Routing

wangth (2018-2021, CC BY-SA)
? (2009-2017)

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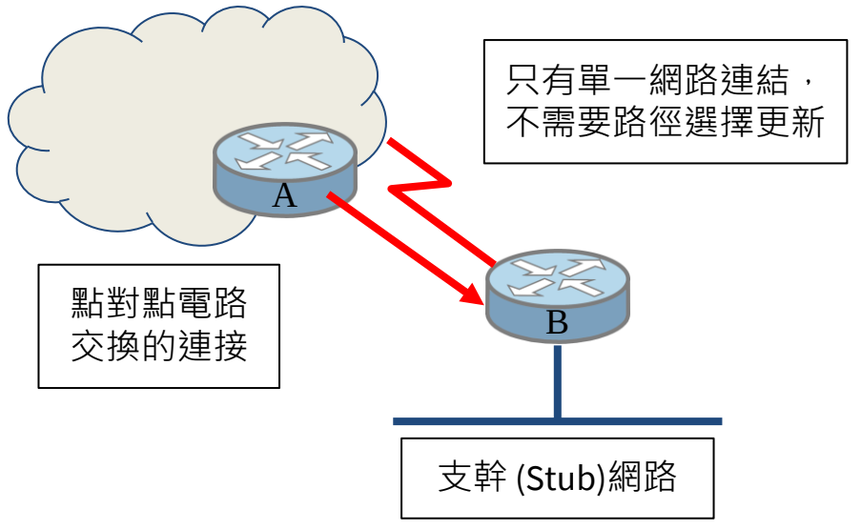
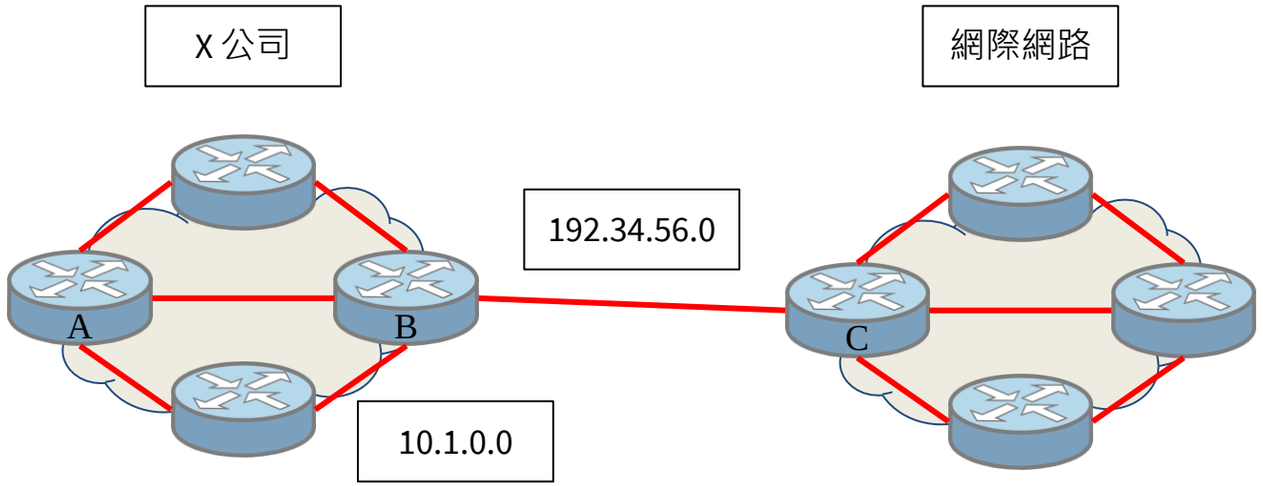
Why dynamic route ? (1)

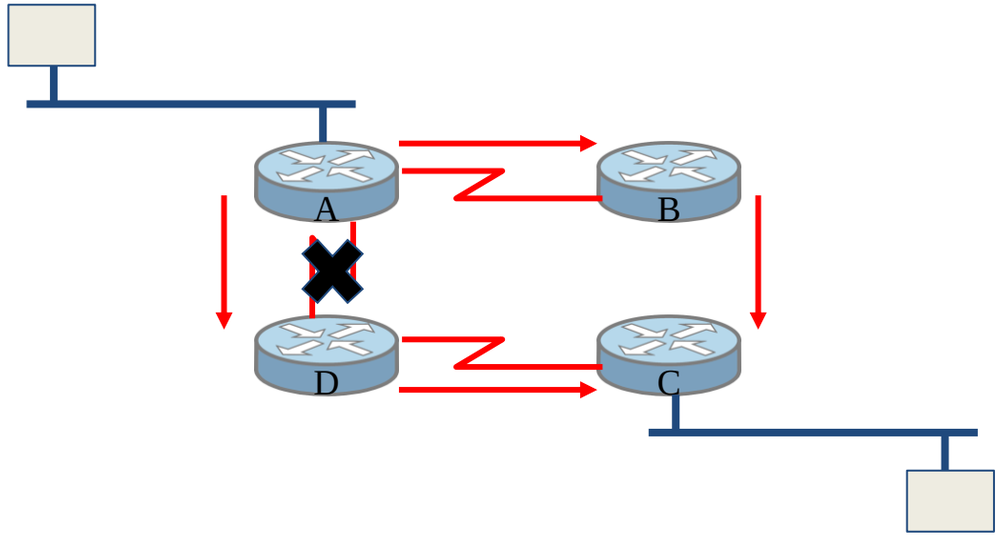
- Static route is ok only when
  - Network is small
  - There is a single connection point to other network
  - No redundant route





