NPTEL ONLINE CERTIFICATION COURSES

Course Name: Ethical Hacking

Faculty Name: Prof. Indranil Sen Gupta

Department : Computer Science and Engineering

Topic

Lecture 11: Routing Protocols (Part I)

CONCEPTS COVERED

- Packet delivery options
- Routing Methods

Internet Routing Protocols

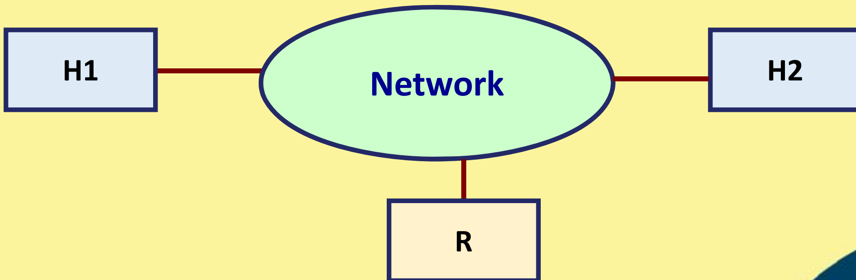
Connection Options

- Broadly two options:
  - **a) Connection-oriented**
    - Network layer protocol first makes a connection.
    - All packets delivered as per the connection.
  - **b) Connection-less**
    - Network layer protocol treats each packet independently.
    - No relationship between packets.
- IP protocol uses connection-less approach for packet delivery.

Packet Delivery Options

1. Direct Delivery

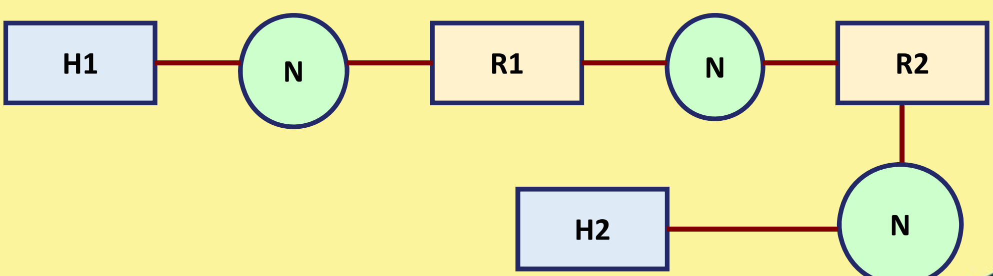
- Host-to-host
- Router-to-host



5

2. Indirect Delivery

- Through one or more routers.



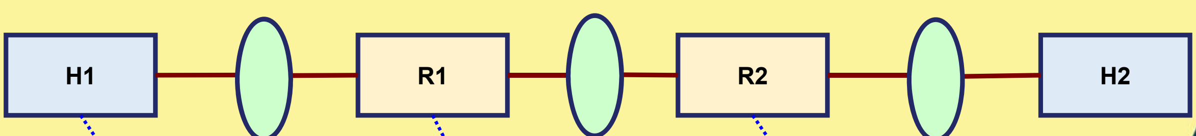
6

Routing Methods

- Several alternatives possible:
  a) Next-hop routing
  b) Network-specific routing
  c) Host-specific routing
  d) Default routing

a) Next-hop routing

- Routing tables based on next hop.



Dest	Next Hop
H2	R1

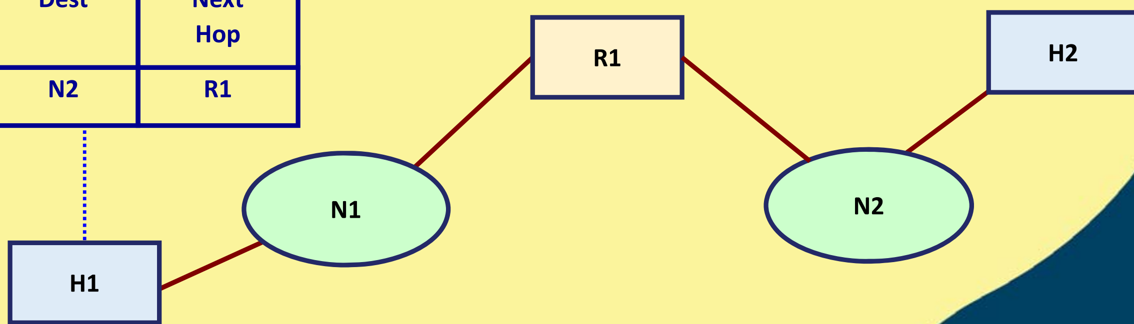
Dest	Next Hop
H2	R2

Dest	Next Hop
H2	--

b) Network-specific routing

- Routing table based on destination network address.

