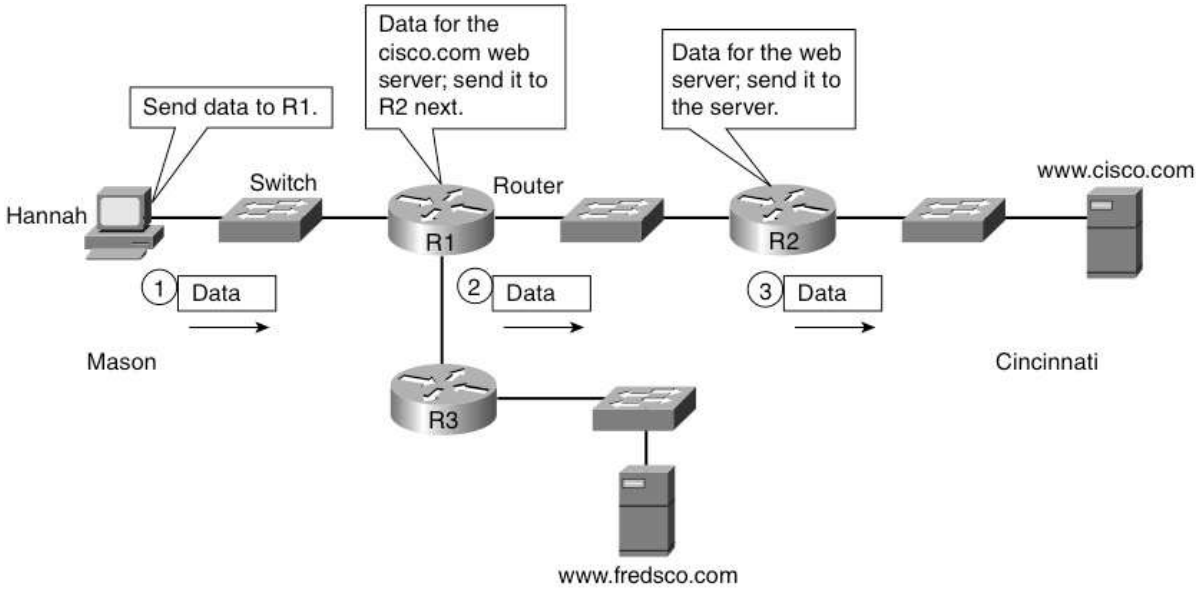
Routing

- Routers are devices that sit at the intersections between two or more networks – shown as cylinder with arrows pointing to center
  - Act to interconnect those networks
    - Forward packets from one network to another
  - Can connect networks of same or different types
- A group of mutually interconnected networks forms an internetwork, or internet
  - Routing is the process of moving data from its source to its destination across an internet

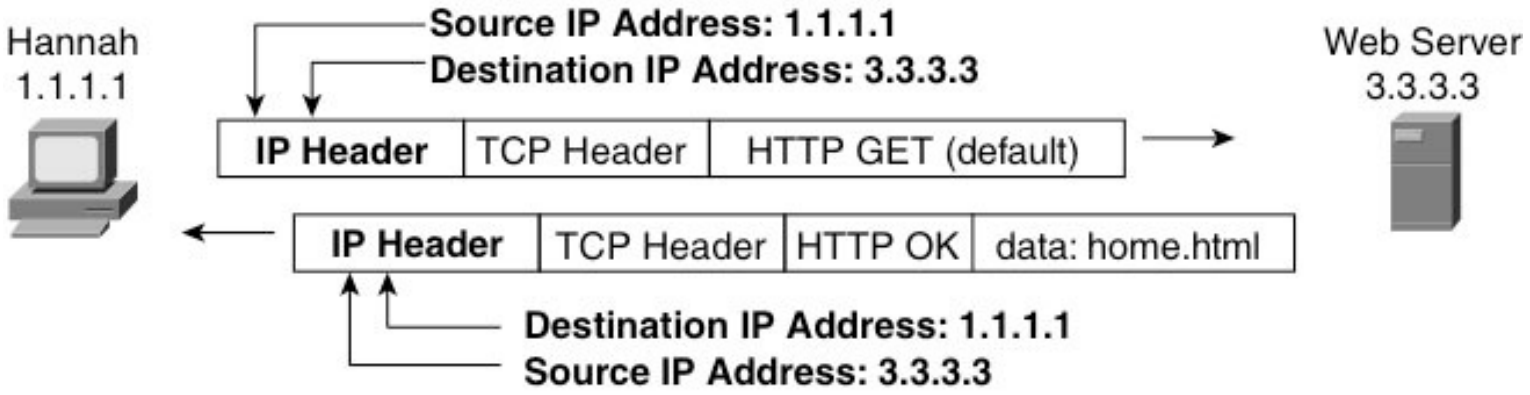


Internet Protocol (IP)

- Layer 3 protocol – defines internet addressing and rules for routing
  - IP addresses
    - Defined to simplify routing
    - 32-bits – canonical (or dotted quad) notation – 4 decimal octets
      - 132.177.4.208 is IP address of wcit.cs.unh.edu
      - 132.177.137.6 is IP address of newton.unh.edu
    - Every network interface must have its own unique IP address
      - Most computers have only one
      - Routers have many
  - Host – any device with a functioning network interface that can send and receive IP packets

