Computer Networks

Intra-AS Routing

RIP and OSPF

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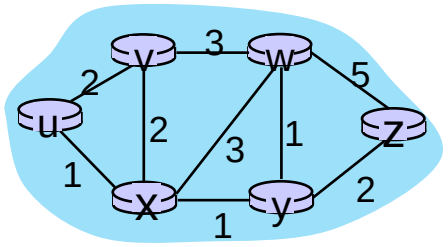
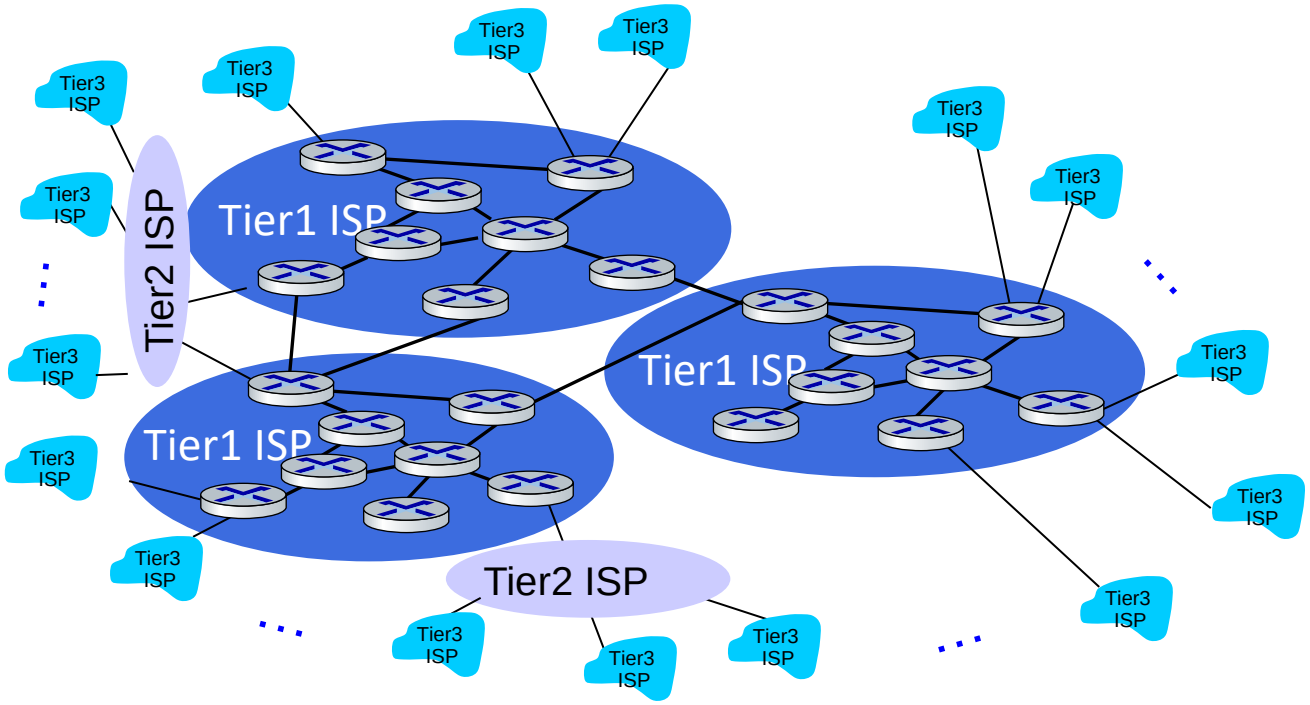


Making Routing Scalable

Routing studied thus far - idealized

- All routers identical
- Network “flat”
- This is not true in practice



Scale: billions of destinations:

- Can’t store all destinations in routing tables
- Routing table exchange would swamp links

Administrative autonomy:

- Internet: a network of networks
- Each network admin may want to control routing in its own network

Internet Approach to Scalable Routing

Autonomous systems (AS) (a.k.a. “domains”): group of routers controlled by a single administrative entity, i.e. an ISP, a company, a university

Intra-AS (aka “intra-domain”):
routing within an AS (“network”)

- All routers in AS must run same intra-domain protocol
- Routers in different AS can run different intra-domain routing protocols
- Gateway router: at “edge” of its own AS, has link(s) to router(s) in other AS’es
- Also called Interior Gateway Protocol

Inter-AS (aka “inter-domain”):
routing among AS’es

- Gateways perform inter-domain routing (as well as intra-domain routing)
- Also called Exterior Gateway Protocol

Uniform Routing Protocol: Within an AS, all routers must run the same intra-domain routing protocol. This is necessary for consistent and efficient data routing within the AS. Examples of intra-domain routing protocols include OSPF (Open Shortest Path First) and RIP (Routing Information Protocol).