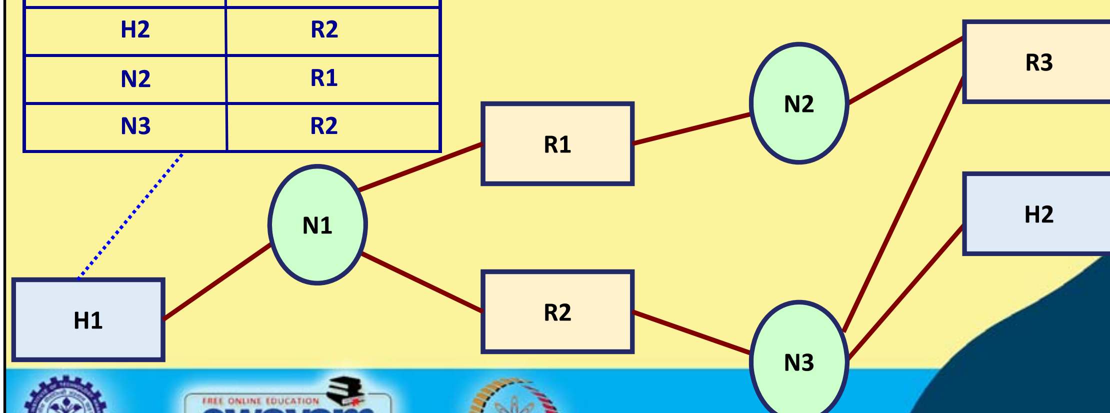
Dest	Next Hop
N2	R1



c) Host-specific routing

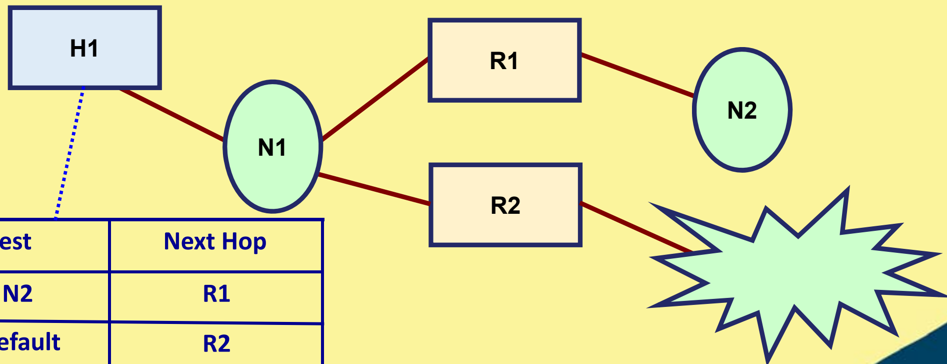
- Can specify the address of a host.

Dest	Next Hop
H2	R2
N2	R1
N3	R2



d) Default routing

- Follow a default path if no match found.



Dest	Next Hop
N2	R1
Default	R2

Types of Routing Table

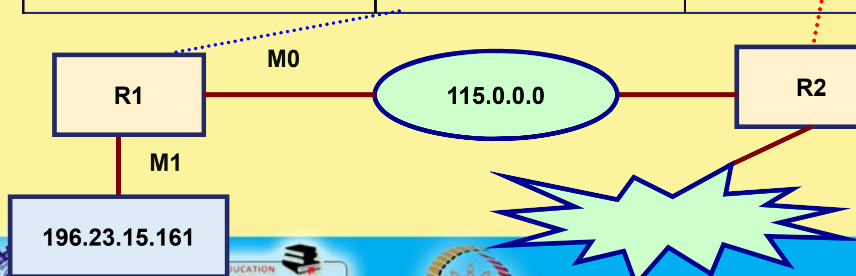
1. **Static**
   - Contains information inserted manually.
   - Does not change with time.
2. **Dynamic**
   - Updated periodically depending on network condition.
   - Uses protocols like RIP, OSPF, BGP, etc.

Typical Fields in a Routing Table

- Subnet mask
- Destination IP address
- Next hop address
- Flags
  - U : router is up and running
  - G : destination is in another network
  - H : host-specific address
  - D : added by redirection
  - M : modified by redirection
- Interface

Example (Routing table for R1)

Mask	Dest	NextHop	Interface
255.0.0.0	115.0.0.0	--	M0
255.255.255.224	196.23.15.161	--	M1
0.0.0.0	0.0.0.0	112.11.35.18	M0



