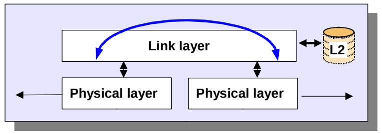
S-38.3192 Verkkopalvelujen tuotanto
S-38.3192 Network Service Provisioning
Lecture 4: MPLS

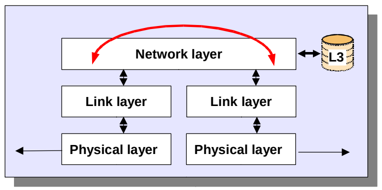
L2 forwarding

- L2 forwarding uses ATM/MAC-addresses in its operation
  - Each device does an independent forwarding decission for each and every packet
    - Hop-by-hop operation
  - Address lookup is based on full address
    - First match in dB is unique
    - HW acceleration



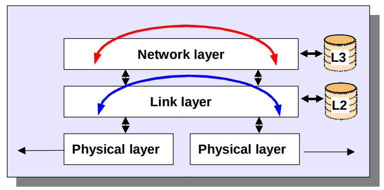
L3 forwarding

- L3 forwarding uses IP addresses in its operation
  - Each router does independent decission on packet forwarding based on destination address
    - Hop-by-hop -operation
  - Address lookup is based on longest match
    - Partial match to address
    - Complicated algorithms
      - Slower
      - More searches

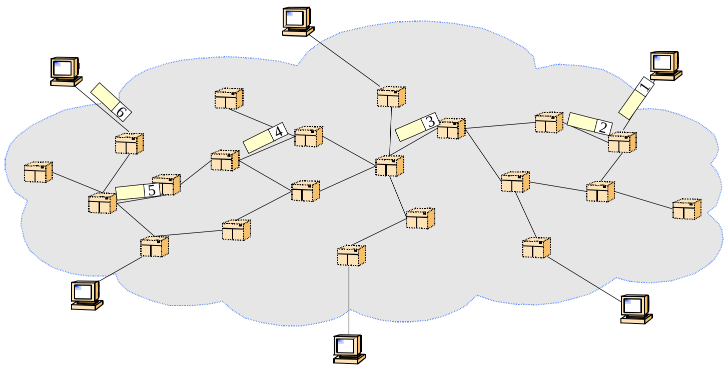


L2+ forwarding

- L2+ forwarding uses strength of the both L2 and L3 forwarding
  - Edge of the network operates on L3 addresses
    - Predefined criterias are used to pass packets through L2 tunnels rather than normal L3 forwarding
      - Cut through -operation
      - Virtual connections between edge routers
        - » Logical links for IP forwarding



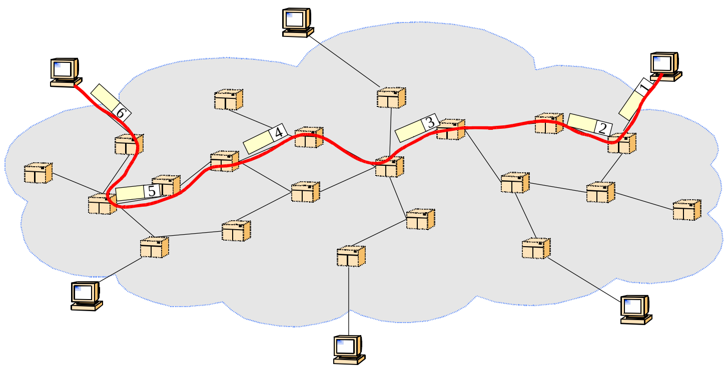
L3 forwarding



L3 forwarding

- Aka message switching
- Pros
  - Efficient use of network resources
    - Each packet is treated as an independent connection
- Cons
  - Independent processing of packets
    - Slow process in L3
    - Depending on internal architecture, may pose certain limitations to the performance
  - Large databases of addresses
  - Terminals are not aware of network status

L2+ forwarding



L2+ forwarding

- Aka virtual circuit switching
- Pros
  - Only a fraction of packet visits in L3 processor
    - All of the packets at the edge of L2+-network
    - At the core, part of the packets that do not belong to any L2+ tunnel
  - Smaller address dB
    - Efficient integration
- Cons
  - Restoration from the fault requires a lot of work
    - Establisment of all tunnels that travel through faulty device or link

