# PART XV

ROUTING: INSIDE AN AUTONOMOUS SYSTEM (RIP, OSPF, HELLO)

Static Vs. Dynamic Interior Routes

- Static routes

  – Initialized at startup

  – Never change

  – Typical for host

  – Sometimes used for router

- Dynamic router

  – Initialized at startup

  – Updated by route propagation protocols

  – Typical for router

  – Sometimes used in host

Illustration Of Topology In Which
Static Routing Is Optimal
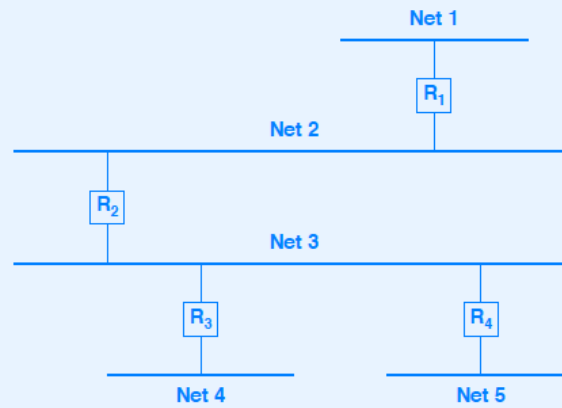
- Only one route exists for each destination

# Illustration Of Topology In Which Dynamic Routing Is Needed
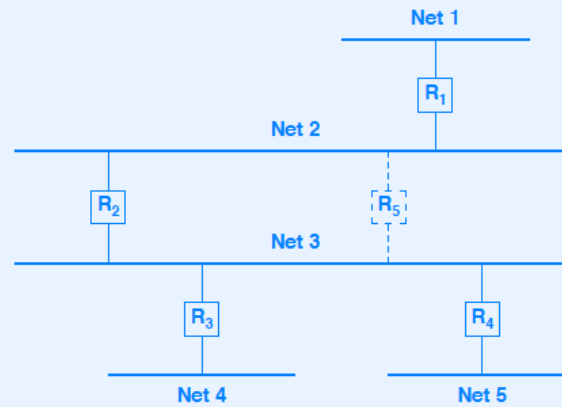
- Additional router introduces multiple paths

Exchanging Routing Information Within An Autonomous System

- Mechanisms called interior gateway protocols, IGPs

- Choice of IGP is made by autonomous system

- Note: if AS connects to rest of the world, a router in the AS must use an EGP to advertise network reachability to other autonomous systems.

Example Of Two Autonomous Systems And the Routing Protocols Used
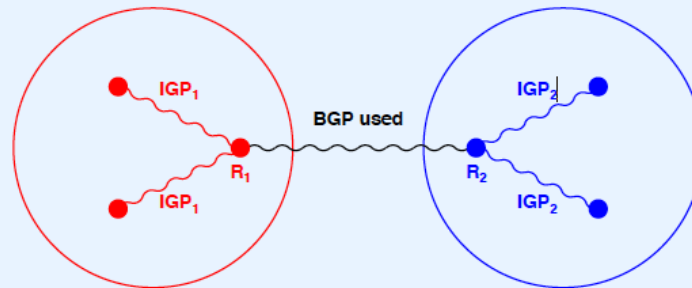
Example IGPs

- RIP

- HELLO

- OSPF

Routing Information Protocol (RIP)

- Implemented by UNIX program *routed*

- Uses hop count metric

- Distance-vector protocol

- Relies on broadcast

- Assumes low-delay local area network

- Uses split horizon and poison reverse techniques to solve inconsistencies

- Current standard is RIP2

Two Forms Of RIP

- Active

  - Form used by routers

  - Broadcasts routing updates periodically

  - Uses incoming messages to update routes

- Passive

  - Form used by hosts

  - Uses incoming messages to update routes

  - Does not send updates

Illustration Of Hosts
Using Passive RIP

To Some Parts Of Internet ← R1

To Some Parts Of Internet R2 →

128.10.0.200

128.10.0.0

128.10.0.209

...
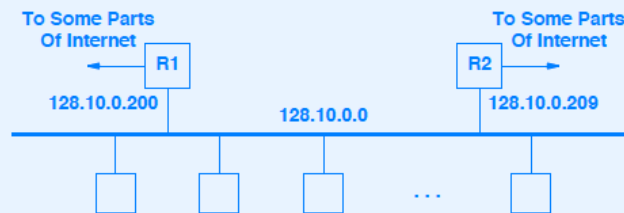
- Host routing table initialized to:

Destination	Route
128.10.0.0	direct
default	128.10.0.200

- Host listens for RIP broadcast and uses data to update table

- Eliminates ICMP redirects

RIP Operation

- Each router sends update every 30 seconds

- Update contains pairs of
  (destination address, distance)

- Distance of 16 is *infinity* (i.e., no route)

Slow Convergence Problem
(Count To Infinity)
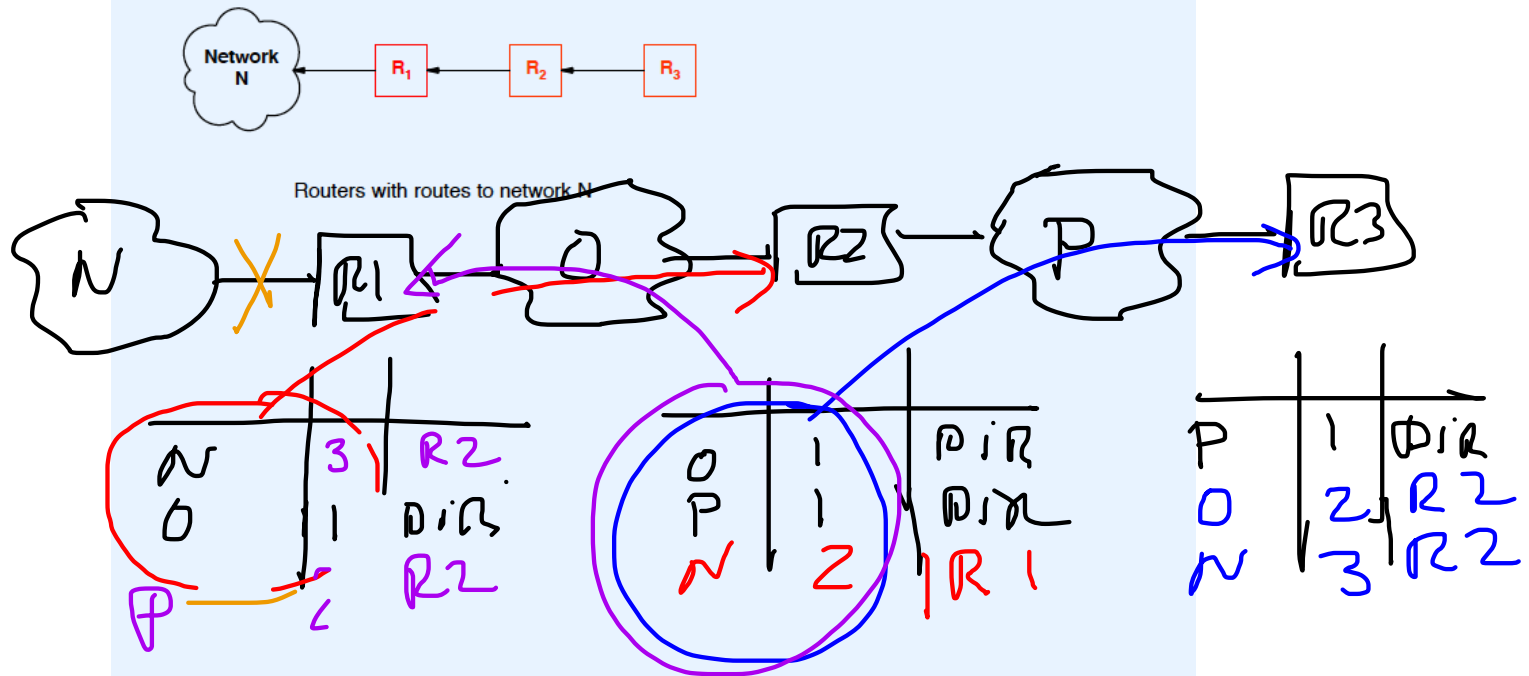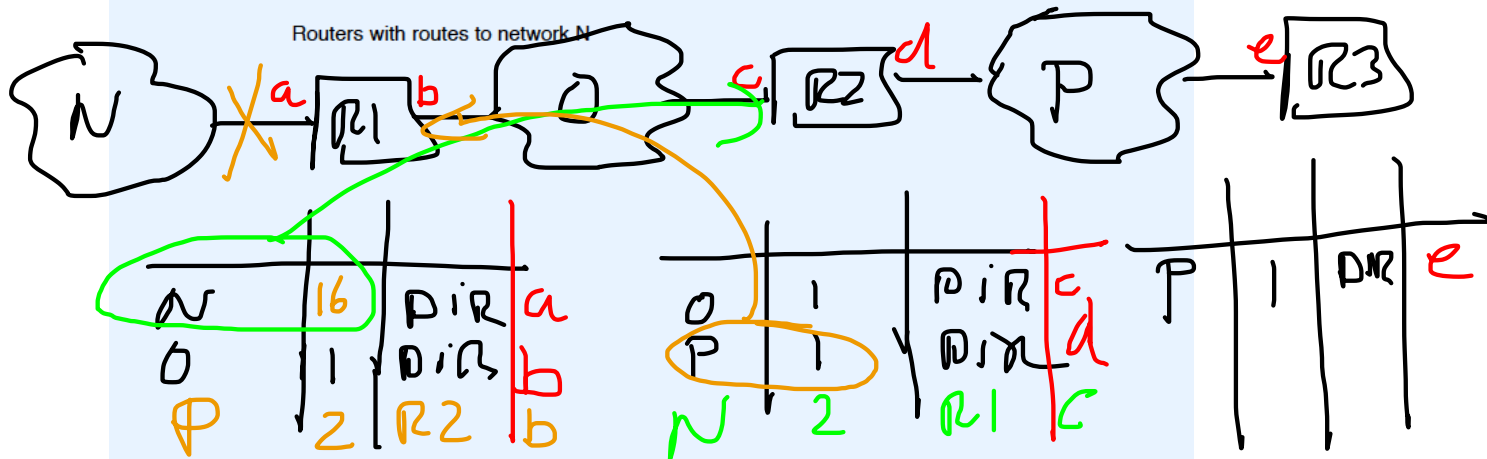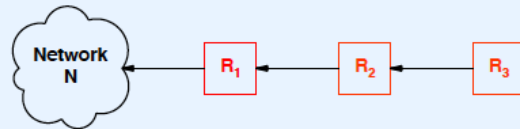
Network N ← R₁ ← R₂ ← R₃

Routers with routes to network N

N	3	R2
O	1	DiR
		R2
P		2

O	1	DiR
P	1	DiR
N	2	R1

P	1	DiR
O	2	R2
N	3	R2

Slow Convergence Problem
(Count To Infinity)

Network N ← R₁ ← R₂ ← R₃

Routers with routes to network N

N	16	DiR	a
O	1	DiR	b
P	2	R2	b

O	1	DiR	c
P	1	DiR	d
N	2	R1	c

P	1	DiR	e

Slow Convergence Problem
(Count To Infinity)

Network N ← R_1 ← R_2 ← R_3
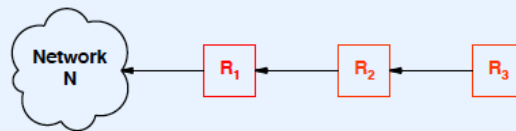
Routers with routes to network N

