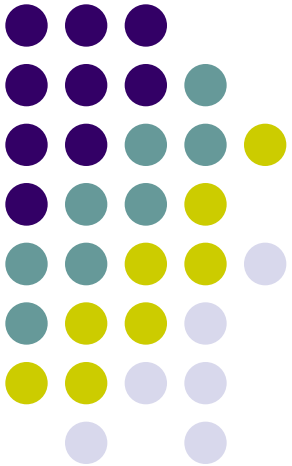
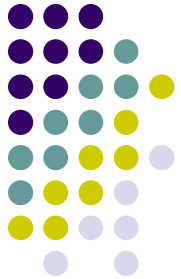
ELEN 4017

Network Fundamentals

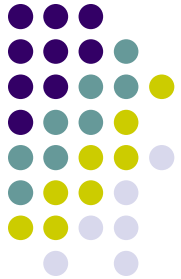
Lecture 27



Purpose of lecture

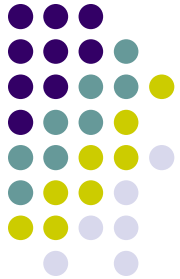


- Network layer
  - Hierarchical routing
  - Intra-AS routing in the Internet

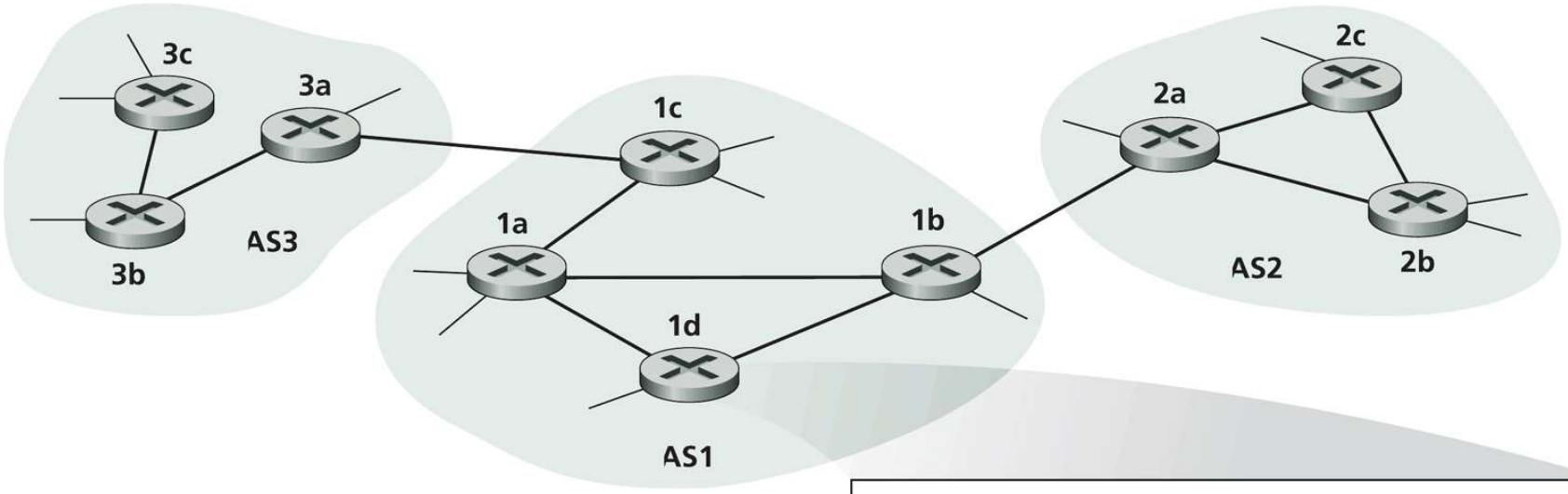


- Up till now we viewed network as a collection of interconnected routers. All routers were treated equally, the network is ‘flat’.
- This model is too simplistic for the following reasons:
- **Scale:**
  - As the number of routers become large, the overhead to exchange information and compute routing is prohibitive. Today’s Internet consists of 100’s of millions of hosts.
  - Thus we would find that the broadcast of link cost would overwhelm the network !
- **Administrative autonomy**
  - Internet is a network of networks. These networks are under different administrative domains e.g. companies. Each network admin would want to be able to administer his/her network autonomously.