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

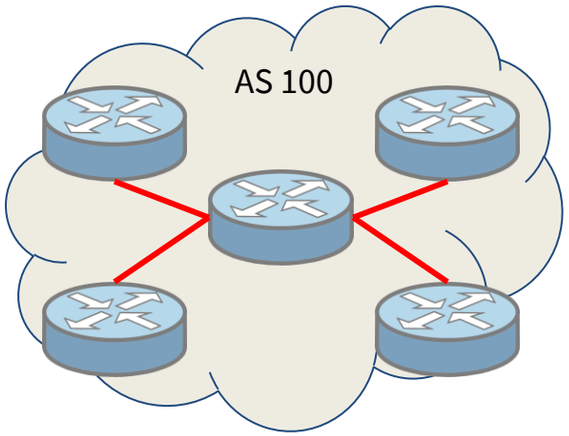


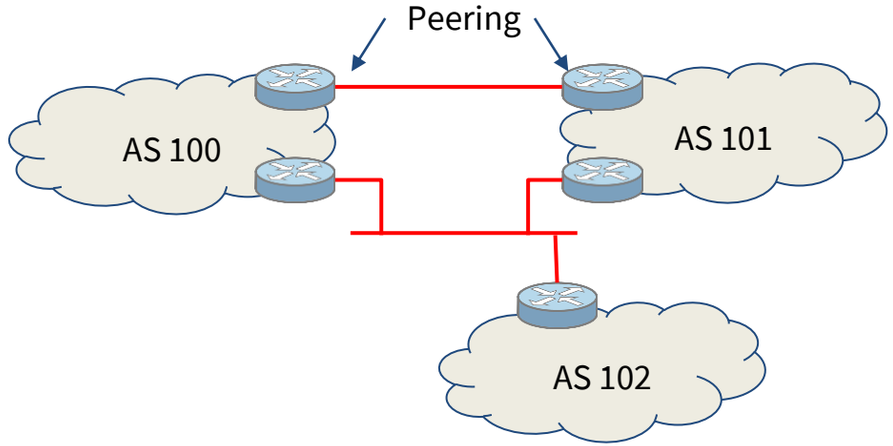
Routing Protocol

- 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

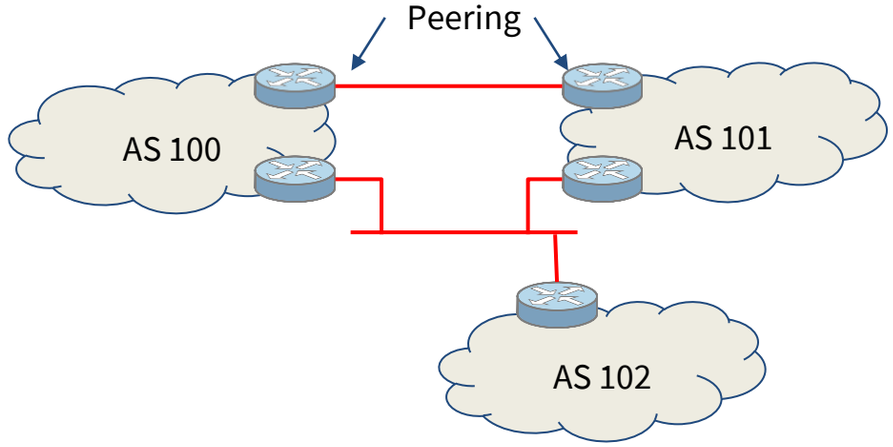
- Autonomous System (AS)
  - Internet is organized into a collection of autonomous system
  - An AS is a collection of networks with same routing policy
    - Single routing protocol
    - Normally administered by a single entity
      - Corporation or university campus
    - All depend on how you want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



