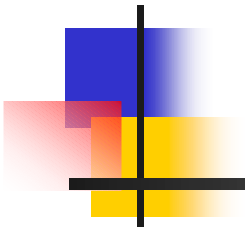
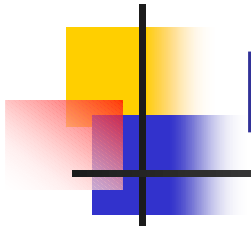
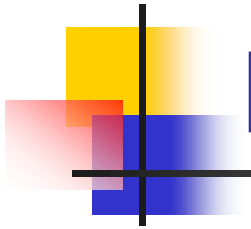


Categorization of Optical Switching Techniques



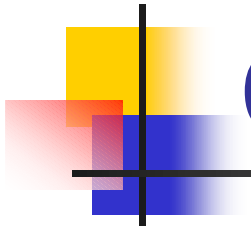
Reconfigurable Switches

- Switches may be called routers, cross-connects or ADMs (add-drop multiplexers).
- Optical switches keep the data stream in the optical domain, although they still may be controlled by electronics.
- Currently these equipment are common in a backbone (core) network.



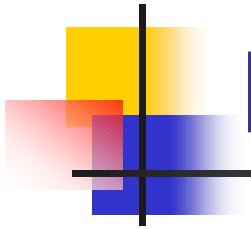
Switching Techniques in Networks

- Circuit Switching
- Packet Switching
- Burst Switching



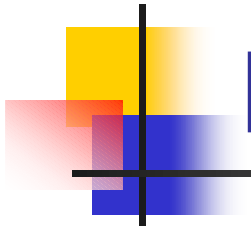
Circuit Switching

- 3 steps:
  1. Circuit set-up
  2. Data transfer
  3. Circuit tear down
- Good for constant bit rate.
- Circuit set up time has to be significantly less than data transfer time.
- No processing needed at the intermediate nodes, once a circuit is established, thus does not heavily rely on fast switches nor does it need to buffer data (no delay jitter).
- Routing is part of circuit set-up.



Fast Circuit Switching

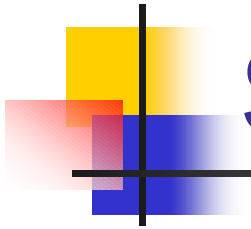
- First step does the routing but does not set-up a circuit.
- Circuit set-up (or tear down) is done at the transmission of the bursts by employing a short control message.
- Circuit set-up can also be a “one-way” process, where no acknowledgement from the network is needed prior sending the burst.



Packet Switching

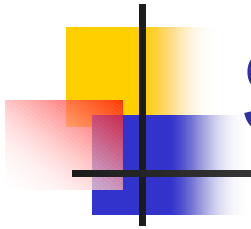
- Data is sent w/o setting up a circuit.
- Usually employs distributed routing control.
- Store-and-forward mechanism needs buffering and dynamically (re)configures the switches.
- Good for bursty traffic => allows statistical sharing. Requires buffers and quick switching.
- Message switching: large sized packets packets are assembled together at the end-nodes. Requires larger buffers and message delay will be high(er).

Datagram Based Packet Switching



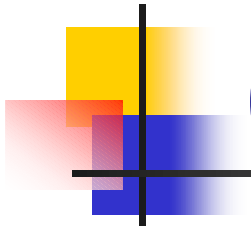
- Packet header (control information) and payload are sent over the same channel. Headers are “glued” to the payloads. (E.g., IP)

Virtual Circuit based Packet Switching



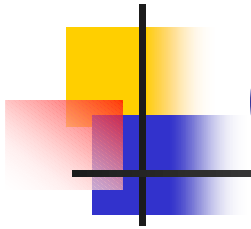
- Two (3) phases:
  1. Setting up a VC (or routing)
  2. Sending packets over the VC (switching)
  3. (tearing down the VC)
- Setting up a VC does not require dedicated bandwidth – just an entry in the routing tables of intermediate nodes along the selected path. These entries map the VC identifier (sent together with each packet) to the route it has to go on to. This table lookup is easier than making a routing decision. (E.g., ATM has this capability)

Multiprotocol Label Switching (MPLS)

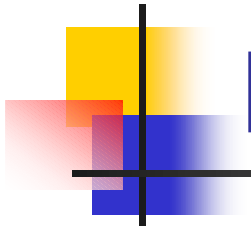


- [Callon, 1997] Is currently standardized by IETF.
- Similar to VC packet switching.
- Label-switched paths (LSPs) are established (instead of VCs). Routing decision is made only once at the establishment of the LSP.
- MPLS can handle different traffic types (packets belonging to the same source and destination pairs can have different LSPs depending o their importance – and routing can consider these metrics).

