

Advanced Computer Networks

MPLS

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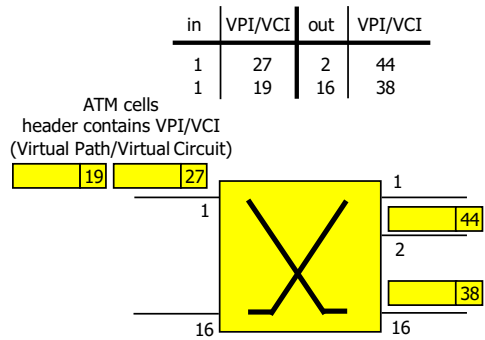
Contents

- MPLS (Multi Protocol Label Switching)
 - Label swapping
 - Elements of MPLS
 - Label switching
 - Label distribution
 - Interaction with IGP
 - Traffic engineering

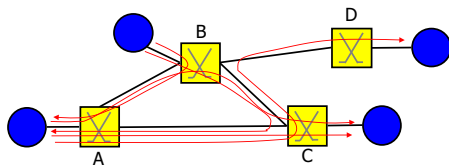
MPLS

- IGP limits
 - IP routing may ignore the real physical topology
 - OSPF algorithms send traffic on a shared path and may ignore unloaded links
 - even if load balancing can be done in some cases (Equal Cost)
- Goals of MPLS
 - increase forwarding performance
 - provide more flexibility than IGP routing
 - explicit routing, QoS routing
 - backup routes, load balancing, VPN
 - multiprotocol - a unifying view at 2.5 layer - a unified way of controlling the underlying Layer 2 network
 - Ethernet, PPP, SDH/DWDM

Virtual Circuits ATM VPI/VCI switching



Label swapping



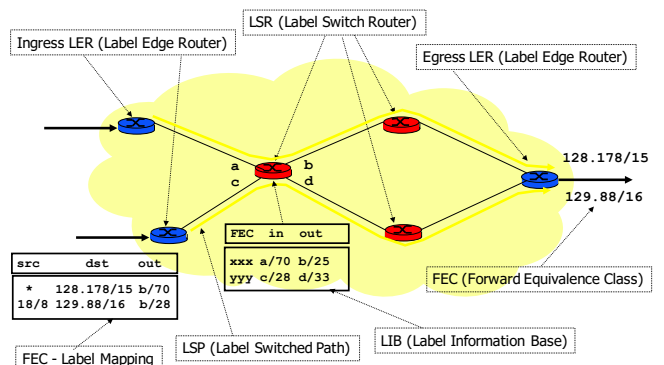
VC table at A:

| in | VPI/VCI | out | VPI/VCI |
|----|---------|-----|---------|
| H | 0 | B | 0 |
| H | 1 | C | 0 |
| C | 1 | H | 2 |
| B | 1 | H | 3 |
| H | 4 | C | 2 |

Virtual circuits opened in the following order:

- ABC
- AC
- BCA
- BA
- ACBD

MPLS elements



MPLS Principles

- Labels
 - ingress LER classifies packets to identify FEC that determines a label; inserts the label (32 bits)
 - LSR switches based on the label
 - label swapping - label has meaning local to one LSR (requires label distribution protocol)
 - egress LER removes the label
- LSR
 - contains LIB - switching table that determines the path in the network (LSP)
 - LSP - similar to a ATM/FR virtual circuit
- Change of the forwarding paradigm
 - instead of hop by hop
 - LSP determined at entry in function of FEC, source, or other

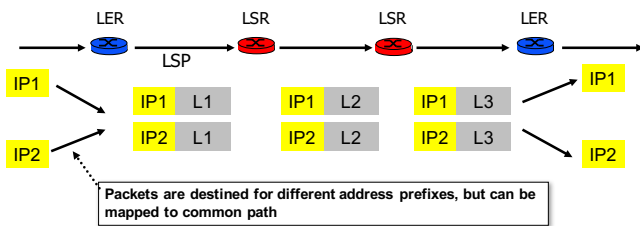
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Forwarding Equivalence Classes

- FEC - group of IP packets
 - forwarded in the same manner, over the same path, and with the same forwarding treatment
- FEC may correspond to
 - destination IP subnet
 - source and destination IP subnet
 - traffic class that LER considers significant
- For example, all traffic with a certain value of IP precedence may constitute a FEC
- FEC in our examples
 - IP prefix

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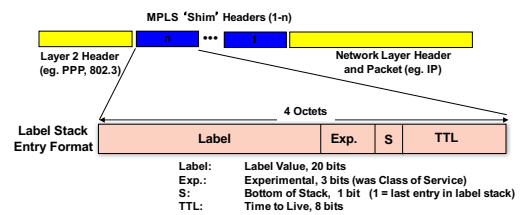
Forwarding Equivalence Classes



