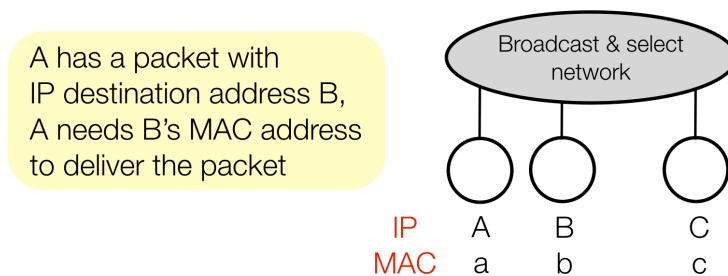


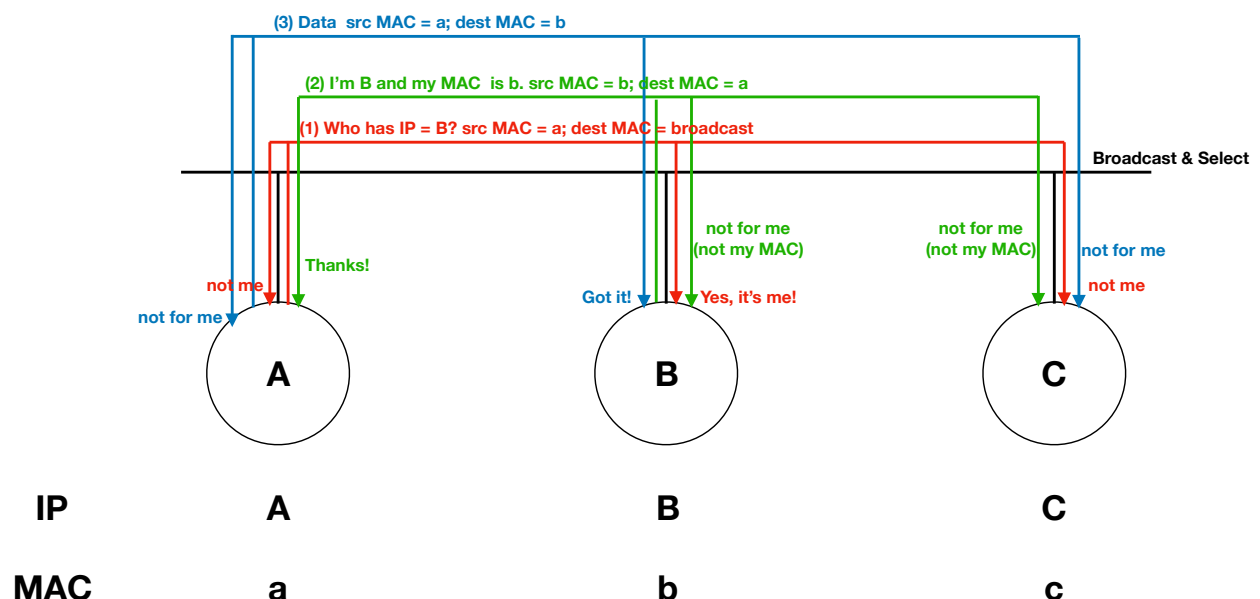
Networking Fundamentals (II)

Address Resolution

- Packet transmission in a L2 broadcast & selected network is based on the MAC address. Suppose you are on dori and want to send a message to your friend on kili. You know the hostname kili, which can be mapped to its IP address. But **how can dori tell the MAC address of kili?**
- When dori transmits a packet, it will consult its arp table first.
 - What is the arp table?
 - It's a table maps MAC addresses to IP addresses, maintained by the computer.
 - How do you check the arp table of your computer?
 - Use command line `arp -a`
- If the IP address exists in the table, then packet is sent to another machine in on the same subnet. Otherwise, the system will use **ARP** - **Address Resolution Protocol**.
 - How does ARP work?
 - Suppose a L2 network with three nodes shown in the figure below. A wants to send a packet to B. A knows B's IP but has no idea about its MAC address.



- The way ARP works is demonstrated in the figure below.



- The broadcast MAC address is a reserved MAC address, FF-FF-FF-FF-FF-FF. When using broadcast MAC address, every node in the L2 network is the destination for that packet.
- After knowing the MAC address of B, A will update its arp table including the record for B into the table.
 - Suppose kili was not in dori's arp table initially. After you ping kili from dori and check dori's arp table again, you will find the entry for kili in the updated arp table.
- Please note that if the destination IP is not in the updated arp table, the packet will be sent to the router, the default gateway.

Subnetting

- When a packet arrives at L2 network, it can be delivered via MAC address using ARP table, but **how does the network decide whether an IP address belongs to a L2 network?**
- Nodes on a local network (and only those) have IP addresses within a specific range.
- For example, Colby has its own IP address ranges. All nodes connect to Colby network has IP addresses within that range.
- In computer networks, the way to specify a range of consecutive IP addresses is via **IP Prefix**.

