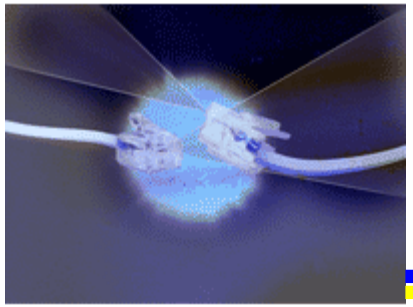
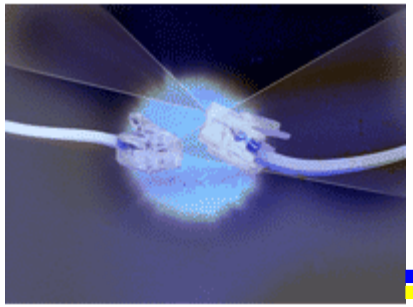


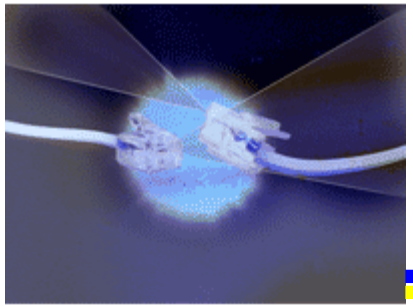
Internetworking

- Connecting networks together
- Main problems:
  - *Heterogeneity* – not all networks are of the same type
  - *Scale* – how can it work as the connect network grows much larger (i.e. the Internet)
    - *Routing* – how do you find a path through a huge network
    - *Addressing* – how do you identify huge numbers of nodes



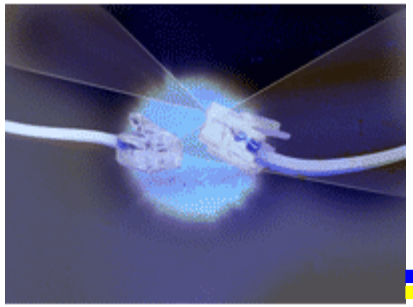
Simple Internetworking

- An internetwork, or internet, is a connection of LANs and/or switched networks – a *logical* network formed from connecting *physical* networks
- Devices connecting physical networks are called *routers* or *gateways*



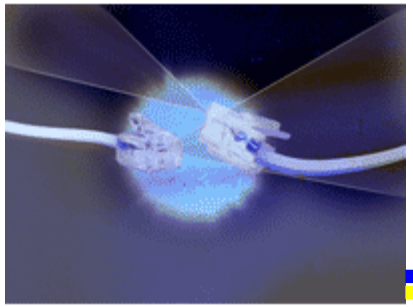
Internet Protocol (IP)

- Primary internetworking tool used today
- Invented by John Kahn and Vinton Cerf
- Best case study of an internetworking protocol, since it has had widest acceptance, but there have been other alternatives
  - IPX from Novell, XNS from Xerox
- Runs on all nodes (hosts and routers) in internetwork



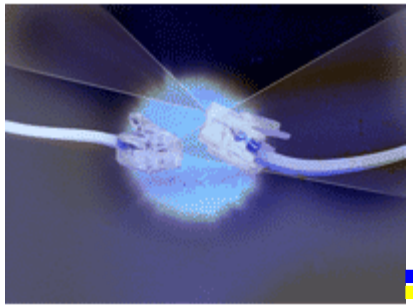
Service Model

- Defines which host-to-host services, or functionality, will be provided
  - Can only deliver services that can be provided by every physical network that might be connected
- IP service model is very simple
  - Addressing scheme
  - Datagram delivery model – best effort delivery (tries hard, but no guarantees)