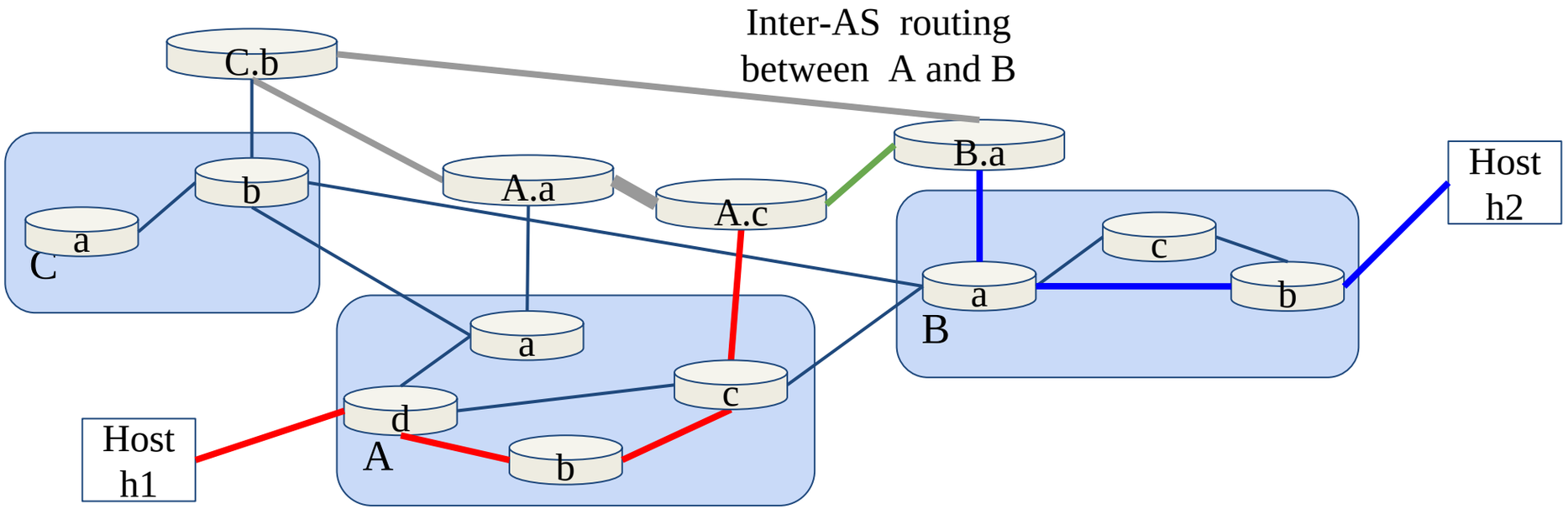


Category of Routing Protocols – by AS

- 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)

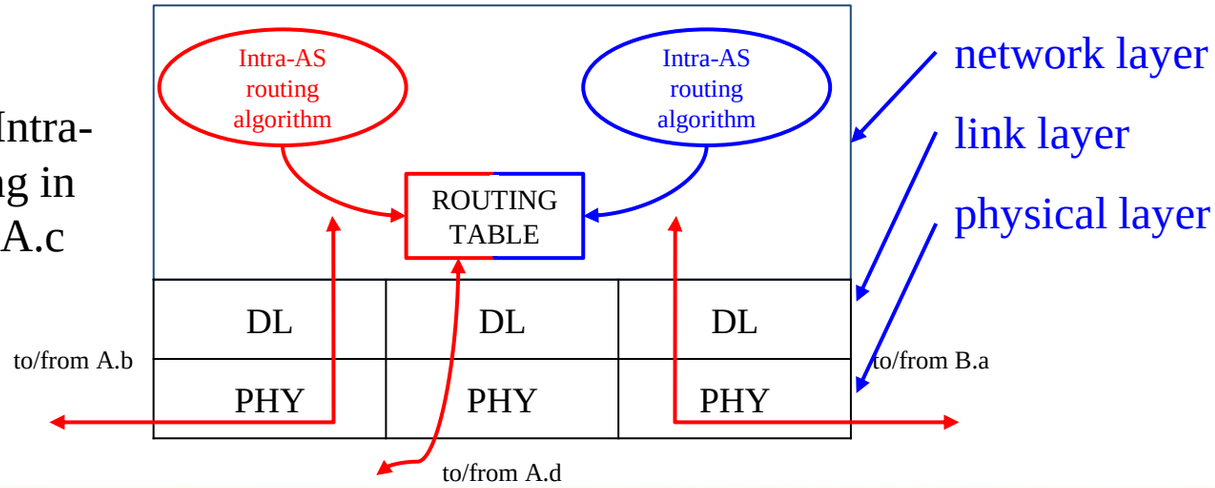


Intra-AS and Inter-AS routing



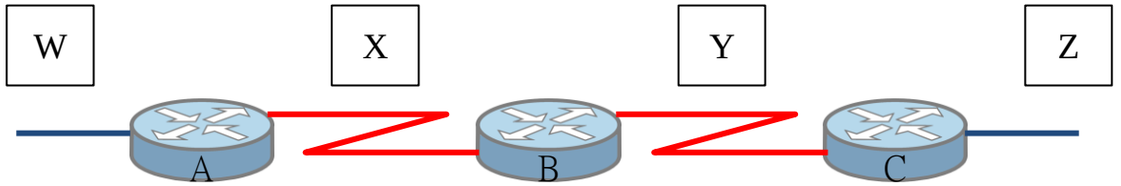
Intra-AS routing
within AS A

Inter-AS, Intra-
AS routing in
gateway A.c



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



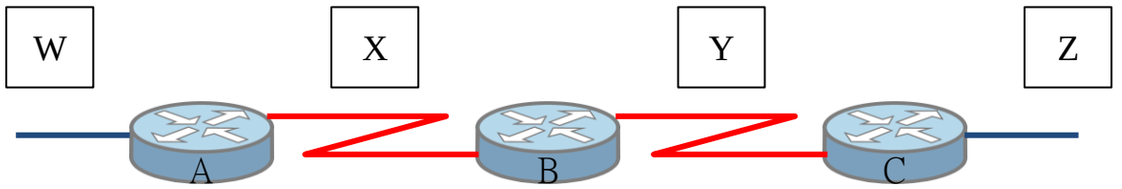
Routing Table of A		
W	←	0
X	→	0
Y	→	1
Z	→	2