- FEC = "A subset of packets that are all treated the same way by a router"
- Conventional routing: a packet is assigned to a FEC at each hop (i.e. L3 look-up), in MPLS it is only done once at the network ingress

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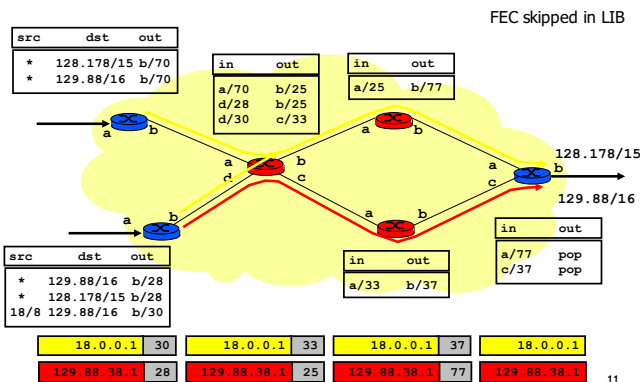
MPLS Encapsulation - PPP & LAN



- MPLS on PPP links and LANs uses shim header
 - inserted between layer 2 and 3 headers

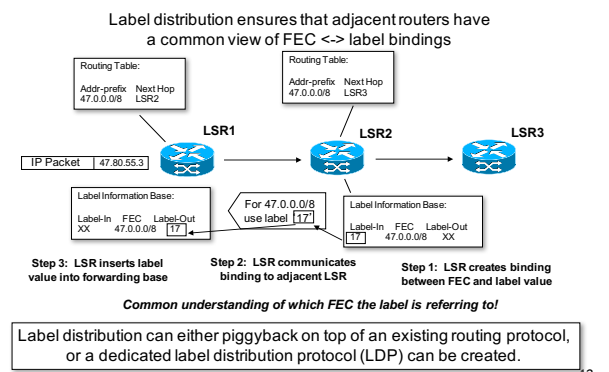
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MPLS example



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Label Distribution Protocol (LDP)

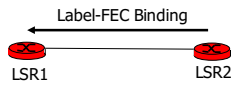


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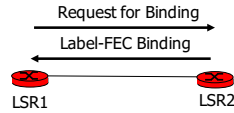
Label distribution

- Label distribution is always done from downstream to upstream

- downstream-unsolicited:** new route => send new label

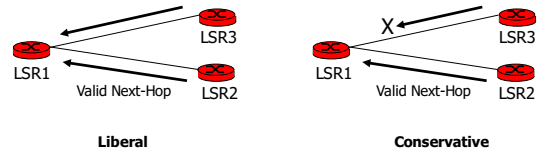


- downstream-on-demand:** upstream LSR asks for a label



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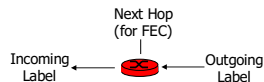
Label retention



- Label retention can be
 - liberal:** memorize all labels from downstream LSR (faster)
 - conservative:** memorize only selected labels (less memory)

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Label control



- Label control can be
 - ordered:** LSR only binds and advertise a label for a particular FEC if
 - it is the egress LSR for that FEC or
 - it has already received a label binding from its next-hop
 - LSP formation 'flows' from egress to ingress
 - independent:** LSR binds a Label to a FEC independently, whether or not the LSR has received a label from the next-hop for the FEC
 - LSR then advertises the label to its neighbor
 - LSP is formed as incoming and outgoing labels are spliced together

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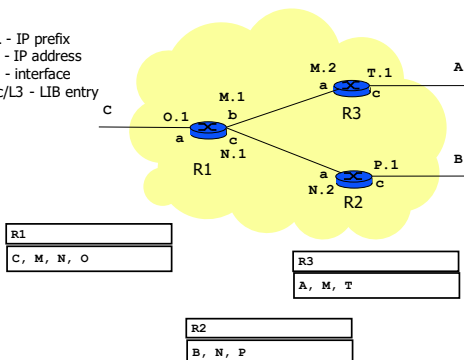
Label distribution

- Different label distribution protocols
 - LDP (Label Distribution Protocol)
 - defined for MPLS
 - Extension of BGP
 - Extension of RSVP
 - RSVP-TE: traditional RSVP + Explicit Route
 - CR-LDP (Constraint-Based LDP)
 - LDP + Explicit Route

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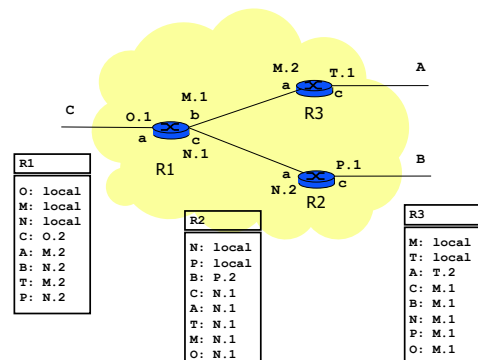
Label distribution example - OSPF

