



**IP over ...  
... ATM ... SDH ... DWDM**

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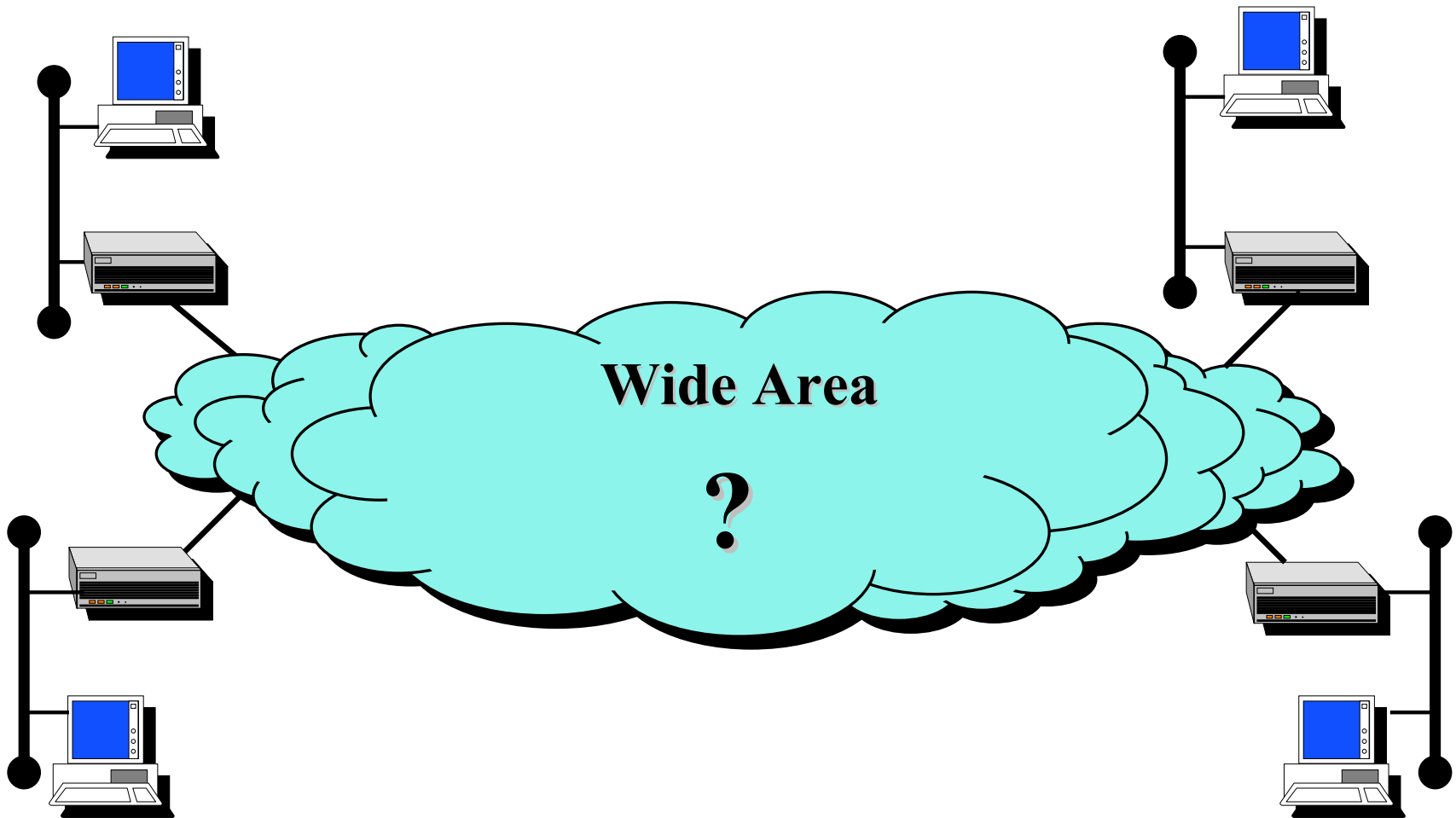
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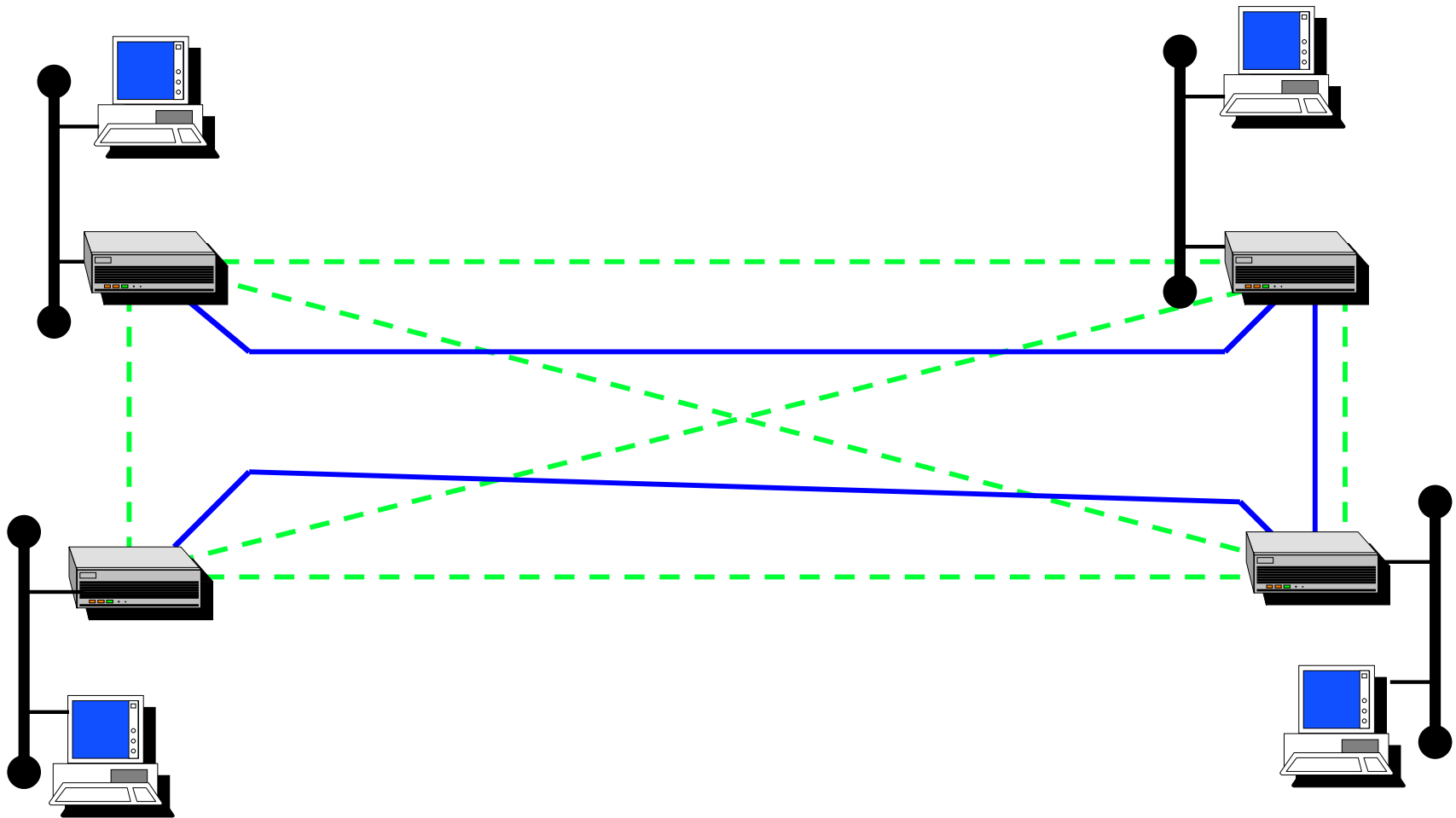
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# IP Everywhere. Anything else?