Routing Table of B		
X	←	0
Y	→	0
Z	→	1
W	←	1

Routing Table of C		
Y	←	0
Z	→	0
W	←	1
W	←	1

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
  - Protocol
    - OSPF

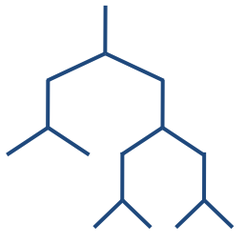


Routing Table of A		
W	←	**0**
X	→	**0**

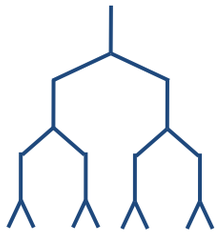
Routing Table of B		
X	←	**0**
Y	→	**0**

Routing Table of C		
Y	←	**0**
Z	→	**0**

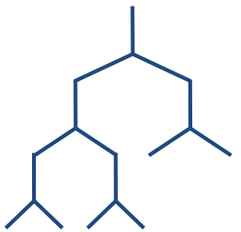
SPF 結構樹



SPF 結構樹



SPF 結構樹

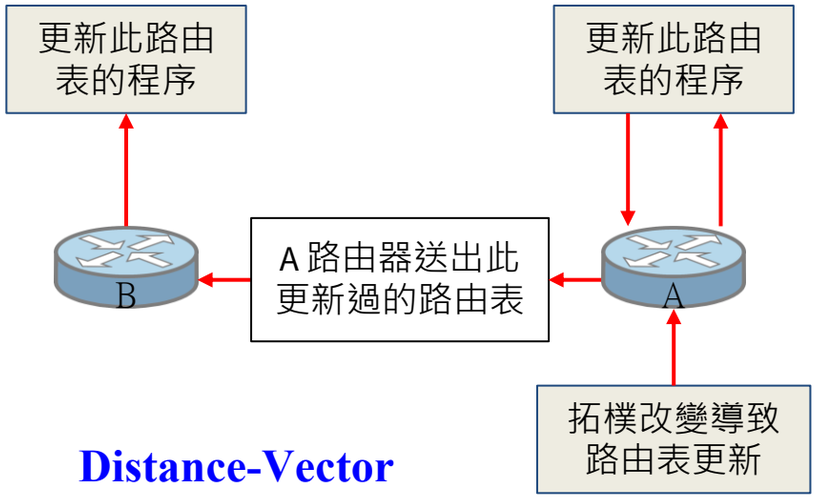


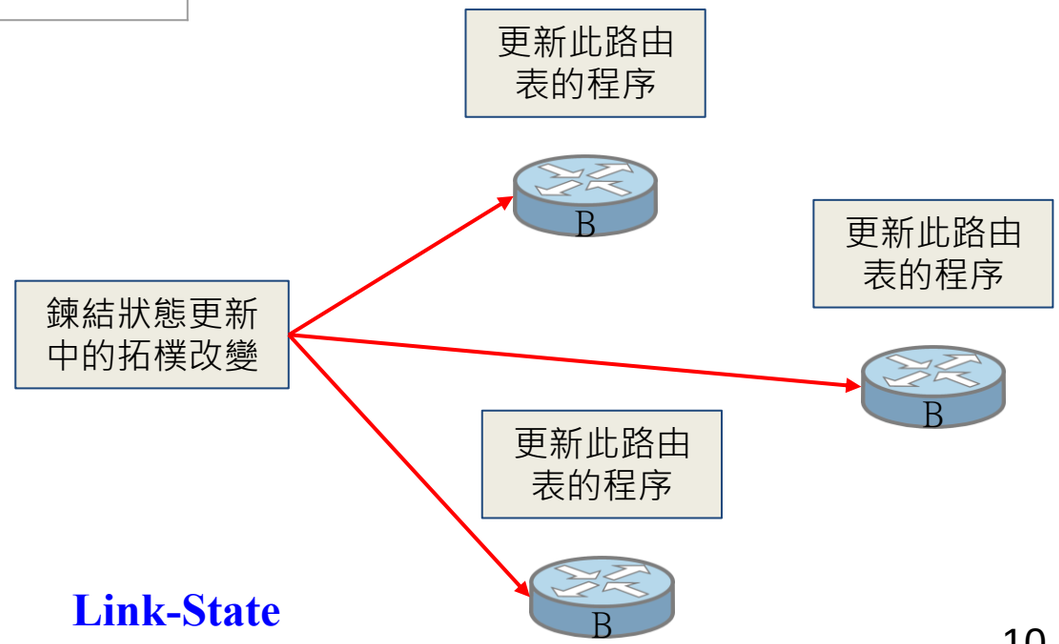
Difference between Distance-Vector and Link-State

- Difference

	Distance-Vector	Link-State
Update	Updates neighbor (propagate new info.)	Update all nodes
Convergence	Propagation delay cause slow convergence	Fast convergence
Complexity	Simple	Complex

- Information update sequence





Routing Protocols

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

RIP

- RIP
  - Routing Information Protocol
- 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	# of hops to destination
1	A	2
20	B	2
30	B	7