MPLS

- Is basically networking technology based on L2+ forwarding
  - Builds
    - On top of real L2 network additional virtual connections
    - Virtual connections are for L3 protocols as real as actual L2 associations
  - Based on L2+ header
    - MPLS shim header
      - Ethertype xxxx
    - Virtual connection identifier
      - ATM: VPI/VCI
      - FrameRelay: DLCI

MPLS-shim header

- Label (20bit)
  - Virtual connection identifier
- CoS (3bit)
  - FEC used for the packet
- Stacking bit (1 bit)
  - Bottom of label stack
- TTL (8 bits)
  - IP-packets TTL value which is decremented as if forwarding would have been done in L3

- Shim header is used with networking technologies that do not support virtual connections
  - Ethernet

IP otsikko			
Label	CoS	S	TTL
L2 otsikko			

CoS

- **Forwarding Equalency Class (FEC)**
  - Defines
    - How particular packet is queued with respect to other packets
      - Class based queueing
      - Packets from different label paths share common queues
  - Roughly resembles
    - DiffServ PHB
    - IntServ service class
    - ATM traffic class

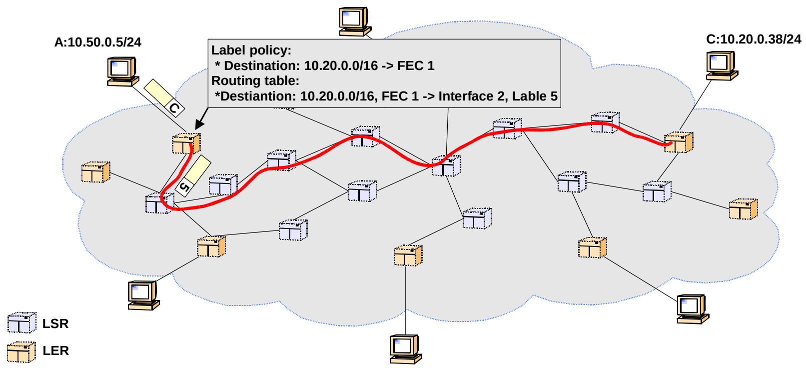
Label

- Label is a packet dependent identifier that associates the packet to certain L2+ tunnel (label switched path)
- Label has only local meaning
  - It is unique within single link
  - Labels are swapped in each hop of the network
    - Certain occasions labels may also be
      - Pushed: added additional outer label (stacking)
      - Popped: outer label is removed (stack is lowered by one)
- Labels are associated through separate protocol
  - Label distribution protocol (LDP)
  - Resource reservation protocol (RSVP)
  - Border gateway protocol (BGP)

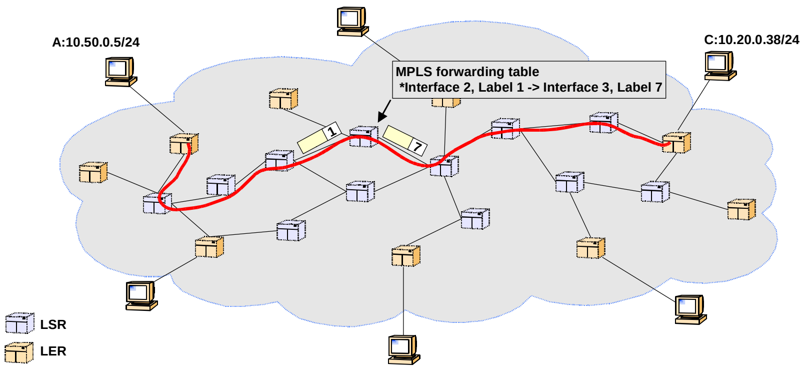
Terminology

- **Label Switch Router (LSR)**
  - Router capable of doing both IP routing and label switching
    - **Label edge router (LER)** is special case a router that does not do switching only popping and pushing
- **Label Switched Path (LSP)**
  - A chain of individual label swap relations between two label edge routers
- **Penultimate router**
  - Router next to terminating LER enroute certain LSP

