ITEC 414
Network Programming

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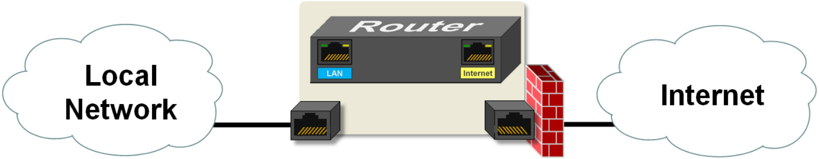
TCP/IP Protocol Suite

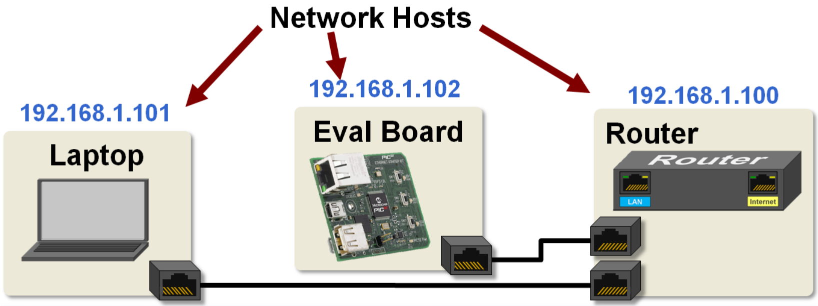
Routers in Local Networks

- Routers connect one network to another.
- They create local networks, control access to them, and route TCP/IP traffic on them.
- They also enable local network TCP/IP traffic to move to and from the Internet using Network Address Translation (NAT).
- Routers also use a firewall to restrict public Internet access to the local network.


Local Network
Router
LAN
Internet
Internet

IP Addresses

- IP addresses are used to uniquely identify every host (also known as a **network node**) on a Transmission Control Protocol/Internet Protocol (TCP/IP) network.
- They are virtual addresses assigned by routers. Each of the **four 8-bit** fields is represented by a decimal number ranging from 0 to 255.
- IP addresses are typically owned and controlled by a DHCP server running in the local network's router.
- Devices requesting to join a local network could be assigned any available local IP address and the assigned IP address could change at any time.



As a side note, the IP address examples shown here are IPv4 addresses. IPv4 is still used for the vast majority of internet communications, but it will eventually be replaced with IPv6 which uses eight 16-bit fields of addressing.

Obtaining IP Addresses

- Before communicating with a device over a local network, we need to join the network.
- The router creates a local network and controls access to it.
- It has the job of *allocating and assigning* the IP addresses used on its local network.
- When a device connects to a network, it will automatically request an IP address from the router.

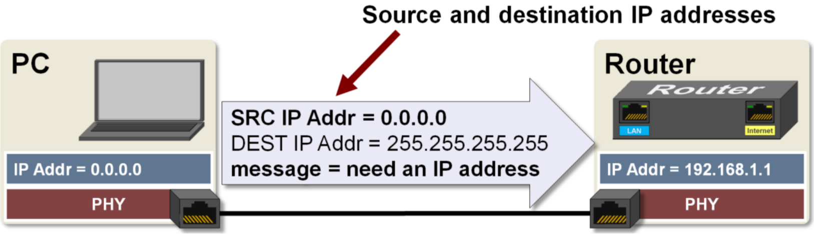
Obtaining IP Addresses

The following steps show a simplified TCP/IP transaction to get an IP address:

1. PC Generates Request for IP Address
2. IP Address Request Received in Router
3. Router offers an IP address to the PC
4. PC receives IP address from router
5. PC configures its IP address

1. PC Generates Request for IP Address

- Note that the PC’s IP Address is 0.0.0.0 before it is assigned.
- Also note the PC and the router are physically connected together with an Ethernet cable.
- The end of every Ethernet cable or Wi-Fi antenna is connected to a network PHY (physical layer of the TCP/IP Protocol).
- This PHY is a transceiver responsible for generating and driving the signals that propagate on the wire.
- It will also receive and decode signals generated by the PHY at the other end of the connection.


