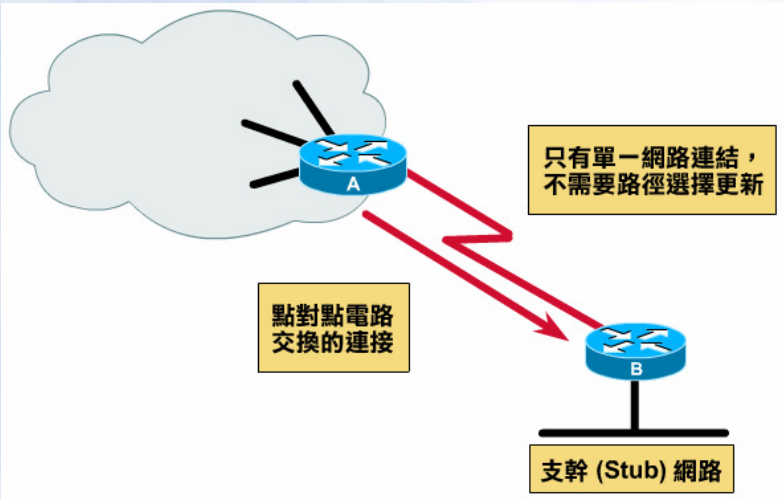
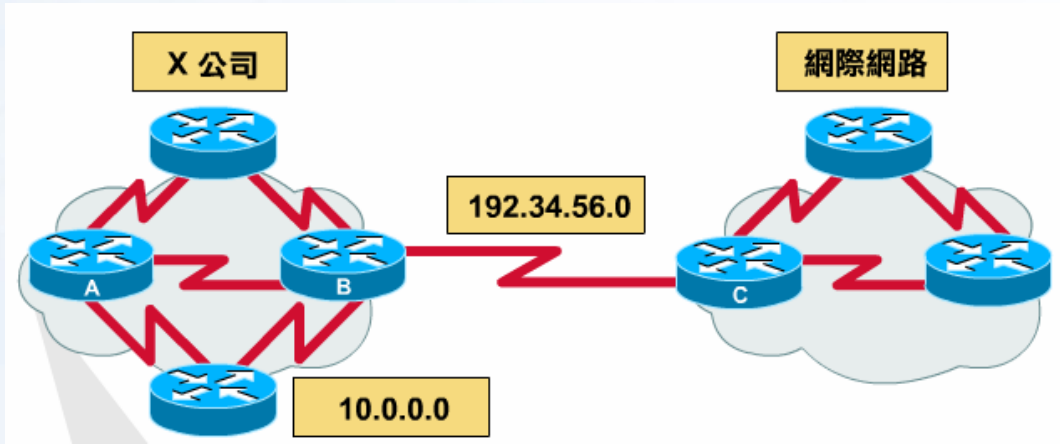
Routing

Why dynamic route ? (1)

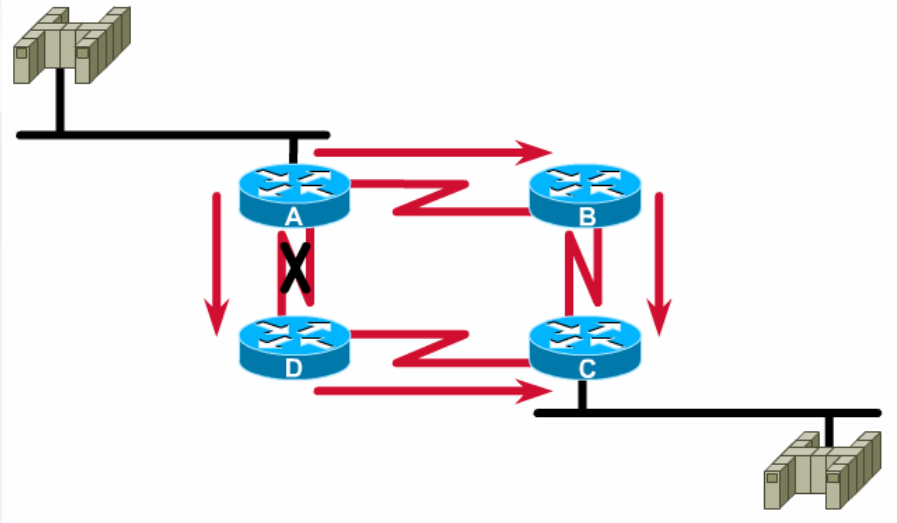
- Static route is ok only when
  - **Network is small**
  - **There is a single connection point to other network**
  - **No redundant route**





Why dynamic route ? (2)

- Dynamic Routing
  - **Routers update their routing table with the information of adjacent routers**
  - **Dynamic routing need a routing protocol for such communication**
  - **Advantage:**
    - They can react and adapt to changing network condition