A, B... - IP prefix
M.1... - IP address
a, b... - interface
a/L1-c/L3 - LIB entry



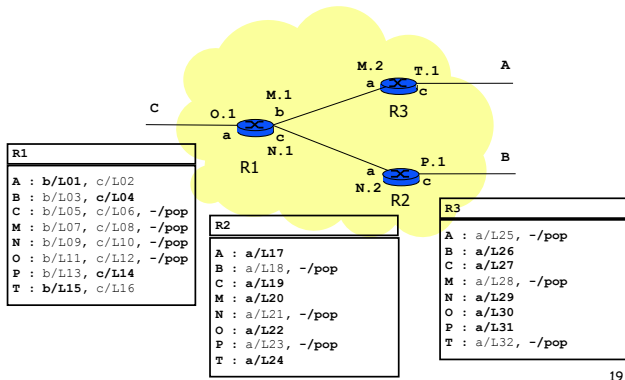
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OSPF - routing tables



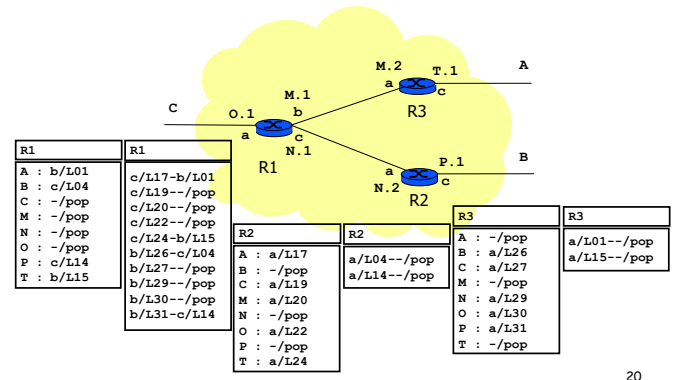
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Label bindings



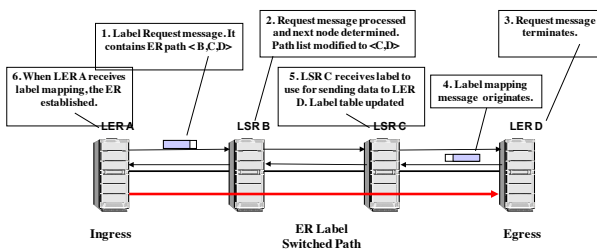
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Switching tables



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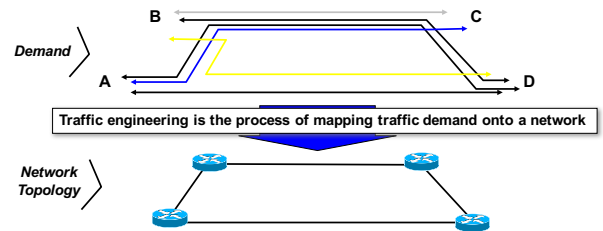
ER-LSP setup using CR-LDP



- Explicit Route setup
- CR-LDP can also be used to reserve resources
 - peak rate, committed rate, burst size

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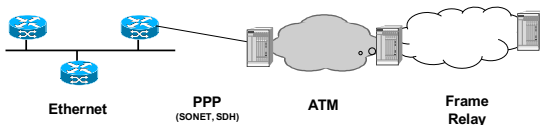
Traffic Engineering with MPLS



- Maximize utilization of links and nodes
- Engineer links to achieve required delay
- Spread the network traffic across network links, minimize impact of single failure
- Ensure available spare link capacity for re-routing traffic

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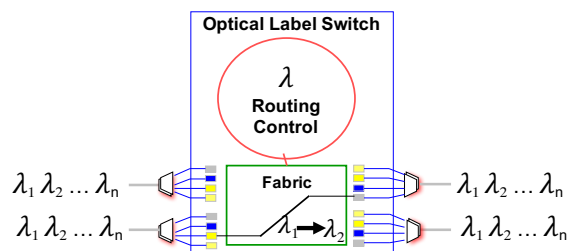
Unifying forwarding paradigm



- MPLS offers an end-to-end unifying forwarding paradigm
 - MPLS is "multiprotocol" below (link layer) as well as above (network layer)
 - provides for consistent operations, engineering across multiple technologies
 - allows operators to control different technologies in a unified manner

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GMPLS/MPλS



- Optical networks such as DWDM
 - λ is just another label to distribute - no new protocols required

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Facts to remember

- MPLS allows flexible packet classification and network resources optimization
- Labels are distributed by different protocols
 - LDP, RSVP, BGP
- Labels have local (LSR) significance
 - no need for global (domain) wide label allocation/numbering
- Different link layer protocols may co-exist in the same LSR