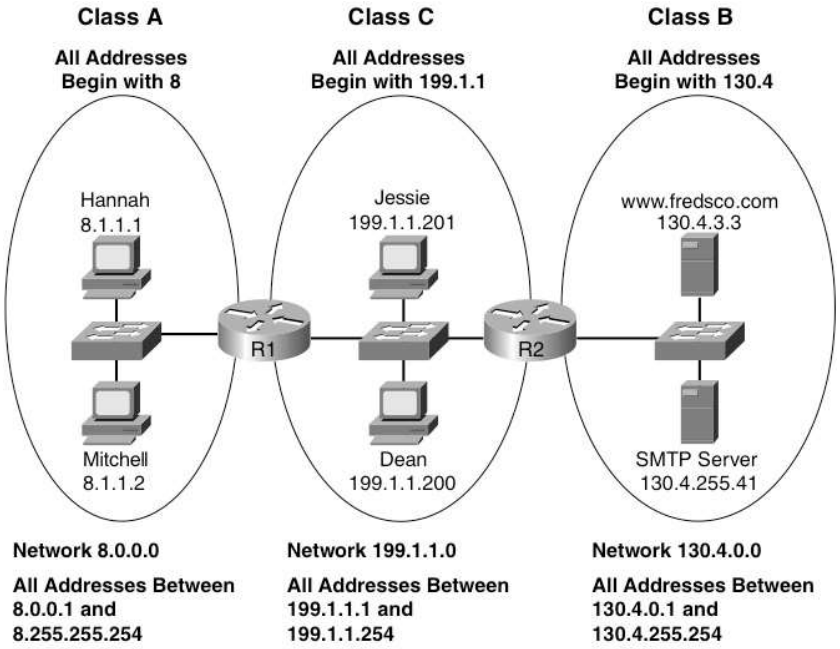
IP packets

- IP header + data payload = IP packet
  - Packet is a Layer 3 term (datagram is also common)
    - Segment is a Layer 4 term
    - Frame is a Layer 2 term
  - IP header is 20-bytes long
    - Includes source and destination IP addresses
  - Data payload is often a TCP segment
    - IP provides for the end-to-end delivery of TCP segments
    - Connectionless, best-effort system



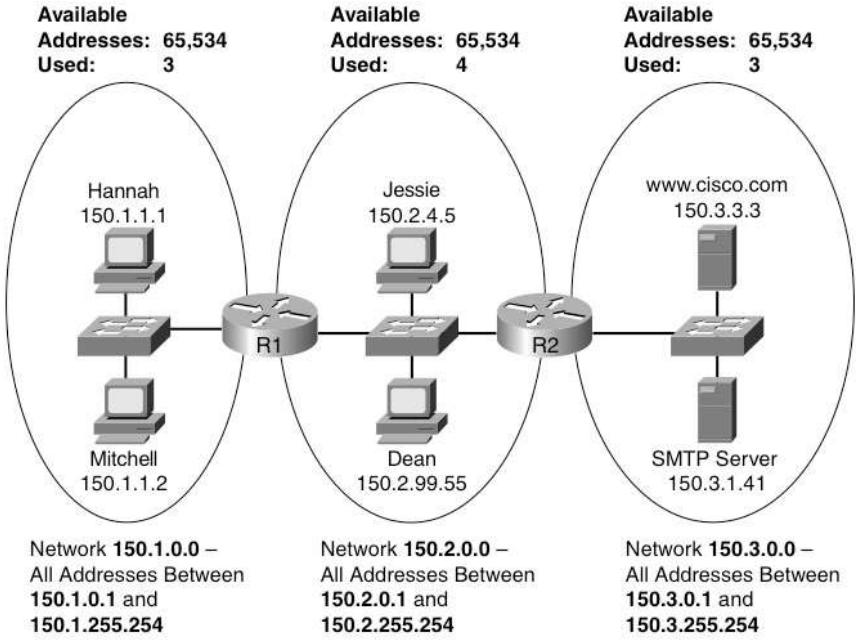
IP addresses

- All IP addresses on the same physical network have an initial portion in common
  - IP network number – similar to a Zip code
    - Written like an IP address, but only shared portion is indicated, rest zeroes
    - Shared portion is called network portion, remainder is host portion
  - Simplifies routing
    - Routers don't need to know where each individual address is, just where each network is
- Class A
  - 1 octet specified (1st is 0-127)
    - 128 networks
    - 16,777,216 addresses each
- Class B
  - 2 octets specified (1st is 128-191)
    - 16,384 networks
    - 65,536 addresses each
- Class C
  - 3 octets specified (1st is 192-223)
    - 2,097,152 networks
    - 256 addresses each



Limitations of IP addresses

- Routers only work with network portion of IP addresses
  - Cannot distinguish individual hosts on a single IP network
  - So we need one IP network per physical network
  - But few physical networks need all their IP addresses
    - Many IP addresses are wasted
- IPv4 provides at most 4,294,967,296 unique addresses
  - Over 20,000,000,000 devices on the Internet as of March 2016
    - Not enough, so wasted addresses should be minimized
  - Migrating to IPv6 which provides up to about 3.402 x 10^{38} addresses
    - More than 7 addresses for every atom in every human body on the planet



IP subnetting

- Most LANs connect at most a couple hundred hosts
  - Using a class A or class B network for such a LAN would waste most of its addresses
- Avoids wasting IP addresses by relaxing the rules
  - Allows IP networks to be subdivided into subnets
    - Each subnet gets treated as a separate network
    - Devices in same subnet cannot be separated by a router
    - Devices in different subnets must be separated by a router
  - Works by extending network portion of IP addresses into host portion
    - Each IP address on the subnet begins with the extended network portion