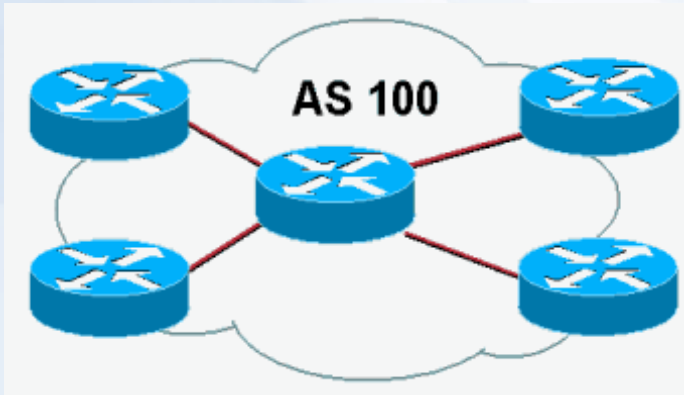


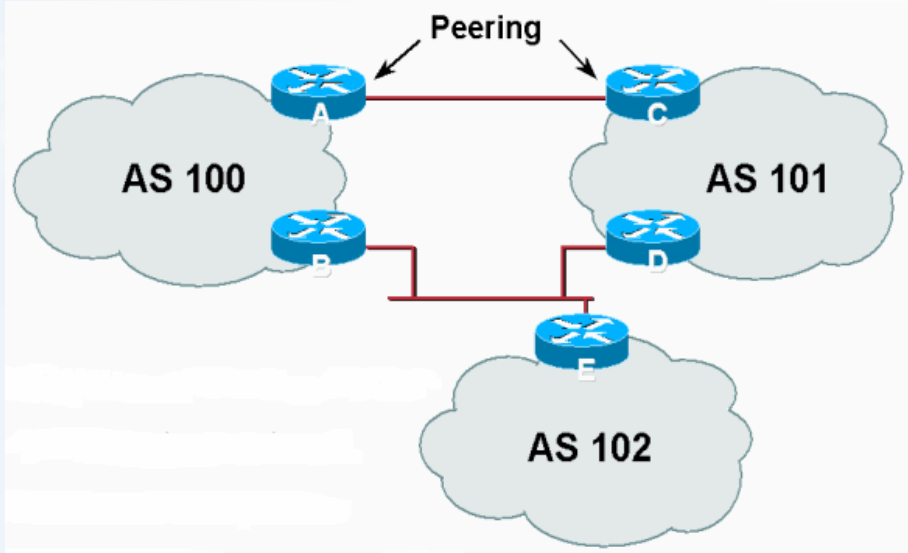
Routing Protocol

- Used to change the routing table according to various routing information
  - **Specify detail of communication between routers**
  - **Specify information changed in each communication,**
    - Network reachability
    - Network state
    - Metric
- Metric
  - **A measure of how good a particular route**
    - Hop count, bandwidth, delay, load, reliability, …
- Each routing protocol may use different metric and exchange different information

Autonomous System

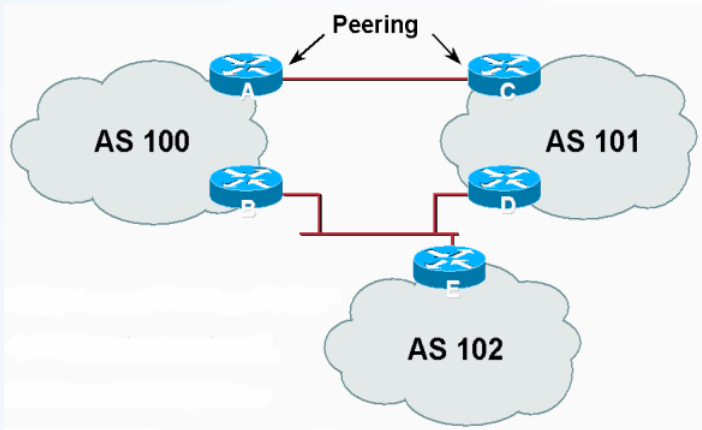
- Autonomous System (AS)
  - **Internet is organized in to a collection of autonomous system**
  - **An AS is a collection of networks with same routing policy**
    - Single routing protocol
    - Normally administered by a single entity
      - Corporation or university campus
    - All depend on how you want to manage routing





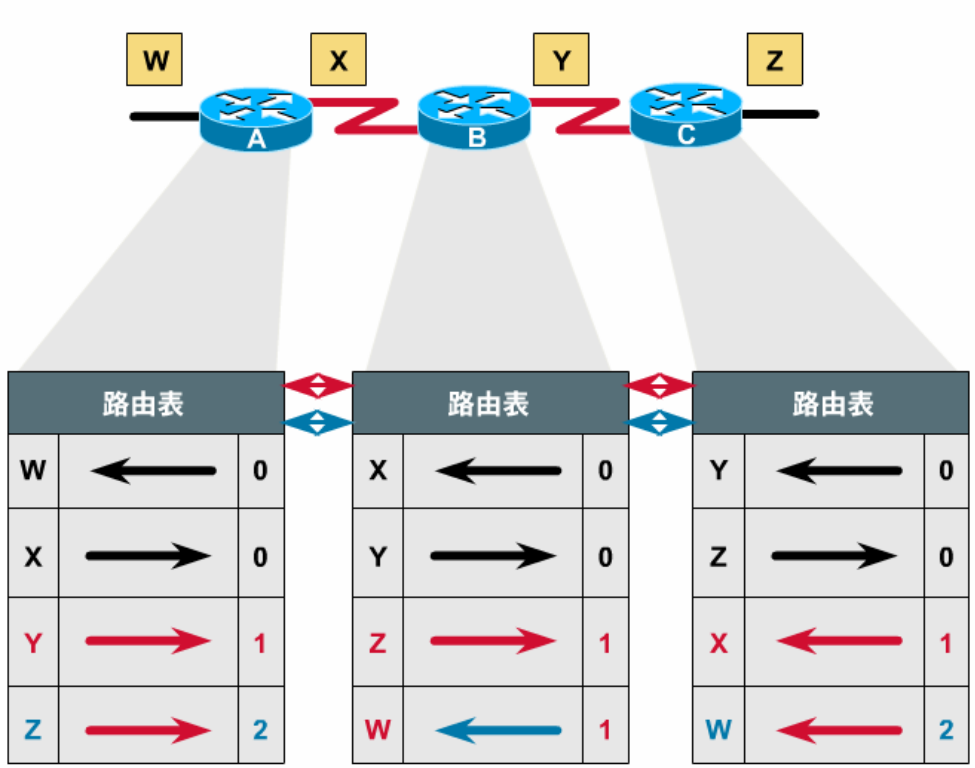
Category of Routing Protocols – by AS

- AS-AS communication
  - **Communications between routers in different AS**
  - **Interdomain routing protocols**
  - **Exterior gateway protocols (EGP)**
  - **Ex:**
    - BGP (Border Gateway Protocol)
- Inside AS communication
  - **Communication between routers in the same AS**
  - **Intradomain routing protocols**
  - **Interior gateway protocols (IGP)**
  - **Ex:**
    - RIP (Routing Information Protocol)
    - IGRP (Interior Gateway Routing Protocol)
    - OSPF (Open Shortest Path First Protocol)



