements are not flooded

■ Not-So-Stubby areas

- Not-so-stubby areas allow external routes to be flooded within the area

■ Transit areas

- Pass traffic from one adjacent area to the backbone
- Traffic does not originate in, nor is it destined for, the transit area

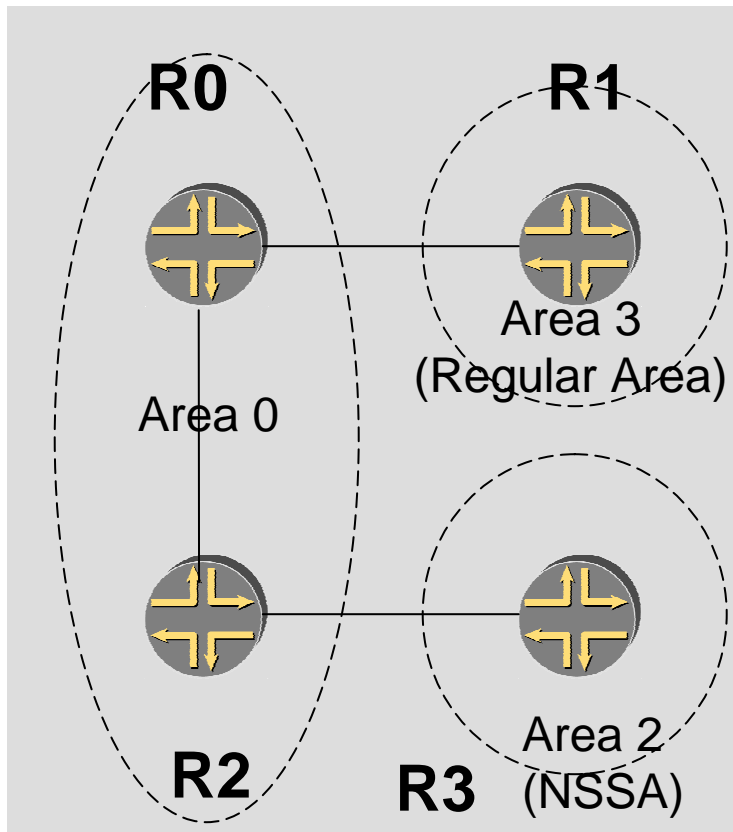
Media Support

■ OSPF

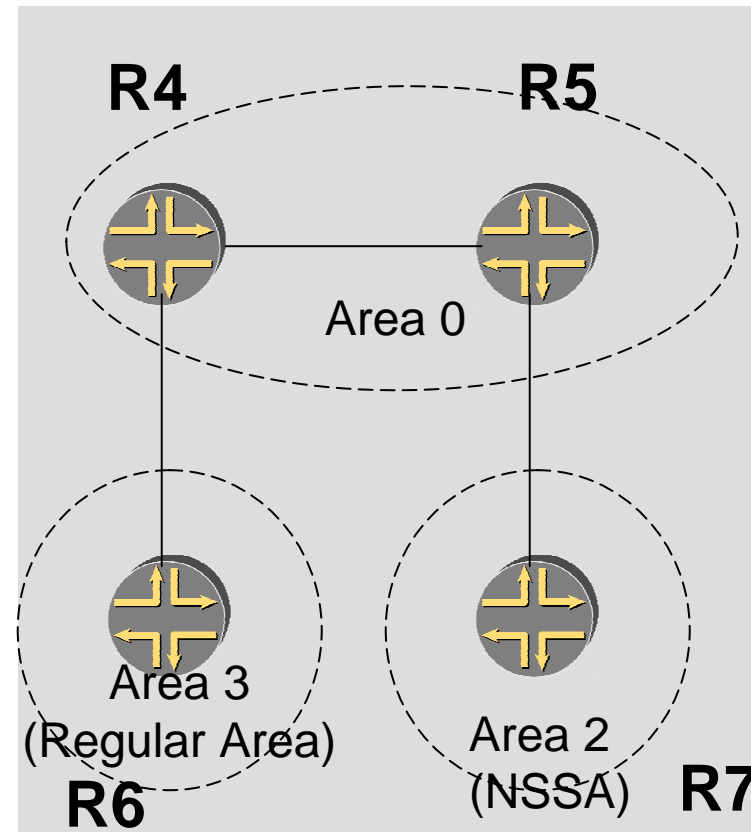
- Broadcast (LANs)
- Point-to-point
- Point-to-multipoint
- NBMA