# Which is the Best Interconnection Topology?





# Even if You Know It, You Know It only *Now!*

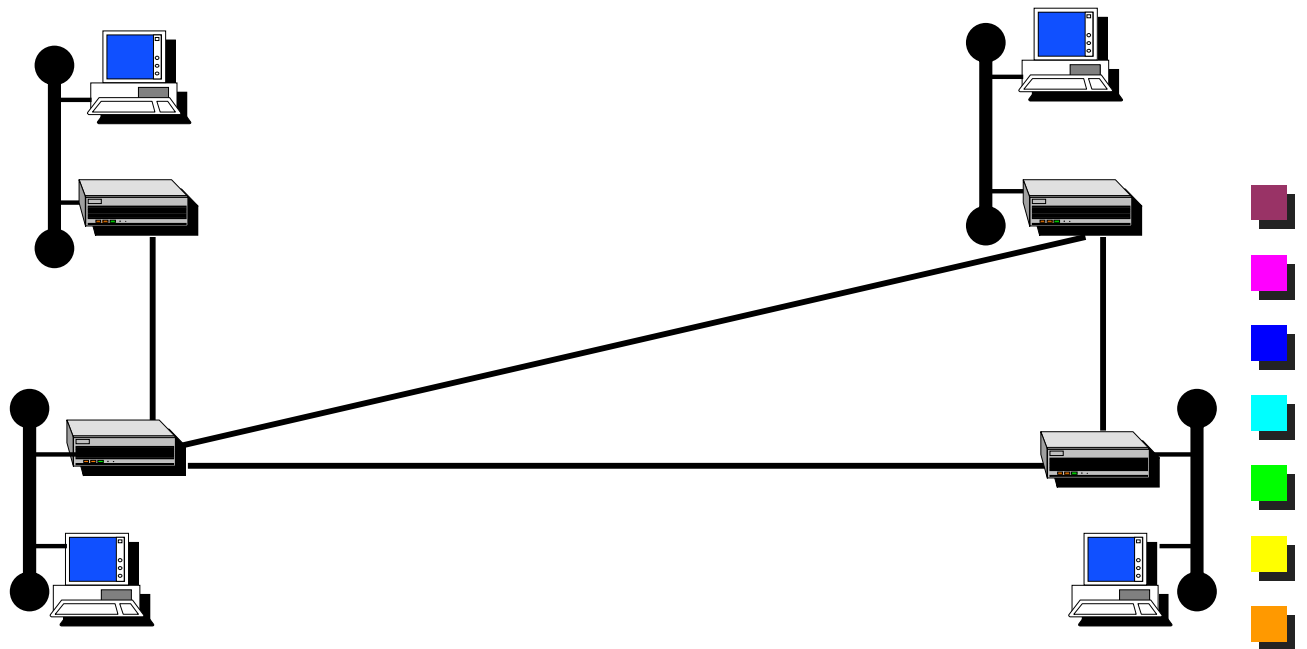
- It can change on a monthly base
  - different customers
  - different customer needs
- It can change on a weekly base
  - events
- It can change on a daily base
  - business users during week-days, residential users during the week-end
- It can change on a hourly base
  - business hours
  - evening entertainment

