ECE453 – Introduction to Computer Networks

Lecture 10 – Network Layer (Routing II)

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Hierarchical Routing

- Problem with maintaining one routing table
  - ???
- Administrative autonomy
  - Autonomous System (AS)
  - routers in same AS run same routing protocol - "intra-AS" routing protocol (intra-domain routing)
  - routers in different AS can run different intra-AS routing protocol – "inter-AS" routing (inter-domain routing)

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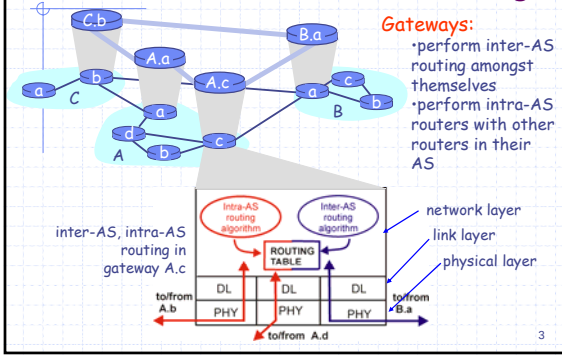
Intra-AS and Inter-AS Routing



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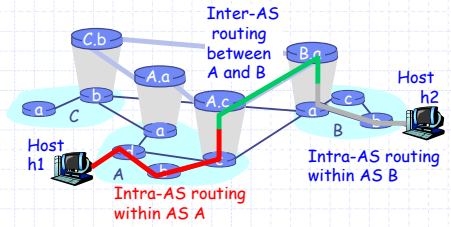
Intra-AS and Inter-AS Routing



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Routing in the Internet

- The Global Internet consists of Autonomous Systems (AS) interconnected with each other:
  - **Stub AS**: small corporation
  - **Multihomed AS**: large corporation (no transit)
  - **Transit AS**: provider (ISP)
- Two-level routing:
  - **Intra-AS:** administrator is responsible for choice
  - **Inter-AS:** unique standard

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Intra-AS Routing

- Also known as Interior Gateway Protocols (IGP)
- Most common IGPs:
  - RIP: Routing Information Protocol (distance vector) – RIP v2
  - OSPF: Open Shortest Path First (link state) – OSPF v2

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RIP (Routing Information Protocol)

- Distance vector algorithm
- Included in BSD-UNIX Distribution in 1982
  - Originate from Xerox Network System (XNS)
- Distance metric: # of hops (max = 15 hops)
  - Use # of hops as the link cost
- Distance vectors: exchanged every 30 sec via Response Message (also called **advertisement**), is actually the routing table
- Each advertisement: route to up to 25 destination nets

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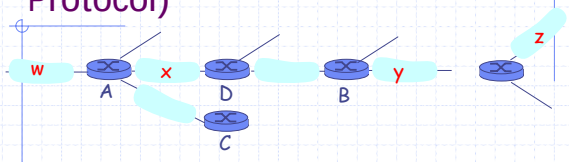
RIP (Routing Information Protocol)



Destination Network	Next Router	Num. of hops to dest.
w	A	2
y	B	2
z	B	7
x	--	1
....	....	....

Routing table in D

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RIP: Link Failure and Recovery

If no advertisement heard after 180 sec --> neighbor/link declared dead

- routes via neighbor invalidated
- new advertisements sent to neighbors
- neighbors in turn send out new advertisements (if tables changed)
- link failure info quickly propagates to entire net

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RIP Table Example

Router: *giroflee.eurocom.fr*

Destination	Gateway	Flags	Ref	Use	Interface
127.0.0.1	127.0.0.1	UH	0	26492	lo0
192.168.2.	192.168.2.5	U	2	13	fa0
193.55.114.	193.55.114.6	U	3	58503	le0
192.168.3.	192.168.3.5	U	2	25	qaa0
224.0.0.0	193.55.114.6	U	3	0	le0
default	193.55.114.129	UG	0	143454	

Three attached class C networks (LANs)
Router only knows routes to attached LANs
Default router used to "go up"
Route multicast address: 224.0.0.0
Loopback interface (for debugging)

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OSPF (Open Shortest Path First)

- "open": publicly available
- Uses Link State algorithm
  - LS packet dissemination
  - Topology map at each node
  - Route computation using Dijkstra's algorithm
- Advertisements disseminated to entire AS (via flooding)
- Run on top of IP and send out through raw socket

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OSPF "Advanced" Features (not in RIP)

- Security: all OSPF messages authenticated (to prevent malicious intrusion) – over IP
- Multiple same-cost paths allowed (only one path in RIP) – traffic load balancing
- Hierarchical OSPF in large domains (RIP doesn't support hierarchical routing.)

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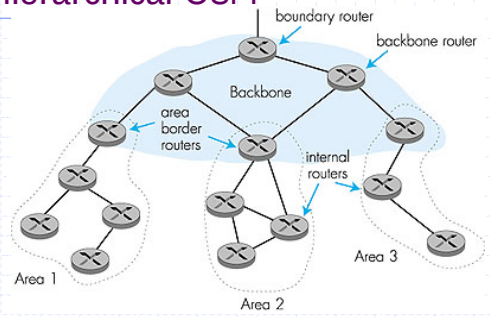
Hierarchical OSPF



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Hierarchical OSPF

- Two-level hierarchy: local area, backbone
  - Link-state advertisements only within area
  - each nodes has detailed area topology; only know direction (shortest path) to nets in other areas
- **Area border routers:** "summarize" distances to nets in own area, advertise to other Area Border routers
- **Backbone routers:** run OSPF routing limited to backbone
- **Boundary routers:** connect to other AS's

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3-Phase Routing Database Synchronization Procedure

- Hello Phase – each router establishes neighbor relationship by saying "I am here"
- DB Exchange Phase: each router tells its neighbors about his knowledge on the "partial maps"
- Flooding Phase: each router will flood the new information it receives on the "partial maps" from others

the process will cease after DB is synchronized

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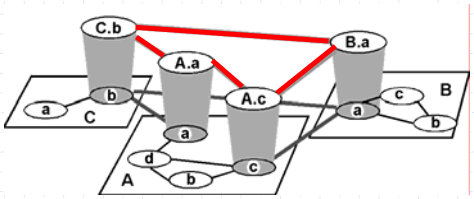
Inter-AS Routing



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Internet Inter-AS routing: BGP

- BGP (Border Gateway Protocol): *the* de facto standard, the current version is 4, known as BGP4
- **Path Vector** protocol:
  - similar to Distance Vector protocol
  - each Border Gateway broadcasts to neighbors (peers) *entire path* (I.e, sequence of ASs) to destination
  - E.g., Gateway X may send its path to dest. Z:

Path (X,Z) = X,Y1,Y2,Y3,...,Z

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