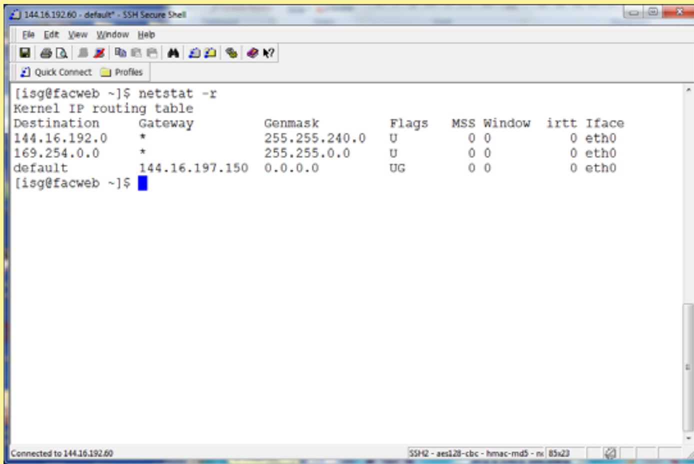
How to view the routing table?

- On Unix / Linux system:

  `netstat –r`

- On Windows system:

  `route print`



15

NPTEL ONLINE CERTIFICATION COURSES

Course Name: Ethical Hacking

Faculty Name: Prof. Indranil Sen Gupta

Department : Computer Science and Engineering

Topic

Lecture 12: Routing Protocols (Part II)

CONCEPTS COVERED

- Interior and exterior routing protocols
- Routing information protocol (RIP)
- Open shortest path first (OSPF)

Routing Protocols

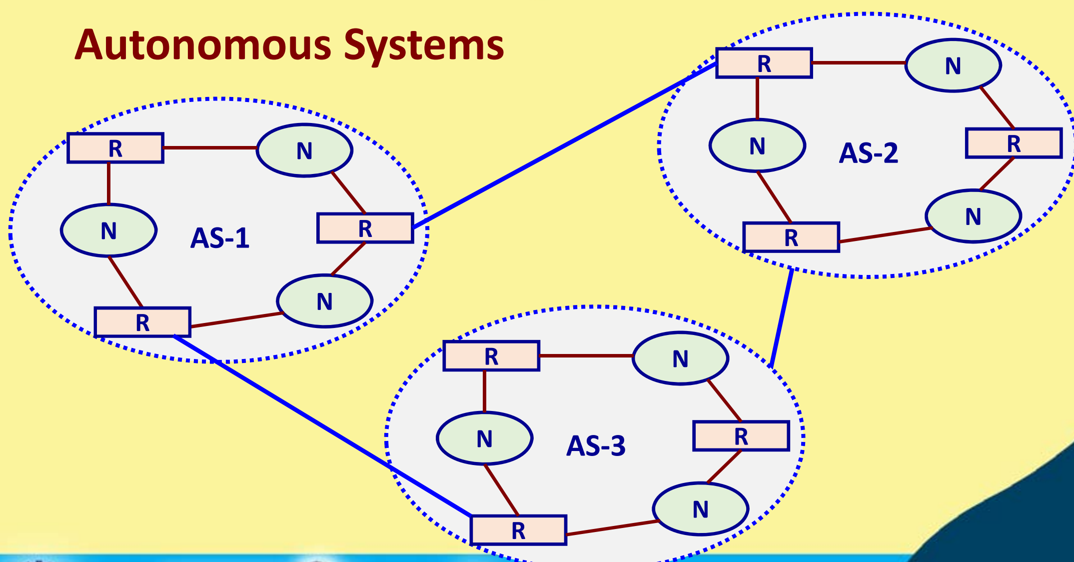
Routing Protocols

- Two broad classes of protocols are used in the Internet:
  - **a) Interior**
    - Routing Information Protocol (RIP)
    - Open Shortest Path First (OSPF)
  - **b) Exterior**
    - Border Gateway Protocol (BGP)

Autonomous Systems (AS)

- What is an AS?
  - A set of routers and networks ***managed by a single organization***.
  - The routers within the AS exchange information using a common routing protocol.
  - The AS graph is connected (in the absence of failure).
- Every autonomous system is assigned a unique ***AS number***.
- Routing protocols within an AS and across different AS's can be different.
  - **Interior** versus **Exterior**.

Autonomous Systems



- Which class of protocols to use?
  - Use interior router protocols to exchange information between routers within an AS.
    - ❖RIP or OSPF.
  - Use exterior routing protocol to pass exchange routing information between routers in different AS's.
    - ❖BGP.

Routing Information Protocol (RIP)

- It is an interior routing protocol.
- Routers within an autonomous system exchange messages.
  - Distance vector routing using hop count.
  - Table entries updated using values received from neighbors.
  - Maintain timers to detect failed links.
  - Used in first generation ARPANET.