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# IP over Photons

- Routers are connected by optical fibers
  - The optical signal transmitted by a router is received by the other
- Layer 2 framing as in any synchronous transmission
  - PPP
  - IEEE 802.3





# Pros and Cons



**No overhead**



**Physical connections: no reconfigurability**



**One interface per connection**

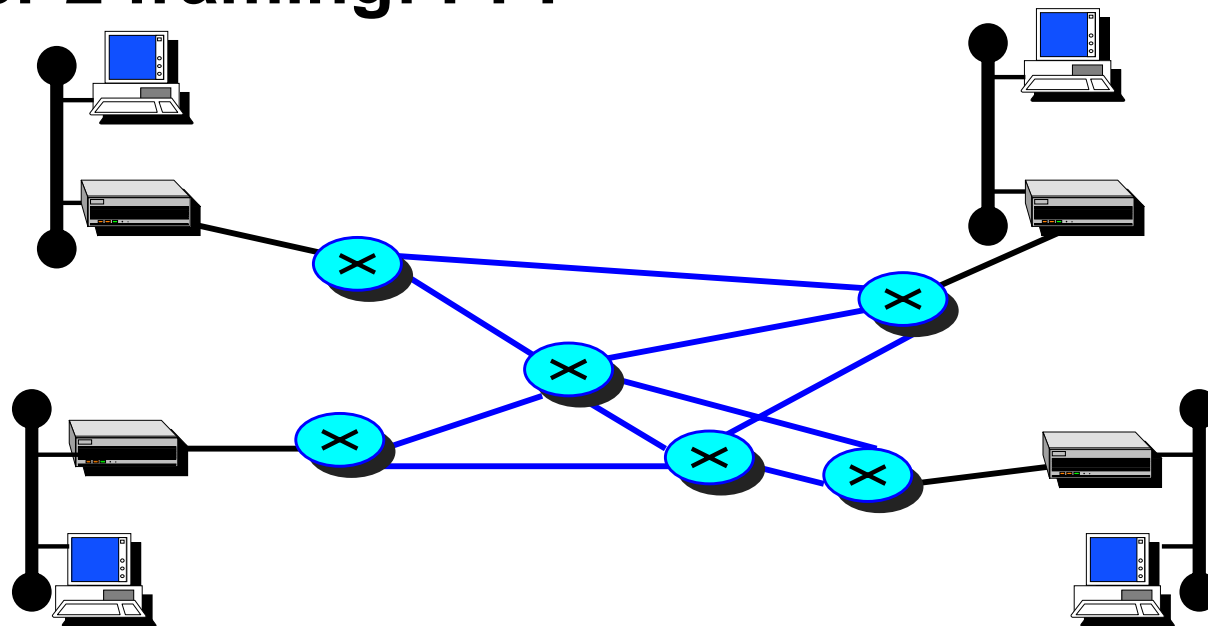


**No standard management infrastructure**



# IP over Dense Wavelength Division Multiplexing (DWDM)

- Many transmissions with different wavelengths (colors) on the same fiber
- Multiplies fiber capacity
- Optical switches with wavelength routing
- Layer 2 framing: PPP