OSPF Topology

AS 100



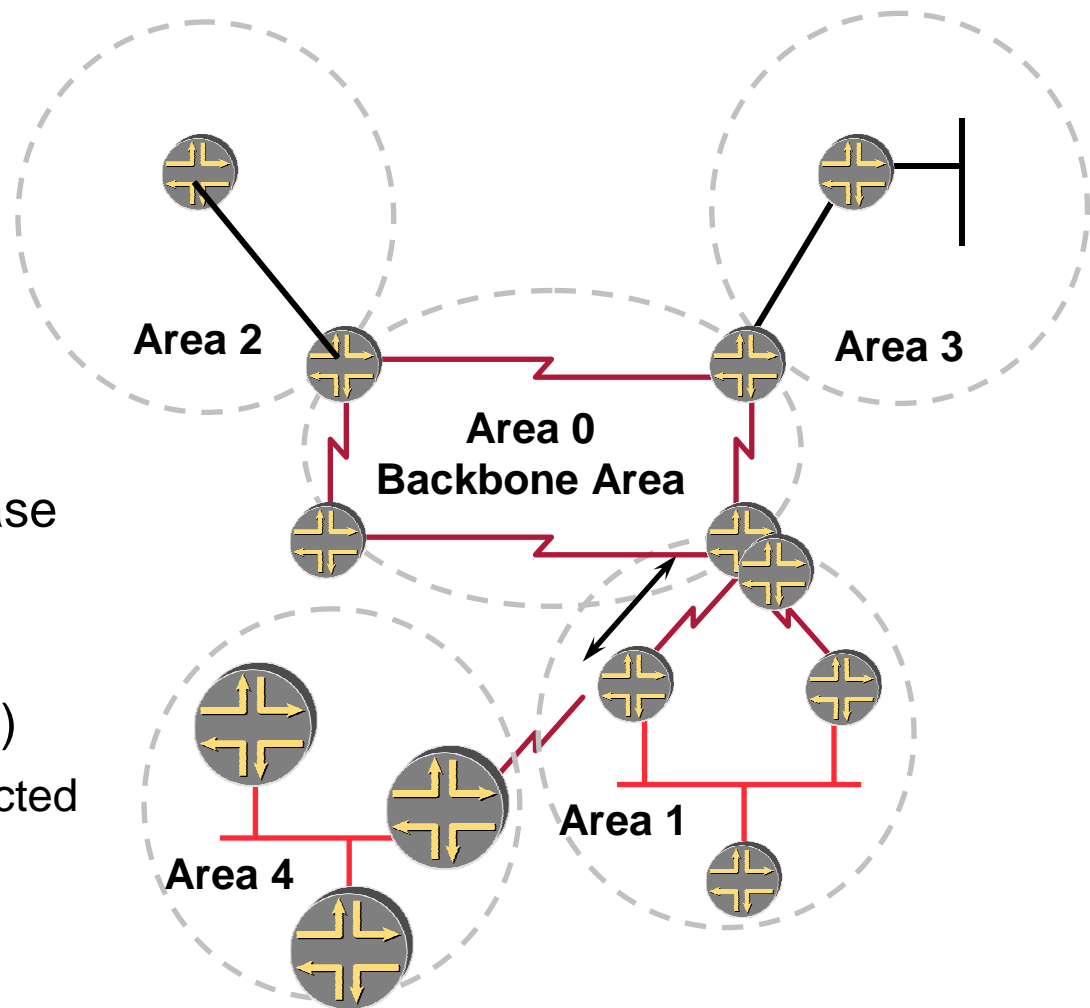
AS 200



OSPF Areas

■ OSPF areas

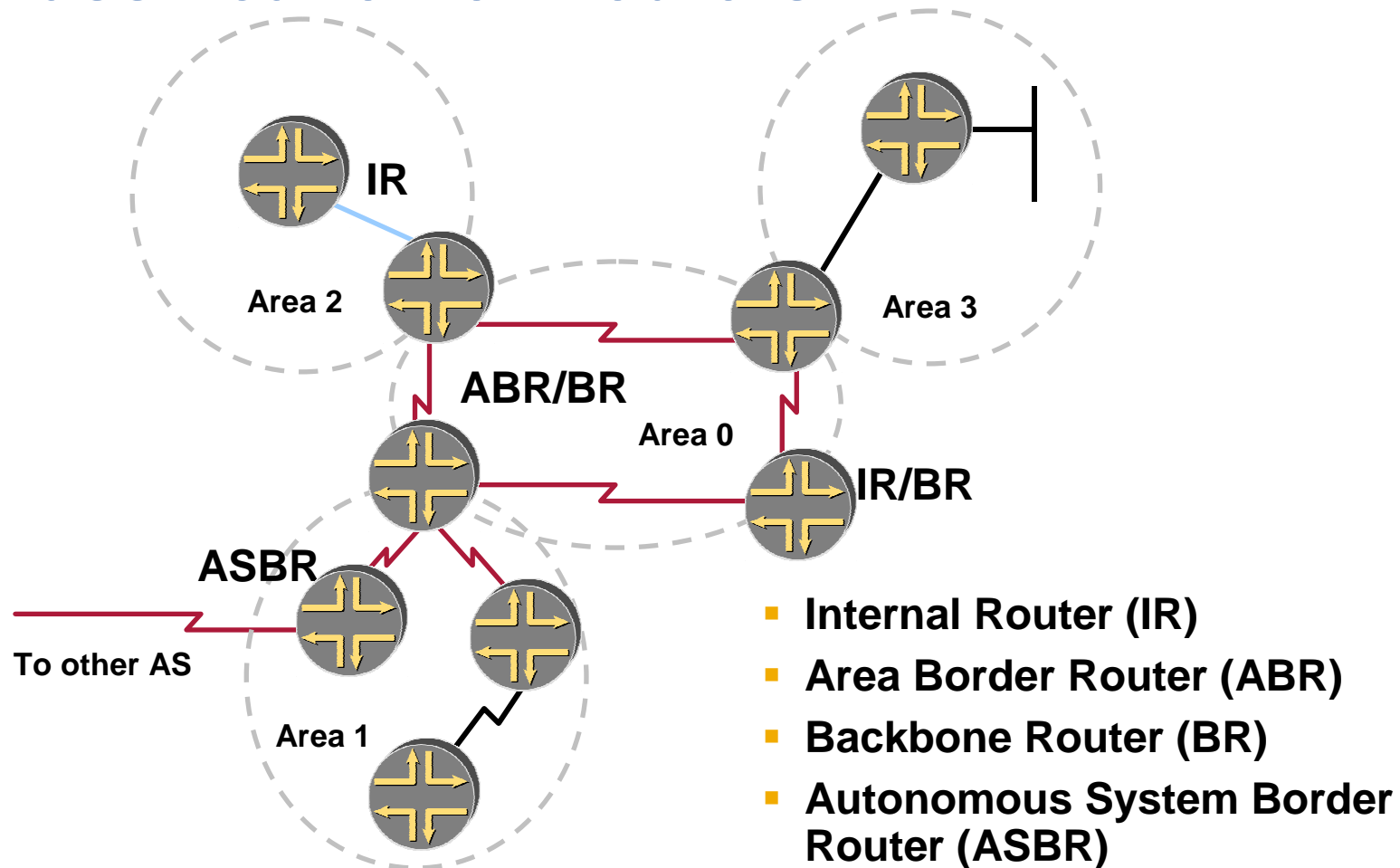
- Group of contiguous hosts and networks
- Per area topological database
- Invisible outside the area
- Reduction in routing traffic
- Backbone area (contiguous)
- All other areas must be connected to the backbone
- Virtual links