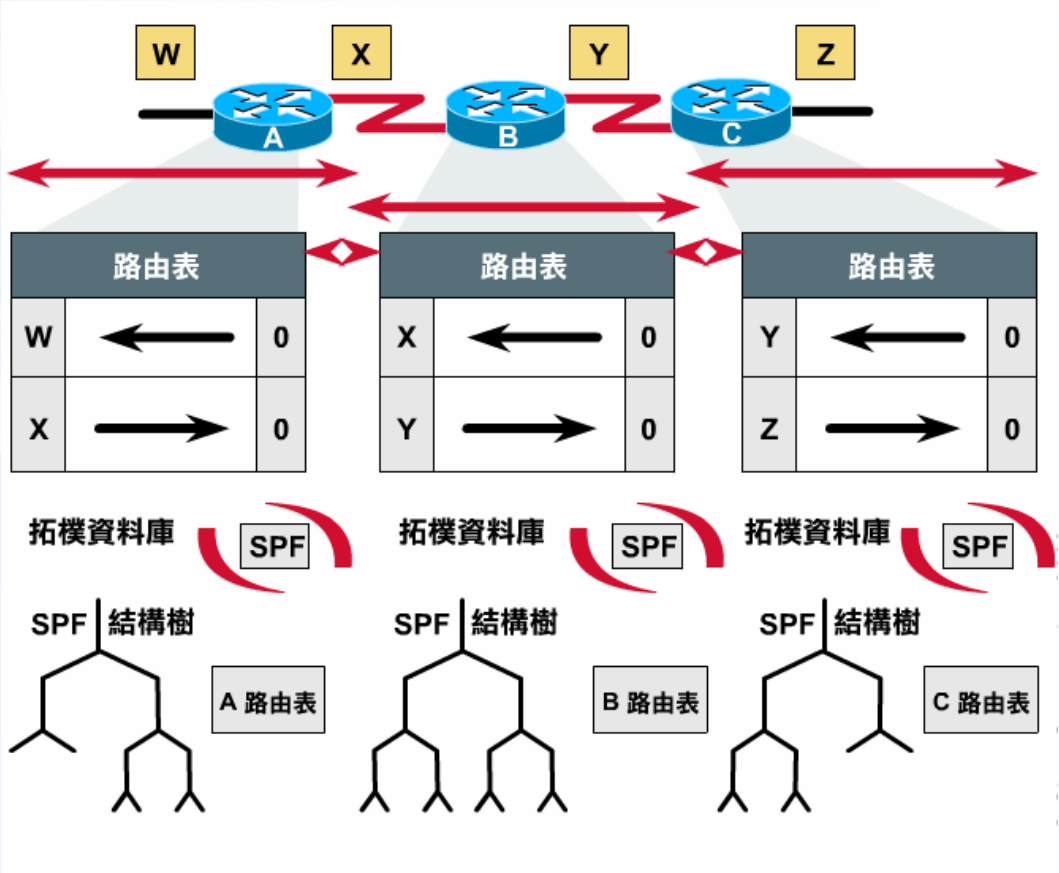
Category of Routing Protocols – by information changed (1)

- Distance-Vector Protocol
  - **Message contains a vector of distances, which is the cost to other network**
  - **Each router updates its routing table based on these messages received from neighbors**
  - **Protocols:**
    - RIP
    - IGRP
    - BGP



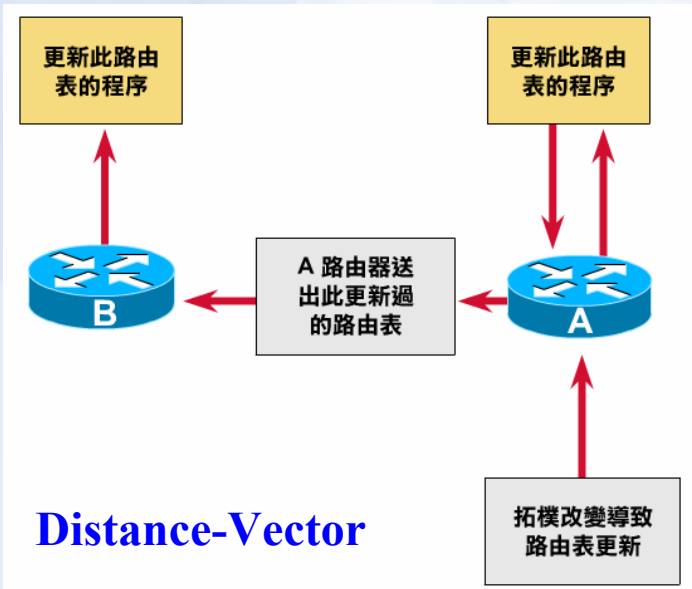
Category of Routing Protocols – by information changed (2)