# Pros and Cons

 **Very high capacity**

 **Virtual connections with optical routing**

 **No standard management infrastructure**

 **Static multiplexing**

 **Reconfiguration Flexibility?**

 **One interface for many connections?**

 **How about IP addresses?**

 **One per physical interface?**

 **One per wavelength?**

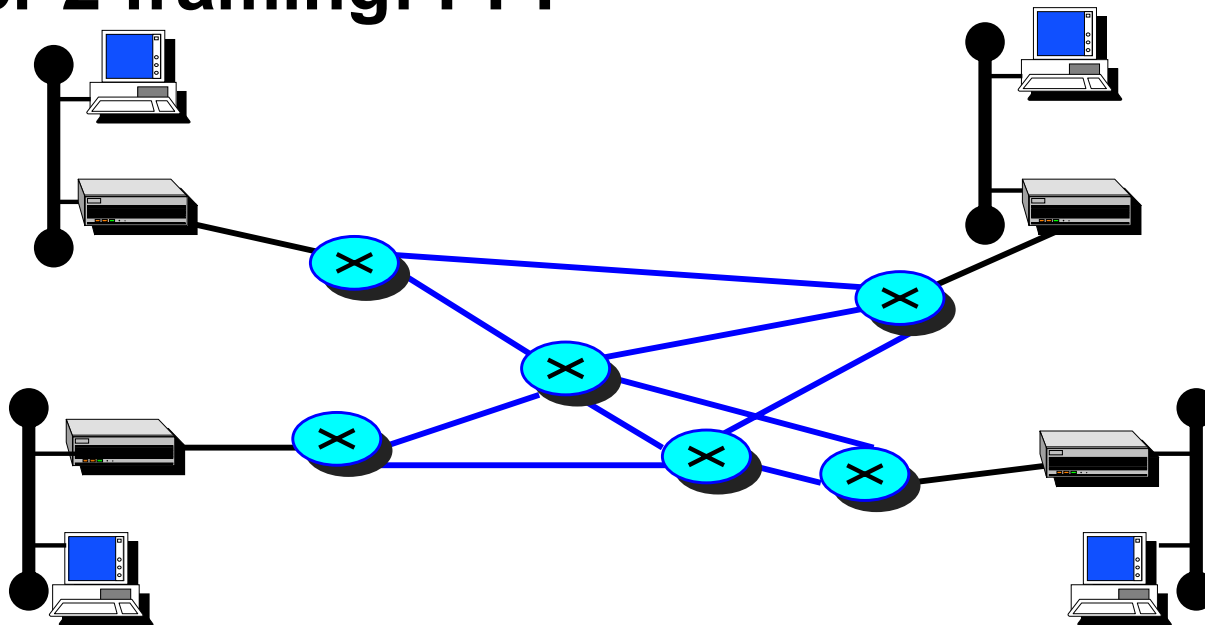




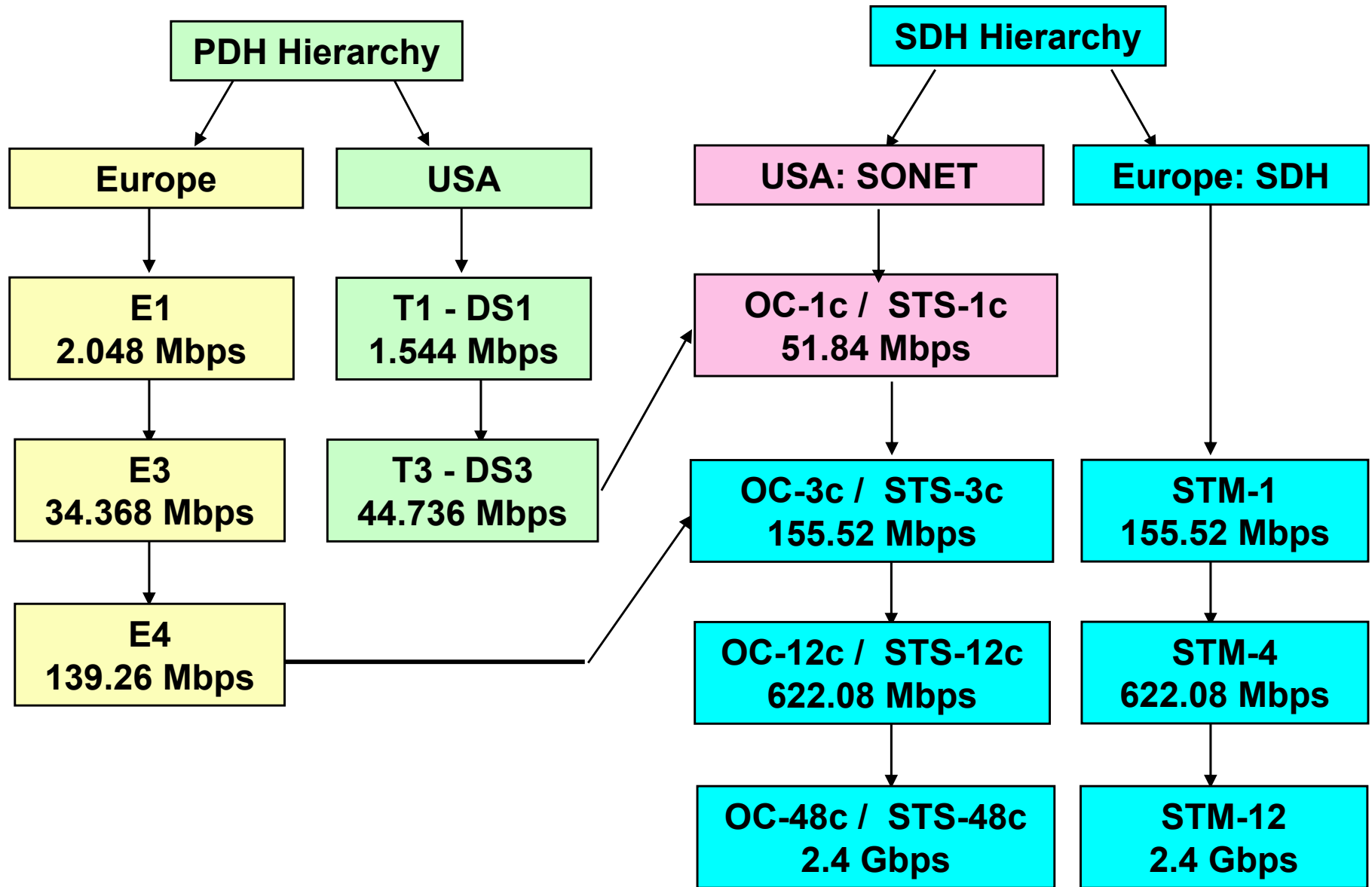
# IP over SONET/SDH

(Synchronous Optical Network  
Synchronous Digital Hierarchy)

- Physical layer framing
- Cross connect
- Fine allocation granularity
- Management framework
- Layer 2 framing: PPP