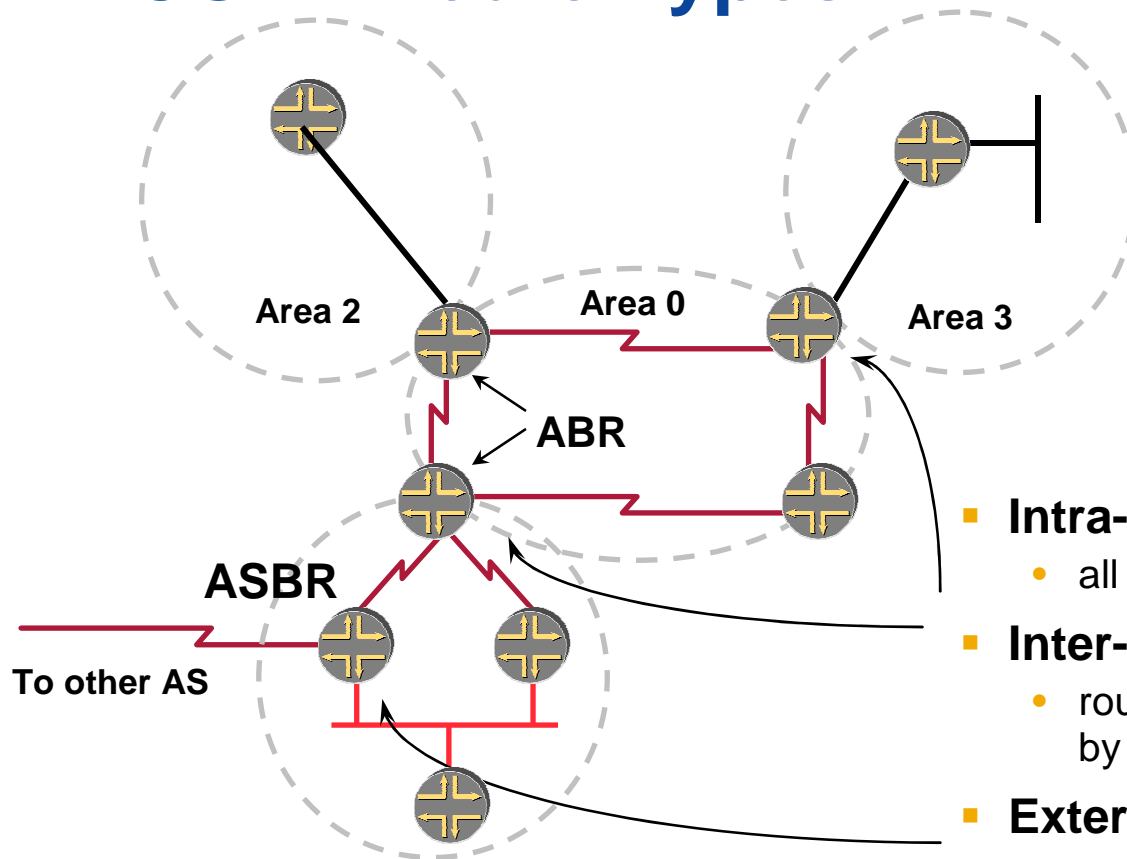
Router and Area IDs: OSPF

- **Router ID and area ID specified separately**
- **Each is 32-bit number (a.b.c.d)**
- **AID associated with interface**
- **RID**
 - Explicitly specified RID
 - Loopback address
 - Highest interface IP address

Classification of Routers



OSPF Route Types



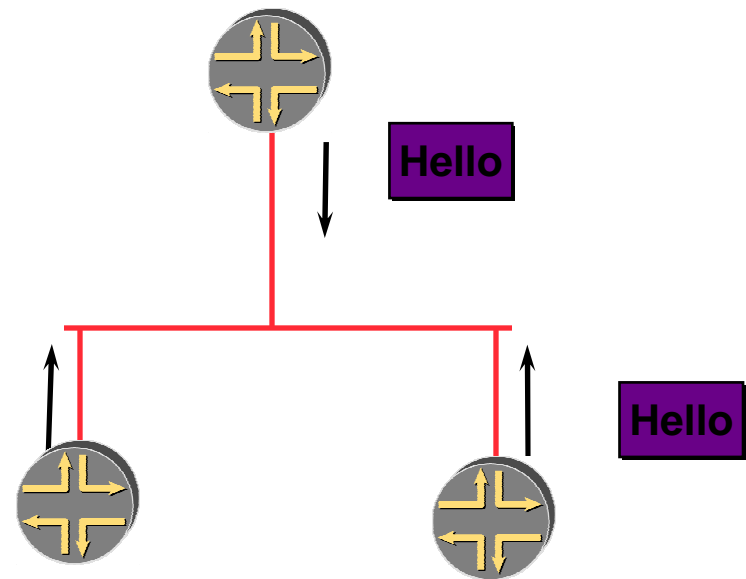
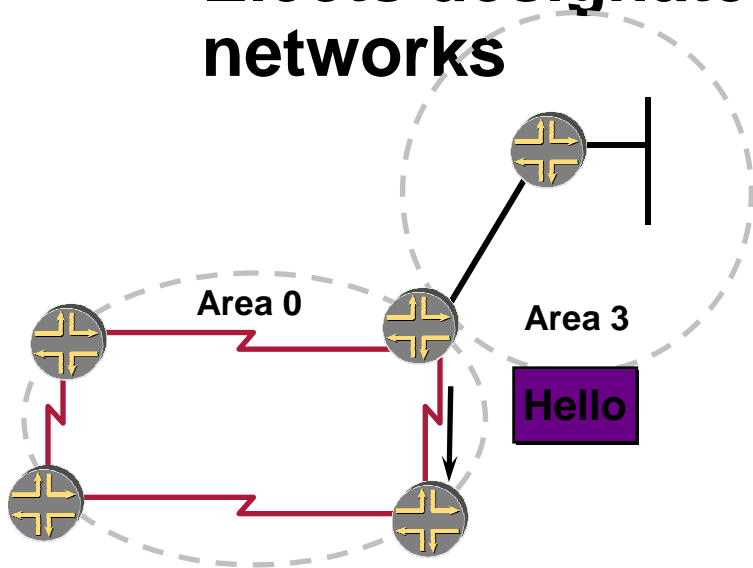
- **Intra-area Route**
 - all routes inside an area
- **Inter-area Route**
 - routes advertised from one area to another by an Area Border Router
- **External Route**
 - routes imported into OSPF from other protocol or static routes

OSPF Packet Types

- **OSPF systems send five types of packets**
 - Hello packets
 - Database description packets
 - Link-state request packets
 - Link-state update packets
 - Link-state acknowledgment packets
- **Link-state request, link-state update, and link-state acknowledgment packets reliably flood link-state advertisement packets**
- **There are several types**

The Hello Protocol

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



Designated Routers: OSPF

- **Highest priority becomes DR**
 - 0-255, default 128
 - Highest router ID tie-breaker
- **Backup designated router**
 - Speeds recovery from failed DR
- **DR cannot be pre-empted**
 - The DR is usually the first active router
- **Adjacencies formed only with DR and BDR**

Neighbor Discovery and Maintenance: OSPF

■ Hello packets

- Establish two-way communication
- Advertise optional capabilities
- DR/BDR election/discovery
- Serve as keepalives
- 10s default hello interval, dead interval 4X

■ Most hello fields must match for adjacency

- Area ID, authentication, network mask, hello interval, router dead interval, options
- Changing values causes adjacency disruption

OSPF LSAs

- Multiple LSA types

Type	LSA
1	Router LSA
2	Network LSA
3	Network Summary LSA
4	ASBR Summary LSA
5	AS External LSA
6	Group Membership LSA
7	Not-so-stubby Area LSA
8	External Attributes LSA
9-11	Opaque LSAs

Major OSPF LSAs

■ Router LSA

- LSA type 1
- Sent by all routers to describe state and cost of the router's links to the areas
- Flooded throughout a single area only

■ Network LSA

- LSA Type 2
- Sent by DRs to describe the network segment and all the routers attached to the segment
- Flooded throughout a single area only

Major OSPF LSAs

■ Network summary LSA

- LSA Type 3
- Sent by ABRs to describe the routes that they know about in other areas
- Flooded throughout the ABR's associated areas