Source and destination IP addresses
PC
IP Addr = 0.0.0.0
PHY
SRC IP Addr = 0.0.0.0
DEST IP Addr = 255.255.255.255
message = need an IP address
Router
Router
LAN
Internet
IP Addr = 192.168.1.1
PHY

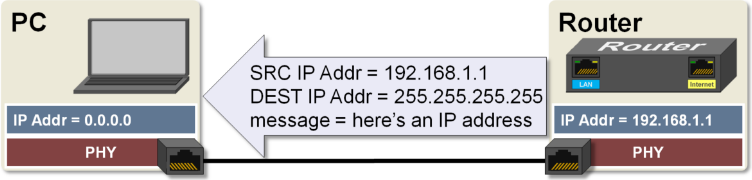
- The MAC address has been intentionally left out of this slide to simplify it. This will be discussed later.
- The broadcast IP address is 255.255.255.255.
- Dynamic Host Configuration Protocol (DHCP) is the specific application used to request and grant IP addresses.

2. IP Address Request Received in Router

- The router receives the packet and finds it has been sent to everyone on the network.
- It, therefore, has to pay attention to the packet. The router sees the sender of the packet needs an IP address assigned to it.
- That's the router's job, so it creates a new IP address for it.
- All other hosts on the local network will eventually discard the packet once they discover the content of the message and realize they cannot provide an IP address.

3. Router offers an IP address to the PC

- The router allocates a new IP address for the PC and generates a broadcast message containing this IP address.


PC
IP Addr = 0.0.0.0
PHY
SRC IP Addr = 192.168.1.1
DEST IP Addr = 255.255.255.255
message = here's an IP address
Router
Router
LAN
Internet
IP Addr = 192.168.1.1
PHY

As a side note, this frame sent by the router will include the destination MAC address of the PC. The IP address is a broadcast address, but the frame also includes the specific destination MAC address of the PC. A switch will use the MAC address to forward this frame to the PC only. The MAC address is the physical address of a network node.

Question:
Why does the router use the broadcast IP address instead of sending it directly to the PC's IP address?

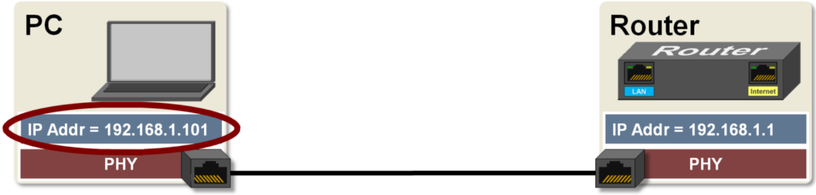
Answer:
It can't send it to the PC because the PC doesn't know its IP address yet and therefore doesn't have the ability to filter packets based on its IP address.

4. PC receives IP address from router

- The PC receives a **packet** that has been broadcast to everyone on the network.
- It opens the packet and finds it contains a message for someone requesting to have an IP address assigned to it.
- This is the message it has been waiting for!!

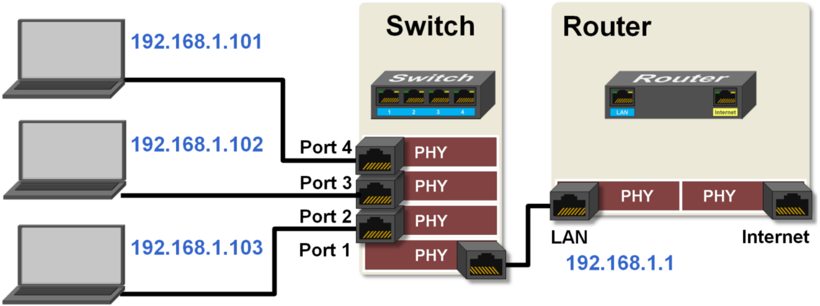
5. PC configures its IP address

The PC uses the IP address contained in the message to configure its network interface. It is now able to communicate on the network with it.



Switches in Local Networks

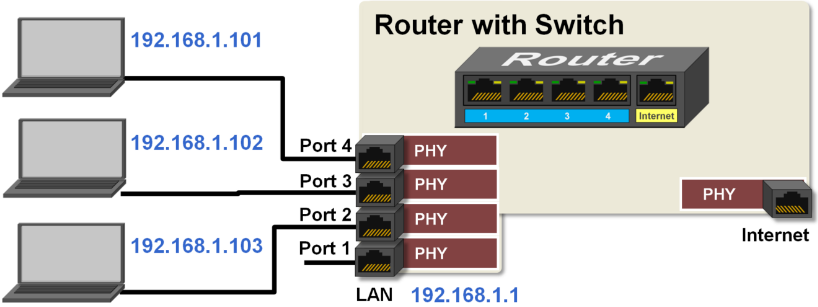
- A switch enables the connection of multiple devices to the same network.
- Note that each network interface to the switch has its own dedicated PHY responsible for driving the signals on each wire.