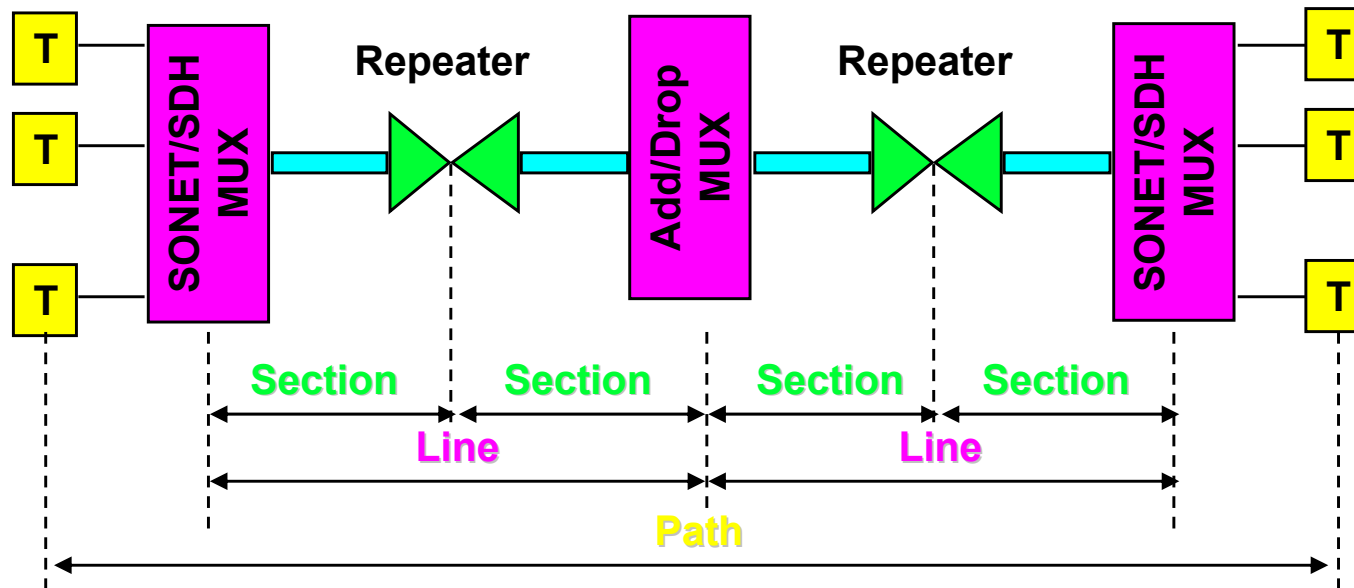


# Transmission Hierarchy



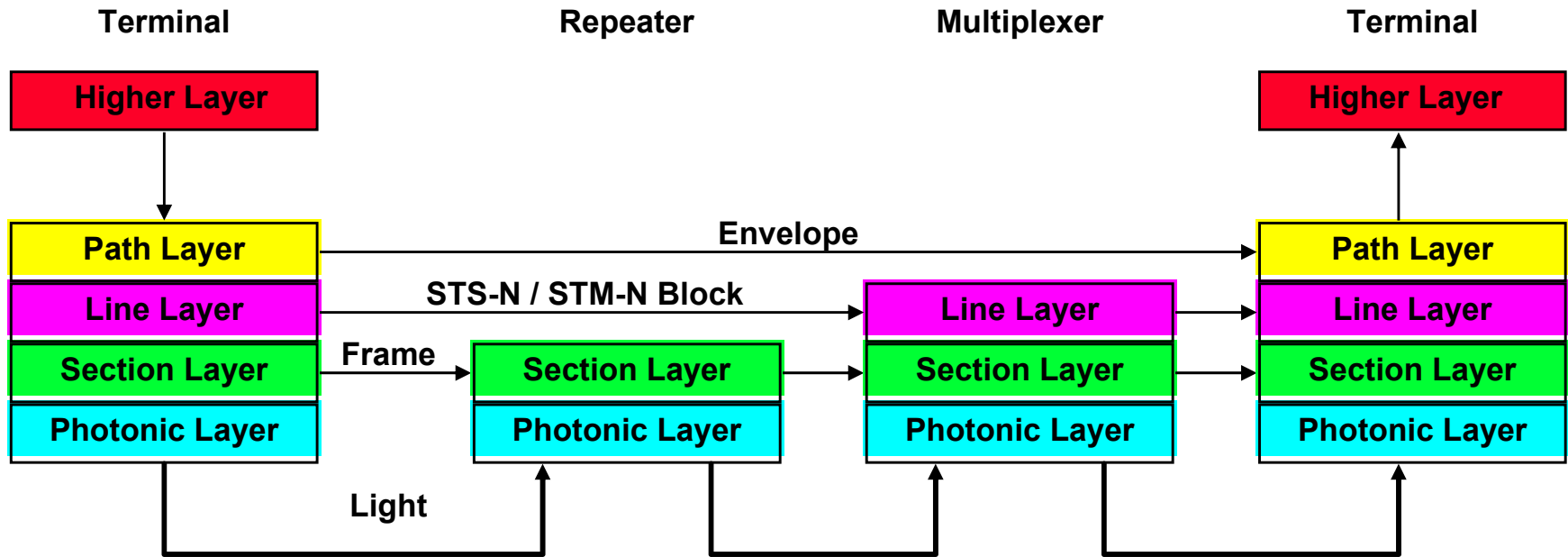
# Physical Architecture

- **Section:** fiber optics trunk between transceivers
- **Line:** sequence of sections between devices which operates on the frame
- **Path:** end-to-end leased line