■ ASBR summary LSA

- LSA Type 4
- Sent by ABRs to describe the location of ASBRs, which are originating AS external LSAs
- Flooded throughout the ABR's associated areas

Major OSPF LSAs

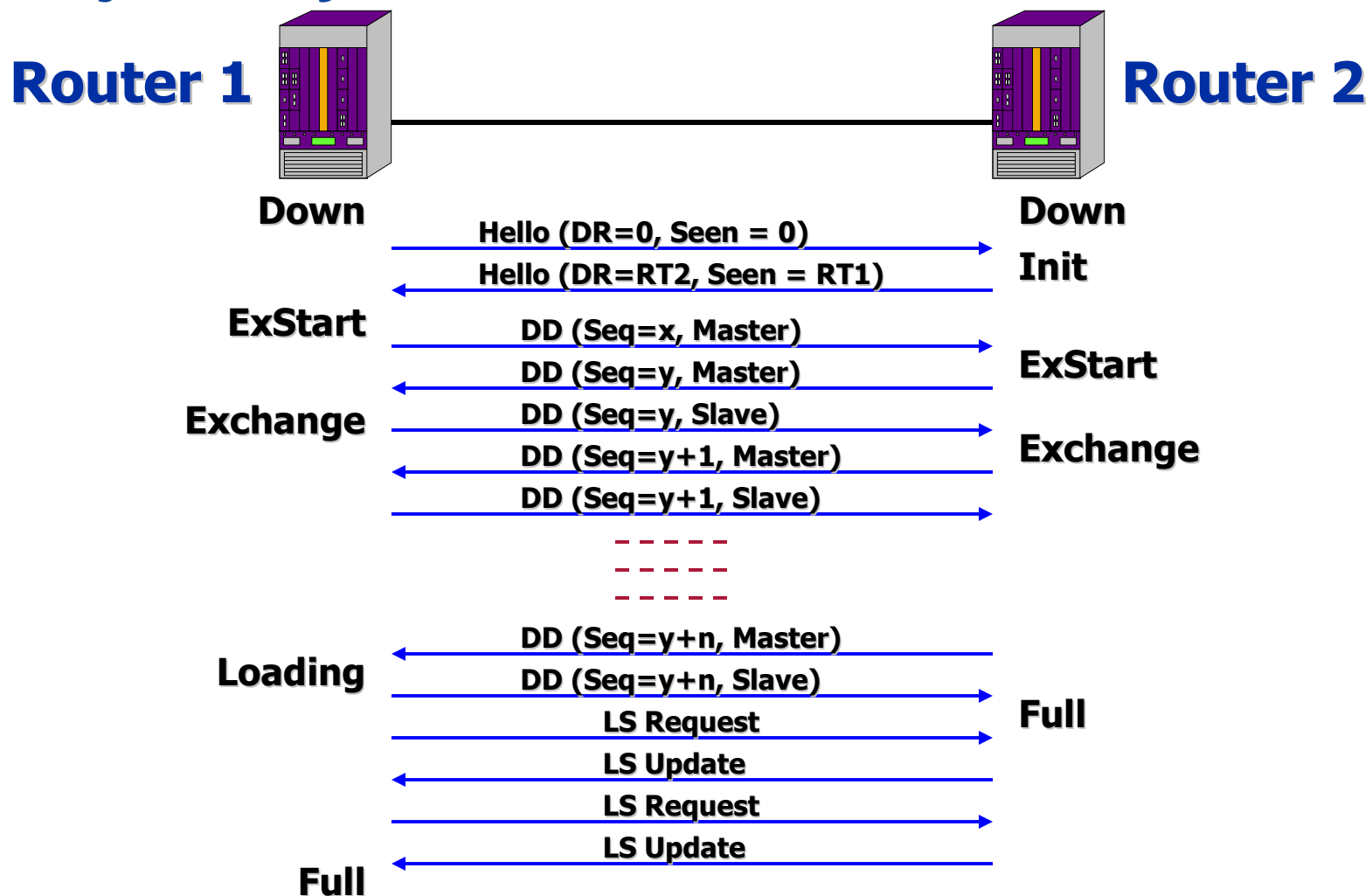
■ AS external LSA

- LSA Type 5
- Sent by ASBRs to describe external routes they know about
- Flooded throughout the AS (except into stub areas)

■ NSSA external LSA

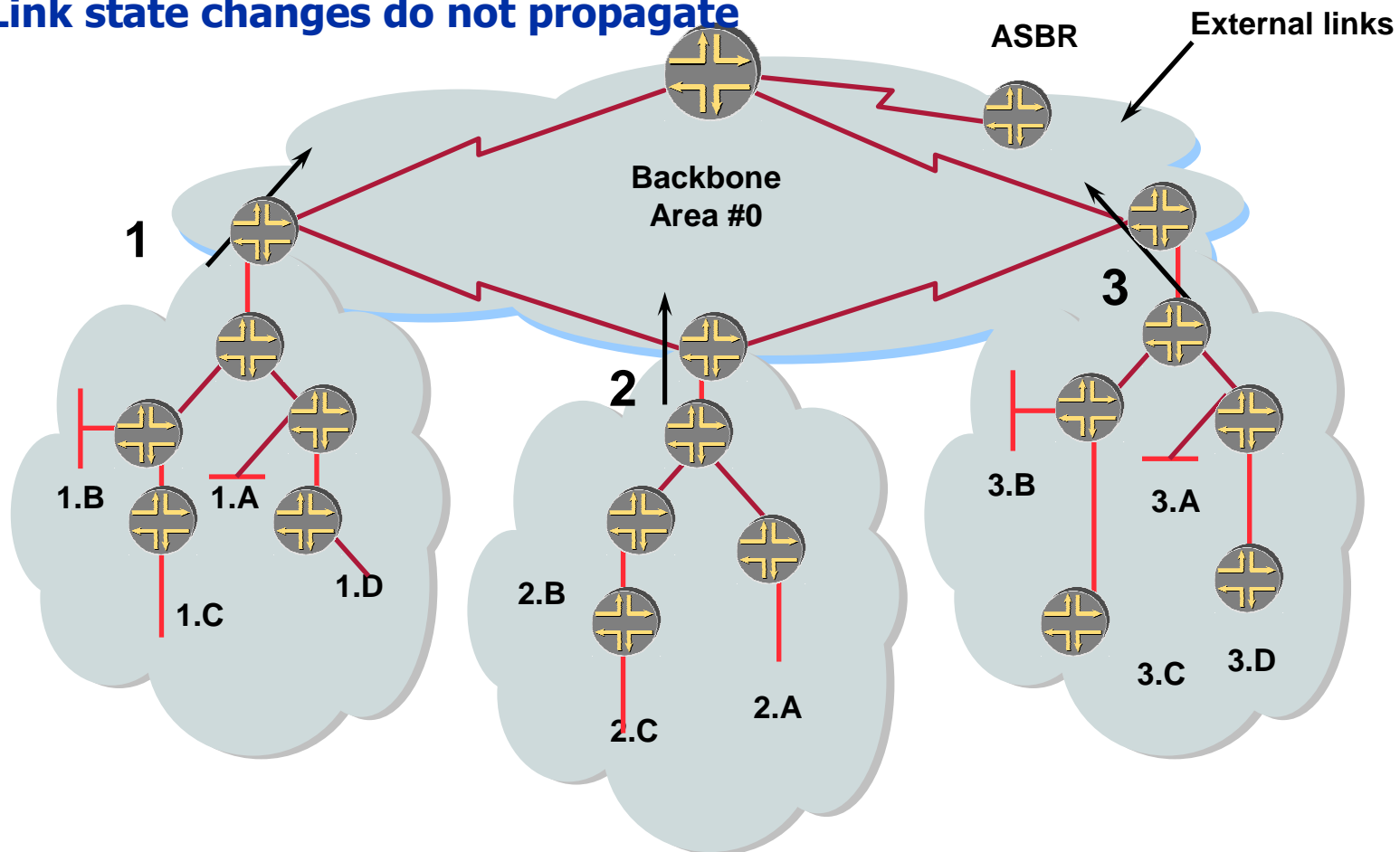
- LSA Type 7
- Used by not-so-stubby routers to import a selected number of external routes into the stub area
- Flooded throughout the stub area only
- Translated into AS external LSAs by an ABR

