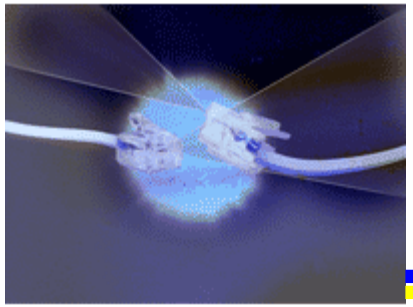
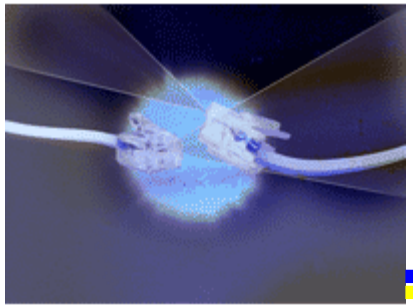


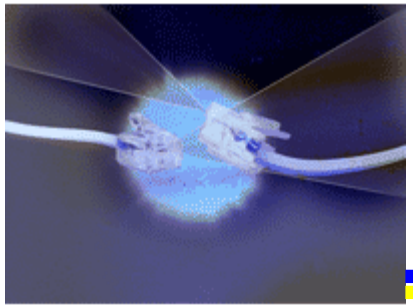
Switching / Forwarding

- A *switch* is a device that allows interconnection of links to form larger networks
  - Multi-input, multi-output device
  - Packet switch transfers packets from an input to one or more outputs
- Creates a *star* topology
  - Can connect switches to each other and to nodes with point-to-point links
  - Connecting a new node does not necessarily decrease the performance of the network for other connected nodes



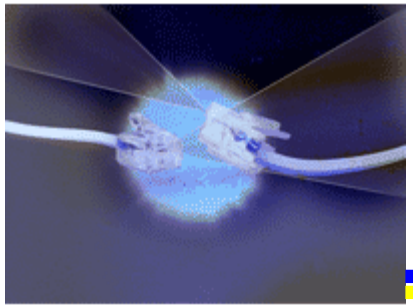
Switched Networks

- More scalable than shared-media networks
  - Can interconnect switches to increase size of network
  - Can support much higher overall speeds if switches have enough aggregate capacity
- Switch runs appropriate data link protocol on each link – all ports don't have to be the same



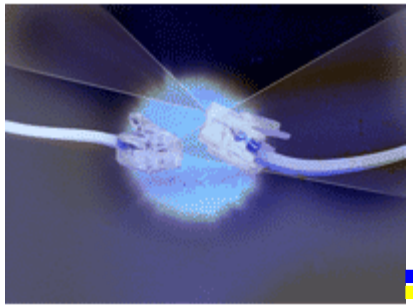
Port Selection

- Switch must decide to which output port to send each packet – process called *switching* or *forwarding*
- Main function of OSI network layer (3)
- Switch looks in header of packet for destination address
  - Addresses must be *globally unique* to allow accurate switching



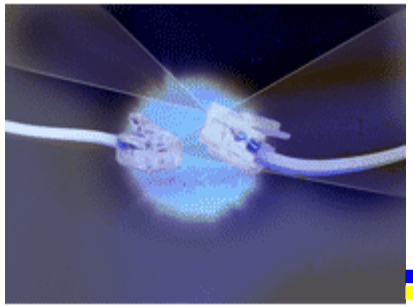
Port Selection (cont.)

- Different techniques:
  - Datagram (connectionless)
  - Virtual circuit (connection-oriented)
  - Source routing



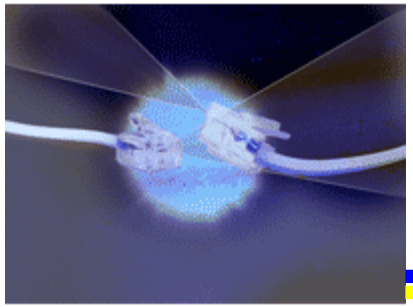
Datagram Switching

- Each packet must contain enough info to enable every switch to route it to its final destination (i.e. the destination address)
  - Switch needs a *forwarding table* to decide which port to use for each destination address
  - For small, static networks, table can be configured manually on each switch
  - For larger networks, or networks that change dynamically, need *routing* techniques to keep table up to date



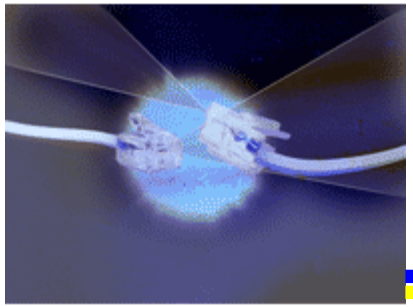
Datagram Switching (cont.)