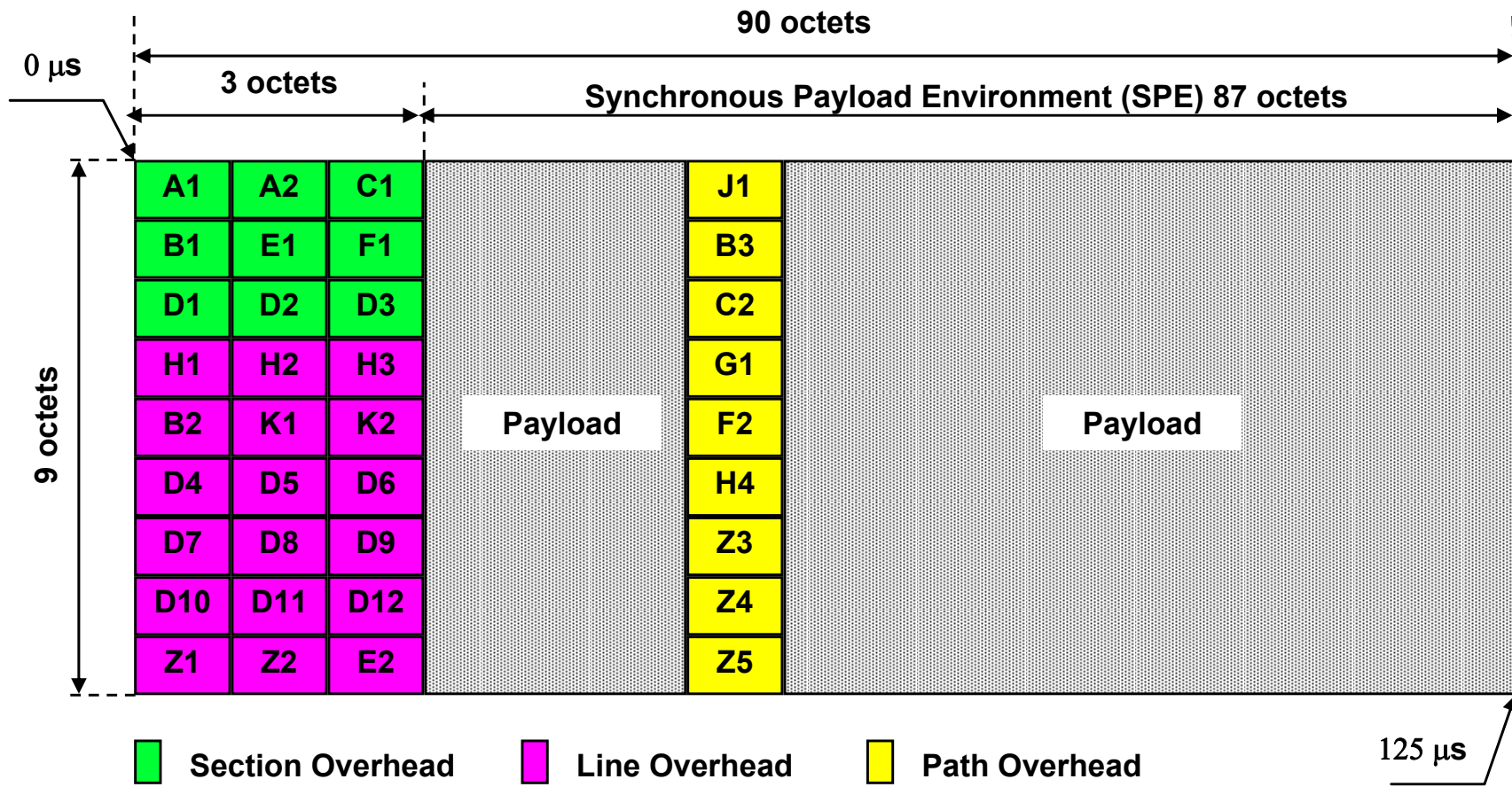
# Protocol Architecture

- **Photonic Layer:** fiber, laser
- **Section Layer:** frames, OAM (Operation Administration and Management)
- **Line Layer:** synchronization, multiplexing, switching, OAM
- **Path Layer:** end-to-end data (bytes) transfer