Multiprotocol Label Switching (MPLS)

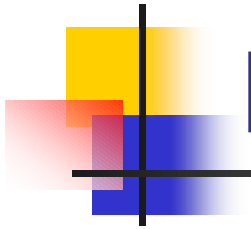


- The establishment of LSPs can be:
  - control driven (performed by the network according to its topology)
  - Or data-driven (e.g., the first couple of packets are routed by IP at each node, but when the destination receives a given amount of packets it triggers the establishment of an LSP (e.g., for one TCP stream).



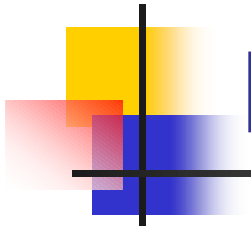
Burst Switching

- Packets to the same destination are assembled into bursts, that are sent over the network with one connection set-up (routing).
- One-way reservation: no acknowledgment from the network is needed, thus pre-transmission delay of the burst is reduced.



Burst Switching

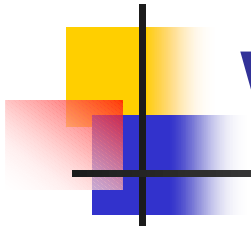
- Three variations for bandwidth releasing:
  - Tell-and-go (TAG): as soon as burst is transmitted the sender sends an explicit release message to tear down the circuit (like circuit switching).
  - Reserve-a-fixed-duration (RFD): each set-up request specifies the duration for the circuit.
  - In-band-terminator (IBT): a burst contains a header and tail (terminator) to indicate the end of the burst. (like packet-switching)



Burst Switching

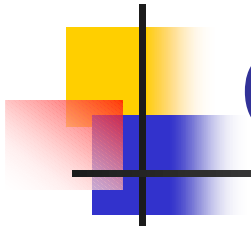
- Let T be the time between the issuance of the set-up request and the transmission begin of data.
- T can be shorter with on-way reservation and TAF or RFD than the time required to set up all immediate switches.
- Although, if T is too small, buffering is needed. Virtual cut-trough is the technique where if the next hop is established the burst can be sent right away (even when it is still being received).

Switching in Optical Networks



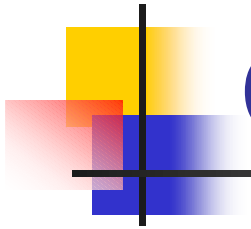
Wavelength Routing

- Basically circuit switching in an optical network.
- All-optical path (no OEO conversions are needed) and is established before data can be sent.
- They provide high speed high-bandwidth “pipes”.
- Lightpaths may be dynamically established.
- Not efficient for bursty Internet traffic.



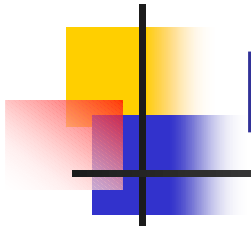
Optical Packet/Label Switching

- Data remains in the optical domain while headers may be processed electronically (or optically – not mature yet).
- Since limited optical processing is available , VC based packet switching is more popular than datagram (NO OPTICAL RAM).



Optical Burst Switching (OBS)