Adjacency Formation



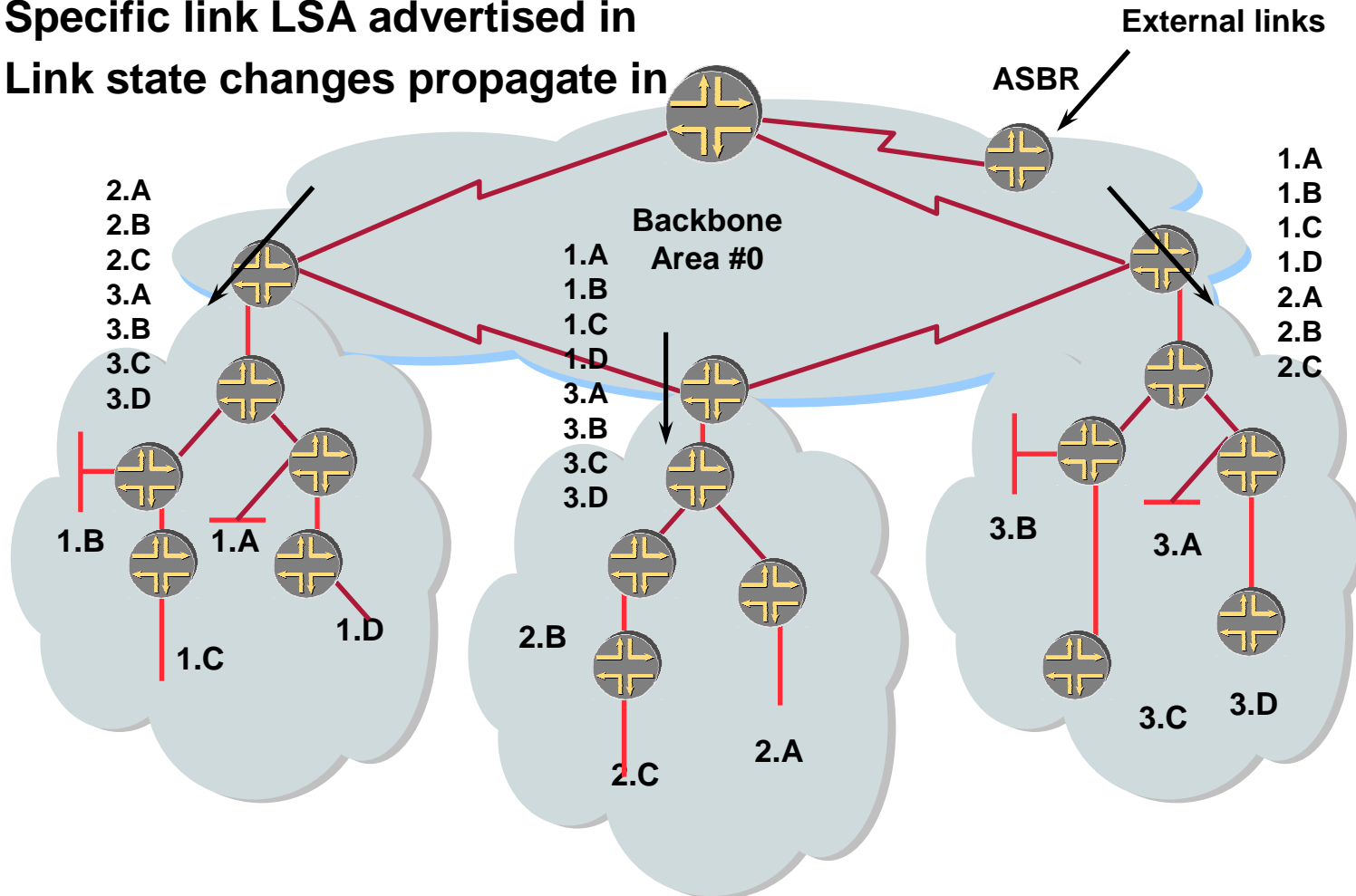
Summarized: Summary Links

Only summary LSA advertised out
Link state changes do not propagate



Not Summarized: Specific Links

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

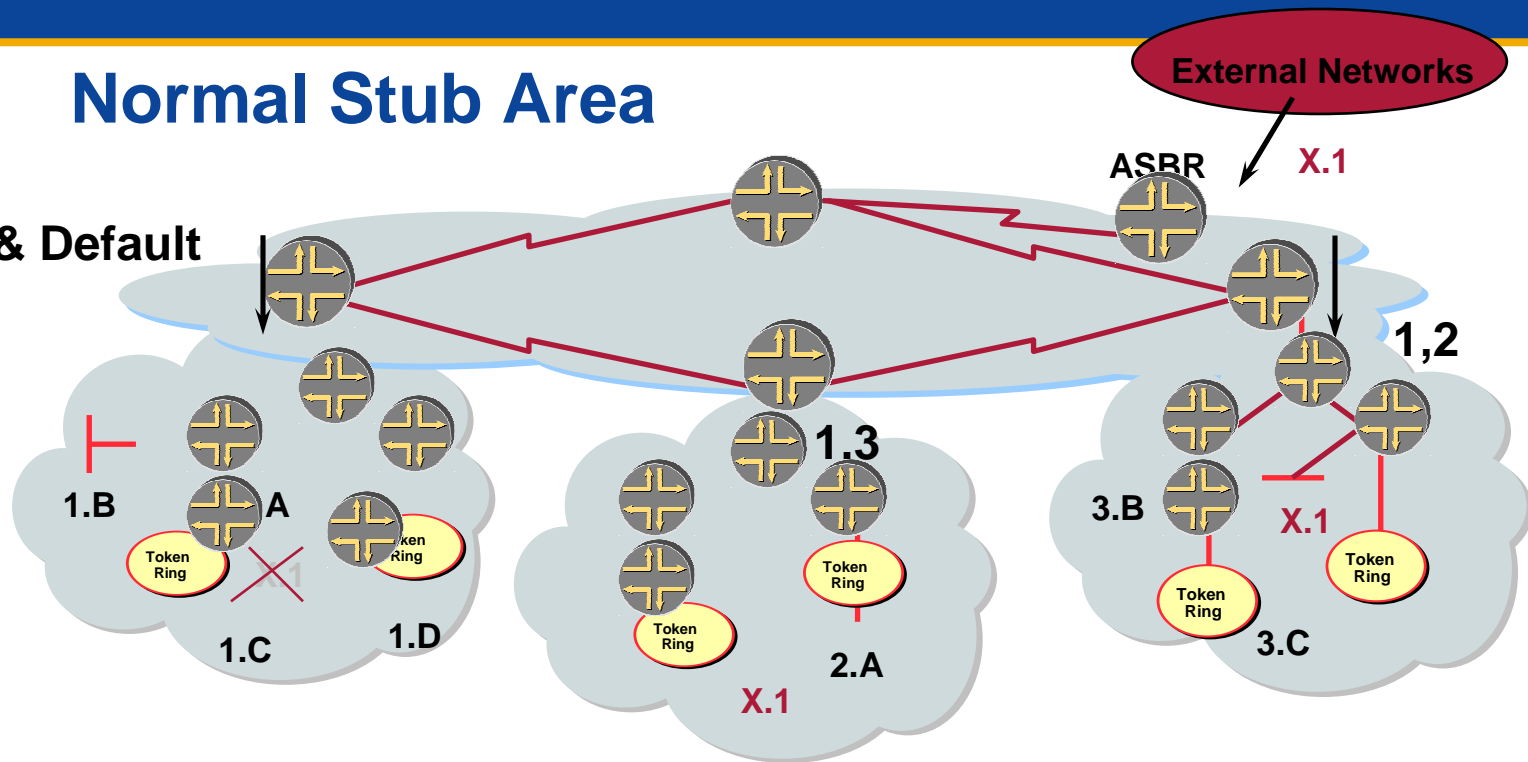


Stub Areas

- **Trade routing precision for improved scalability**
- **OSPF**
 - Stub areas eliminate type 5 LSA load
 - Totally stubby areas extend the concept
 - All area routers must understand stubbiness