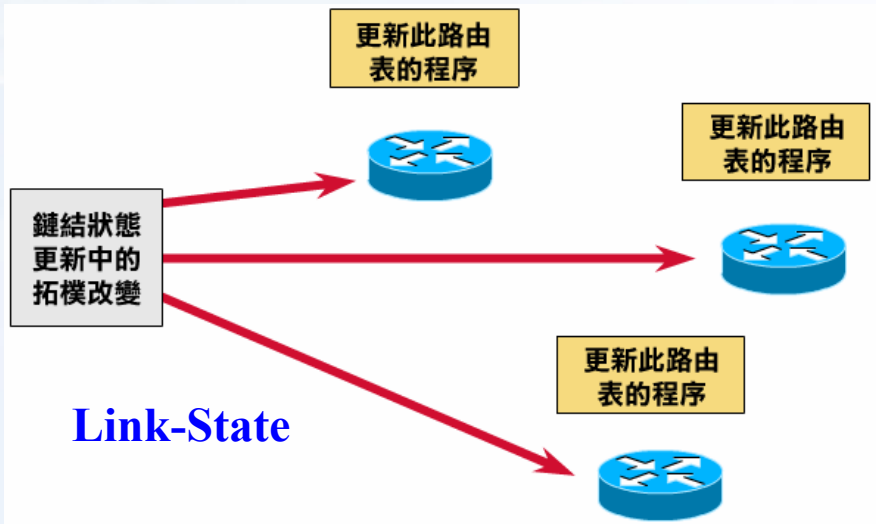
- Link-State Protocol
  - **Broadcast their link state to neighbors and build a complete network map at each router using Dijkstra algorithm**
  - **Protocols:**
    - OSPF



Difference between Distance-Vector and Link-State

- Update
  - Distance-Vector: updates neighbor (propagate new info.)
  - Link-State: update all nodes
- Convergence:
  - Distance-Vector: Propagation delay cause slow convergence
  - Link-State: Fast convergence
- Complexity:
  - Distance-Vector: simple
  - Link-State: complex
- Information update sequence





Routing Protocols

RIP	IGP, DV
IGRP	IGP, DV
OSPF	IGP, LS
BGP	EGP

RIP –
Routing Information Protocol

RIP (1)

- Category
  - **Interior routing protocol**
  - **Distance-vector routing protocol**
    - Using "hop-count" as the cost metric
- Example of how RIP advertisements work

Destination network	Next router	Number of hops to destination
1	A	2
20	B	2
30	B	7

Routing table in router before Receiving advertisement

Destination network	Next router	Number of hops to destination
30	C	4
1	--	1
10	--	1

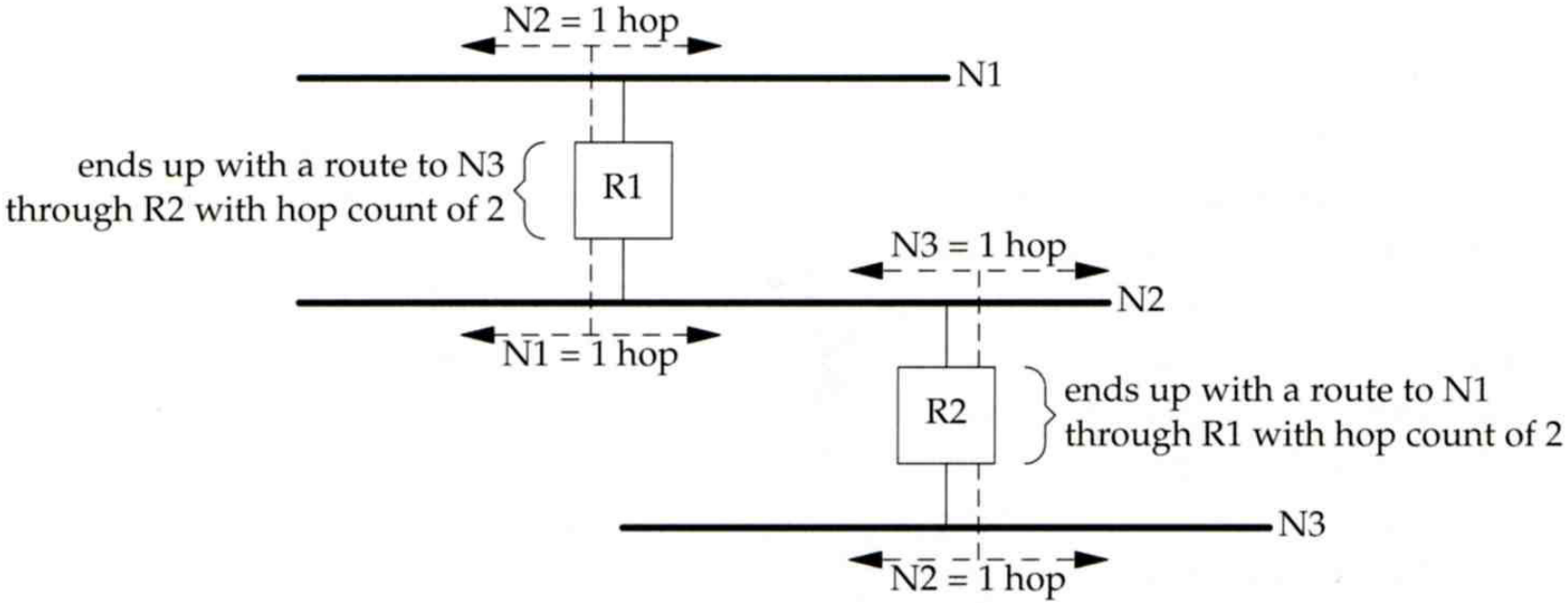
Advertisement from other router A

Destination network	Next router	Number of hops to destination
1	A	2
20	B	2
30	A	5