- Datagram network characteristics:
  - Node can send packet anywhere at any time; switch can immediately forward packet when it shows up (if forwarding table in place)
  - Switch doesn't know whether a packet can reach its destination when the packet is sent
  - Each packet is forwarded independently of previous packets, even to same destination
  - Switch or link failure not necessarily a problem if an alternate route can be found and forwarding table is updated (adds robustness to network)



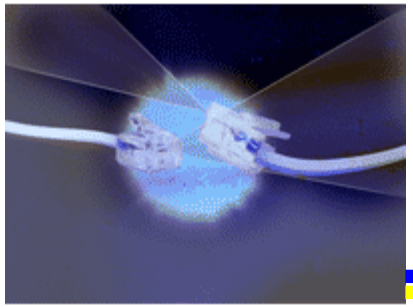
Virtual Circuit Switching

- Virtual Circuit (VC) established between source and destination before first packet can be sent
  - Two stages: connection setup, then data transfer
- Connection setup establishes *connection state* in each switch between source and destination



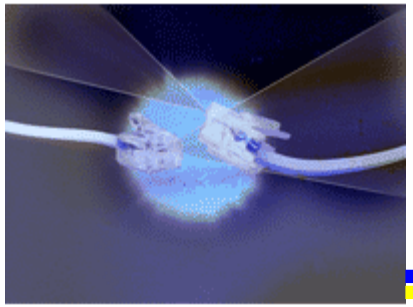
VC Switching (cont.)

- Each switch contains a VC table. Each entry includes
  - Virtual circuit identifier (VCI) – unique identifier for connection for the switch. Only has *link-local scope*
  - Incoming interface port
  - Outgoing interface port
  - Possibly new VCI to use for outgoing packets



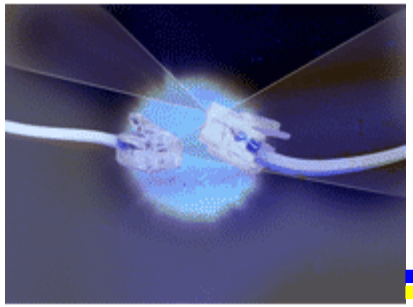
Virtual Circuit Types

- Permanent (PVC)
  - Established by network administrator
  - Can be deleted, so it's really just long-lived
- Switched (SVC)
  - Node sends messages to network to establish connection (*signalling*)
  - No administrator involvement required



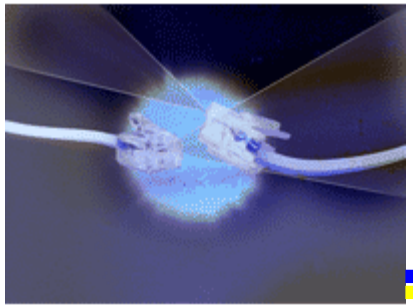
VC Data Transfer

- Source node needs to determine VCI associated with destination node, puts that value in packet header
- Switch receiving packet uses incoming port and VCI to locate entry in VC table, finds outgoing port and new VCI, updates packet, and sends it on
- Destination port can identify sender by the VCI in the packet when it arrives



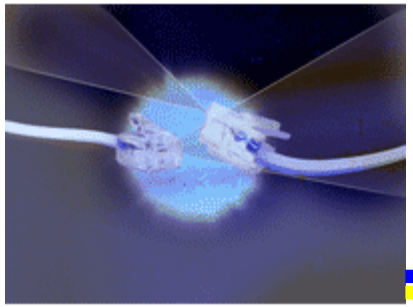
Signalling Process

- Source node sends a setup message to first switch
  - Message contains full destination address
  - Each switch must contain something like datagram forwarding table to get setup message across network to destination
  - Switch creates entry in VC table, assigns VCI, and sends setup message to next switch/node



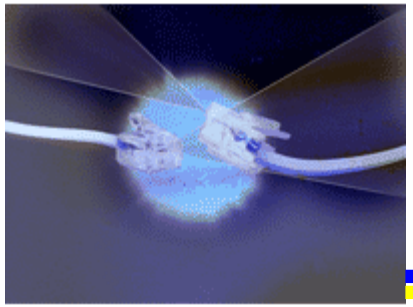
Signalling Process (cont.)