Problems with RIP

- Slow convergence for larger networks.
- If a network becomes inaccessible, it may take a long time for all other routing tables to know this.
  - After a number of message transfers.
  - A drawback of routing table updation using distance vectors.
- Routing loops may take a long time to be detected.
  - Counting to infinity problem.
- Too much bandwidth consumed by routing updates.

9

Open Shortest Path First (OSPF)

- Widely used as the interior routing protocol in TCP/IP networks.
  - Updates routing tables based on link state advertisements.
- Basic concept:
  - Computes a route that incurs the least cost.
    - ❖User configurable: delay, data rate, cost, etc.
  - Each router maintains a database.
    - ❖Topology of the autonomous system to which the router belongs.
    - ❖Vertices and edges.

10

- Two types of vertices:
  a) Router
  b) Network
- Two types of (weighted) edges:
  a) Two routers connected to each other by direct point-to-point link.
  b) A router is directly connected to a network.
- A router calculates the least-cost path to all destination networks.
  - Using Dijkstra's algorithm.
  - Only the next hop to the destination is used in the forwarding process.

- In the steady state
  - All routers know the same network topology.
  - "Hello" packets sent every 10 seconds (configurable) to neighbors.
  - Link State Advertisement (LSA) flooded initially from each router.
  - Absence of "Hello" packet for 40 seconds indicate failure of neighbor.
    - ❖Causes LSA to be flooded again.
  - LSAs re-flooded every 30 minutes anyway.

OSPF Header Format

0	8 15	16 31
Version	Type	Message Length
Source Address		
Area Id		
Checksum		Authentication Type
Authentication		
ROUTING DATA		

Authentication

OSPF Packets

- Packet types :
  1. **Hello** (check if neighbor is up)
  2. **Database Description** (synchronize database at beginning)
  3. **Link State Request** (request specific LSA)
  4. **Link State Update** (LSAs flooded)
  5. **Link State Acknowledgement** (flooded LSAs are explicitly ack-ed – reliable flooding)
- Authentication type:
  - Cleartext
  - Encrypted (MD5 Hash, others possible)


FREE ONLINE EDUCATION
swayam
शिक्षित भारत, उन्नत भारत
NPTEL ONLINE CERTIFICATION COURSES
Thank you!
15

NPTEL ONLINE CERTIFICATION COURSES

Course Name: Ethical Hacking

Faculty Name: Prof. Indranil Sen Gupta

Department : Computer Science and Engineering

Topic

Lecture 13: Routing Protocols (Part III)

CONCEPTS COVERED

- ❑ Border gateway protocol (BGP)
- ❑ Message types in BGP

Border Gateway Protocol (BGP)

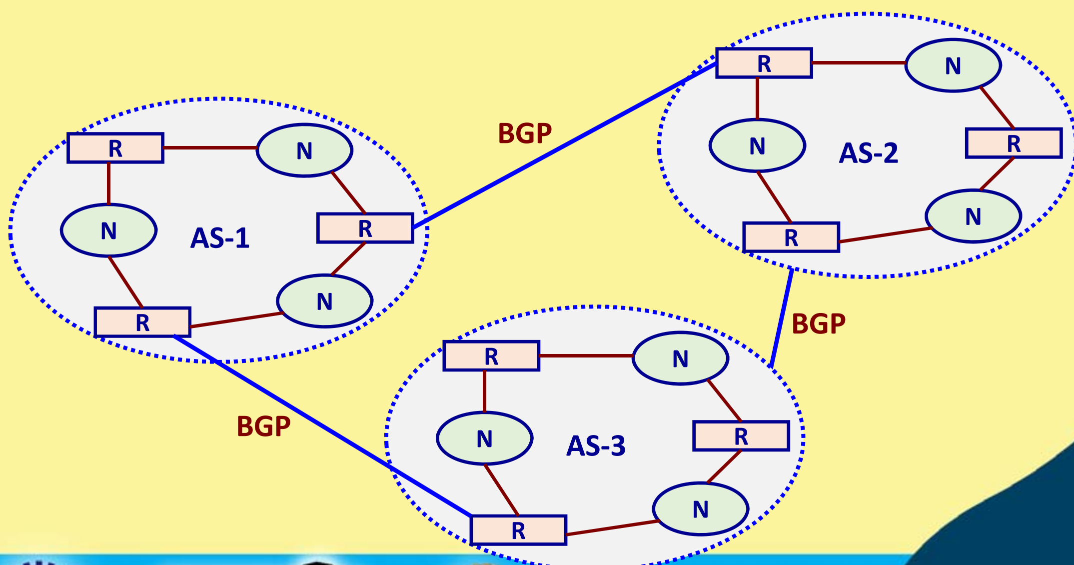
What is BGP?