# Frame Format

STS-1: 810 octets every 125  $\mu$ s  $\rightarrow$  51.84 Mbps



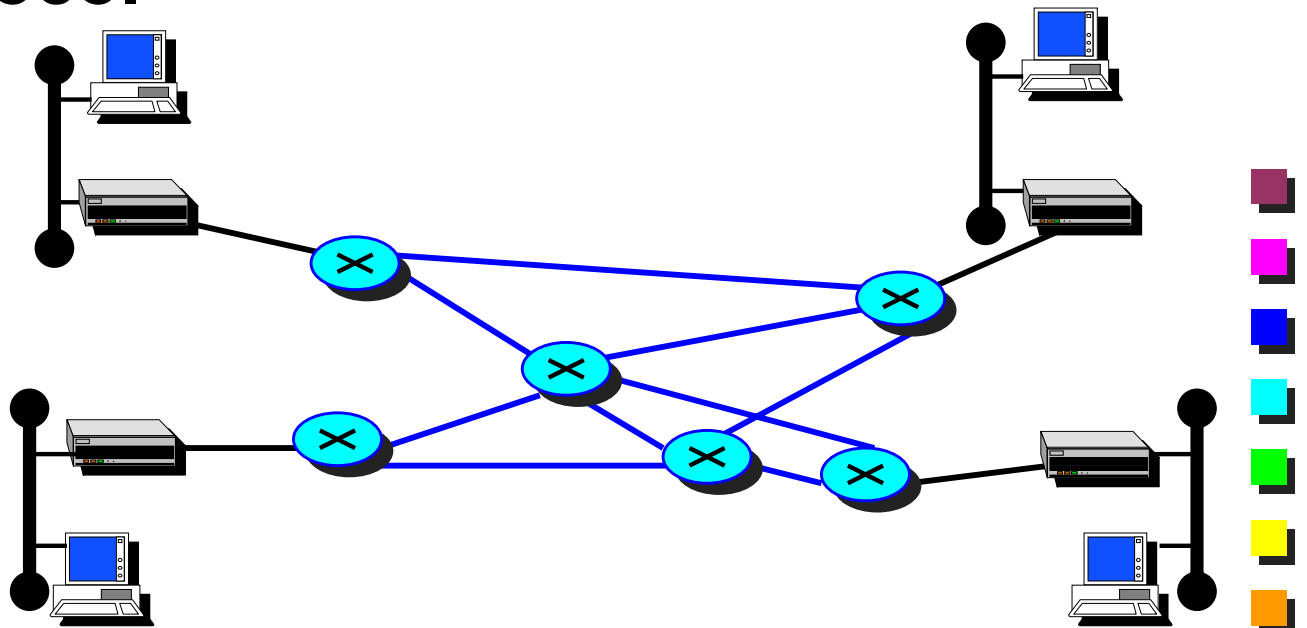


# Pros and Cons

-  **Standard OAM architecture**
  -  **Virtual connections**
  -  **One interface per connection**
  -  **Static multiplexing**
  -  **Limited reconfiguration flexibility**
- 

# IP over ATM (Asynchronous Transfer Mode)








- Cell switching
  - flexible multiplexing
- Semi-permanent and switched virtual connections
- Layer 2 protocol
  - no need for layer 2 framing