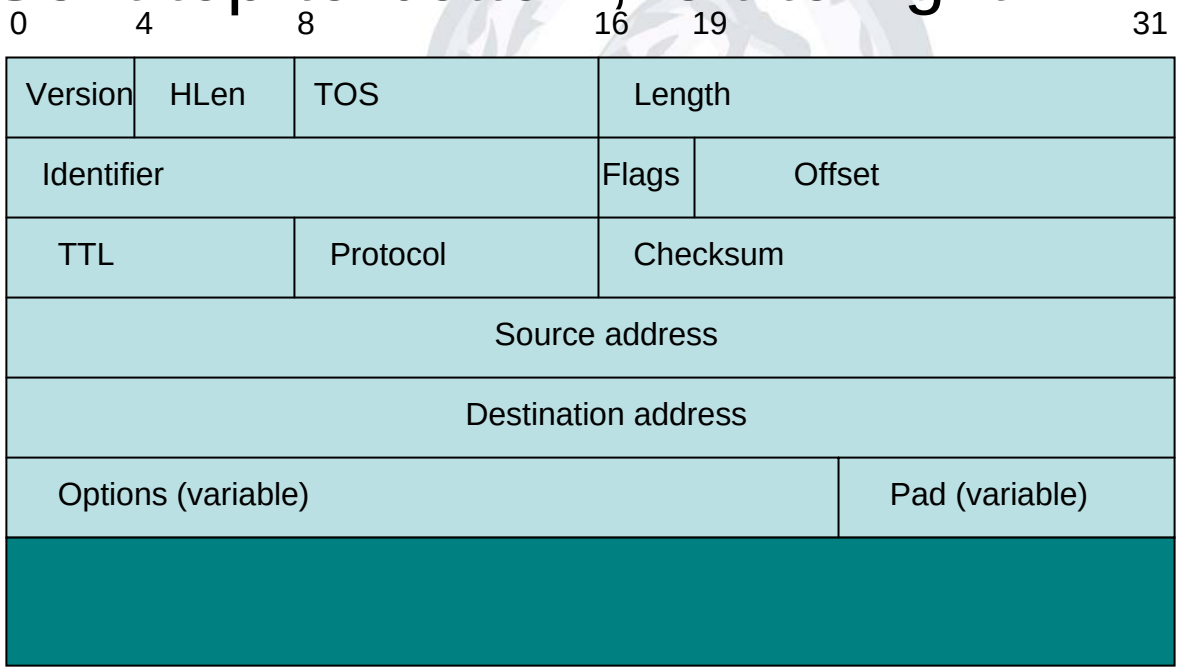
Datagram Delivery

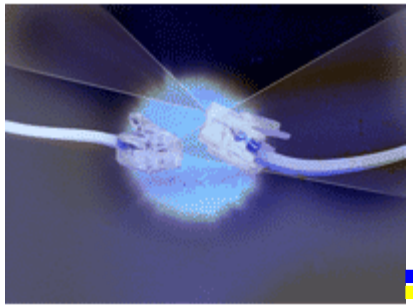
- Datagram == connectionless interchange
- Also == unreliable service
- Simplest service internetwork can provide
  - Should be provided by any underlying physical network you want to connect
- Potential problems: lost packets, out-of-order packets, multiple copies delivered



Packet Format

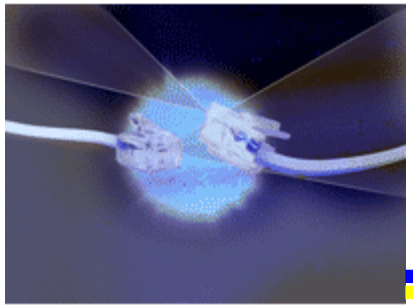
- IP datagram format
  - Designed to align on 32-bit boundaries
  - Sent top-to-bottom, left-to-right





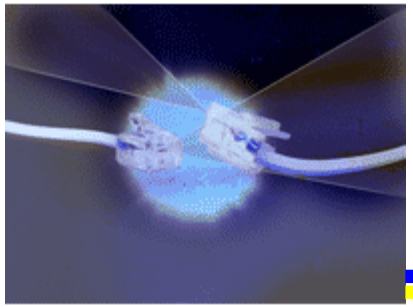
Header Fields

- Version – currently 4 (hence IPv4)
- HLen – header length in 32-bit longs (usually 5)
- TOS – type of service
- Length – bytes in packet, including header (max 65,535)
  - Might require fragmentation/reassembly; second long of header for this purpose



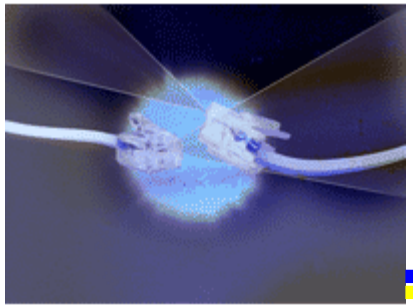
Header Fields (cont.)

- TTL – time to live: hop count, --TTL in each router. Initial value typically 64
- Protocol – higher level protocol ID. UDP is 17, TCP is 6
- Checksum – calculated over header, by adding 16-bit values with one's complement arithmetic, then taking one's complement of result
- Options – rarely used



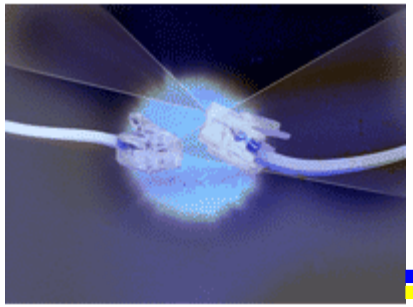
Addressing

- Datagram packet switching used, so every packet must contain full source and destination addresses
- Every address should be globally unique
- Addresses belong to interfaces, rather than hosts (so router has multiple addresses)
- Desirable to have a *hierarchical* address space, instead of a flat address space like MAC addresses
  - IP address has network and host parts



IP Addresses

- Three different *classes*
  - Class A: first bit is 0, next 7 bits are network, last 24 bits are host (half of all addresses)
  - Class B: first bits are 10, next 14 bits are network, last 16 bits are host (quarter of all)
  - Class C: first bits are 110, next 21 bits are network, last 8 bits are host (eighth of all)
- Values 0 and all 1s reserved, so class A has 126 networks, class B has 65,534, and class C has 2^{21} networks, but only 254 nodes on each



IP Addresses (cont.)

- Typically written in *dotted-decimal* form:
  192.168.0.1, 64.25.129.148
- Some values reserved
  - 192.16.0 network is for local use
  - 127.0.0.1 is *localhost*