- Most widely used exterior router protocol for the Internet.
- Allows routers belonging to different autonomous systems to exchange routing information.
  - Sent as messages over TCP connections.
  - The router tables get updated.

BGP Overview

- Currently in version 4.
- Inter-AS routing protocol for exchanging network reachability information among BGP routers.
- Uses TCP on port number 179 to send routing messages.
- It is a distance vector protocol.
  - Unlike RIP, BGP contain complete routes.

5



6

Message Types in BGP

- Four types of messages:
  1) **Open**: used to open a neighbor connection with another router.
  2) **Update**: used to transmit information about a single route, advertise new routes, withdraw infeasible paths.
  3) **Keepalive**: used to periodically confirm the neighbor connection.
  4) **Notification**: used to notify about some error condition.

The Basic Idea

- Two BGP routers exchanging information on a connection are called peers.
  - Initially, BGP peers exchange the entire BGP routing table.
  - Subsequently, only incremental updates are sent as the routing tables change.
  - Keepalive messages are sent periodically to ensure that the connection between the BGP peers is alive.
  - Notification messages are sent in response to errors or special conditions.
- BGP can also be used by routers within the same AS.

- Types of error conditions reported:
  - **Message header error** – authentication and syntax.
  - **Open message error** – syntax errors and unrecognized options.
  - **Update message error**.
  - **Hold timer expired** – used to close a connection if periodic messages are not received.
  - **Cease** – used by a router to close a connection with another router in the absence of any other error.

Functional Procedures in BGP

a) Neighbor Acquisition

- Two routers agree to be neighbors by exchanging messages.