LSP

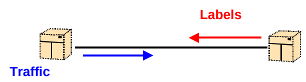


LSP



Building LSPs

- LSPs are constructed to upstream
  - Opposite to traffic flow
- Downstream router binds a label to certain FEC which is then transmitted to upstream
  - Upstream LSR uses this label to reach particular destination through downstream router



Label Retention

- **Conservative**
  - Labels which arrive are only kept if they come from the valid next hop in label switched path
    - Depends on routing and FEC
  - Spares the label space if network is large (contains a lot of neighbourig relations)
  - Slowers the adoption of new routes in error situations
    - New labels need to be spread
- **Liberal**
  - All labels coming form neighbours are kept even though there is not valind next hop in forwarding table
    - Within the limits of memory
  - Fast re-routes
    - Labels are already at the network
  - Uses a lot of memory in case of large number of peers

Label Distribution

- **Downstream-unsolicited**
  - An LSR may issue a label binding to an FEC without an explicit request from an upstream LSR
  - The label binding to FEC is sent to all label distribution peers.
  - This is the way LDP typically functions
- **Downstream-on-demand**
  - LSR sends an explicit request for a label binding to an FEC to a next-hop
    - The reaction of the downstream LSR to this request depends on the label advertising mode supported on the next hop
  - This is the way RSVP-TE typically works

Label Advertising

- **Ordered Label Distribution**
  - A label binding to FEC will not be distributed to the upstream unless LSR has corresponding label binding to FEC in table
    - In case of non existing mapping a LSR makes a request to the downstream
      - This continues up until
        - » There is a binding
        - » We reach the egress and create the label
- **Independent Label Distribution**
  - A label binding to FEC is executed even though a LSR has not corresponding binding itself
    - After this it makes own label request
      - Could lead
        - » Loops
        - » Black-Holes

Route Selection

- **Route selection for LSP depends on the IP routing protocol**
  - All label bindings relate to FIB in the router
  - FIB can be created in form of
    - Static routes
      - Heavy process if large number of LSRs
    - Routing protocol inference
      - Mainly link-state routing protocols
        - » If traffic engineering is pursued

Route Selection

- **LDP** uses IGP routing table to form label switched paths
  - Uniform view of network
  - Unable to have traffic engineering
- **RSVP-TE** uses
  - Manual paths configuration
  - IGP formed LSDB and TED to calculate label switched paths
    - Disjoint view of network
      - Multiconstrained route calculation

RSVP-TE

- PATH message contains the information of used routing
  - **Hop-by-hop**
    - IGP routing table is used to select best next hop for the PATH-message
  - **Explicit**
    - Route is injected from the ingress point in to the network
      - Manually
      - Through C-SPF calculation
    - Route is in form of Explicit Route Object (ERO)

Explicit Route Object

- ERO makes possible to inject predefined route for the LSP
  - **Traffic Engineering**
- ERO list is populated from
  - Manual selection
    - Works well in small networks
  - External route calculation server
    - Different facilites for primary path and backup
      - Endurance to large scale network problems
  - Internal C-SPF calculation of route for the LSP

ERO route

- **Strict route**
  - PATH message follows strictly the ERO list of LSR interfaces
    - If LSRs in ERO list are not peers LSP is not set up
    - If resources enroute the ERO path are not available, LSP is not set up
  - Malfuntion on the LSP ceases the traffic if no backups are defined
- **Loose route**
  - PATH message follows loosely the ERO list of LSRs
    - If LSRs are not peers IGP routing is used in between
    - If resources are not available, a detour is searched with IGP routing
  - Malfunction of the LSP creates a new signaled LSP

RSVP-TE

- When PATH message reaches the egress of the network a RESV message is generated to the upstream
  - Contains label bindings in a hop-by-hop manner
  - Associates resources to the label
  - Activates the forwarding
    - **Label Information Base (LIB)** in HW is populated with the received downstream label and our upstream label

LDP vs RSVP-TE

- LDP relies on IGP in restoration of LSP:s
  - IGP time-out + SPF-calculation + LSP formation
- RSVP-TE does not necessarily rely on IGP
  - Protection paths can be predefined
  - Any mechanism can be used to decide the quality of LSP