Inter-AS Independence: Routers in different ASes can run different intra-domain routing protocols. This means that each AS can choose a routing protocol that best fits its internal network design and requirements without affecting how other ASes operate.

Gateway Routers: These are special routers located at the edge of their own AS. They have links to routers in other ASes, acting as a point of interaction between different ASes. Gateway routers handle the task of routing data between ASes using inter-domain routing protocols like BGP (Border Gateway Protocol).

Interior Gateway Protocols (IGP): This term is another name for intra-domain routing protocols. IGPs are used to manage how data is routed within the AS. They handle the exchange of routing information between routers in the same AS to ensure that data packets can find the best path to their destination.

Autonomous Systems (AS):
An Autonomous System (AS) is a group of routers that are controlled by a single administrative entity. This entity could be an Internet Service Provider (ISP), a company, a university, or any organization that manages a portion of the internet infrastructure. Each AS is assigned a unique identification number called an Autonomous System Number (ASN).

Intra-AS Routing (Intra-domain):
Intra-AS routing, also known as intra-domain routing, refers to the routing process within an AS. All routers within the same AS must run the same intra-domain routing protocol. This ensures consistent routing behavior and facilitates efficient communication within the AS. Intra-AS routing protocols are responsible for determining the best paths for data packets to travel within the AS.

Inter-AS Routing (Inter-domain):
Inter-AS routing, also known as inter-domain routing, involves routing traffic between different ASes. Gateways, also known as border routers or edge routers, are responsible for performing inter-domain routing. These gateways connect the AS to routers in other ASes. Inter-AS routing protocols, often referred to as Exterior Gateway Protocols (EGP), are used to exchange routing information between ASes and determine the optimal paths for traffic to traverse between them.

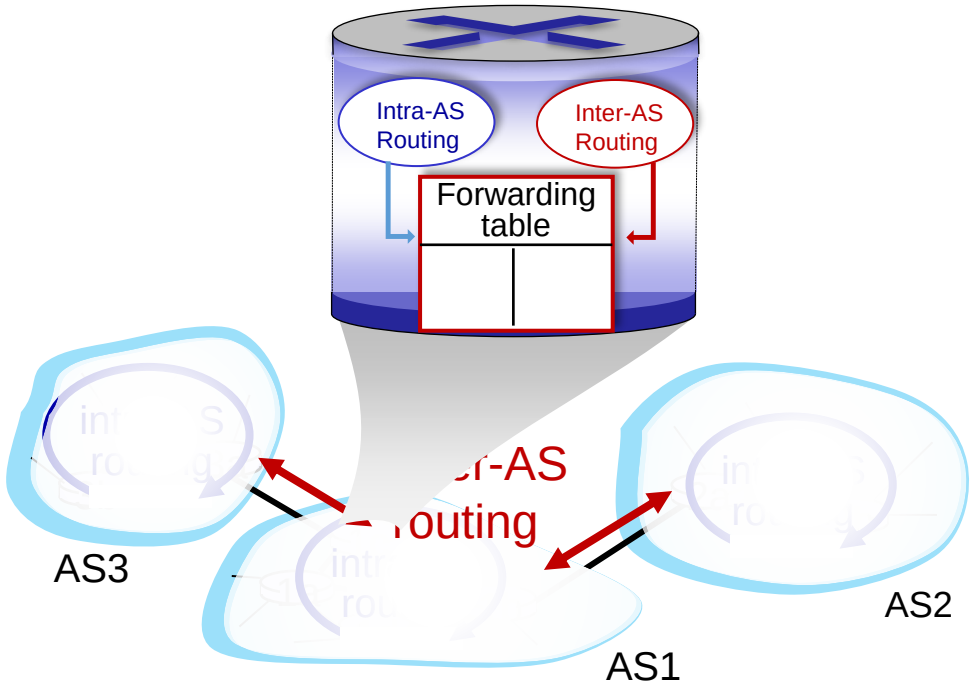
Key Points:

Intra-AS Routing: Routing within an AS, where all routers use the same intra-domain routing protocol.
Inter-AS Routing: Routing between different ASes, where gateways perform both intra-domain and inter-domain routing.
Gateway Routers: These routers serve as the connection points between ASes and are responsible for exchanging routing information between them.
Scalability: This approach allows for scalable routing on the internet by dividing the routing process into manageable domains (ASes) and facilitating efficient routing within and between these domains.

Interconnected ASes

Forwarding table configured by intra- and inter-AS routing algorithms

- Intra-AS routing determine entries for destinations within AS
- Inter-AS & intra-AS determine entries for external destinations

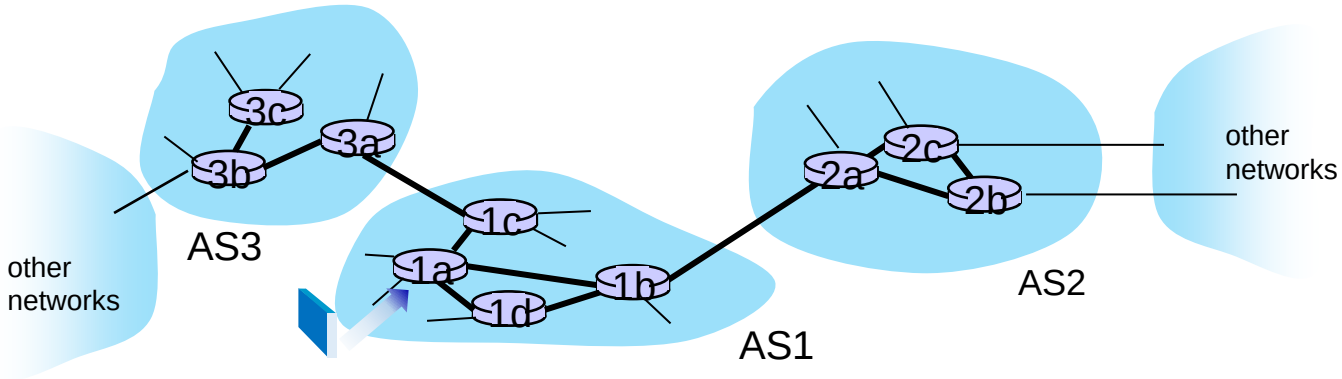


Inter-AS Routing: A Role in Intra-domain Forwarding

- Suppose router in AS1 receives datagram destined outside of AS1:
  - Router should forward packet to gateway router in AS1, but which one?

AS1 inter-domain routing must:

1. Learn which destinations reachable through AS2, which through AS3
2. Propagate this reachability info to all routers in AS1



Intra-AS Routing: Routing within an AS

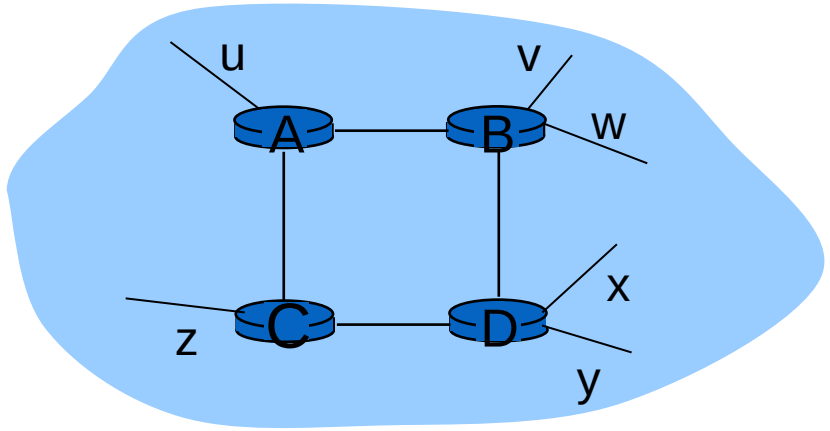
Most common intra-AS routing protocols:

- RIP: Routing Information Protocol [RFC 1723]
  - Classic DV
  - No longer widely used
- EIGRP: Enhanced Interior Gateway Routing Protocol
  - DV based
  - Formerly Cisco-proprietary for decades (became open in 2013 [RFC 7868])
- OSPF: Open Shortest Path First [RFC 2328]
  - Link-state routing
  - IS-IS protocol (ISO standard, not RFC standard) essentially same as OSPF

Routing Information Protocol

RIP (Routing Information Protocol)

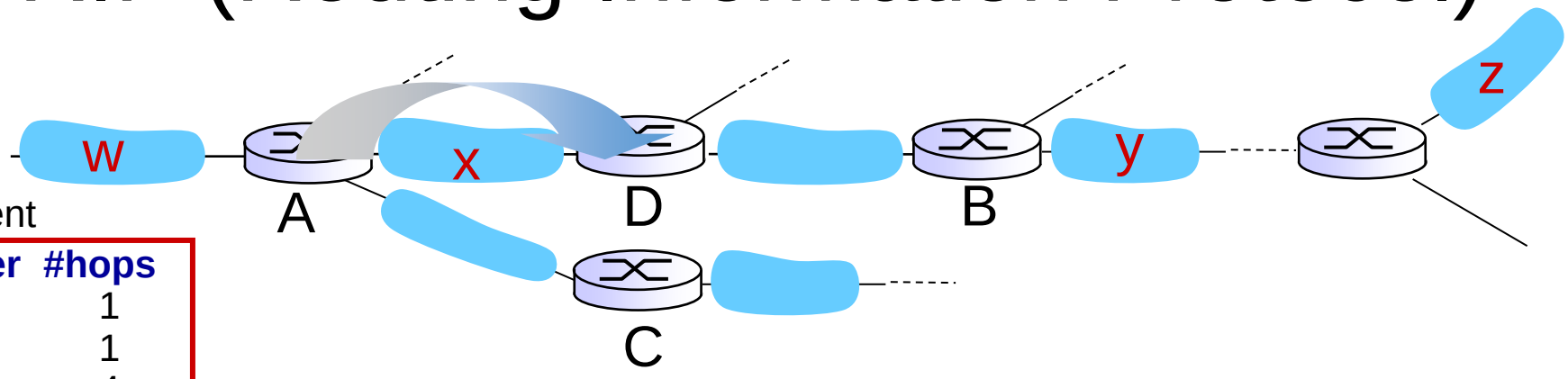
- Included in BSD-UNIX distribution in 1982
- Distance vector algorithm
  - Distance metric: # hops (max = 15 hops), each link has cost 1
    - Hop: number of subnets traversed along the shortest path from source router to destination subnet
  - DVs exchanged with neighbors every 30 sec in response message (aka advertisement)
  - Each advertisement: list of up to 25 destination subnets (in IP addressing sense)



From router A to destination subnets:

Subnet	Hops
u	1
v	2
w	2
x	3
y	3
z	2

RIP (Routing Information Protocol)



A-to-D advertisement

Dest	Next-router	#hops
w	-	1
x	-	1
z	C	4

Routing table in router D

Destination subnet	Next-router	# hops to dest
w	A	2
y	B	2
z	B A	7 5
x	--	1
….	….	….

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
- Poisoned reverse used to prevent ping-pong loops (infinite distance = 16 hops)

OSPF (Open Shortest Path First) Routing

OSPF (Open Shortest Path First) Routing

- “Open”: Publicly available
- Classic link-state
  - Each router floods OSPF link-state advertisements to all other routers in entire AS
  - Multiple link costs metrics possible: bandwidth, delay
  - Each router has full topology, uses Dijkstra’s algorithm to compute forwarding table

SPF Routing:

OSPF is like a map-sharing game where each player (router) tells everyone else about the roads (links) they know.
Players share information about all the roads in the game (entire network) to find the shortest paths to different destinations.