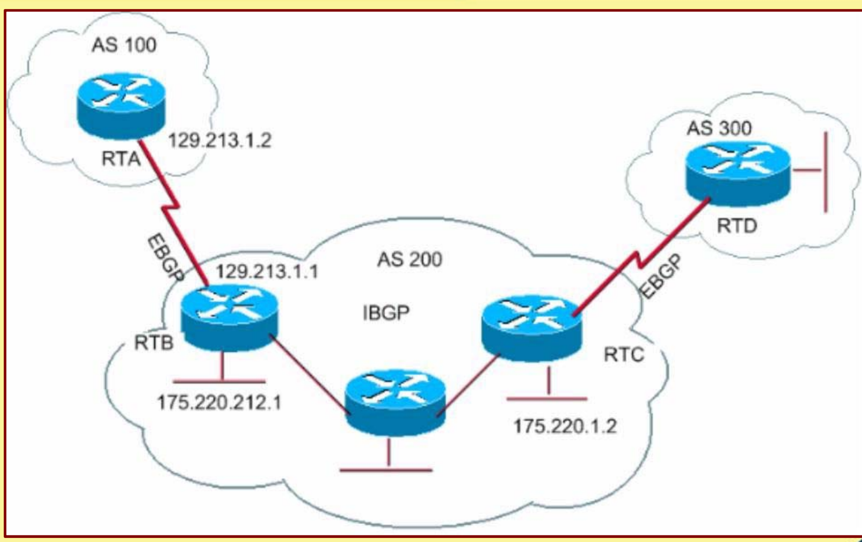
b) Neighbor Reachability

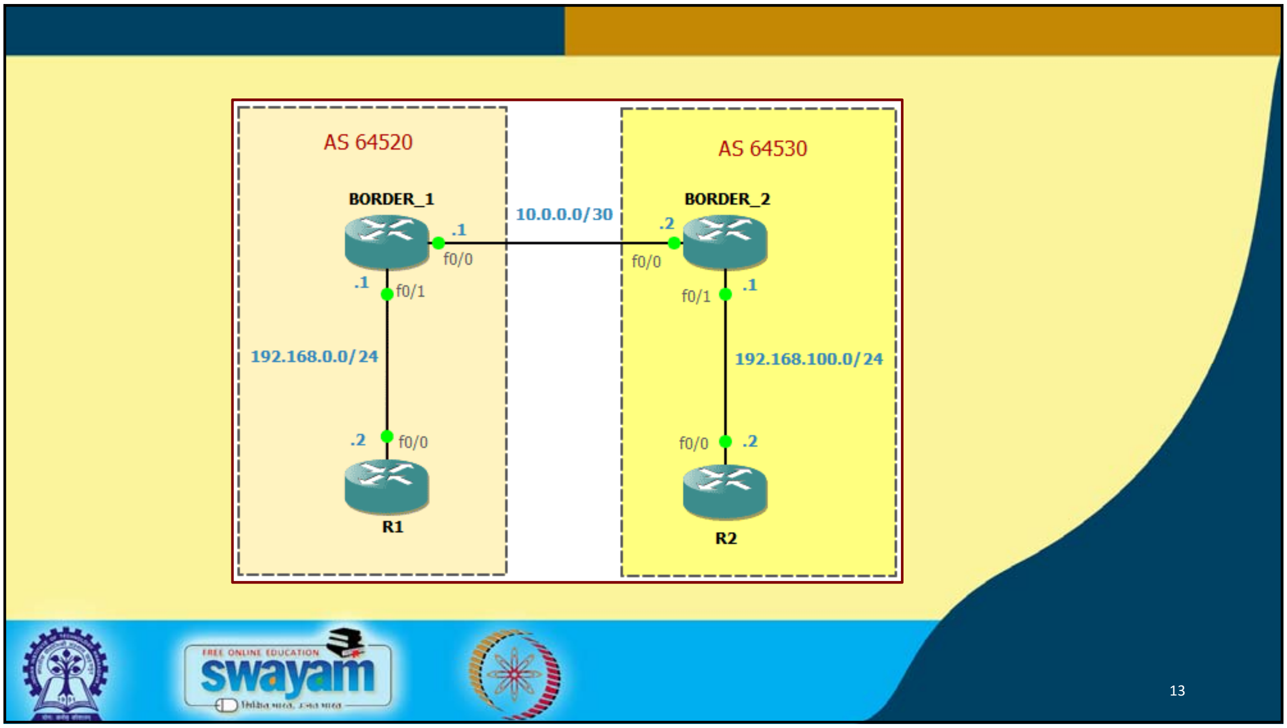
- Check if the neighbor is still alive, and is maintaining the relationship.

c) Network Reachability

- Each router maintains a list of the networks that it can reach, and the preferred routes.

- All modern-day routers support BGP.
  - The routers that are managed by ISPs actually run BGP.
  - Organizational networks in many cases do not run BGP.
    - Rely on the ISP's routers to route packets to the outside world.
    - Default route will be to the ISP router.




AS 64520
AS 64530
BORDER_1
BORDER_2
10.0.0.0/30
.1
.2
f0/0
f0/0
.1
f0/1
f0/1
.1
192.168.0.0/24
192.168.100.0/24
.2
f0/0
f0/0
.2
R1
R2
FREE ONLINE EDUCATION
swayam
13


FREE ONLINE EDUCATION
swayam
NPTEL ONLINE CERTIFICATION COURSES
Thank you!
14

NPTEL ONLINE CERTIFICATION COURSES

Course Name: Ethical Hacking

Faculty Name: Prof. Indranil Sen Gupta

Department : Computer Science and Engineering

Topic

Lecture 14: IP Version 6

CONCEPTS COVERED

- Features of IPv6
- IPv6 datagram format
- Address translation

Introduction

- The IP protocol forms the foundation of the Internet.
  - IP version 4 is used widely today.
  - IPv4 suffers from a number of drawbacks.
  - Need to enhance the capabilities of the protocol.
- IP Next Generation
  - IPng / IPv6

Problems with IPv4

- Limited address space.
  - 32-bit address is inadequate today.
- Applications demanding real-time response.
  - Real-time audio or video.
  - Must avoid changing routes frequently.
- Need for more complex addressing and routing capabilities.
  - Two-level structure of IPv4 may not serve the purpose.

Main Features of IPv6

- Something is common with IPv4:
  - IPv6 is connectionless – each datagram contains destination address and is routed independently.
  - Header contains the maximum number of hops a datagram can make before being discarded.
  - Some of the other general characteristics are also retained.

- New features of IPv6:
  - Address size: 128-bit addresses are used.
    - ❖ 2^{128} total addresses.
    - ❖ 6×10^{23} unique addresses per square meter of the earth's surface.
  - Header format:
    - ❖ IPv6 uses a series of fixed-length headers to handle optional information.
    - ❖ A datagram consists of a base header followed by zero or more extension headers.

- Support for real-time traffic:
  - ❖Allows a pair of stations to establish a high quality path between them.
  - ❖All datagrams flow through this path.
- Increased flexibility in addressing:
  - ❖Includes the concept of an ***anycast*** address, where a packet is delivered to one of a set of nodes.
  - ❖Provides for dynamic assignment of IP addresses.

IPv6 Datagram Format

- An IP datagram begins with a base header, followed by zero or more extension headers, followed by data (transport-layer PDU).
  - 40 bytes base header

Base Header	Extension Header 1	…	Extension Header N	Transport Layer PDU

IPv6 Base Header Format

Version (4 bits)	Priority (8 bits)	Flow Label (20 bits)		
Payload Length (16 bits)			Next Hdr (8 bits)	Hop Limit (8 bits)
Source Address (128 bits)				
Destination Address (128 bits)				

The Fields

- **Version** (4 bits): contains the value 6.
- **Priority** (8 bits): specifies routing priority class.
- **Flow Label** (20 bits): used with applications that require performance guarantee.
- **Payload Length** (16 bits): total length of the extension headers and the transport-level PDU.
- **Next Header** (8 bits): identifies the type of information that immediately follows the current header (IP extension, TCP or UDP).

