Routing Protocols

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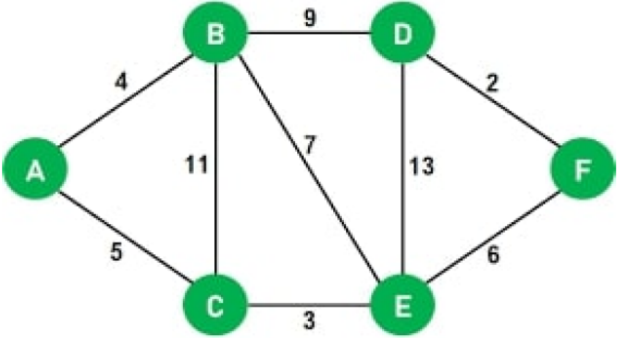
Using Dijkstra's Algorithm, find the shortest distance from source vertex 'A' to the remaining vertices in the following graph.



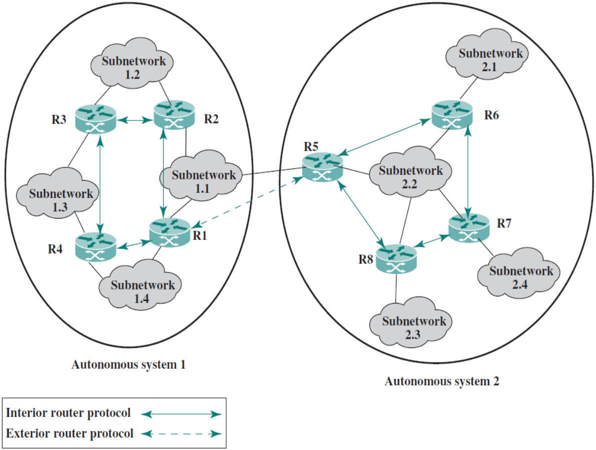
Unicast Routing Protocols

Three common protocols used in the Internet:

- Routing Information Protocol (RIP)
  - Based on the distance-vector algorithm
- Open Shortest Path First (OSPF)
  - Based on the link-state algorithm
- Border Gateway Protocol (BGP)
  - based on the path-vector algorithm
- RIP and OSPF have been used for interior router protocols.
- BGP is preferred exterior router protocol for the Internet

Interior router protocol (IRP): passes routing information between routers within an AS

Exterior router protocol (ERP): used to pass routing information between routers in different ASs

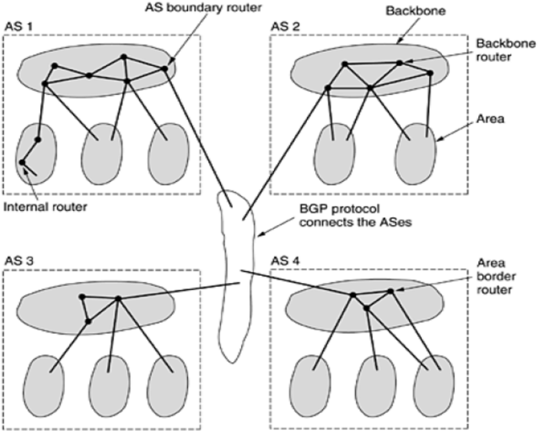


Autonomous Systems

An **Autonomous System** (AS) exhibits the following characteristics

- An AS is a set of routers and networks managed by a single organization
- An AS consists of a group of routers exchanging information via a common routing protocol
- Except in times of failure, an AS is connected
    - There is always a path between any pair of nodes

Autonomous Systems



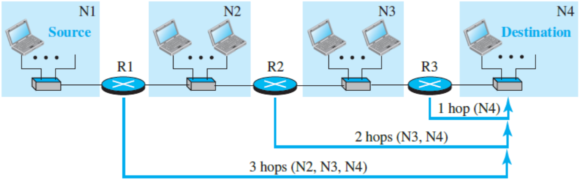
Routing Information Protocol

Routing Information Protocol (RIP)

- Most widely used intradomain routing protocols
- Based on the distance-vector routing algorithm
- It works well in small systems
  - but less well as networks get larger
- It suffers from the count-to-infinity problem and generally slow convergence

Hop Counts in RIP

- RIP routers advertise the cost of reaching different networks
    - The cost is defined as the number of hops,
- Hops: Number of networks (subnets) a packet needs to travel through from the source router to the final destination host
    - The network in which the source host is connected is not counted in this calculation