Autonomous systems



- To solve this, routers can be organized into autonomous systems (AS).
- An AS is a group of routers belonging to the same administrative control.
- Within an AS, all routers run the same algorithm e.g. link-state or distance vector.
- The routing algorithm running within an AS is called the **intra-autonomous system routing protocol**.
- It will be necessary to forward packets outside of the AS, and this task is given to the **gateway router**.



- Bold lines are connections between routers. Thin lines are subnets.
- 3a, 1c, 1b, 2a are gateways.

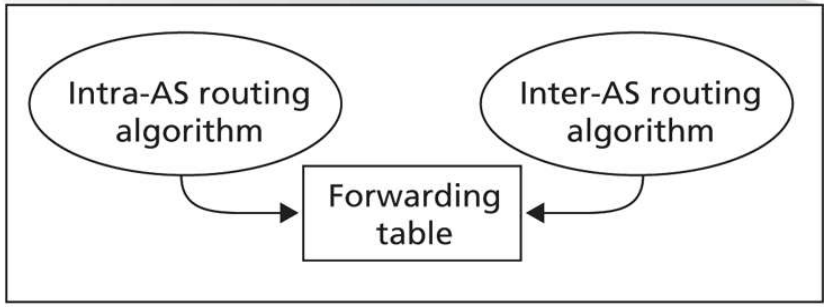
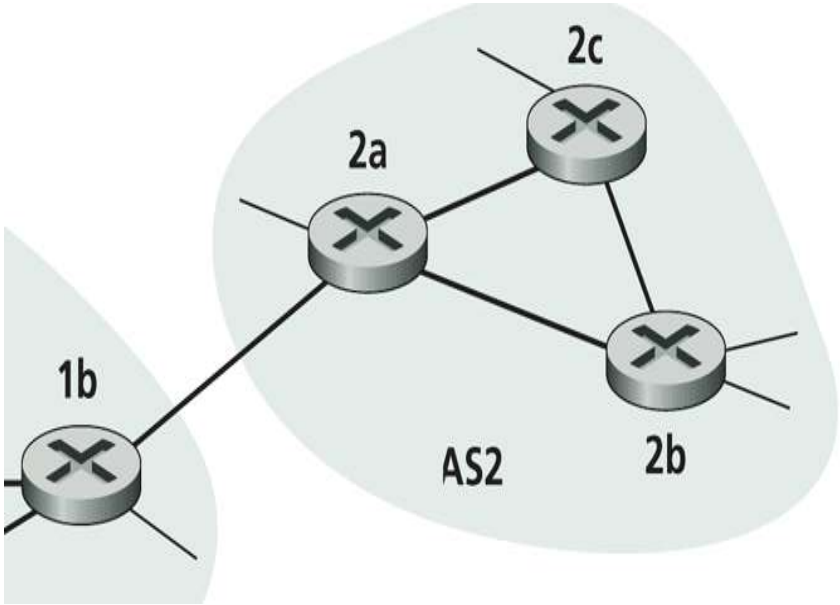