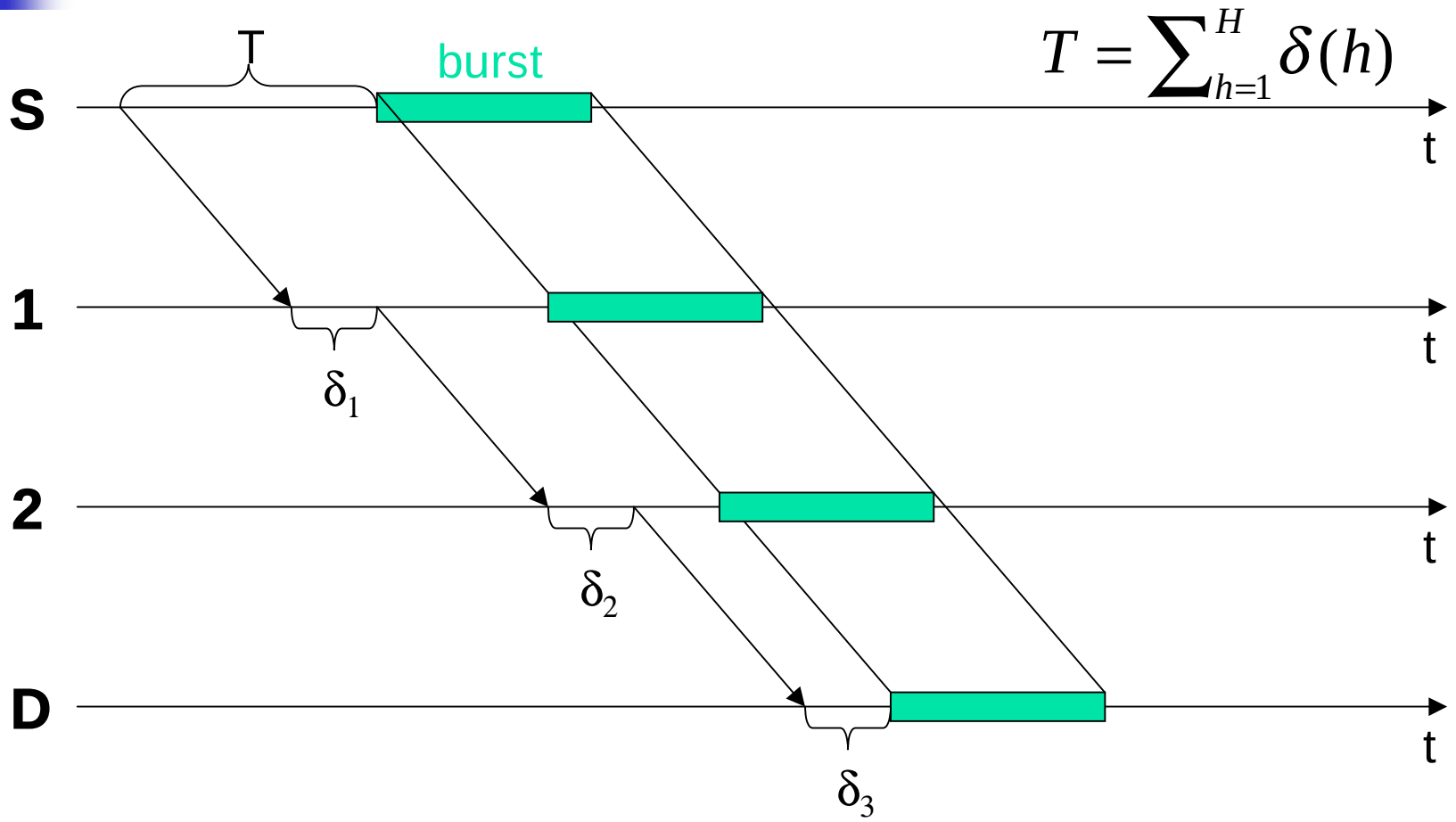
- Provides temporary solution between label and and wavelength switching.
- It is difficult to optically recognize ends of bursts, thus OBS is likely to be TAG and RFD.

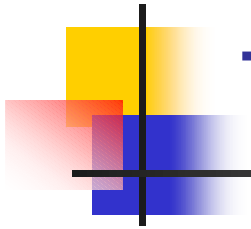


RFD based OBS - JET

- Just Enough Time (JET) [qiao, 1997]
- Offset time between message and control-message is greater than equal to the sum of set-up times for the switches involved.
- Burst is buffered at the source => no buffers or delay lines (FDL) are needed.
- If the requested bandwidth is not available the burst is blocked (and will be dropped if no buffering is available).

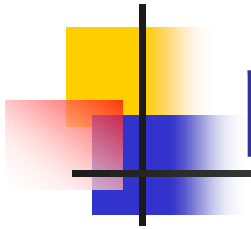
RFD based OBS - JET





TAG based OBS vs. JET

- Explicit tear down signal is used.
- Since loss of tear down signal would result in wasting the bandwidth, each source is required to periodically refresh ongoing reservations (timeouts).
- JET is more bandwidth efficient.



pJET for Differentiated Services

- Prioritized JET, where two classes of bursts are distinguished:
  - Best-effort
  - Real-time
- For real-time bursts, T is expanded by an offset, enabling the network to make reservations way ahead of time.
- The selection of the offset is a trade off between independence of the two types of burst handlings and induced delay for real time traffic.