- **Hop Limit**: decremented by 1 at each hop; discarded when it reaches 0.
- **Source/destination addresses**: 16 octets (128 bits) each.

Base Header **Next=TCP**	**TCP Data**

Base Header **Next=Route**	**Route Header** **Next=TCP**	**TCP Data**

IPv6 Extension Headers

- **Routing Header**
  - Provides source routing.
- **Hop-by-hop Options Header**
  - Defines special options that are processed at each hop.
- **Fragment Header**
  - For fragmentation and reassembly.
- **Authentication Header**
  - For packet integrity & authentication.

All Extension headers are chained in a linked list.

- **Through Next Hdr field.**

A Point About Fragmentation

- IPv6 fragmentation is similar to that in IPv4.
- Required information contained in a separate fragment extension header.
  - Presence of the fragment header identifies the datagram as a fragment.
  - Base header copied into all the fragments.

IPv6 Addressing

- Addresses do not have defined classes.
  - A prefix length associated with each address (flexibility).
- Three types of addresses:
  - **Unicast**: corresponds to a single computer.
  - **Multicast**: Refers to a set of computers, possibly at different locations. Packet delivered to ***every*** member of the set.
  - **Anycast**: Refers to a set of computers with the same address prefix. Packet delivered to ***exactly one*** of the computers in the set.
    - ❖Required to support replication of services.

Colon Hexadecimal Notation

- An IPv6 address is 128 bits long.
  - Dotted decimal notation too long.
  - Use colon-hexadecimal notation. Each group of 16 bits written in hex, with a colon separating groups.
  - Example:

    7BD6:3DC:FFFF:FFFF:0:2D:F321:FFFF
  - Sequence of zeros is written as two colons.

    7BD6:0:0:0:0:0:0:B6 → 7BD6::B6

Aggregate Global Unicast Address

- TLA: top-level aggregation
- NLA: next-level aggregation
- SLA: site-level aggregation
- Interface Id: typically based on hardware MAC address

001	TLA Id (13)	NLA Id (32)	SLA Id (16)	Interface Id (64)

IPv4-Mapped IPv6 Addresses

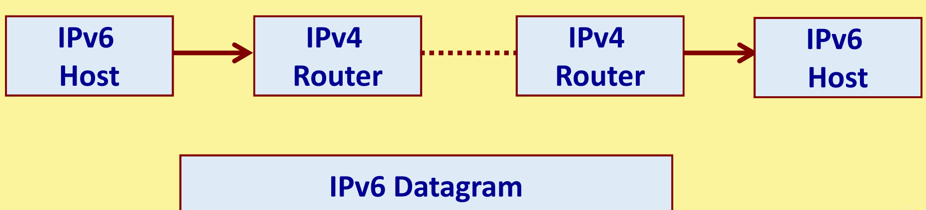
- Allow a host that supports both IPv4 and IPv6 to communicate with a host that supports only IPv4.
  - IPv6 address is based on IPv4 address.
  - 80 0's, followed by 16 1's, followed by a 32-bit IPv4 address.

IPv4 Compatible IPv6 Addresses

- Allows a host supporting IPv6 to talk IPv6 even if the local routers do not talk IPv6.
  - Tell endpoint software to create a tunnel by encapsulating the IPv6 packet in an IPv4 packet.
  - 80 0's, followed by 16 0's, followed by a 32-bit IP address.

Tunnelling

- Done automatically by the OS kernel when IPv4-compatible IPv6 addresses are used.
  - Encapsulates IPv6 packets in IPv4 packets.
  - Use a IPv4 network for packet delivery.



IPv4 Datagram

Transition from IPv4 to IPv6

- Three alternate transition strategies:
  a) **Dual stack**: Both IPv4 and IPv6 protocol stacks supported in the gateway.
  b) **Tunneling**: An IPv6 datagram flows through an intermediate IPv4 network by encapsulating the whole IPv6 packet as payload.
  c) **Header translation**: An IPv4 address is translated into a IPv6 address, and vice versa.

21

22

NPTEL ONLINE CERTIFICATION COURSES

Course Name: Ethical Hacking

Faculty Name: Prof. Indranil Sen Gupta

Department : Computer Science and Engineering

Topic

Lecture 15: Routing Examples

CONCEPTS COVERED

- Worked out examples on routing tables, packet forwarding, and routing

Example 1

- For the following routing table of a router, on which interface will the router forward packets addressed to the destinations **128.35.57.16** and **192.112.17.10** ?

