L14 - Multiprotocol Label Switching

MPLS

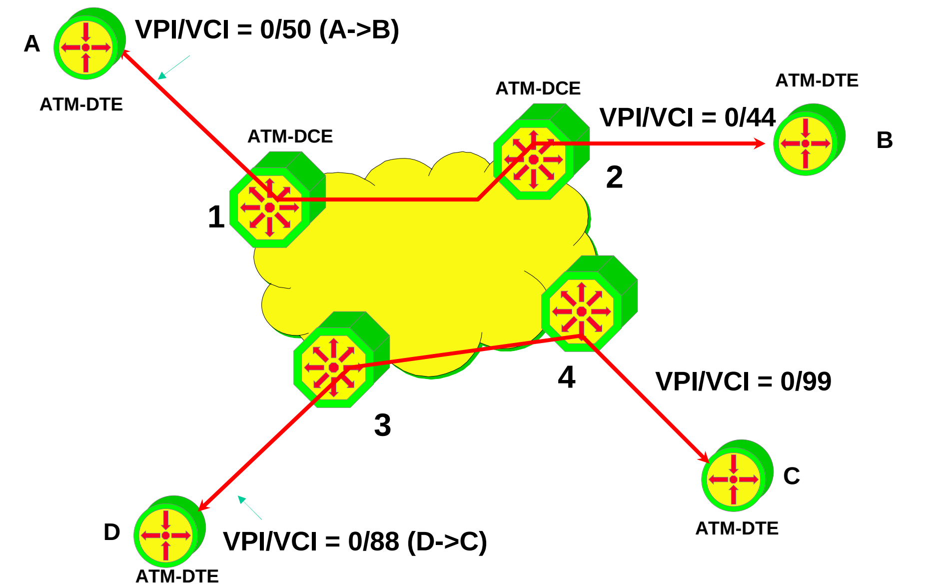
Multi-Protocol Label Switching

Agenda

- **Review ATM**
- **IP over WAN Problems (Traditional Approach)**
- **MPLS Principles**
- **Label Distribution Methods**
- **RFC's**

L14 - Multiprotocol Label Switching

ATM Scenario -> VPI / VCI



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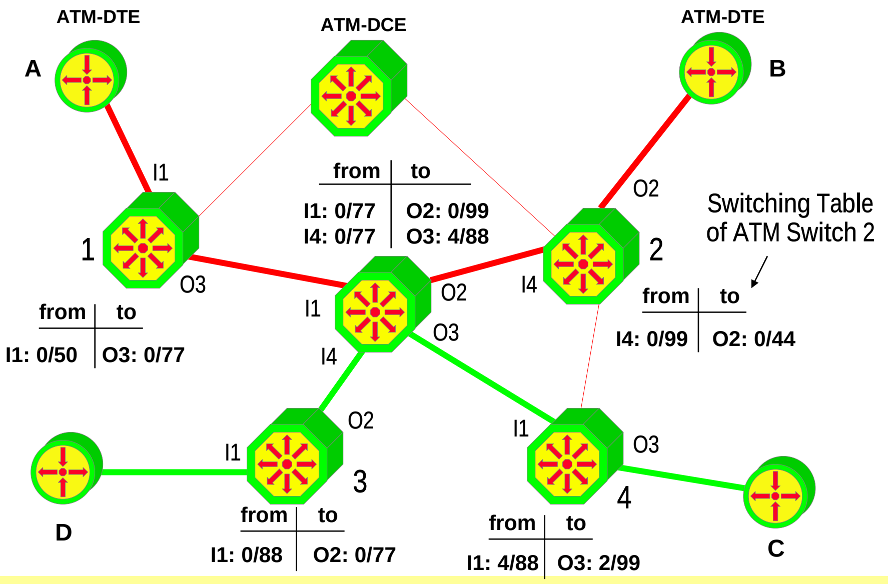
ATM Switching Tables