Routing table in router before Receiving advertisement

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

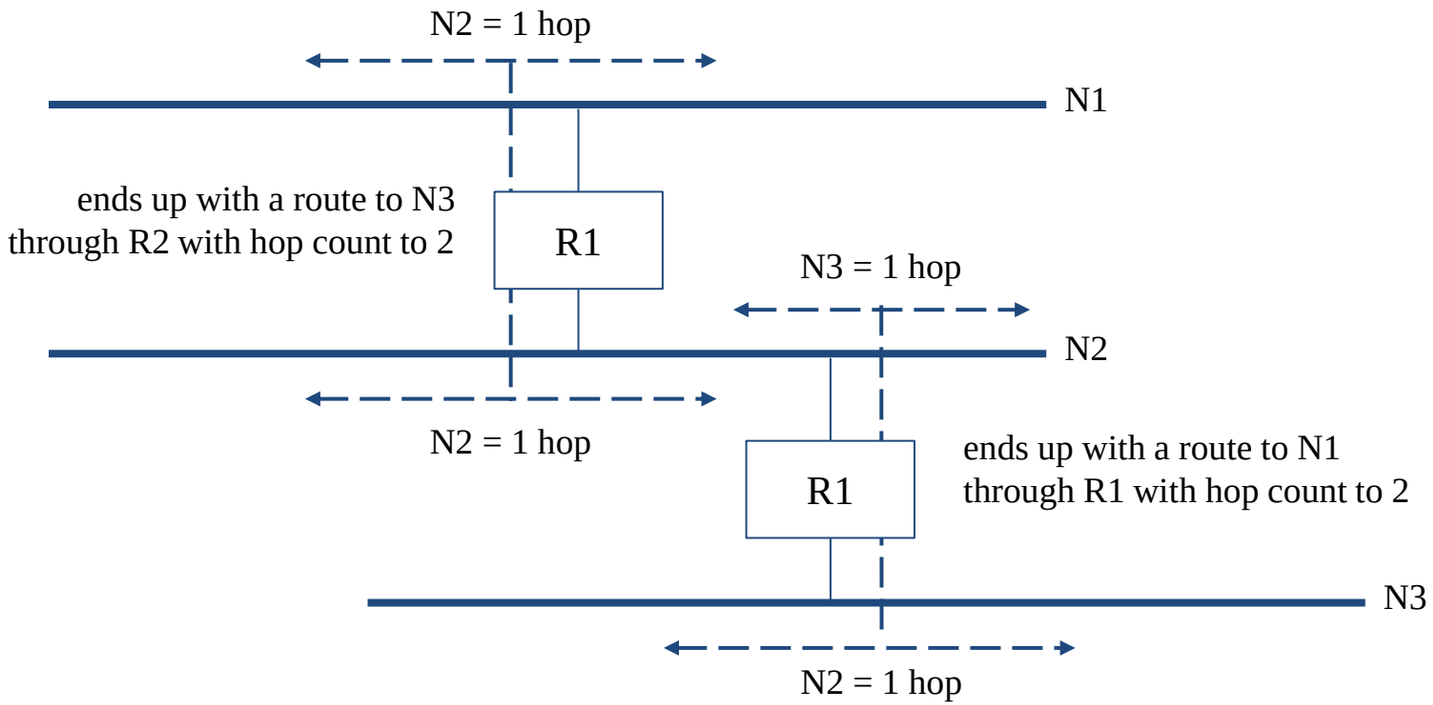
Advertisement from router A

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

Routing table after receiving advertisement

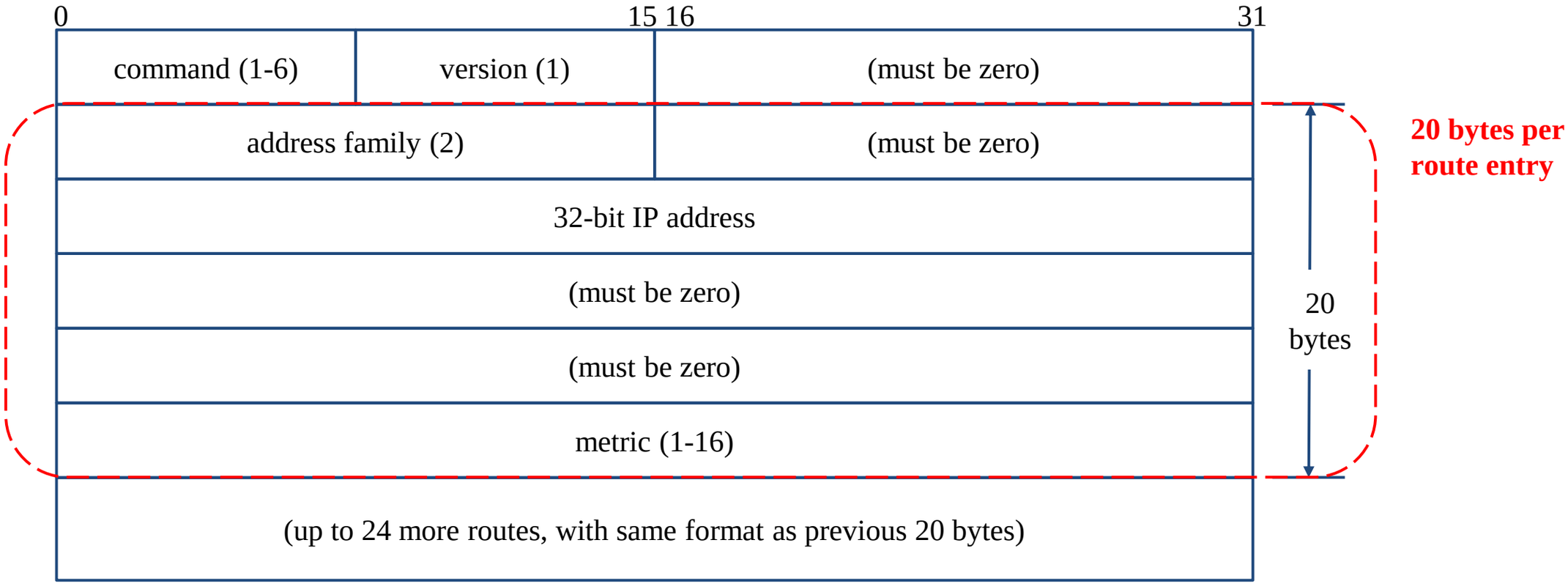
RIP - Example

- 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)

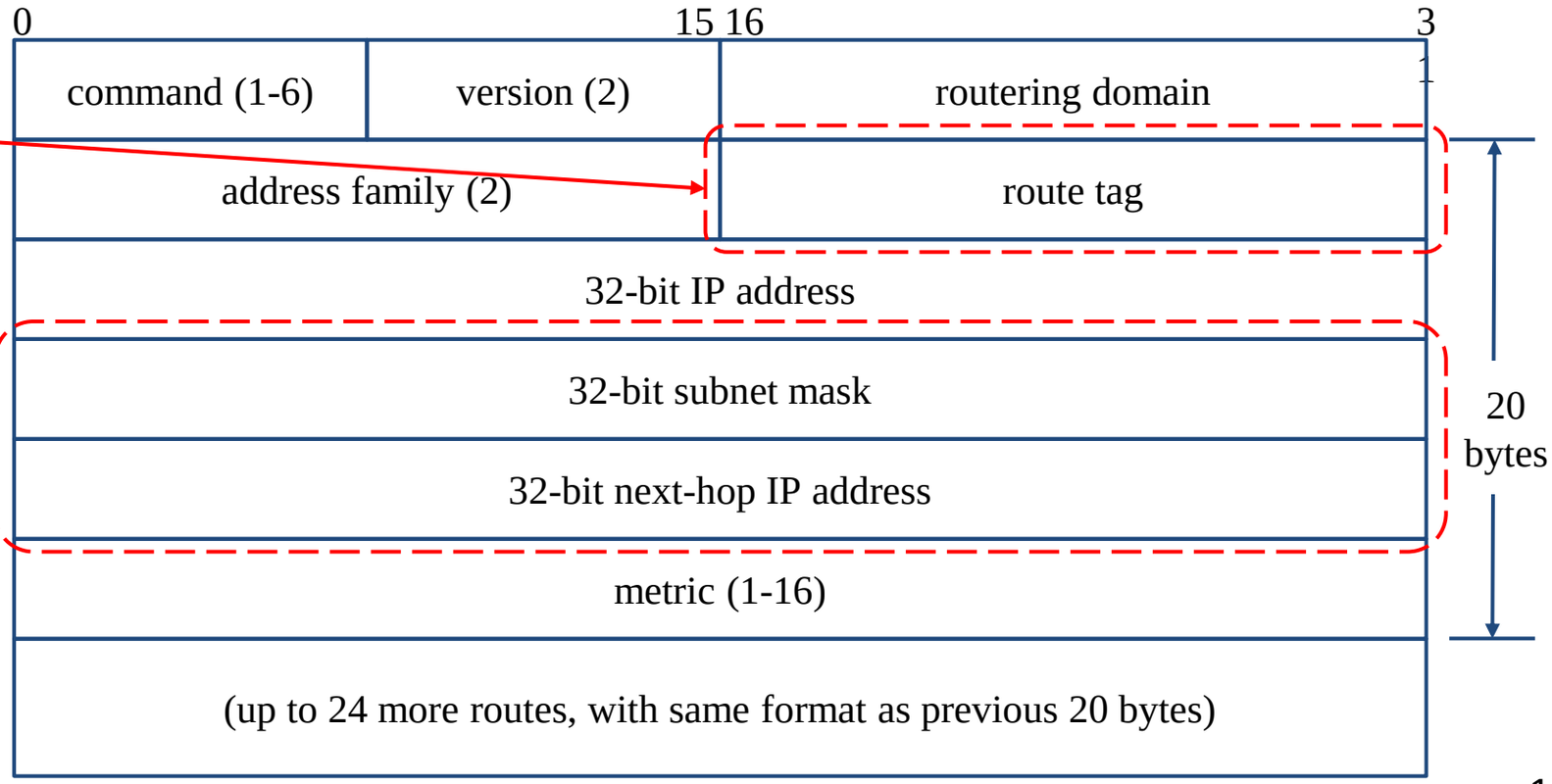


RIP – Operation

- 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 seconds
  - Triggered updates
    - Whenever a route entry's metric change, send out those changed part routing table

RIP – 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 (1)

- IGRP – Interior Gateway Routing Protocol
- 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

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

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

IGRP (2)