Figure 4.29 ♦ An example of interconnected autonomous systems

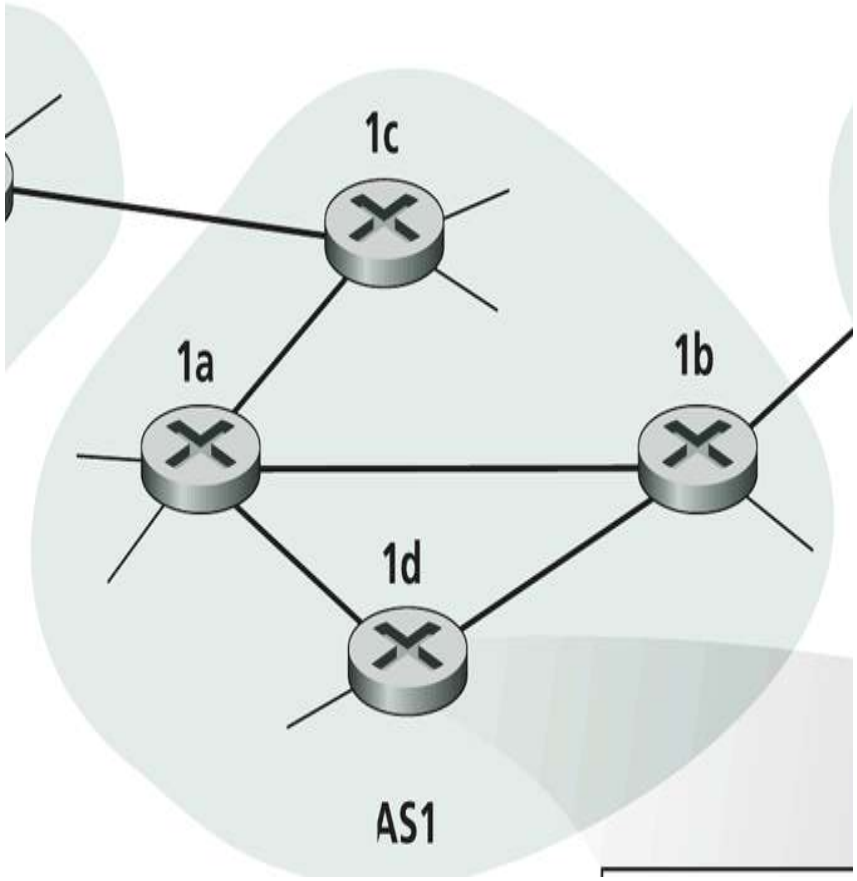
Destination outside the AS

- How does a router within an AS know how to forward a packet to a destination outside the AS ?
- In the case of only 1 gateway, there is only 1 choice. The next AS will then be responsible to route it further.



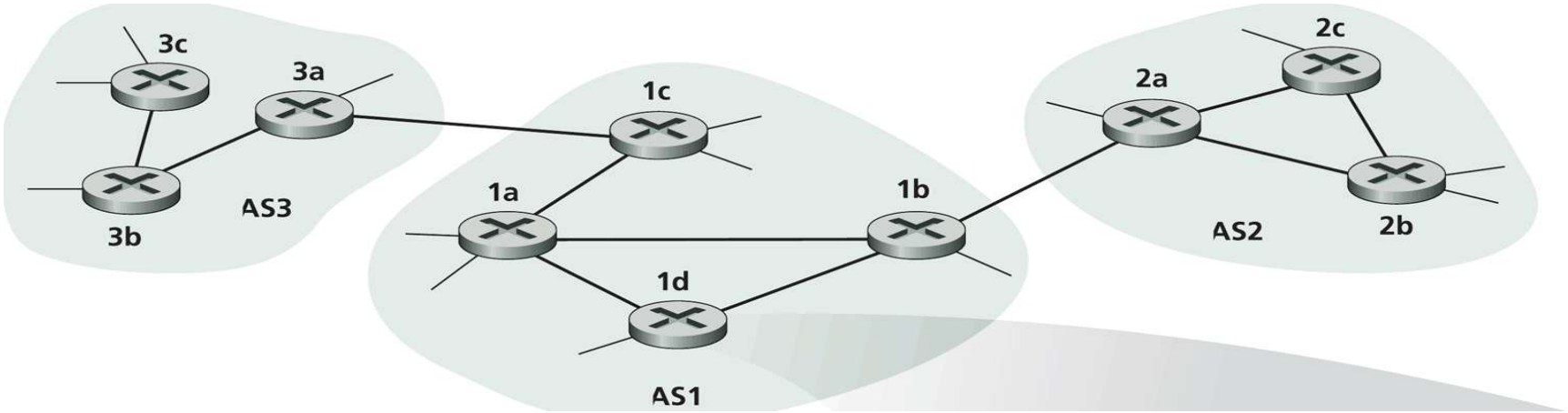
Inter-AS routing protocol

- In the case of multiple gateways, the problem is more complex.
- In the example, AS1 must determine whether 1c or 1b gateways must be used to forward the packet.
- This is the task of the **inter-AS routing protocol**
- The inter-AS routing protocol must be able to learn which destinations are reachable via gateways
- Additionally it must propagate the “reachability” information to each internal router in the AS.