The uplink port on a switch is the same as the regular ports except that the transmit (Tx) and receive (Rx) signals are reversed. This means a crossover cable is not required to connect one switch to another. Most new switches have Auto-MDIX interfaces which automatically switch the Tx and Rx signals if needed.

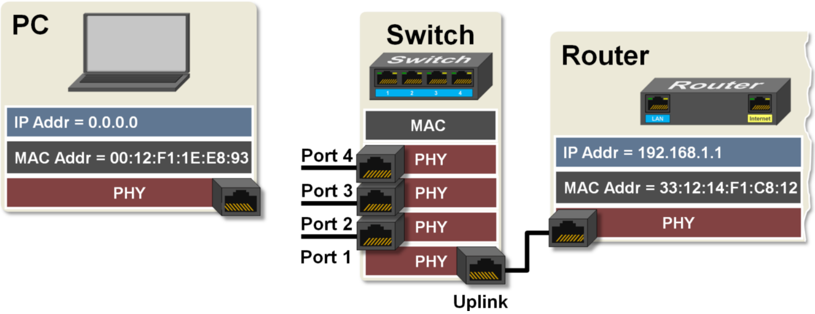
Switches Inside Routers

Most routers for homes and small business have an built-in switch.



Switches use MAC Addresses

- We’ve seen how routers use IP addresses to address hosts on the network.
- Switches don’t have the intelligence to use IP addresses.
- They instead use something called a Media Access Controller (MAC) address.



A switch uses a Media Access Controller (MAC) to forward and filter data based on a host's MAC address, not its IP address.

The MAC controls Layer 2 network functions. It forwards and filters frames based on their MAC addresses.

Every network host has two addresses:

1. IP Address (Layer 3 virtual address)
2. MAC Address (Layer 2 physical address)

Switches use MAC Addresses

- Switches are referred to as Layer 2 devices because they work with Layer 2 (MAC) addresses only.
- Routers are referred to as Layer 3 devices because they work with Layer 3 (IP) addresses only.
- The MAC is responsible for generating the frames that will be sent to the network and receiving frames that come in from the network.
- Frames that are received on a network node that doesn’t contain the node’s MAC address or MAC broadcast address (FF:FF:FF:FF:FF:FF) are not forwarded up to Layer 3.

Switches use MAC Addresses

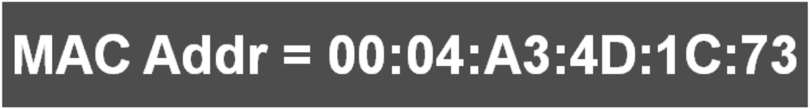
- The MAC allows multiple devices to access the same physical network using Carrier Sense Multiple Access with Collision Detection (CSMA/CD (Ethernet)), or Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA (WLAN)).

MAC Addresses

- All hosts that have an IP address also have a MAC (Media Access Controller) address.
- Unlike IP addresses which are virtual, MAC addresses are fixed hardware based addresses that never change.
- They are programmed into a device when it is manufactured and all MAC addresses are globally unique.
- They are assigned and managed by the IEEE registration authority.

MAC Addresses

MAC addresses contain six eight-bit fields expressed as hex numbers.

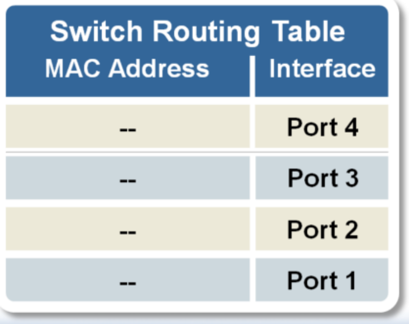


MAC Addr = 00:04:A3:4D:1C:73

NOTE: A switch has a Media Access Controller, but no MAC address. It is transparent to the network. It is never the final destination for network traffic, so it doesn't need a MAC address. A router, however, has two MAC addresses: one used for the local network or LAN, and one used for the Internet or WAN.

Example: Switch Operation on a Local Network

A switch uses a routing table to associate the switch’s port number with the MAC address connected at the other end of the wire.