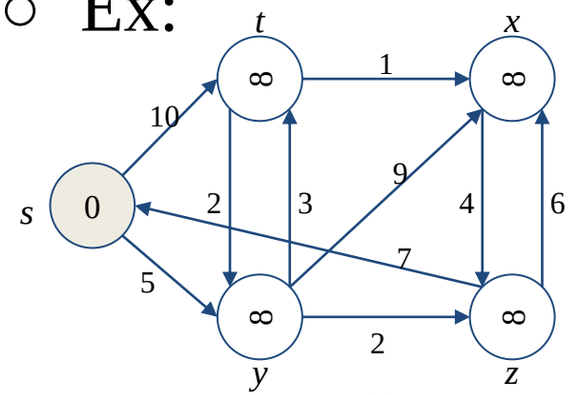
- Advantage over RIP
  - Control over metrics
- Disadvantage
  - Still classful and has propagation delay

OSPF (1)

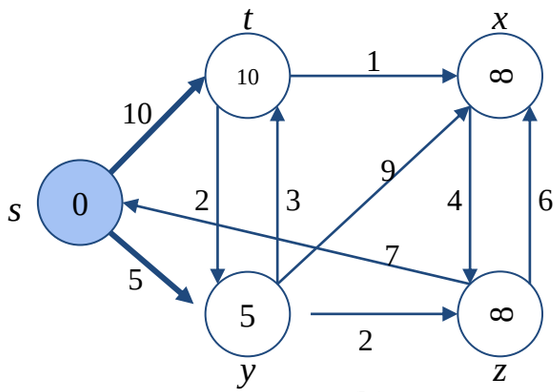
- OSPF
  - Open Shortest Path First
- Category
  - Interior routing protocol
  - Link-State protocol
- Each interface is associated with a cost
  - Generally assigned manually
  - The sum of all costs along a path is the metric for that path
- Neighbor information is broadcast to all routers
  - Each 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:



(a)



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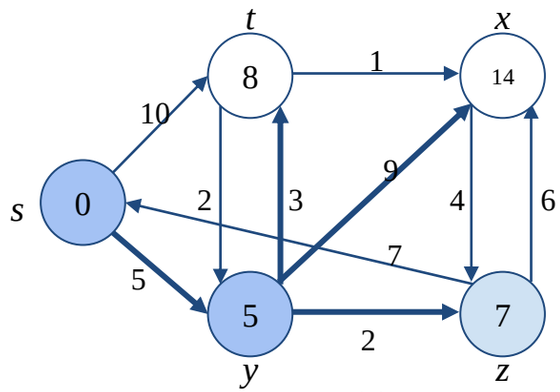
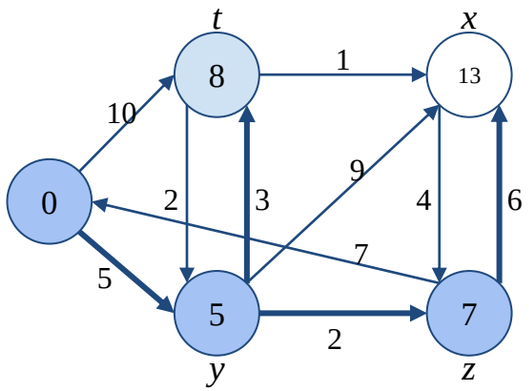
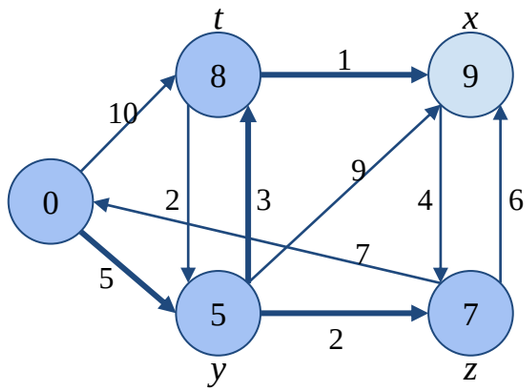


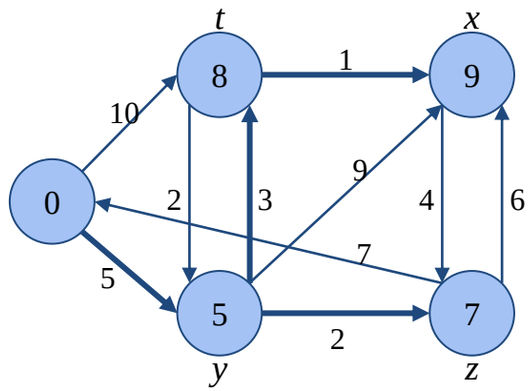
(c)



(d)



(e)

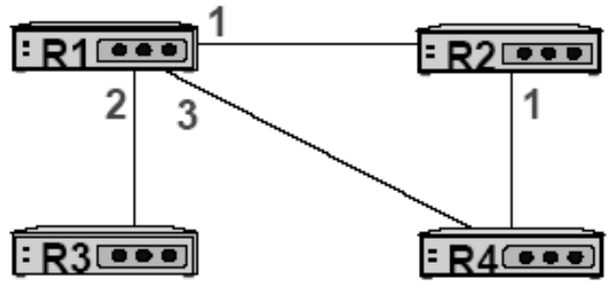


(f)

OSPF – Routing table update example (1)