Destination	Subnet Mask	Interface
128.35.57.0	255.255.255.0	eth0
128.35.57.0	255.255.255.128	eth1
192.112.17.25	255.255.255.255	eth2
default	0.0.0.0	eth3

Example 2

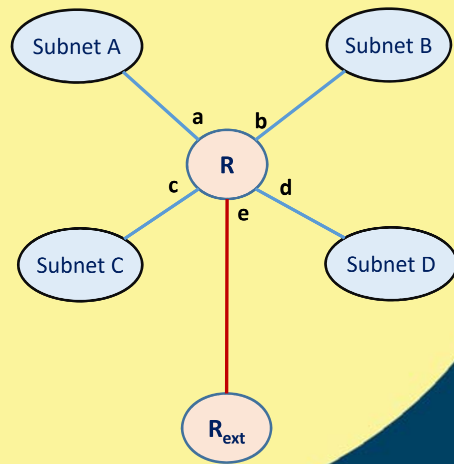
- For the following routing table of a router, on which interface will the router forward packets addressed to the destination **144.16.68.131**?

Destination	Subnet Mask	Interface
144.16.0.0	255.255.0.0	eth0
144.16.64.0	255.255.224.0	eth1
144.16.68.0	255.255.255.0	eth2
144.16.68.64	255.255.255.224	eth3
default	0.0.0.0	eth1

Example 3

- For the network as shown, the IP addresses of the four subnets are:
  - Subnet A: 215.1.2.0
  - Subnet B: 215.1.2.64
  - Subnet C: 215.1.2.128
  - Subnet D: 215.1.2.192
- The routing table of the internal router R is:

Destination	Subnet Mask	Interface
215.1.2.0	255.255.255.192	a
215.1.2.64	255.255.255.192	b
215.1.2.128	255.255.255.192	c
215.1.2.192	255.255.255.192	d
Default	0.0.0.0	e



- How will packets with the following destination IP addresses be forwarded by the router R?
  a) 215.1.2.33
  b) 215.1.2.78
  c) 215.1.2.144
  d) 215.1.2 200

Example 4

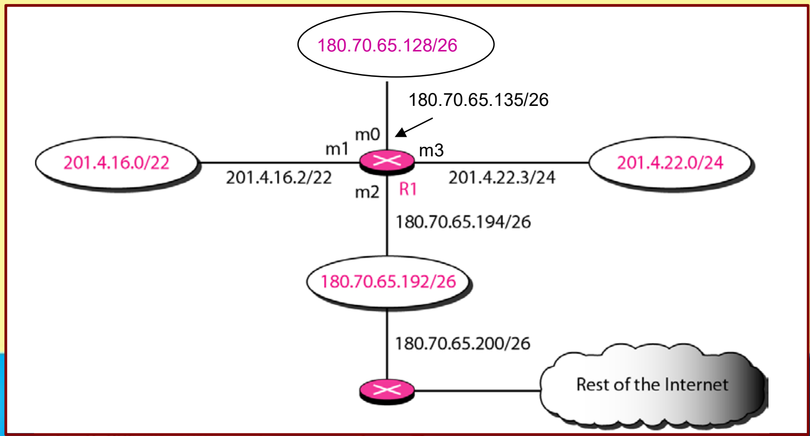
- A part of the IP routing table of a router R is shown below.

  Determine the interface to which incoming IP packets with the following destination IP addresses will be forwarded: (i) 135.46.63.10, (ii) 135.46.52.2, (iii) 190.53.41.50.

Destination	Submet Mask	Flag	Gateway / Next hop	Interface (Output Port)
135.46.56.0	/22	G = 0	-	135.46.59.4
135.46.60.0	/22	G = 0	-	135.46.62.5
190.53.0.0	/24	G = 1	128.156.79.45	128.156.79.46
190.53.40.0	/23	G = 1	156.18.19.43	156.18.19.98
0.0.0.0	/0	G = 1	134.54.78.84	134.54.78.95

Example 5

- The router R1 connects four different networks, through four interfaces m0, m1, m2 and m3. Construct the routing table. How will packets with destination IP addresses (i) 180.70.65.140 and (ii) 201.4.22.35 be routed?



Destination	Network Mask	Next Hop	Interface
180.70.65.192	/26	-	m2
180.70.65.128	/26	-	m0
201.4.22.0	/24	-	m3
201.4.16.0	/22	-	m1
0.0.0.0	/0	180.70.65.200	m2

NPTEL ONLINE CERTIFICATION COURSES

Thank you!