Network N R_1 ⇄ R_2 ← R_3
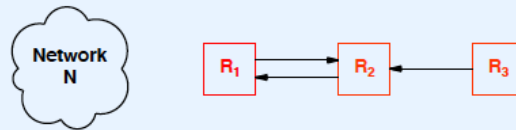
R_1 erroneously routes to R_2 after failure

RIP1 Update Format

0	8	16	31
COMMAND	VERSION (1)	RESERVED	
FAMILY OF NET 1		NET 1 ADDR., OCTETS 1 - 2	
NET 1 ADDRESS, OCTETS 3 - 6			
NET 1 ADDRESS, OCTETS 7 - 10			
NET 1 ADDRESS, OCTETS 11 - 14			
DISTANCE TO NETWORK 1			
FAMILY OF NET 2		NET 2 ADDR., OCTETS 1 - 2	
NET 2 ADDRESS, OCTETS 3 - 6			
NET 2 ADDRESS, OCTETS 7 - 10			
NET 2 ADDRESS, OCTETS 11 - 14			
DISTANCE TO NETWORK 2			
. . .			

- Uses *FAMILY* field to support multiple protocols
- IP address sent in octets *3 - 6* of address field
- Message travels in UDP datagram

Changes To RIP
In Version 2

- Update includes subnet mask

- Authentication supported

- Explicit next-hop information

- Messages can be multicast (optional)

  - IP multicast address is 224.0.0.9

RIP2 Update Format

0	8	16	31
COMMAND	VERSION (1)	UNUSED	
FAMILY OF NET 1		ROUTE TAG FOR NET 1	
NET 1 IP ADDRESS			
NET 1 SUBNET MASK			
NET 1 NEXT HOP ADDRESS			
DISTANCE TO NETWORK 1			
FAMILY OF NET 2		ROUTE TAG FOR NET 2	
NET 2 IP ADDRESS			
NET 2 SUBNET MASK			
NET 2 NEXT HOP ADDRESS			
DISTANCE TO NETWORK 2			
. . .			

- Packet format is backward compatible
- Infinity still limited to *16*
- RIP2 *can* be broadcast

Measures Of Distance
That Have Been Used

- Hops
    - Zero-origin
    - One-origin (e.g., RIP)
- Delay
- Throughput
- Jitter

HELLO: A Protocol That Used Delay

- Developed by Dave Mills

- Measured delay in milliseconds

- Used by NSFNET fuzzballs

- Now historic

How HELLO Worked

- Participants kept track of delay between pairs of routers

- HELLO propagated delay information across net

- Route chosen to minimize total delay

Route Oscillation

- Effective delay depends on traffic (delay increases as traffic increases)

- Using delay as metric means routing traffic where delay is low

- Increased traffic raises delay, which means route changes

- Routes tend to oscillate

Why HELLO Worked

- HELLO used only on NSFNET backbone

- All paths had equal throughput

- Route changes damped to avoid oscillation

Open Shortest Path First (OSPF)