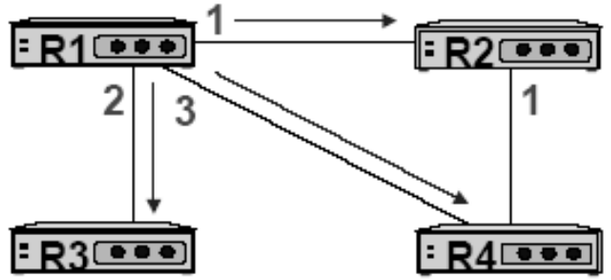
R1

D	Path	M
R1		
R2		
R3		
R4		



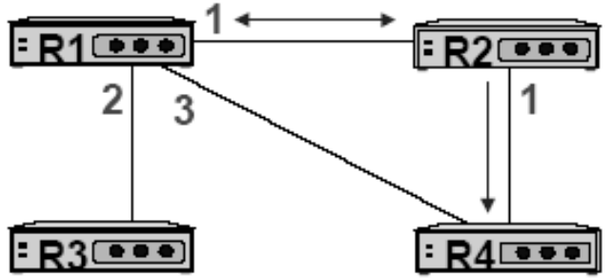
R1

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



R1

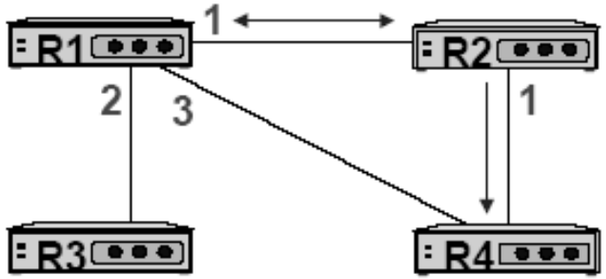
D	Path	M
R1	direct	0
R2	R1-R2	1
R3	*R1-R3*	*2*
R4	*R1-R4*	*3*



OSPF – Routing table update example (2)

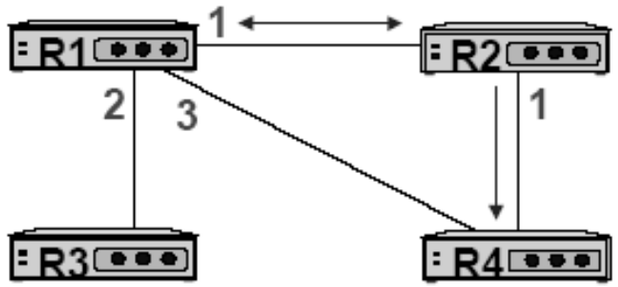
R1

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



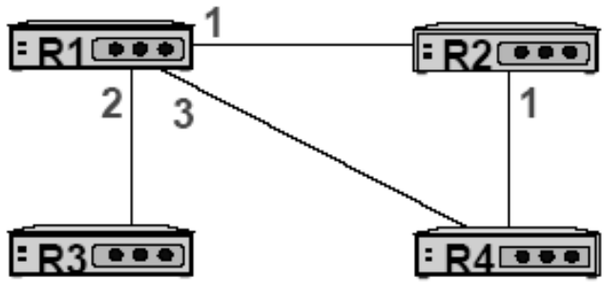
R1

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

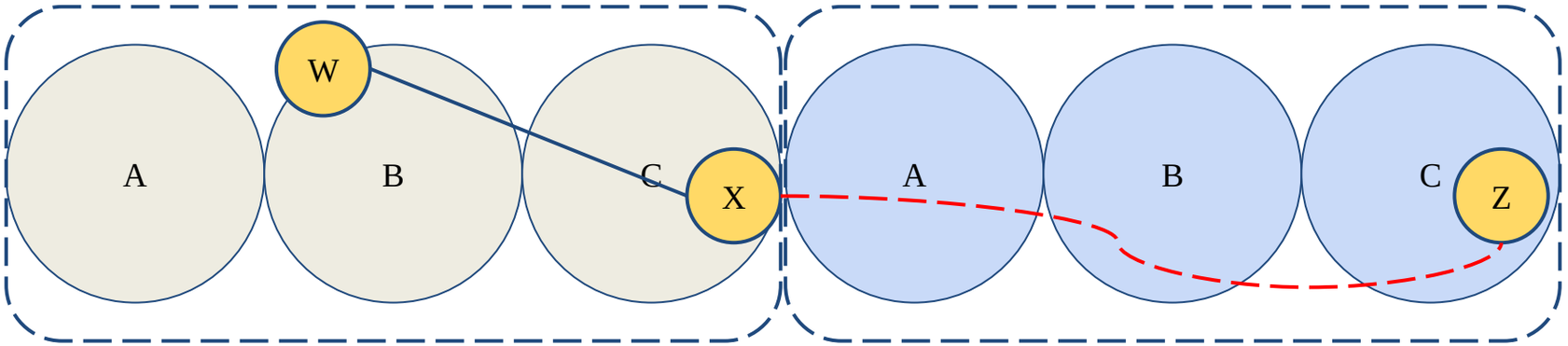
- Advantage
  - Fast convergence
  - CIDR support
  - Multiple routing table entries for single destination, each for one type-of-service
    - Load balancing when cost are equal among several routes
- Disadvantage
  - Large computation

BGP

- BGP
  - Border Gateway Protocol
- 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 Bandwidth	Sum of Int. Cost	Short. AS Path

routed

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