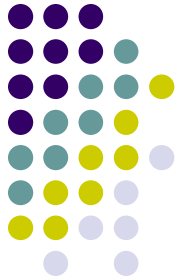


Hot potato routing

- Consider router **1a** needs to route a packet to subnet x, which is outside AS1, AS2 and AS3
- The inter-AS routing protocol has earlier determined that the destination subnet can be reached via both AS2 or AS3.
- If router 1a uses hot potato routing, it will choose the least expensive router-to-gateway path. In this case it will choose gateway **1c**

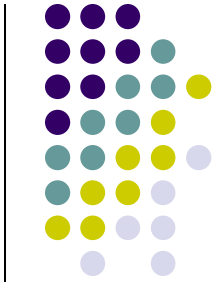


Summary of autonomous systems



- Autonomous systems solve the scale problem, since a router only needs to have information concerning routers within its own AS with respect to least path cost.
- It provides autonomy since each AS administrator can define the intra-AS routing protocol used.
- It does require that all interconnected AS use the same inter-AS routing protocol. In the case of the Internet, the protocol used is **Border Gateway Protocol (BGP).**

Purpose of lecture



- Network layer
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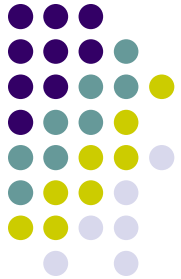
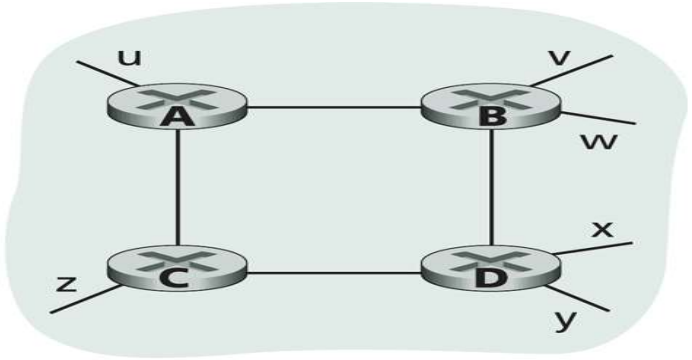


- Another name for Intra-AS routing protocols are **Interior Gateway** protocols.
- Two primary protocols in use on the Internet:
  - Routing Information Protocol (RIP)
  - Open Shortest Path First (OSPF)

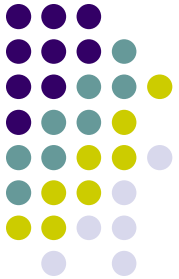
Routing information protocol

- RIP is an earlier protocol and has found widespread use since it was deployed in an early version of BSD Unix.
- It is a distance vector protocol and thus is decentralized.
- The cost is specified as the number of subnets traversed from source to destination (hop).



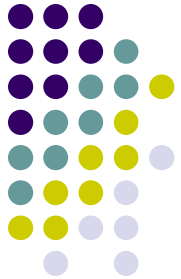
Destination	Hops
u	1
v	2
w	2
x	3
y	3
z	2

Figure 4.31 ◆ Number of hops from source router A to various subnets



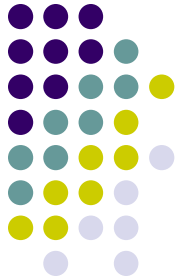
- Routers send RIP request and response messages to each other using a **UDP socket** on port 520.
- Thus the RIP datagrams are carried over normal IP.
- Does this make sense, considering that routers don’t implement protocol stacks above network layer?