- Developed by IETF in response to vendors' proprietary protocols

- Uses SPF (link-state) algorithm

- More powerful than most predecessors

- Permits hierarchical topology

- More complex to install and manage

OSPF Features

- Type of service routing

- Load balancing across multiple paths

- Networks partitioned into subsets called *areas*

- Message authentication

- Network-specific, subnet-specific, host-specific, and CIDR routes

- Designated router optimization for shared networks

- Virtual network topology abstracts away details

- Can import external routing information

OSPF Message Header

0	8	16	24	31
VERSION (1)	TYPE	MESSAGE LENGTH		
SOURCE ROUTER IP ADDRESS				
AREA ID				
CHECKSUM		AUTHENTICATION TYPE		
AUTHENTICATION (octets 0-3)				
AUTHENTICATION (octets 4-7)				
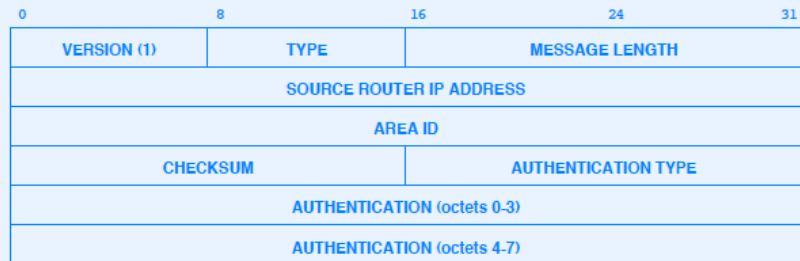
- Each message starts with same header

OSPF Message Types

Type	Meaning
1	Hello (used to test reachability)
2	Database description (topology)
3	Link status request
4	Link status update
5	Link status acknowledgement

OSPF HELLO Message Format

0	8	16	24	31

```
OSPF HEADER WITH TYPE=1

NETWORK MASK

DEAD TIMER        | HELLO INTER    | GWAY PRIO

DESIGNATED ROUTER

BACKUP DESIGNATED ROUTER

NEIGHBOR₁ IP ADDRESS

NEIGHBOR₂ IP ADDRESS

...

NEIGHBORₙ IP ADDRESS
```
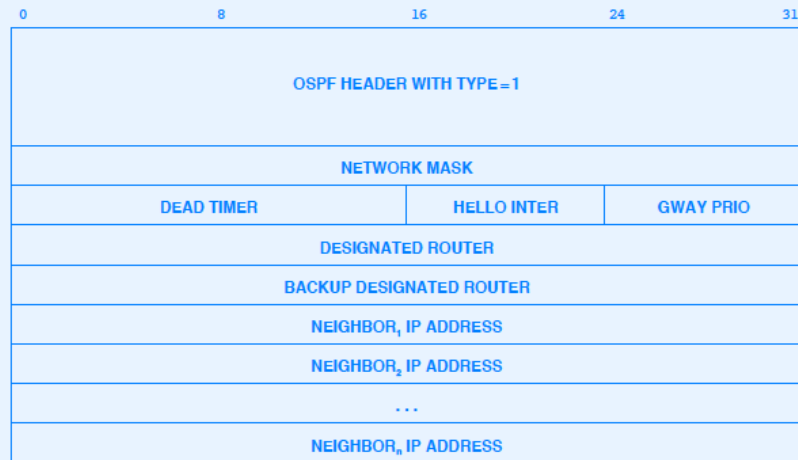
- Used to test reachability

OSPF Database Description Message Format

0	8	16	24	29	31

OSPF HEADER WITH TYPE=2

MUST BE ZERO	I	M	S

DATABASE SEQUENCE NUMBER

LINK TYPE

LINK ID

ADVERTISING ROUTER

LINK SEQUENCE NUMBER

LINK CHECKSUM	LINK AGE

. . .
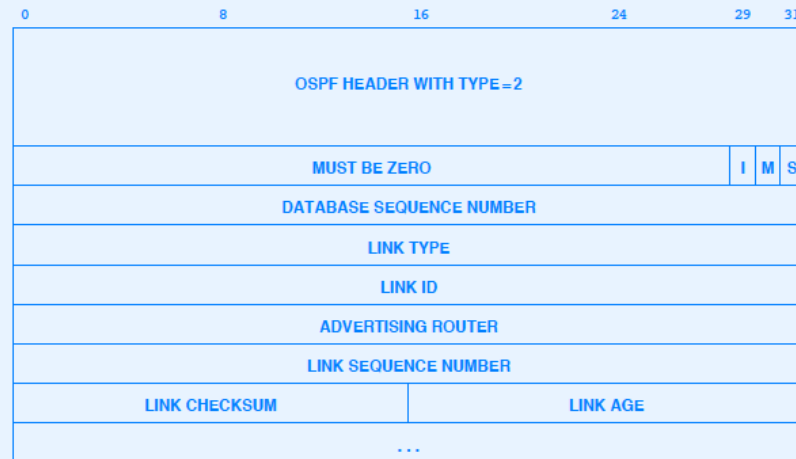
- Fields starting at *LINK TYPE* are repeated

