MPLS
Multi-Protocol Label Switching

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MPLS: introduction

- MPLS (Multi-Protocol Label Switching) is a “new” network technology proposed by the IETF (Internet Engineering Task Force)
- Objective: to improve the Internet behaviour in speed, scalability, Quality of Service support, and traffic engineering
- Use not widespread in Internet
  - Not true anymore

Comparison with traditional IP routing

- In a packet switching network using the datagram service (or connectionless approach) like the Internet, each node executes the forwarding and routing operations independently for each packet, on the basis of the destination address in the packet header
- Each router selects the next-hop (i.e., the output interface) on the basis of the routing table, created through information exchange among routers, according to routing algorithms rules
- Due to the address structure in the Internet (masks) the search procedure in the routing table is a fairly complex “longest prefix matching”

MPLS: the basic idea

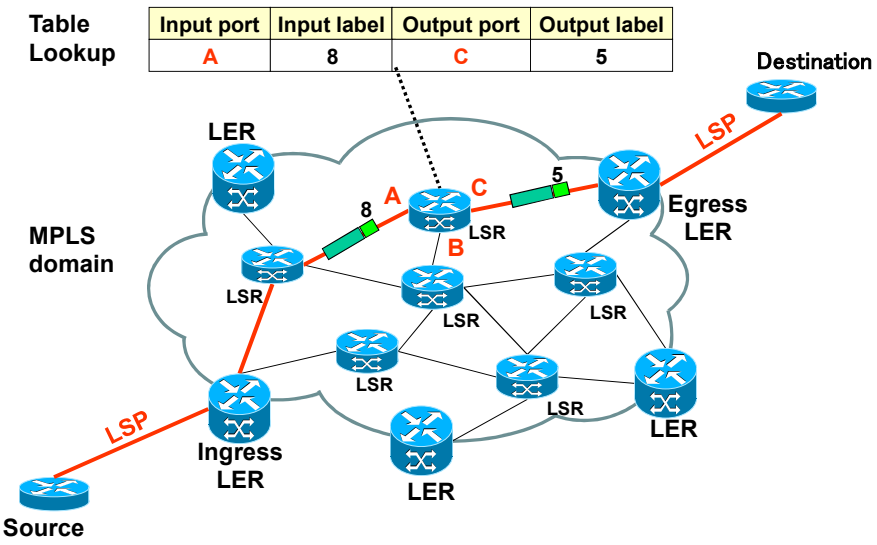
- Routing based on packet label, not on IP address

- Connection-oriented mode of operation over Internet
- How?
  - Label swapping
  - Packet forwarded over pre-computed paths named LSP (Labelled Switched Paths)
- Why?
  - Faster search in the forwarding table
  - Routing determined once per flow, a-priori
  - Enables use of traffic engineering techniques (related to QoS routing)

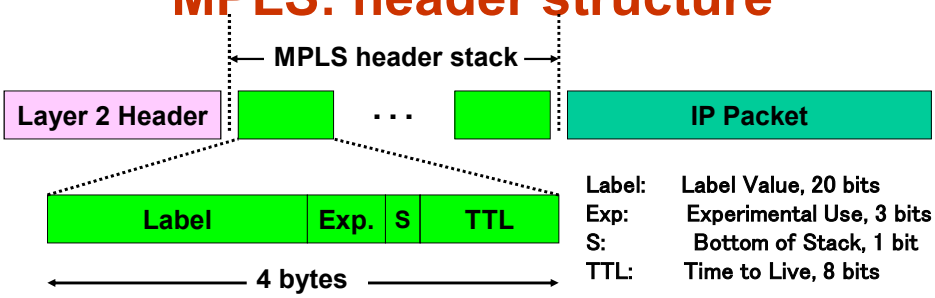
Acronims and defintions

- LSR (Label Switching Router) : router able to execute both MPLS and IP
- FEC (Forwarding Equivalence Class): set of IP packets that:
  - follow the same path in the MPLS network
  - Are processed in the same way by any LSR
- Label: a short identifier, of fixed length, used to identify a FEC. More labels can be stacked, i.e., inserted in a last-in first-out sequence (like in a stack) to create a hierarchy that allows tunneling
- LSP (Label-Switched Path): path through one or more LSR within the same hierarchical level followed by packets in a given FEC
- LER (Label Edge Router): LSR at the border of the MPLS cloud
  - Ingress LERs must classify IP packets (if not already classified) by assigning a proper label
  - Egress LERs remove the label and forward the original IP packet toward the proper destination

Label swapping



MPLS: header structure



Header operations:
Swap (headers)
Push (a new header)
Pop (remove a header from stack)