Switch Routing Table	
MAC Address	Interface
--	Port 4
--	Port 3
--	Port 2
--	Port 1

A Routing Table

Example: Switch Operation on a Local Network

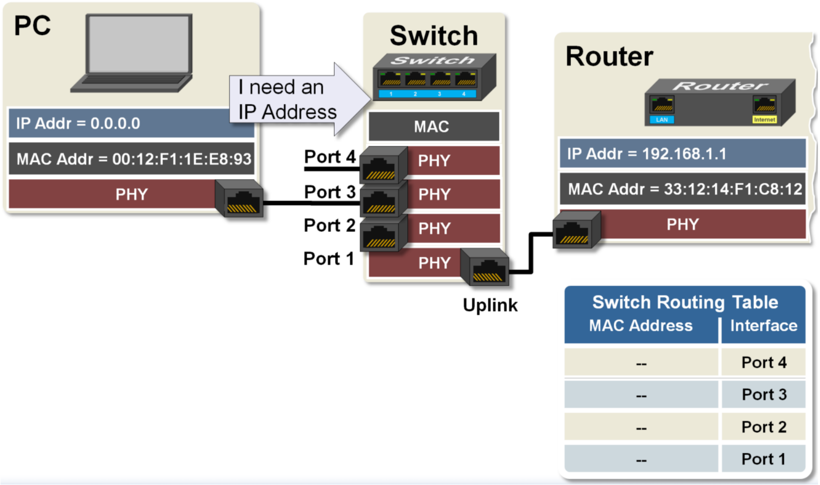
The following steps will show how the switch's routing table is populated.

1. PC Sends a Frame to the Switch
2. Switch Receives Frame
3. Switch Broadcasts Frame to all Nodes
4. Router Sends Reply to PC
5. Switch Forwards Frame to PC

1. PC Sends a Frame to the Switch

- When a host first connects to a network, it attempts to communicate with a router to obtain an IP addresses.
- It creates a packet with a broadcast IP address, then encapsulates the packet into a frame with a broadcast MAC address.
- This frame is then sent to all hosts.

1. PC Sends a Frame to the Switch



Switch Routing Table

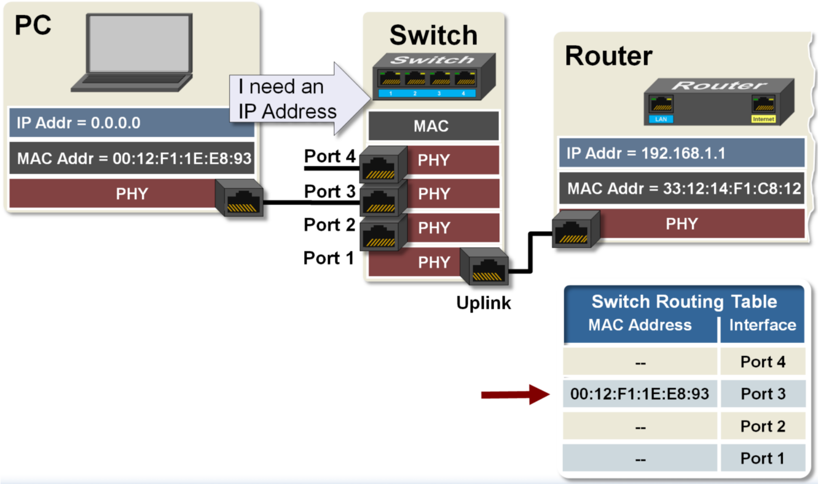
MAC Address	Interface
--	Port 4
--	Port 3
--	Port 2
--	Port 1

The MAC address used to broadcast a frame to all hosts is all ones (FF:FF:FF:FF:FF:FF).

2. Switch Receives Frame

When the switch receives this frame, it uses its routing table to associate the host’s MAC address with the interface that received the frame.

2. Switch Receives Frame



Switch Routing Table

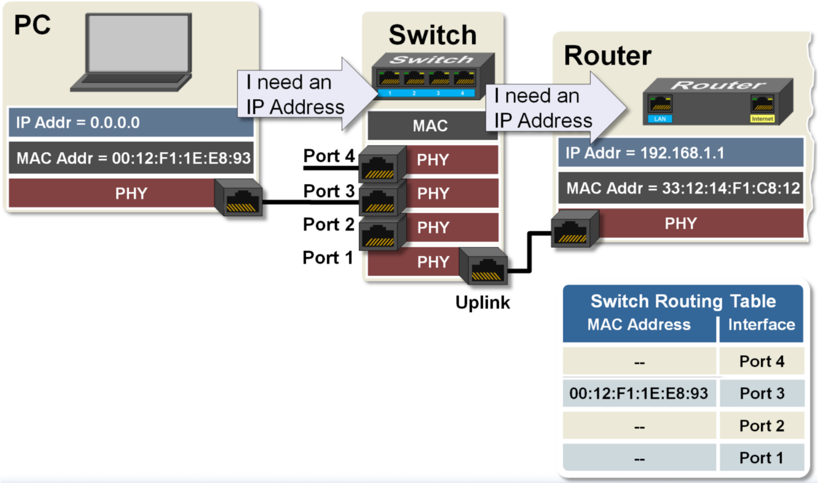
MAC Address	Interface
--	Port 4
00:12:F1:1E:E8:93	Port 3
--	Port 2
--	Port 1

Remember the frame sent to the Dynamic Host Configuration Protocol (DHCP) server in the router contains the source MAC address.