Forwarding table for R1

Destination network	Next router	Cost in hops
N1	——	1
N2	——	1
N3	R2	2
N4	R2	3

Forwarding table for R2

Destination network	Next router	Cost in hops
N1	R1	2
N2	——	1
N3	——	1
N4	R3	2

Forwarding table for R3

Destination network	Next router	Cost in hops
N1	R2	3
N2	R2	2
N3	——	1
N4	——	1

- Forwarding table in RIP defines only the next router in the second column
- It gives the information about the whole least-cost tree $R1 \rightarrow R2 \rightarrow R3 \rightarrow N4$

Performance of RIP

- **Update messages**: Very simple format and are sent only to neighbors
  - They do not create traffic
    - Routers try to avoid sending them at the same time
- **Convergence of forwarding tables**:
  - RIP uses the distance-vector algorithm
  - Converge slowly if the domain is large
  - RIP allows only 15 hops in a domain (16 is considered as infinity)
  - count-to-infinity and loops created in the domain $\Longrightarrow$ Convergence problems
- **Robustness**:
  - Calculation of the forwarding table depends on information received from immediate neighbors
  - Failure or corruption in one router, the problem will be propagated to all routers

OSPF

Open Shortest Path First: OSPF

- OSPF: Unicast and Intradomain routing protocol
- OSPF is more widely used in company networks
- Requirements for OSPF:
  - OSPF is an *open* protocol $\implies$ the specification is a public document.
  - Protocol had to support a variety of distance metrics: Physical distance, delay...
  - It has to be a dynamic algorithm (adapted to changes in the topology)
  - It has to support routing based on type of service
    - Route real-time traffic one way and other traffic a different way
  - OSPF had to do load balancing
    - Splitting the load over multiple lines.
  - Support for hierarchical systems is needed
  - Security was required to prevent spoofing of routers

OSPF Implementation

OSPF is implemented as a program in the network layer

- An IP datagram that carries a message from OSPF sets the value of the protocol field to 89
- The OSPF messages are encapsulated inside datagrams.

0	8	16 31
Version	Type	Message length
Source router IP address		
Area Identification		
Checksum		Authentication type
Authentication		

Figure: OSPF Common Header

- **Authentication**: The OSPF common header has the provision for authentication of the message sender.
  - This prevents a malicious entity from sending OSPF messages to a router

OSPF

OSPF represents the actual network (a) as a graph (b) and then use the link state method to have every router compute the shortest path from itself to all other nodes

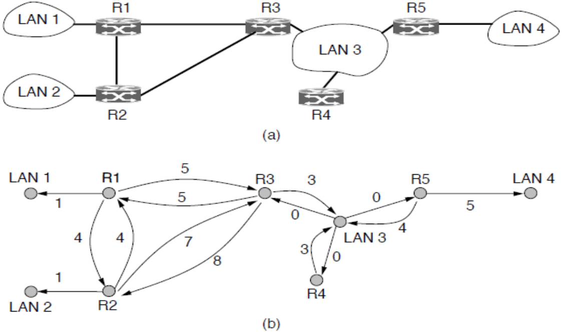


Figure: a) An autonomous system. (b) A graph representation of (a)

OSPF Messages

Five different types of messages

- **Type 1**: The *hello* message
  - It is used by a router to introduce itself to the neighbors and announces all neighbors that it already knows
- **Type 2**: The *database description* message
  - It is normally sent in response to the hello message to allow a newly joined router to acquire the full LSDB[1]
- **Type 3**: The *link-state request* message
  - It is sent by a router that needs information about a specific LS.
- **Type 4**: The *link-state update* message
  - It is the main OSPF message used for building the LSDB.
- **Type 5**: The *link-state acknowledgment* message
  - It is used to create reliability in OSPF; each router that receives a link-state update message needs to acknowledge it.

[1] The collection of states for all links is called the link-state database (LSDB)

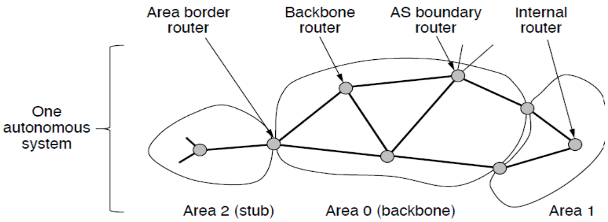


Figure: Relation between ASes, backbones, and areas in OSPF

- OSPF allows an AS to be divided into numbered areas
  - **backbone area** is called *area 0*
- Routers:
  - Routers that lie wholly within an area are called **internal routers**
  - Routers in backbone area are called **backbone routers**
  - Router that is connected to two or more areas: **area border router**.
  - Only one border router out of an area: **Stub area**
  - **AS boundary router**: It injects routes to external destinations on other ASes into the area

Border Gateway Protocol

Border Gateway Protocol

The Border Gateway Protocol version 4 (BGP4) is the only interdomain routing protocol used in the Internet today.