Values In The LINK Field

Link Type	Meaning
1	Router link
2	Network link
3	Summary link (IP network)
4	Summary link (link to border router)
5	External link (link to another site)

OSPF Link Status Request Message Format

0	16	31
OSPF HEADER WITH TYPE=3		
LINK TYPE		
LINK ID		
ADVERTISING ROUTER		
. . .		
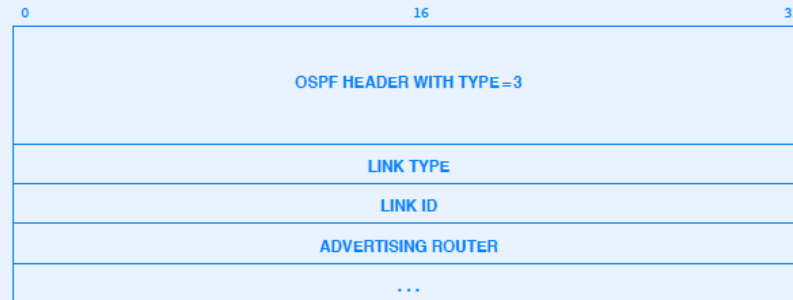
OSPF Link Status Update Message Format

```
0                          16                         31

┌───────────────────────────────────────────────────┐
│                                                     │
│            OSPF HEADER WITH TYPE = 4                │
│                                                     │
├───────────────────────────────────────────────────┤
│          NUMBER OF LINK STATUS ADVERTISEMENTS       │
├───────────────────────────────────────────────────┤
│              LINK STATUS ADVERTISEMENT₁             │
├───────────────────────────────────────────────────┤
│                                                     │
│                        . . .                        │
│                                                     │
├───────────────────────────────────────────────────┤
│              LINK STATUS ADVERTISEMENTₙ             │
└───────────────────────────────────────────────────┘
```
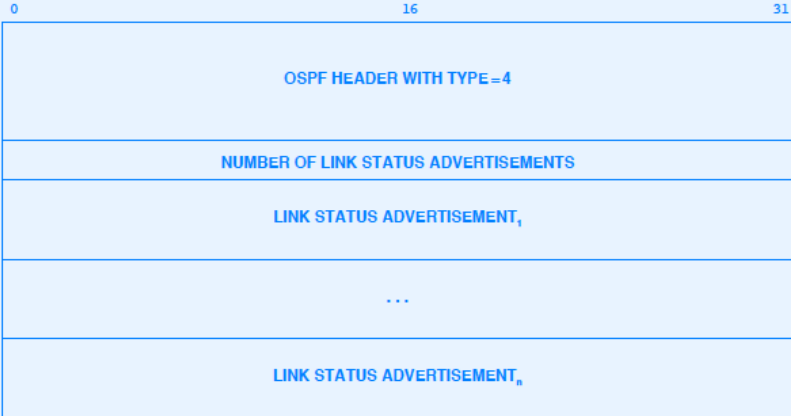
Header Used In OSPF Link Status Advertisements

0	16	31
LINK AGE		LINK TYPE
LINK ID		
ADVERTISING ROUTER		
LINK SEQUENCE NUMBER		
LINK CHECKSUM		LENGTH

- Four possible formats follow

  - Links from a router to given area

  - Links from a router to physical net

  - Links from a router to physical nets of a subnetted IP network

  - Links from a router to nets at other sites

Discussion Question

- What are the tradeoffs connected with the issue of routing in the presence of partial information?

Summary

- Interior Gateway Protocols (IGPs) used within an AS

- Popular IGPs include

    - RIP (distance vector algorithm)

    - OSPF (link-state algorithm)