3. Switch Broadcasts Frame to all Nodes

The MAC in the switch sees this is a broadcast frame, so the switch forwards the frame to all hosts connected to it.

3. Switch Broadcasts Frame to all Nodes



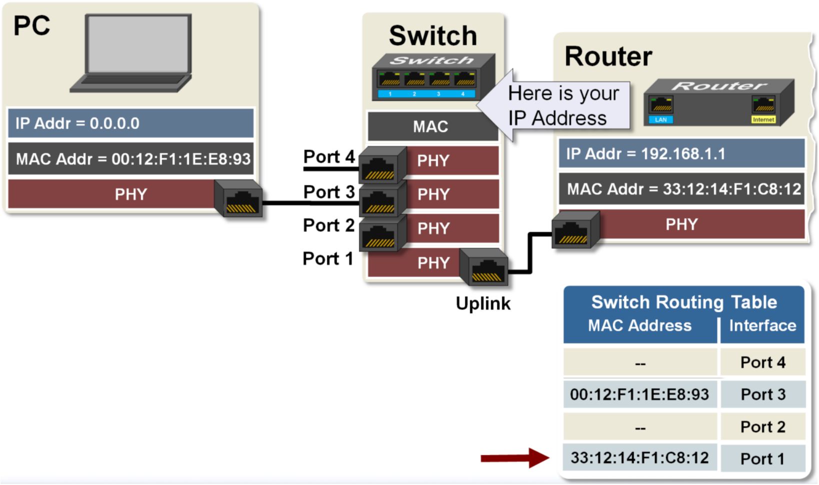
Switch Routing Table

MAC Address	Interface
--	Port 4
00:12:F1:1E:E8:93	Port 3
--	Port 2
--	Port 1

4. Router Sends Reply to PC

When the switch receives the reply from the router, it associates the router’s MAC address with the interface that received the frame.

4. Router Sends Reply to PC



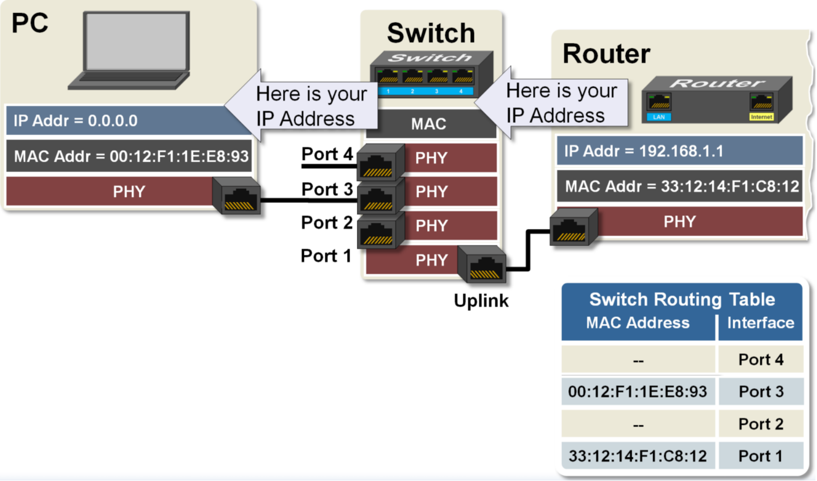
Switch Routing Table

MAC Address	Interface
--	Port 4
00:12:F1:1E:E8:93	Port 3
--	Port 2
33:12:14:F1:C8:12	Port 1

5. Switch Forwards Frame to PC

- The switch looks at this frame to find the destination MAC address and sees that it is already in its routing table.
- The frame is then forwarded to the appropriate port. No other port will see this frame.

5. Switch Forwards Frame to PC



Switch Routing Table

MAC Address	Interface
--	Port 4
00:12:F1:1E:E8:93	Port 3
--	Port 2
33:12:14:F1:C8:12	Port 1

Questions

True / False:

- When a network host connects to a network, it assigns itself an IP address then tells the router what it is.
- Routers assign MAC addresses to hosts on a local network.
- Switches forward frames to hosts based on their IP address.