Normal Stub Area

2,3, & Default



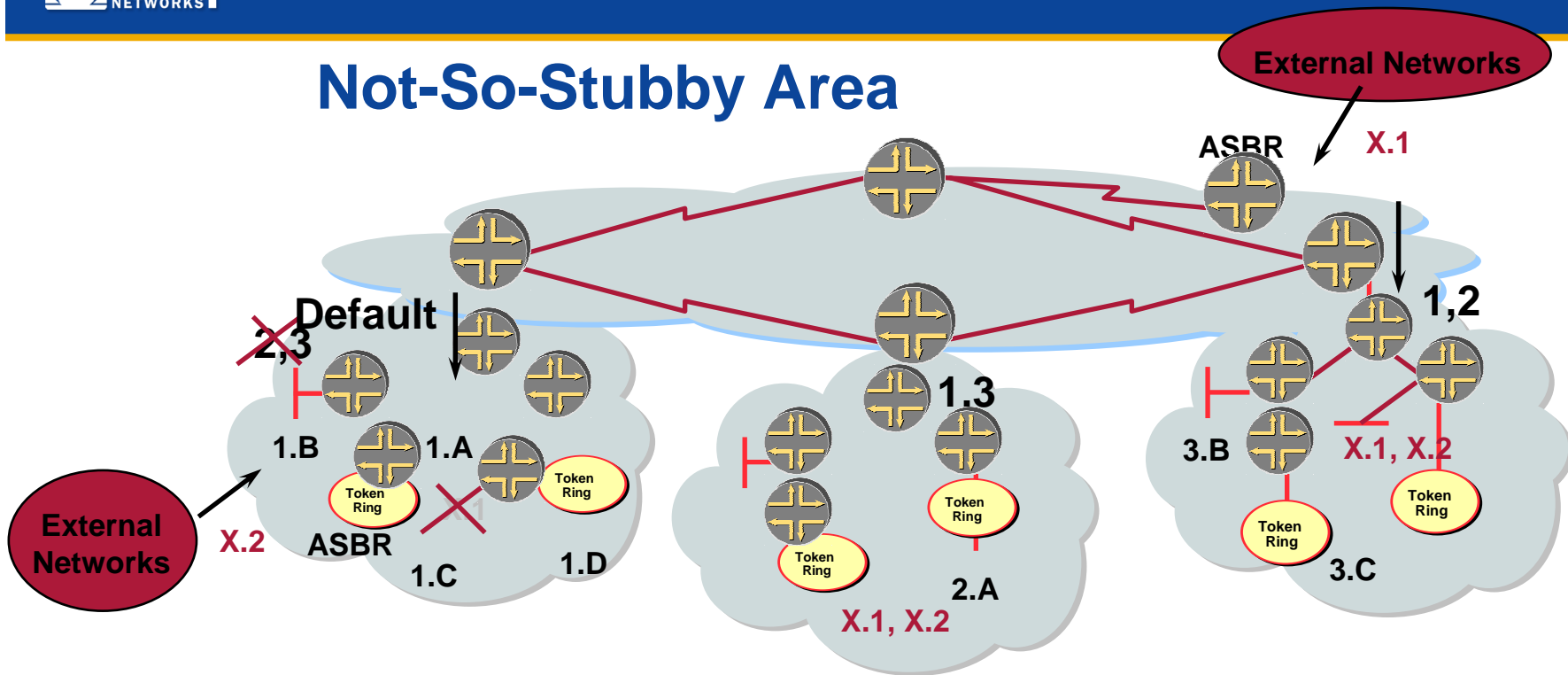
- From area 1's viewpoint
- Summary networks from other areas injected
- Default network injected into the area
 - Represents external links
- Default path to closest area border router
- Define all routers in the area as stub
 - area x stub command

Not-So-Stubby Areas

■ OSPF feature

- “Trick” to allow advertisement of external routes through stub areas (type 5 LSAs illegal)
- All routers in area must understand type 7 LSAs