- When setup message reaches destination node, it also allocates VC table entry, assigns VCI
- Host sends ACK to switch, including its VCI
- Switch locates VC table entry by finding outbound port associated with incoming port on which it received ACK. Updates entry with outgoing VCI
- Switch sends ACK on outgoing port associated with the incoming port in the VC table entry
- ACK eventually gets back to original source; VC setup is complete



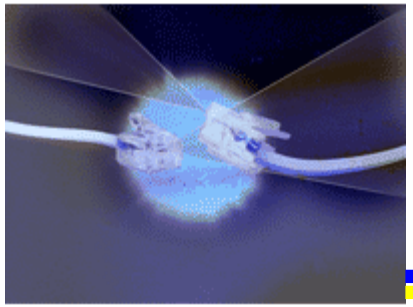
Connection Teardown

- When source no longer needs to send to destination, it *tears down* connection
  - Sends teardown message to first switch
  - Switch finds VC table entry, gets outbound port and VCI, and removes VC table entry
  - Switch updates teardown message with new VCI and sends it on to next switch
  - Continues until destination receives teardown message



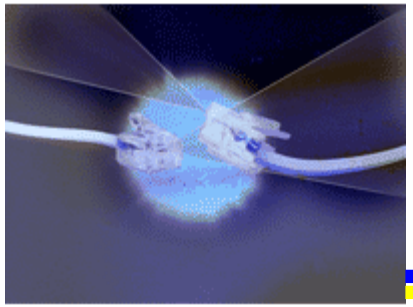
VC Properties

- Source node needs to wait for at least one RTT for connection setup to traverse network
- Connection request contains full global address for destination, but data packets contain small VCI value
- If switch or link fails, connection is broken and must be reestablished. Old circuit must also be torn down to free up VC table entries
- Switch also needs routing algorithm to decide how to send connection setup message; same problem as datagram switching



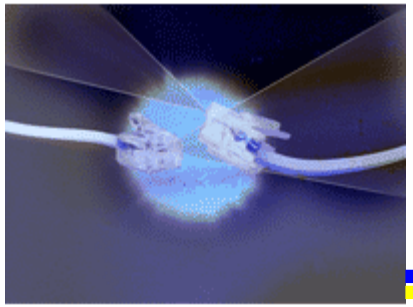
VC Properties (cont.)

- By the time connection is established, source knows destination is alive and reachable
- Resources can be allocated during setup
  - Buffer space reserved
  - Sliding window with flow control initialized between pairs of nodes/switches
  - Circuit setup rejected if insufficient buffers available
  - *Hop-by-hop* flow control
- Possible to provide different *quality of service* (QoS) for each circuit



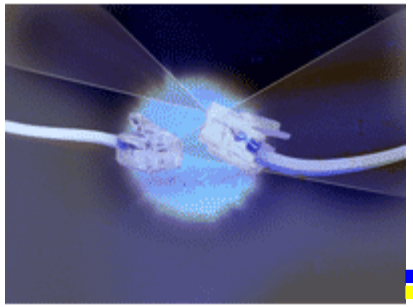
VC Properties (cont.)

- Popular VC technologies:
  - Frame Relay
    - Virtual Private Networks (VPNs)
  - Asynchronous Transfer Mode (ATM)



Source Routing

- All information required to switch packet provided by source node
  - Source could put FIFO list of output port IDs in header of packet
  - Each switch would remove port ID from header and send updated packet on that port
  - Could also rotate list, so when packet arrives at destination, it can see complete route from source
- Undesirable requirements
  - Source must know topology of entire net – not scalable
  - Variable length packet headers



Source Routing (cont.)

- Can be used with either datagram or VC networks
- IP includes source routing option