Routing table after receiving advertisement

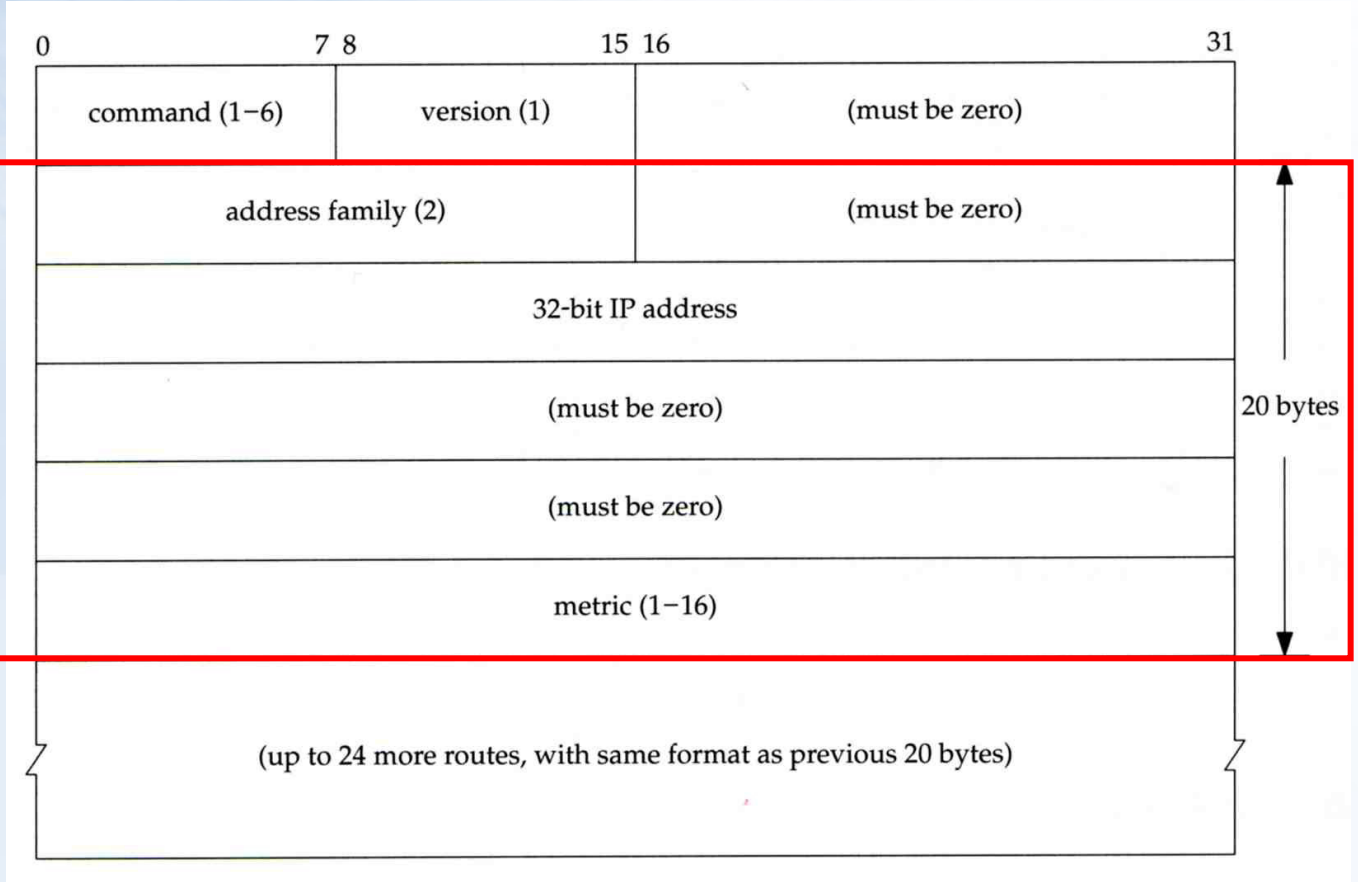
RIP (2)

> Another example



RIP Message Format

- RIP message is carried in UDP datagram
  - **Command: 1 for request and 2 for reply**
  - **Version: 1 or 2 (RIP-2)**