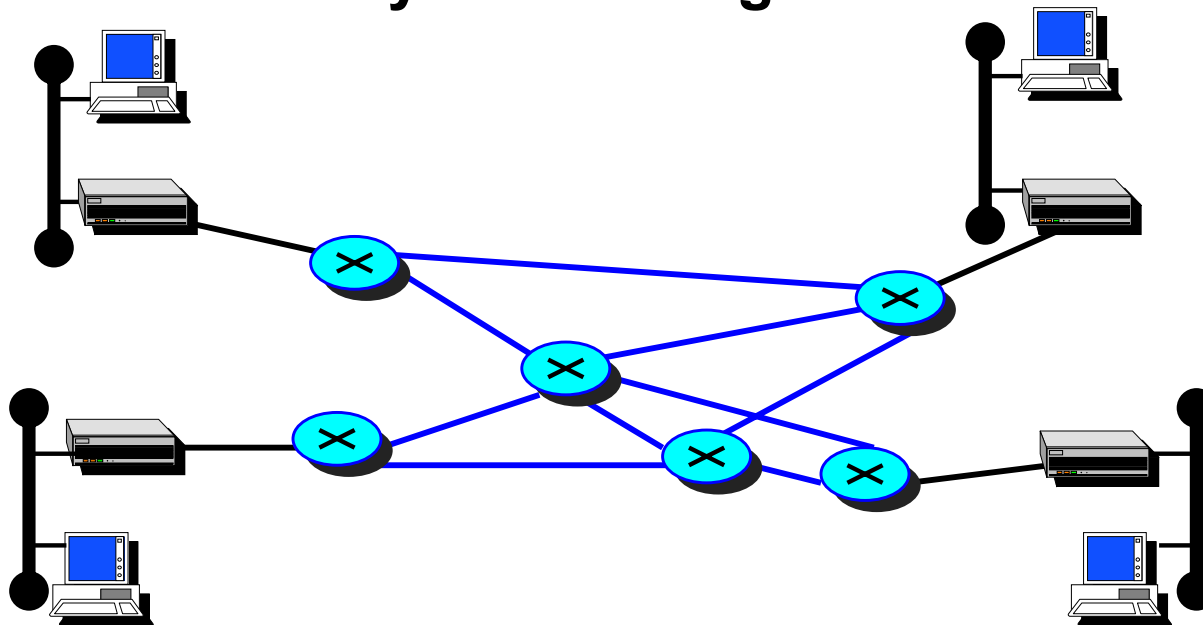


# Pros and Cons

-  **Virtual connections**
  -  **Multiple connections per interface**
  -  **Total reconfiguration flexibility**
  -  **Support for other services (e.g., frame relay)**
  -  **Flexible multiplexing**
  -  **High protocol overhead (more than 10%)**
- 





# IP over FR (Frame Relay)

- Frame switching
  - flexible multiplexing
- Semi-permanent virtual connections
- Layer 2 protocol
  - no need for layer 2 framing





## Pros and Cons

-  **Virtual connections**
-  **Multiple connections per interface**
-  **Large installed base**
-  **No Quality of Service Guarantees**

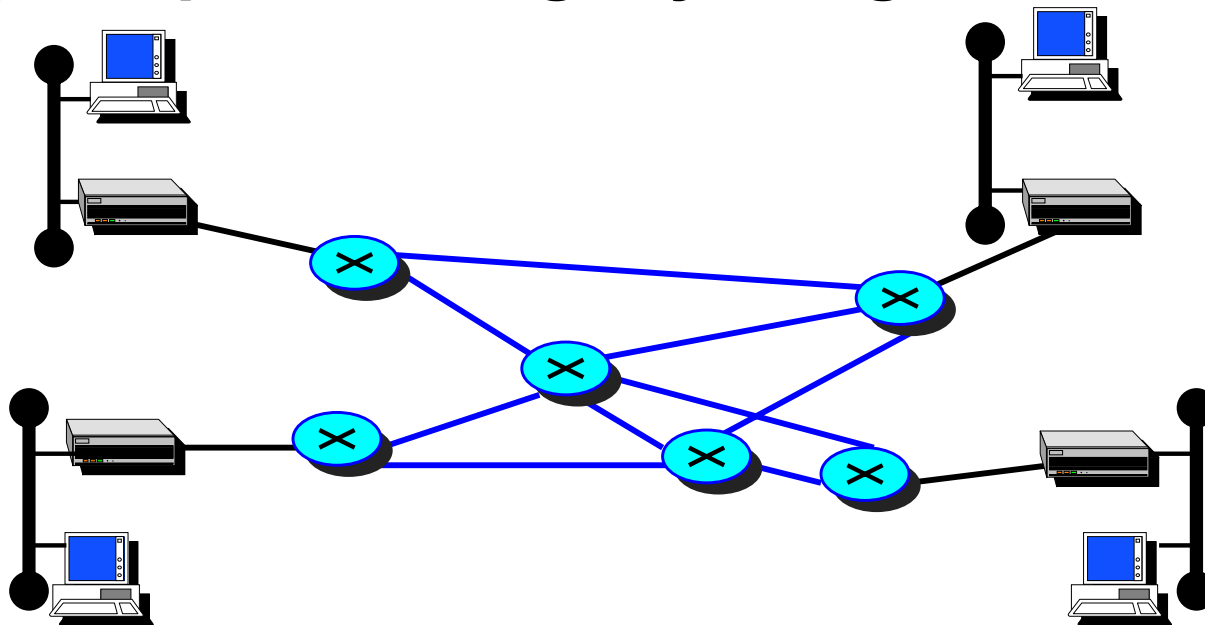
**Why is another packet switching layer needed?**

**Because IP lacks traffic engineering capability**







# MPLS (Multi-Protocol Label Switching)

- Frame switching
  - flexible multiplexing
- Dynamic virtual connections (label switched paths)
- Layer 2 protocol tightly integrated with layer 3





# Pros and Cons

-  **Virtual connections**
-  **Multiple connections per interface**
-  **One control plane: no “IP over”**
-  **No Quality of Service Guarantees**