- BGP is been designed to allow many kinds of routing policies
  - Typical policies involve political, security, or economic considerations
- BGP4 is based on the path-vector algorithm
- **Path-vector routing**: to allow the packet to reach its destination more efficiently without assigning costs to the route
- The best route is determined by the source using the policy it imposes on the route
  - "Never send traffic from the Pentagon on a route through Iraq"
  - "Do not carry commercial traffic on the educational network"

BGP Transit service

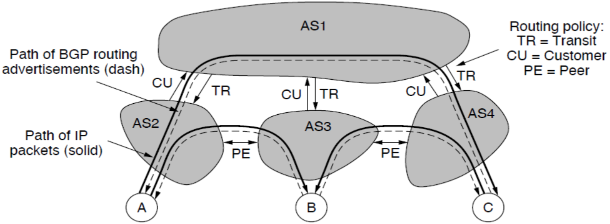


Figure: Routing policies between autonomous systems

- Common policy is that a customer ISP pays another provider ISP to receive/deliver packets to/from any other destination
- The customer ISP is said to buy **transit service**
- AS2, AS3, and AS4 are customers of AS1
- when source A sends to destination C, the packets travel from AS2 to AS1 and finally to AS4

BGP

- The routing advertisements travel in the opposite direction to the packets
- AS4 advertises C as a destination to AS1
- AS1 advertises a route to C to its other customers (AS2-AS4)
- Customers know that they can send traffic to C via AS1
- **Settlement-free peering or settlement-free interconnection**
- Suppose that AS2 and AS3 exchange a lot of traffic
  - They can use a different policy
    - They can send traffic directly to each other for free
- In settlement-free peering, traffic will not pass from AS4 to AS3 to AS2

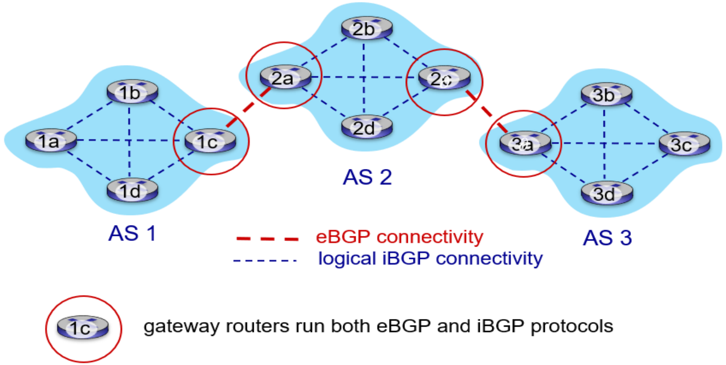


Figure: eBGP and iBGP Connection

eBGP and iBGP

- **External BGP (eBGP)**
  - Used to exchange routing information between different ASes.
  - Info: Obtain destination network reachability info from neighboring ASes
  - Often used for internet routing.
- **Internal BGP (iBGP)** is an intradomain protocol
  - To propagate BGP routes from one side of the ISP to the other
  - Propagate reachability information to all AS-internal routers
  - Used within the same AS to distribute routes.
  - Requires full mesh connectivity

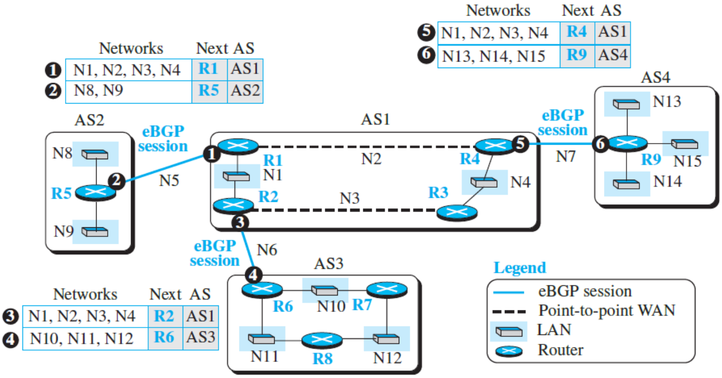


Figure: eBGP operation

Route Selection Steps

- Prefer the route with the highest local preference value
- Prefer the route with the shortest AS path length.
- Prefer routes learned via external connections (i.e., via eBGP) over those learned from internal connections (i.e., via iBGP).
- Prefer routes with the lowest multiple exit discriminator (MED) value

Acknowledge various sources for the images.

Thankyou