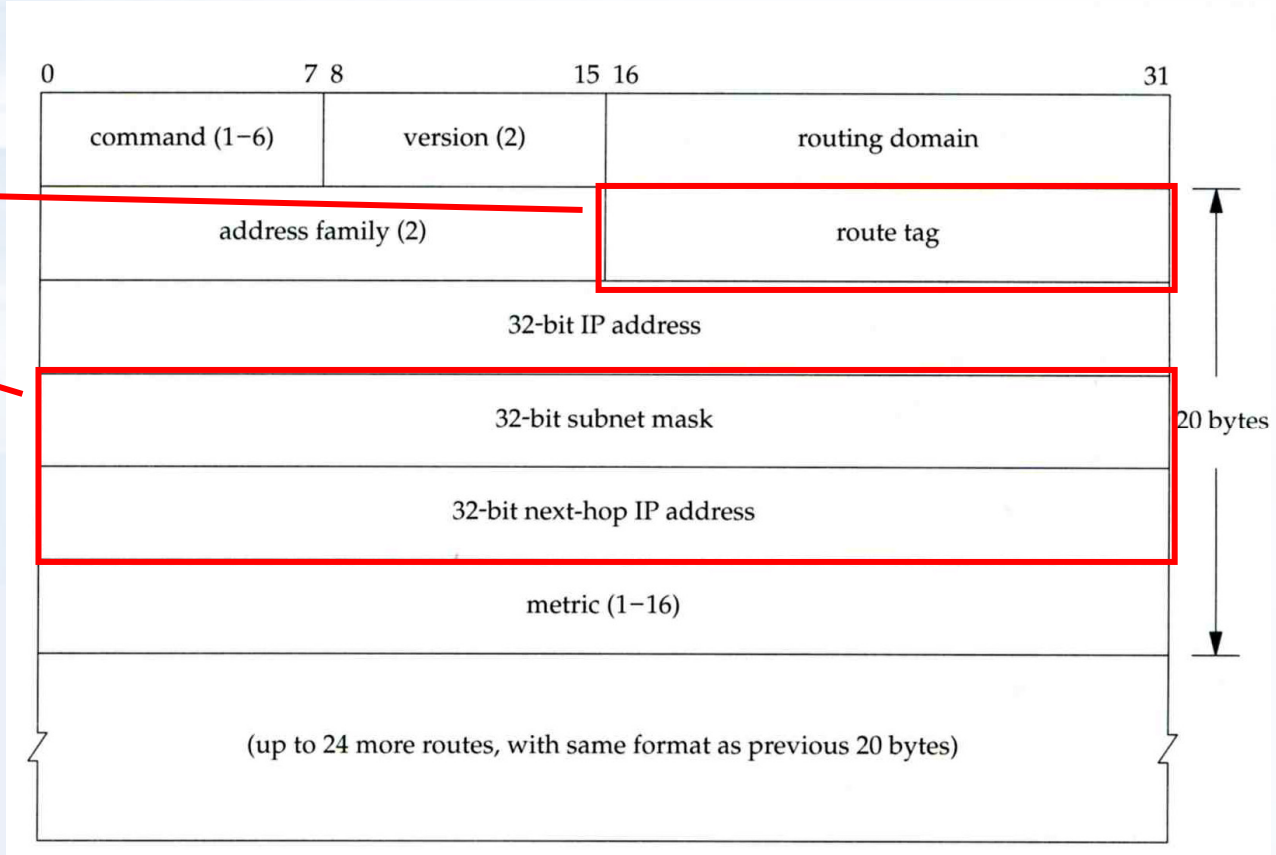


RIP Operation

- routed – RIP routing daemon
  - **Operated in UDP port 520**
- Operation
  - **Initialization**
    - Probe each interface
    - send a request packet out each interface, asking for other router's complete routing table
  - **Request received**
    - Send the entire routing table to the requestor
  - **Response received**
    - Add, modify, delete to update routing table
  - **Regular routing updates**
    - Router sends out their routing table to every neighbor every 30 minutes
  - **Triggered updates**
    - Whenever a route entry's metric change, send out those changed part routing table

Problems of RIP

- Issues
  - 15 hop-count limits
  - Take long time to stabilize after the failure of a router or link
  - No CIDR
- RIP-2
  - EGP support
    - AS number
  - CIDR support



IGRP –
Interior Gateway Routing Protocol

IGRP (1)

- Similar to RIP
  - **Interior routing protocol**
  - **Distance-vector routing protocol**
- Difference between RIP
  - **Complex cost metric other than hop count**
    - delay time, bandwidth, load, reliability
    - The formula

$$\left(\frac{bandwith\_weight}{bandwith*(1-load)}+\frac{delay\_weight}{delay}\right)*reliability$$

  - **Use TCP to communicate routing information**
  - **Cisco System's proprietary routing protocol**

IGRP (2)

- Advantage over RIP
  - **Control over metrics**
- Disadvantage
  - **Still classful and has propagation delay**