They use a smart strategy (Dijkstra's algorithm) to figure out the quickest way to get to each place and write it down in their own map (forwarding table)

OSPF : Advanced Features

- Security: All OSPF messages can be authenticated (to prevent malicious intrusion)
- Multiple same-cost paths allowed (only one path in RIP)
- For each link, multiple cost metrics for different ToS
  - Satellite link cost set low for best effort ToS; high for real-time ToS
- Integrated unicast and multicast support:
  - Multicast OSPF (MOSPF) uses same topology data base as OSPF
- Hierarchical OSPF in large domains

Advanced Features:

Security:

OSPF ensures that only trusted players can share maps and no one can cheat by pretending to know better routes.

Support for Multiple Paths:

OSPF allows players to find and use different ways to reach the same destination, giving them more options if one route is busy or slow.

Differentiated Services (ToS):

OSPF lets players choose different roads based on how fast they need to get there. For example, they might take a faster road for urgent deliveries and a slower one for regular ones.

Integrated Unicast and Multicast Support:

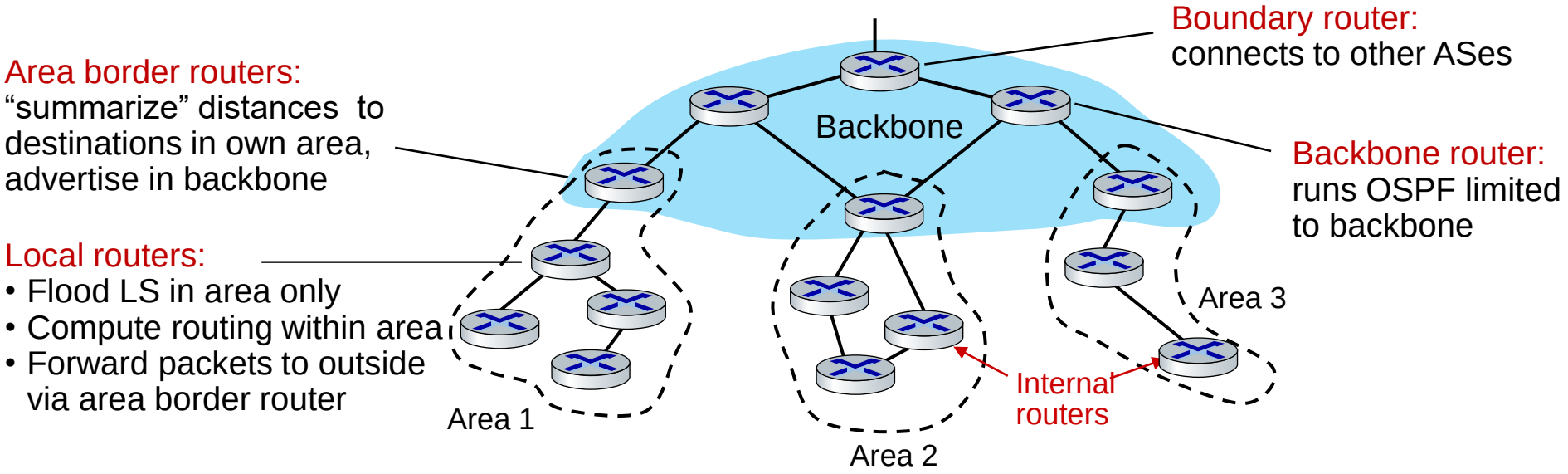
OSPF helps players deliver messages to single destinations (unicast) or to groups of destinations (multicast) using the same map-sharing game.

Hierarchical OSPF:

In big games with lots of players, OSPF divides the map into smaller areas, making it easier to manage and play the game without getting overwhelmed by too much information.

Hierarchical OSPF

- Two-level hierarchy: local area, backbone.
  - Link-state advertisements flooded only in area, or backbone
  - Each node has detailed area topology; only knows direction to reach other destinations



Summary

- Internet Approach to Scalable Routing:
  - Intra-AS and Inter-AS

- Intra-AS routing:
  - RIP: Routing Information Protocol
  - OSPF: Open Shortest Path First