IP Prefix

- An IP prefix consists of a **subnet id** and a **prefix length (N)**
- For example, the prefix for Colby network is **137.146.0.0/16**, the **subnet id** is **137.146.0.0** and the **prefix length** is **16**.
- An **IP address belongs to a range** specified by a prefix **if the leftmost N bits of the IP address are the same as those in the subnet id**
- E.g., IP address 137.146.183.19 belongs to the range 137.146.0.0/16, as the first 16 bits of the IP address are the same as those in the subnet id.

Subnet Mask

- Another way to specify **prefix length**.
- It is a 32 bit, IP address-like string. The **leftmost N** bits of the string are **1s**, and the remaining bits are 0s.
 - E.g., the subnet mask represents the prefix length /16 is
 - 1111 1111.1111 1111.0000 0000. 0000 0000 (in binary)
 - 255.255.0.0 (in decimal, **a typical representation**)
 - ff.ff.00.00 (in hexadecimal)

- Prefix length and subnet mask (netmask) are equivalent for all practical purposes:
 - E.g., 137.146.183.0 with net mask 255.255.255.0 is equivalent to 137.146.183.0/24
 - But, subnet mask is easier for computers to conduct bit operations such as AND to decide whether a IP address belongs to the range or not.
- You will need to know subnet mask when you configure the network on some OS (e.g., Ubuntu).

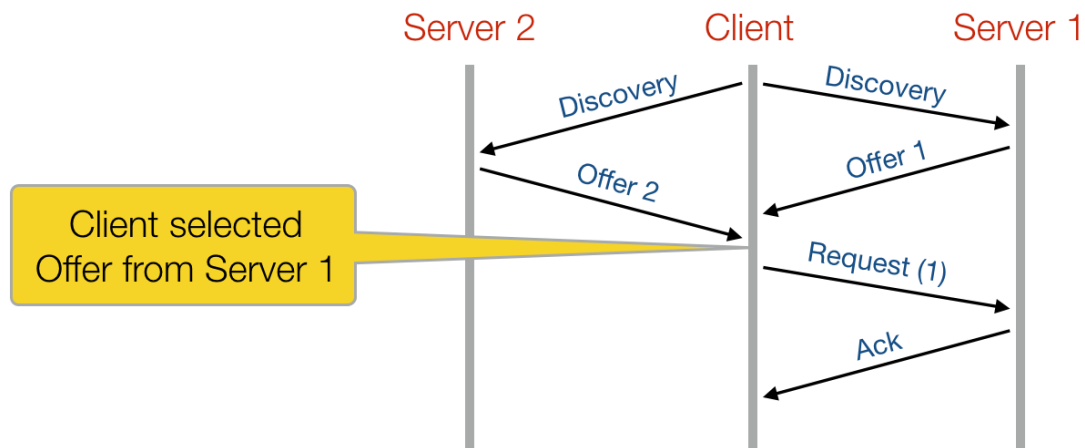
Example for IP Address Calculations

- Given IP address 192.168.152.30 and prefix length 26, answer the following questions.
 - Subnet ID: 192.168.152.0
 - First host: 192.167.152.1
 - Broadcast address: 192.168.152.63
 - Last host: 192.168.152.62
 - Subnet mask: 255.255.255.192
- Subnet mask: the leftmost 26 bits are 1s, and the rest bits are 0s, which is 11111111.11111111.11111111.11 000000. In decimal, it's 255.255.255.192.
- Subnet ID

11000000.10101000.10011000.00 011110	
AND 11111111.11111111.11111111.11 000000	
11000000.10101000.10011000.00 000000	-> 192.168.152.0
- Range represented by 192.168.152.0/26: start with 192.168.152.00 000000, end with 192.168.152.00 111111, which is 192.168.152.0 ~ 192.168.152.63
- **First host**: the first address in the range that can be assigned to a host, which is subnet ID + 1. In this question, it's 192.168.152.1
- **Broadcast address**: the maximum address in the range, usually reserved for broadcasting in the subnet specified by the range. The maximum address in this range 192.168.152.0/26 is 11000000.10101000.10011000.00 111111 (the rightmost 32-26 = 6 bits are all 1s, and the rest bits remain the same as what they were in subnet ID). In decimal, the broadcast address is 192.168.152.63.
- **Last host**: the last address in the range that can be assigned to a host, which is broadcast address - 1. In this question, it's 192.168.152.62

DHCP

- We know that when a computer joins into a subnet, it will be assigned a new IP address in the address range of that subnet without any human intervention. How does the network assign an IP address to a newly joined computer automatically?
- **Dynamic Host Configuration Protocol**
 - application layer protocol
 - plug-and-play or **zero-configuration** protocol, alleviate the workload of administrator
 - to obtain IP address and other configuration params (e.g., how long you can use the IP)
 - one or more DHCP servers on the same subnet (to reduce congestions and improve reliability)
 - utilizes IP broadcast (255.255.255.255) and UDP
 - **Four steps** to acquire an IP address:
 - **Discovery**: find a DHCP server
 - **Offer**: proposed IP address and IP address lease time (several hours or days)
 - **Request**: choose from one of the offers, echo back the configuration parameters
 - **Ack**: confirm the request parameters



Disclaimer: Notes adapted from the textbook and online resources.