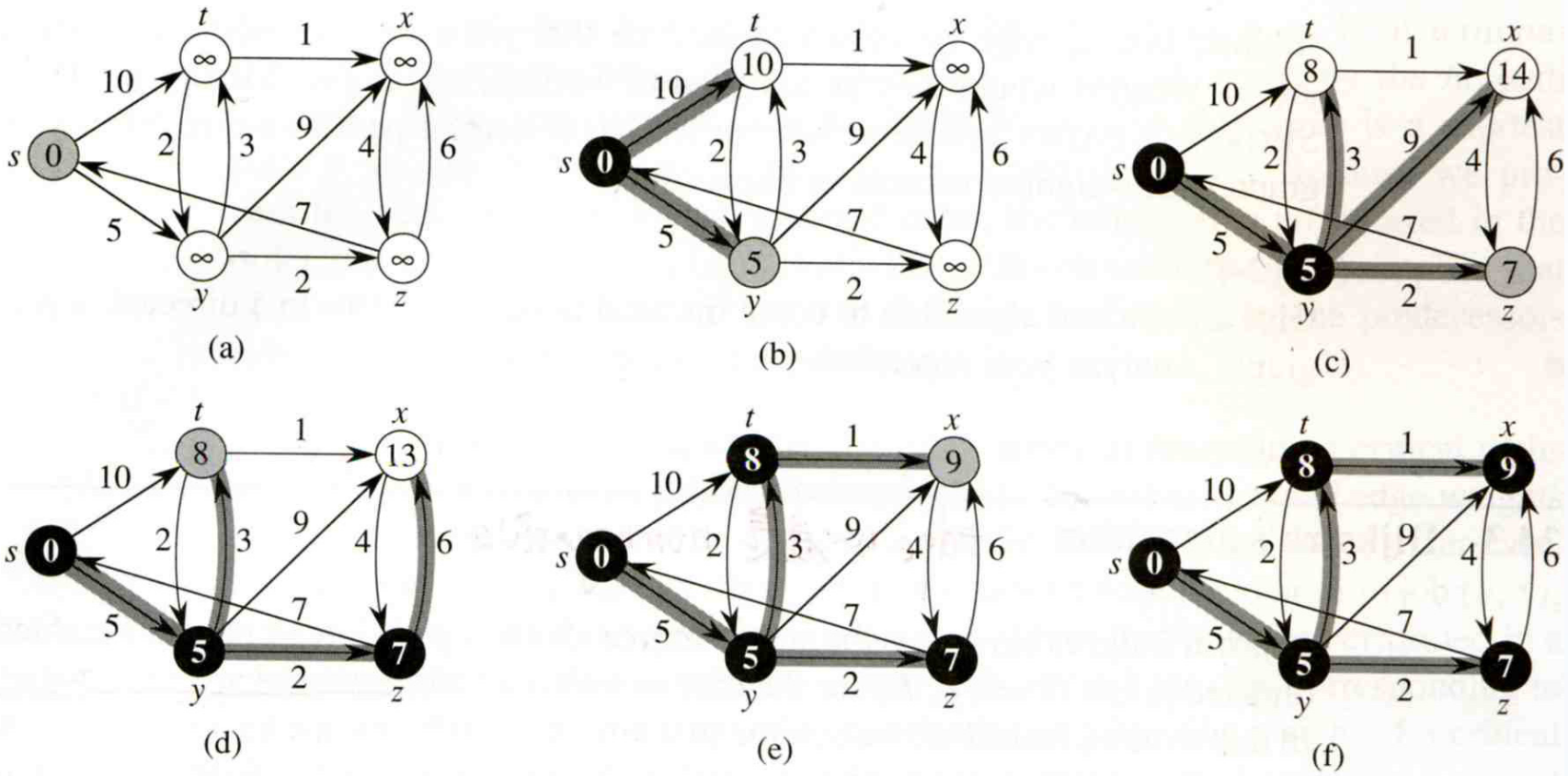
OSPF –
Open Shortest Path First

OSPF (1)

- Category
  - **Interior routing protocol**
  - **Link-State protocol**
- Each interface is associated with a cost
  - **Generally assigned manually**
  - **The sum of all costs along a path is the metric for that path**
- Neighbor information is broadcast to all routers
  - **Each router will construct a map of network topology**
  - **Each router run Dijkstra algorithm to construct the shortest path tree to each routers**

OSPF - Dijkstra Algorithm

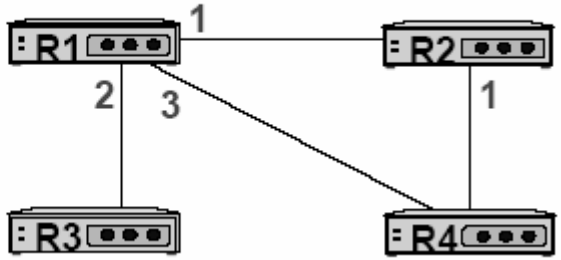
- Single Source Shortest Path Problem
  - **Dijkstra algorithm use "greedy" strategy**
  - **Ex:**



OSPF – Routing table update example (1)

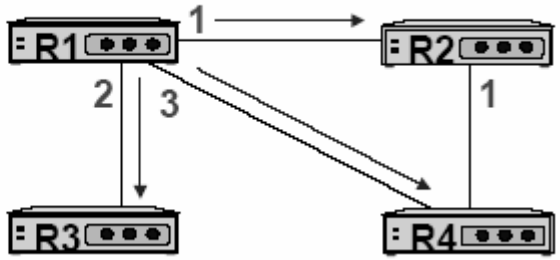
R1

D	Path	M
R1		
R2		
R3		
R4		



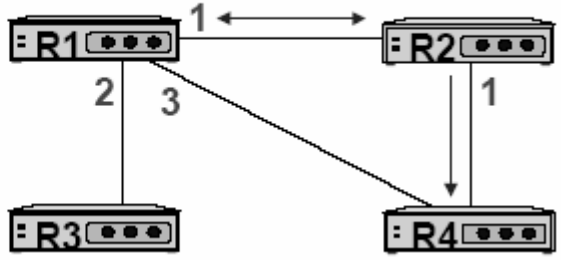
R1

D	Path	M
R1	direct	0
R2	*R1-R2*	*1*
R3	*R1-R3*	*2*
R4	*R1-R4*	*3*



R1

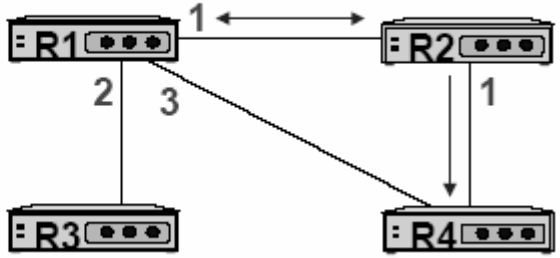
D	Path	M
R1	direct	0
R2	R1-R2	1
R3	*R1-R3*	*2*
R4	*R1-R4*	*3*



OSPF – Routing table update example (2)

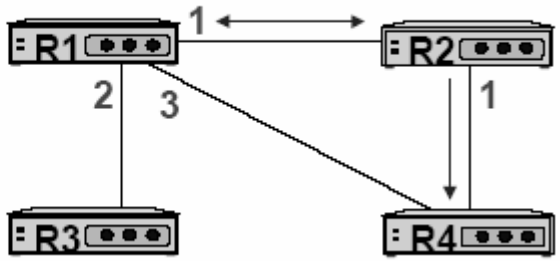
R1

D	Path	M
R1	direct	0
R2	R1-R2	1
R3	*R1-R3*	*2*
R4	*R1-R4*	*3*



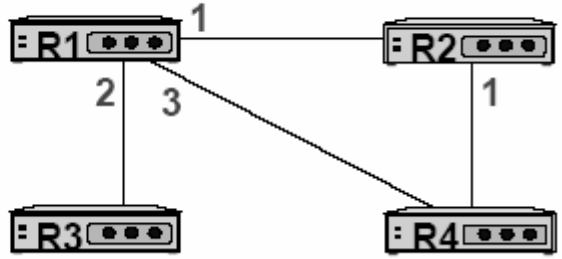
R1

D	Path	M
R1	direct	0
R2	R1-R2	1
R3	*R1-R3*	*2*
R4	*R1-R2-R4*	*2*



R1

D	Path	M
R1	direct	0
R2	R1-R2	1
R3	R1-R3	2
R4	R1-R2-R4	2



OSPF – summary

- Advantage
  - **Fast convergence**
  - **CIDR support**
  - **Multiple routing table entries for single destination, each for one type-of-service**
    - Load balancing when cost are equal among several routes
- Disadvantage
  - **Large computation**