Not-So-Stubby Area



- **New optional type of OSPF area**
 - Supported as of 11.2 software version
- **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**

Virtual Links

- **Useful for**
 - Patching partitioned backbone areas
 - Area migrations
- **Should be a temporary solution!**
- **Full OSPF support**

OSPF Commands

■ **show ospf neighbor ?**

- View status of OSPF neighbors

- **user@host> show ospf neighbor ?**

- **Possible completions:**

- **<[Enter]>**

Execute this command

- **brief**

Show brief status

- **detail**

Show detailed status

- **extensive**

Show extensive status

Show OSPF Neighbor Example

▪ user@host> **show ospf neighbor brief**

Address	Intf	State	ID	Pri	Dead
192.168.254.225	ge-1/2/0.0	2Way	10.250.240.32	128	36
192.168.254.230	ge-1/2/0.0	Full	10.250.240.8	128	38
192.168.254.229	ge-1/2/0.0	Full	10.250.240.35	128	33
10.1.1.129	ge-2/0/0.0	Full	10.250.240.12	128	23
10.1.1.131	ge-2/0/0.0	Full	10.250.240.11	128	24
10.1.2.1	ge-2/1/0.0	Full	10.250.240.9	128	32
10.1.2.81	ge-2/1/0.0	Full	10.250.240.10	128	33

Show OSPF Neighbor

- **show ospf neighbor extensive**
 - View detailed information about an OSPF neighbor

▪ user@host> **show ospf neighbor extensive**

Address	Intf	State	ID	Pri	Dead
192.168.254.225	ge-1/2/0.0	2Way	10.250.240.32	128	35
area 0.0.0.0, opt 0x2, DR 192.168.254.230, BDR 192.168.254.229					
Up 1w5d 18:09:18					
192.168.254.230	ge-1/2/0.0	Full	10.250.240.8	128	32
area 0.0.0.0, opt 0x2, DR 192.168.254.230, BDR 192.168.254.229					
Up 1w5d 19:21:39, adjacent 1w5d 19:21:38					
192.168.254.229	ge-1/2/0.0	Full	10.250.240.35	128	31
area 0.0.0.0, opt 0x2, DR 192.168.254.230, BDR 192.168.254.229					
Up 1w5d 19:21:39, adjacent 1w5d 19:21:39					

Clear OSPF Neighbor

- **clear ospf neighbor**
 - Clears and restarts an adjacency
 - `user@host> clear ospf neighbor 192.168.254.225`
- **Deletes entries in OSPF link-state acknowledgement database**

Show OSPF Interfaces

- **show ospf interface ?**
 - View status of an interface

```
user@host> show ospf interface ?
```

Possible completions:

<[Enter]>	Execute this command
brief	Show brief status
detail	Show detailed status
extensive	Show extensive status

```
user@host> show ospf interface brief
```

Intf	State	Area	DR ID	BDR ID	Nbrs
ge-1/2/0.0	DRother	0.0.0.0	10.250.240.8	10.250.240.35	3
ge-2/0/0.0	DR	1.0.0.0	10.250.240.17	10.250.240.11	2
ge-2/1/0.0	DR	1.0.0.0	10.250.240.17	10.250.240.9	1
ge-4/1/0.0	DR	1.0.0.0	10.250.240.17	10.250.240.10	1

Show OSPF Interfaces

- **show ospf interface extensive**
 - View more extensive OSPF interface information

```
user@host> show ospf interface extensive
```

Intf	State	Area	DR ID	BDR ID	Nbrs
ge-1/2/0.0	Drother	0.0.0.0	10.250.240.8	10.250.240.35	3
Type LAN, address 192.168.254.227, mask 255.255.255.240, MTU 1500, cost 1					
DR addr 192.168.254.230, BDR addr 192.168.254.229, adj count 2					
ge-5/1/0.0	DR	1.0.0.0	10.250.240.17	10.250.240.11	2
Type LAN, address 10.1.1.130, mask 255.255.255.128, MTU 1500, cost 1					
DR addr 10.1.1.130, BDR addr 10.1.1.131, adj count 2					
ge-6/2/0	DR	1.0.0.0	10.250.240.17	10.250.240.9	1
Type LAN, address 10.1.2.2, mask 255.255.255.240, MTU 1500, cost 1					
DR addr 10.1.2.2, BDR addr 10.1.2.1, adj count 1					

Show OSPF SPF Calculations

■ show ospf log

- View SPF calculation statistics

```
user@host> show ospf log
```

When	Type	Elapsed
1w4d 17:25:58	Stub	0.000017
1w4d 17:25:58	SPF	0.000070
1w4d 17:25:58	Stub	0.000019
1w4d 17:25:58	Interarea	0.000054
1w4d 17:25:58	External	0.000005
1w4d 17:25:58	Cleanup	0.000203
1w4d 17:25:58	Total	0.000537

View OSPF Statistics

- **show ospf statistics**
 - View basic OSPF protocol statistics

```
user@host> show ospf statistics
```

Packet type	Total		Last 5 seconds	
	Sent	Received	Sent	Received
Hello	505739	990495	4	5
DbD	20	26	0	0
LSReq	6	5	0	0
LSUpdate	27060	15319	0	0
LSAck	10923	52470	0	0

```
LSAs retransmitted: 16, last 5 seconds: 0
```

```
Receive errors:
```

```
862 no interface found
```

```
115923 no virtual link found
```

Show OSPF Routes

■ **show ospf route**

- View OSPF-related routes only

user@host> show ospf route ?

Possible completions:

<[Enter]>	Execute this command
abr	Show OSPF routes to area border routers
asbr	Show OSPF routes to AS border routers
detail	Show detail view
extern	Show external OSPF routes
inter	Show inter-area OSPF routes
intra	Show intra-area OSPF routes

Show OSPF Route Example

```
user@host> show ospf route detail
```

Prefix	Route/Path	Type	Metric	Next hop i/f	Next hop addr
1.1.1.0/24	Ext2	Network	0	ge-0/0/0.0	10.10.0.16
area 0.0.0.0, options 0x0, origin 1.1.1.1					
1.1.1.1/32	Intra	AS BR	1	ge-0/0/0.0	10.10.0.16
area 0.0.0.0, options 0x0, origin 1.1.1.1					
1.2.3.0/24	Ext2	Network	0	ge-0/0/0.0	10.10.0.16
area 0.0.0.0, options 0x0, origin 1.1.1.1					

View OSPF Database

- **show ospf database**

- View the LSA database

user@host> show ospf database ?