The MPLS label may be directly coded on ATM VPI/VCI (ATM) or Frame Relay DLCI

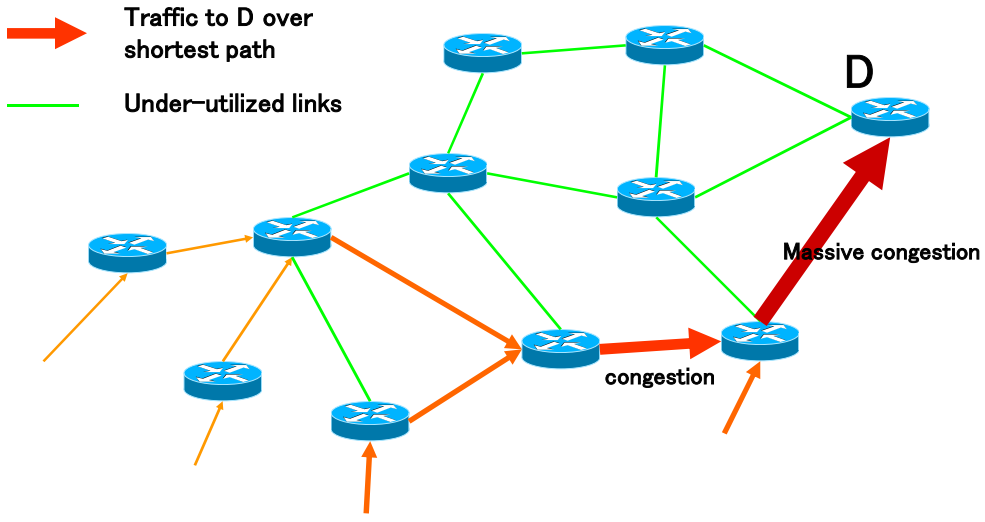
MPLS and layered models

- MPLS is not a layer 3 (Network)
  - Does not define addresses and routing but exploits IP
- MPLS is not a layer 2 (Data Link)
  - Operates with various layer 2 technologies (SONET, Ethernet, ATM, etc…)
- MPLS is not a layer in the OSI sense
  - Does not define a unique format to transport data (exploits “shim” on SONET, VCI/VPI on ATM, DLCI on Frame Relay, wavelengths in optical networks, …)

LSP assignment

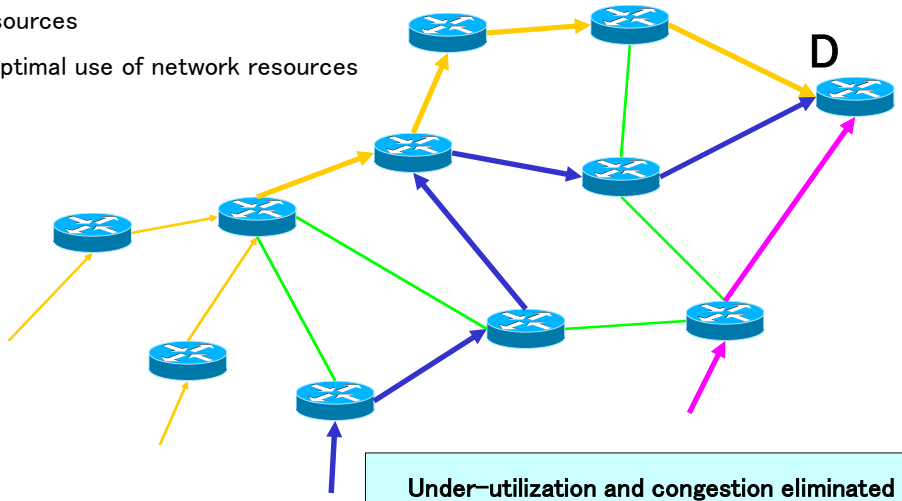
- **Label assignment:** performed by the downstream LSR that informs the upstream LSR of the decision. Labels distributed from downstream to upstream
- **Label distribution protocol:** a control plane is needed to determine a LSP. Not a single standardized solution:
  - **Topology based method:** extensions of standard routing protocols (OSPF, IS-IS, BGP) to transport info on labels
  - **On demand method**: exploits RSVP, thus operating on user request
  - **LPD (**Label Distribution Protocol): a completely new label distribution protocol
  - **CR-LPD**: Constraint-based Routing (CR): accounts for link status (bit rate, delay) to provide QoS and traffic engineering

Traffic engineering



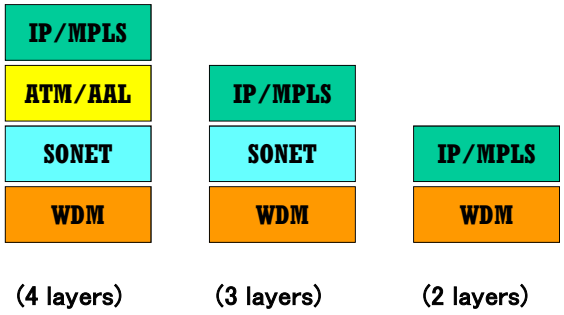
Traffic engineering

- Redistribute traffic over available resources
- Optimal use of network resources



Under–utilization and congestion eliminated

MPLS goal



(4 layers) (3 layers) (2 layers)

MPLS and WDM

- The WDM (Wavelength-Division Multiplexing) technology makes available a huge fiber transmission capacity
- DWDM (Dense WDM) systems may further enhance the fiber capacity
- Intelligence needed in the optical control plane to guarantee:
  - Real time lightpaths provisioning with traffic engineering capabilities
  - Protectionand restoration
  - Interoperability
- Multi-Protocol Label Switching is today considered the most promising technology to integrate IP and WDM

GMPLS

- Generalized Multi Protocol Label Switching (formerly MPλS) is a generalization of MPLS to integrate IP and WDM

Labels ←→ Lambdas (Wavelenghts)

Label Switching Router ←→ Optical Cross-Connect (OXC)

Label Switched Path ←→ Lightpath

MPLS vs GMPLS

- Differences among OXCs and LSRs
  - LSR operate at the packet level
  - Forwarding info is explicit on the packet, implicit on the wavelength
  - Number of lightpaths that an OXC is able to manage is smaller, with a high bandwidth granularity
- Differences among LSP and lightpaths
  - LSP support label stacking
  - LSP may be mixed (mixing)

MPLS: summary

- Use in the core part of the network
- Flexibility in FEC definition: ingress router may force packets to follow paths according to peculiar policies (QoS, traffic engineering)
  - Forwarding MPLS may be changed dynamically by devices able to analyze network status
- Permits
  - Traffing Engineering
    - Support for QoS (IntServ) and CoS (DiffServ)
  - VPN (Virtual Private Network)
    - Policy based routing
- MPLS provides tunnelling capabilities
  - Label stacking
- MPLS easily interoperates with IP