BGP –
Border Gateway Protocol

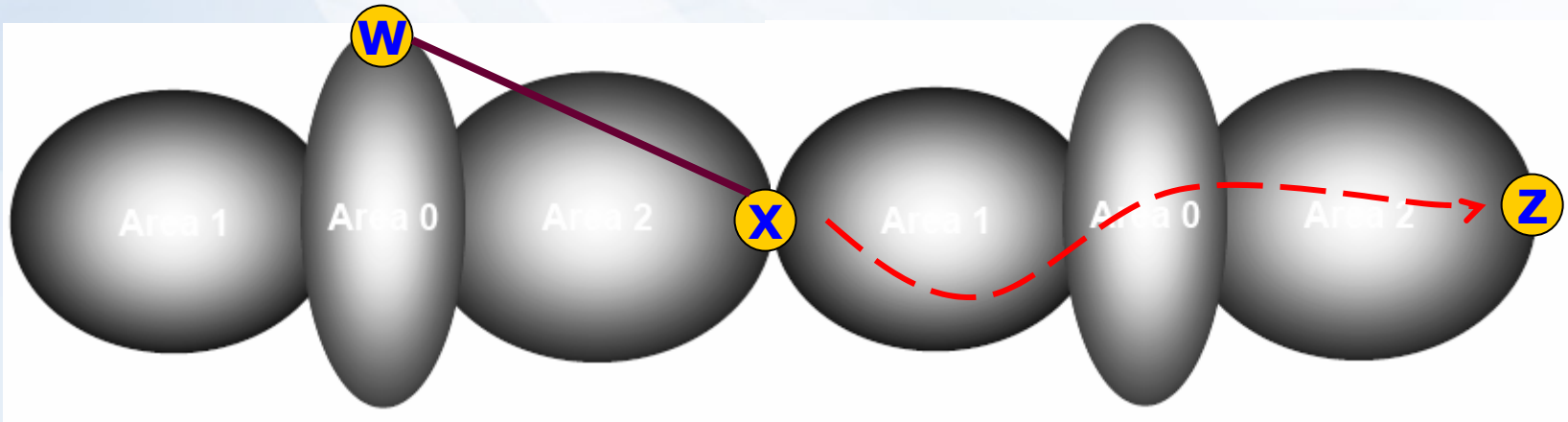
BGP

- Exterior routing protocol
  - **Now BGP-4**
  - **Exchange network reachability information with other BGP systems**
- Routing information exchange
  - **Message:**
    - Full path of autonomous systems that traffic must transit to reach destination
    - Can maintain multiple route for a single destination
  - **Exchange method**
    - Using TCP
    - Initial: entire routing table
    - Subsequent update: only sent when necessary
    - Advertise only optimal path
- Route selection
  - **Shortest AS path**

BGP
Operation example

> How BGP work

- **The whole Internet is a graph of autonomous systems**
- **X→Z**
  - Original: X→A→B→C→Z
  - X advertise this best path to his neighbor W
- **W→Z**
  - W→X→A→B→C→Z



Routing Protocols Comparison

	RIP	IGRP	OSPF	BGP4
DV or LS	DV	DV	LS	Path Vec
TCP/UDP & Port	U - 520	IP - 9	T - 89	T - 179
Classless	No	No	Yes	Yes
Updates	Per.	Per.	Both	Trig.
Load Balance	No	Yes	Yes	No
Internal / External	Int.	Int.	Int.	Ext.
Metric	Hop Count	Load Errors Delay Bdwth	Sum of Int. Cost	Short. AS Path

routed and gated

routed

- Routing daemon
  - **Speak RIP (v1 and v2)**
  - **Supplied with most every version of UNIX**
  - **Two modes**
    - Server mode (-s) & Quiet mode (-q)
    - Both listen for broadcast, but server will distribute their information
  - **routed will add its discovered routes to kernel's routing table**
  - **Support configuration file - /etc/gateways**
    - Provide static information for initial routing table

```
net Nname[/mask] gateway Gname metric value <passive | active | extern>

host Hname gateway Gname metric value <passive | active | extern>
```

gated (1)

- Development
  - **Originally coordinated by Cornell University**
  - **Turn over to the Merit GateD Consortium in 1992**
    - Free for academic users with license agreement
- Supported routing protocols
  - **Both interior and exterior, including**
    - RIP (v1, v2), OSPF, BGP, IS-IS, EGP
  - **It can share routes among different protocols**
- Configuration file
  - **/etc/gated.conf**
- Runtime manipulation command
  - **gdc**

gated (2)

- % gdc "command"
  - **interface**
    - Force gated to re-check the list of active NICs
  - **reconfig**
    - Force gated to re-read gated.conf
  - **checkconf**
    - Parse and check syntax of gated.conf
  - **toggletrace {all|normal|policy|route|general}**
    - Start or stop logging
  - **stop | start | restart**

gated (3)

- /etc/gated.conf
  - **Statements separated by semicolons**
- Class of statements:
  - **Option**
  - **Network interface definition**
  - **Configuration of individual protocols**
  - **Static routes**