Open shortest path first (OSPF)



- **Open** refers to the fact that the protocol is in public domain – not proprietary.
- It is a **link state protocol** that uses Dijkstra's least cost algorithm
- Each router in the AS constructs a topological map (graph) of all routers within the AS.
- The individual link costs are administrable.
  - They can all be set = 1, thus achieving minimum hop routing.
  - They could be inversely proportional to the link speed capacity, and will thus discourage use of slower links.
- OSPF achieves additional robustness by broadcasting its link state **to all routers within the AS** under the following conditions:
  - Change in link state
  - Periodically

Improvements in OSPF



- Security: Exchanges between OSPF routers can be authenticated.
- Multiple same-cost paths: when multiple paths exist which have the same cost, OSPF allows multiple paths to be used.
- Support for multi-cast routing (covered later)
- Support for a hierarchy within a single routing domain.

Hierarchy within the AS

- AS divided into areas.
- Each area runs its own OSPF algorithm
- Backbone area provides inter area communication.

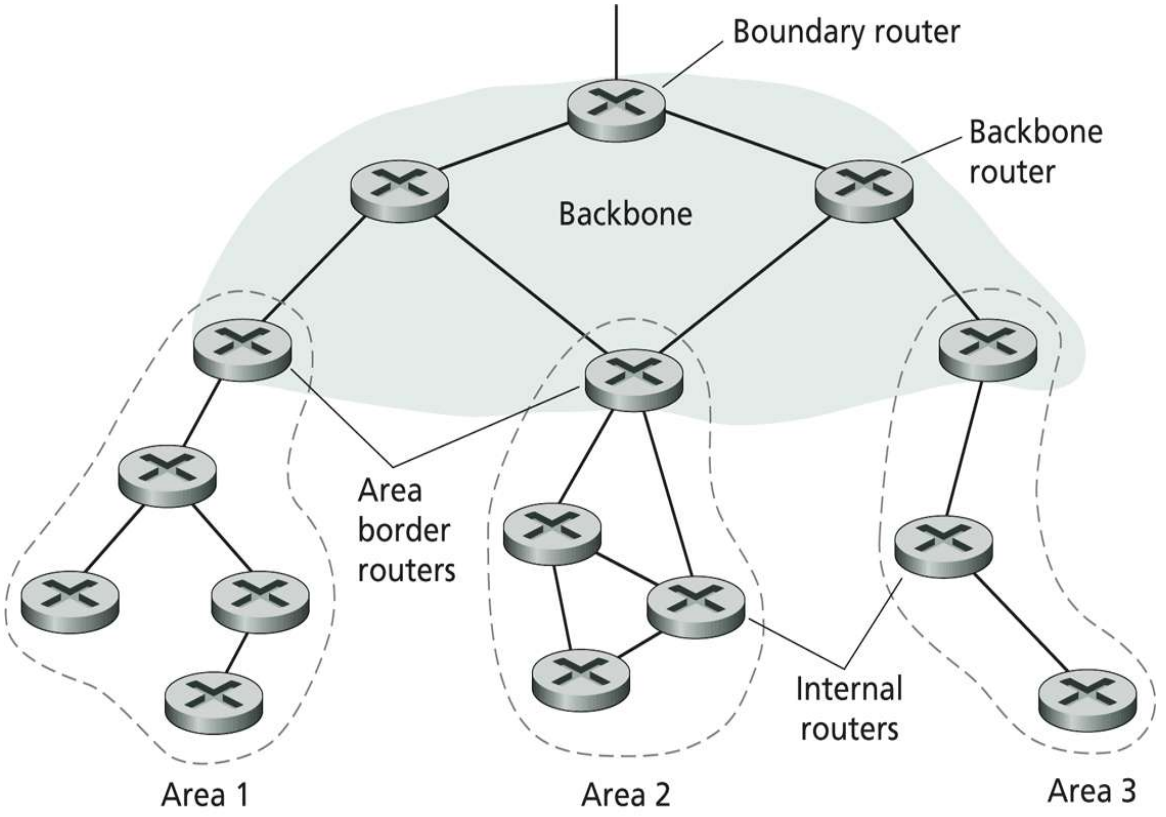


Figure 4.37 ♦ Hierarchically structured OSPF AS with four areas