Possible completions:

<[Enter]>	Execute this command
advertising-router	Router ID of advertising router
area	OSPF area ID
asbrsummary	Show OSPF summary ASBR link-state database
brief	Show brief view
detail	Show detailed view
extensive	Show extensive view
extern	Show OSPF external link-state database
lsa-id	LSA ID
netsummary	Show OSPF summary network link-state database
network	Show OSPF network link-state database
nssa	Show OSPF NSSA link-state database
router	Show OSPF router link-state database
summary	Show summary view

Show OSPF Database Example

```
user@host> show ospf database brief
```

```
OSPF link state database, area 0.0.0.0
```

Type	ID	Adv Rtr	Seq	Age	Cksum	Len
Router	*10.250.240.8	10.250.240.8	0x800001fc	2388	0x3684	36
Router	10.250.240.17	10.250.240.17	0x80000217	1835	0x444c	36
Router	10.250.240.32	10.250.240.32	0x80000232	1876	0x0158	36
Router	10.250.240.35	10.250.240.35	0x80000291	1100	0x4aa5	36
Network	192.168.254.230	10.250.240.8	0x800001cc	117	0xab67	40
Summary	10.1.2.0	10.250.240.17	0x80000216	1535	0x1729	28
Summary	10.1.3.34	10.250.240.8	0x8000013a	2217	0x842f	28

```
OSPF link state database, area 1.0.0.0
```

Type	ID	Adv Rtr	Seq	Age	Cksum	Len
Router	10.250.240.9	10.250.240.9	0x80000267	116	0x1bb3	36

```
[additional information]
```

Security

- **OSPF support authentication**
 - Plain-text passwords (sniffable!)
 - MD5 cryptographic hash
- **Authentication especially important with OSPF**
 - Runs over IP, so subject to spoofing and other attacks

Checkpoint

- **Can you now describe**
 - OSPF protocol basics?
 - Each LSA type?



Basic OSPF Configuration

Basic OSPF configuration, 1

Enable IP on All Router Interfaces

```
[edit] set interface interface-name unit 0 family inet  
[edit]
```

Enable all interfaces on area 0.0.0.0

```
[edit]  
[edit protocols ospf]  
[edit protocols ospf]  
[edit protocols ospf]  
  
[edit protocols ospf]  
[edit]  
  
edit protocols OSPF  
set area 0 interface all  
set area 0 interface fxp0 disable  
set area 0 interface interface-name  
metric metric-value  
top  
commit
```

To check the network

To see the OSPF interfaces

[edit] exit

user@host> show ospf interface brief / extensive

To see OSPF neighborss :

user@host> show ospf neighbor brief / extensive

To see OSPF routes :

user@host> show ospf route detail

To see the database

user@host> show OSPF database brief

Show OSPF Interfaces

- **show ospf interface ?**

- View status of an interface

```
user@host> show ospf interface ?
```

Possible completions:

<[Enter]>	Execute this command
brief	Show brief status
detail	Show detailed status
extensive	Show extensive status

```
user@host> show ospf interface brief
```

Intf	State	Area	DR ID	BDR ID	Nbrs
ge-1/2/3.0	DRother	0.0.0.0	10.250.240.8	10.250.240.35	3
ge-2/0/0.0	DR	1.0.0.0	10.250.240.17	10.250.240.11	2
ge-2/1/9.0	DR	1.0.0.0	10.250.240.17	10.250.240.9	1
ge-4/1/3.0	DR	1.0.0.0	10.250.240.17	10.250.240.10	1

Show OSPF Interfaces

- **show ospf interface extensive**
 - View more extensive OSPF interface information

```
user@host> show ospf interface extensive
```

Intf	State	Area	DR ID	BDR ID	Nbrs
ge-1/2/3.0	Drother	0.0.0.0	10.250.240.8	10.250.240.35	3
Type LAN, address 192.168.254.227, mask 255.255.255.240, MTU 1500, cost 1					
DR addr 192.168.254.230, BDR addr 192.168.254.229, adj count 2					
fxp2.0	DR	1.0.0.0	10.250.240.17	10.250.240.11	2
Type LAN, address 10.1.1.130, mask 255.255.255.128, MTU 1500, cost 1					
DR addr 10.1.1.130, BDR addr 10.1.1.131, adj count 2					
fxp1.0	DR	1.0.0.0	10.250.240.17	10.250.240.9	1
Type LAN, address 10.1.2.2, mask 255.255.255.240, MTU 1500, cost 1					
DR addr 10.1.2.2, BDR addr 10.1.2.1, adj count 1					

View OSPF Statistics

- **show ospf statistics**
 - View basic OSPF protocol statistics

```
user@host> show ospf statistics
```

Packet type	Total		Last 5 seconds	
	Sent	Received	Sent	Received
Hello	505739	990495	4	5
DbD	20	26	0	0
LSReq	6	5	0	0
LSUpdate	27060	15319	0	0
LSAck	10923	52470	0	0

```
LSAs retransmitted: 16, last 5 seconds: 0
```

```
Receive errors:
```

```
862 no interface found
```

```
115923 no virtual link found
```

Show OSPF Route Example

user@host> **show ospf route detail**

Prefix addr	Route/Path	Type	Metric	Next hop i/f	Next hop
1.1.1.0/24 10.10.0.16	Ext2	Network	0	ge-0/0/0.0	
area 0.0.0.0, options 0x0, origin 1.1.1.1					
1.1.1.1/32 10.10.0.16	Intra	AS BR	1	ge-0/0/0.0	
area 0.0.0.0, options 0x0, origin 1.1.1.1					
1.2.3.0/24 10.10.0.16	Ext2	Network	0	ge-0/0/0.0	
area 0.0.0.0, options 0x0, origin 1.1.1.1					

View OSPF Database

- **show ospf database**

- View the LSA database

```
user@host> show ospf database ?
```

Possible completions:

<[Enter]>	Execute this command
advertising-router	Router ID of advertising router
area	OSPF area ID
asbrsummary	Show OSPF summary ASBR link-state database
brief	Show brief view
detail	Show detailed view
extensive	Show extensive view
extern	Show OSPF external link-state database
lsa-id	LSA ID
netsummary	Show OSPF summary network link-state database
network	Show OSPF network link-state database
nssa	Show OSPF NSSA link-state database
router	Show OSPF router link-state database
summary	Show summary view

Show OSPF Database Example

```
user@host> show ospf database brief
```

```
OSPF link state database, area 0.0.0.0
```

Type	ID	Adv Rtr	Seq	Age	Cksum	Len
Router	10.250.240.8	10.250.240.8	0x800001fc	2388	0x3684	36
Router	10.250.240.17	10.250.240.17	0x80000217	1835	0x444c	36
Router	10.250.240.32	10.250.240.32	0x80000232	1876	0x0158	36
Router	10.250.240.35	10.250.240.35	0x80000291	1100	0x4aa5	36
Network	192.168.254.230	10.250.240.8	0x800001cc	117	0xab67	40
Summary	10.1.2.0	10.250.240.17	0x80000216	1535	0x1729	28
Summary	10.1.3.34	10.250.240.8	0x8000013a	2217	0x842f	28