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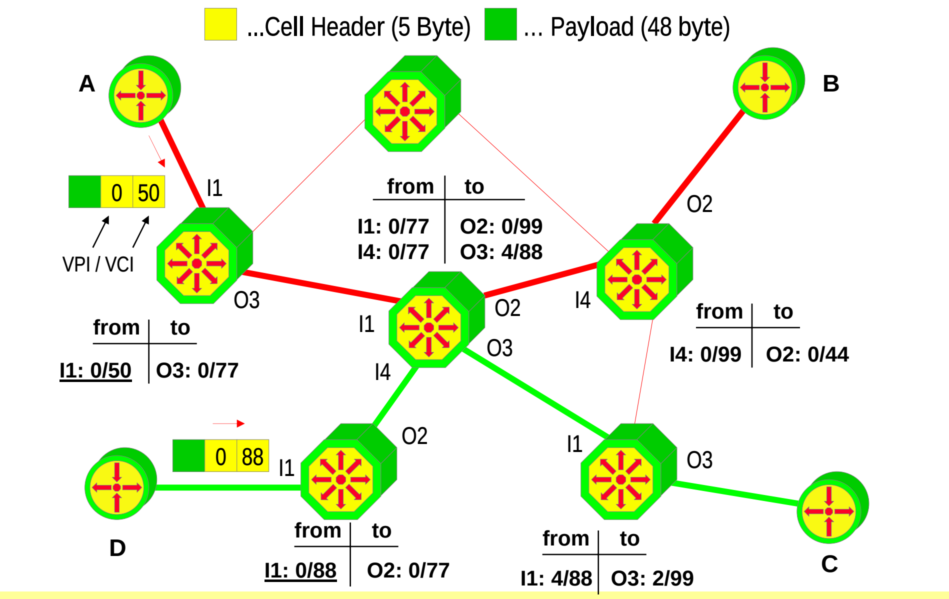
Cell Forwarding / Label Swapping 1



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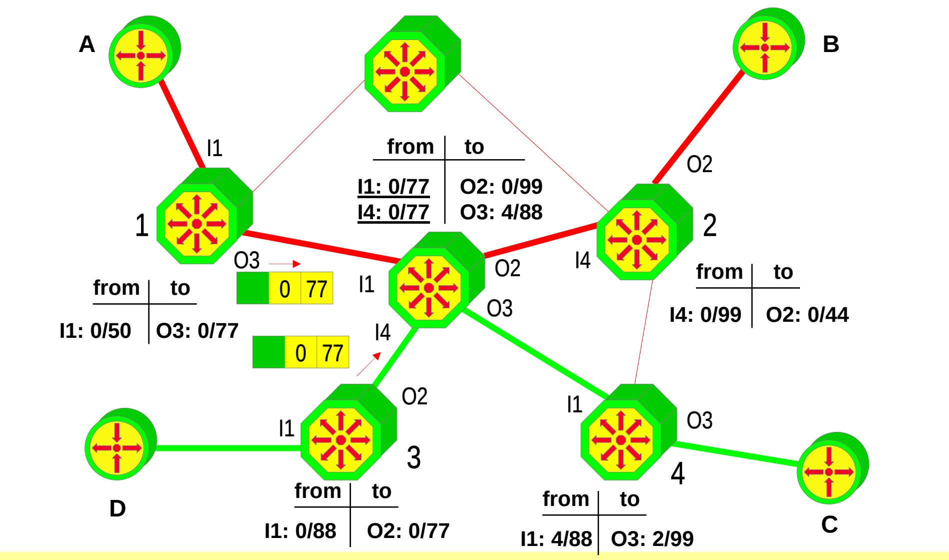
Cell Forwarding / Label Swapping 2



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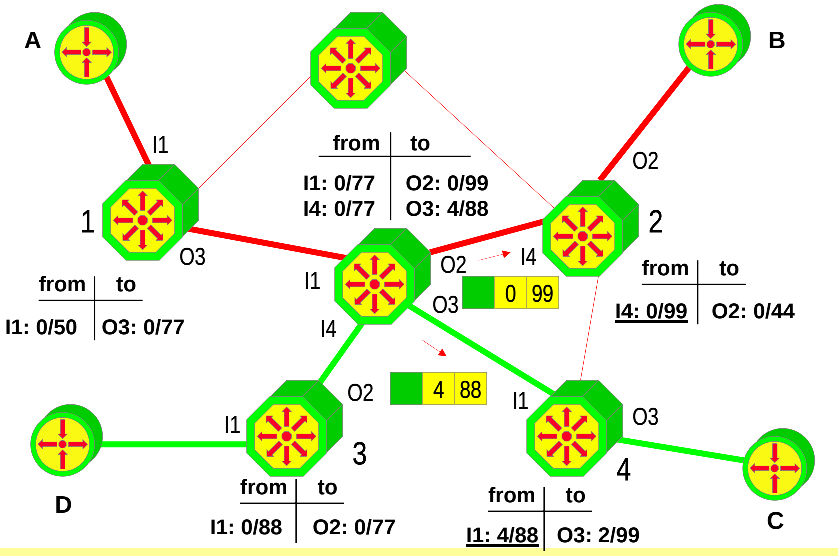
Cell Forwarding / Label Swapping 3



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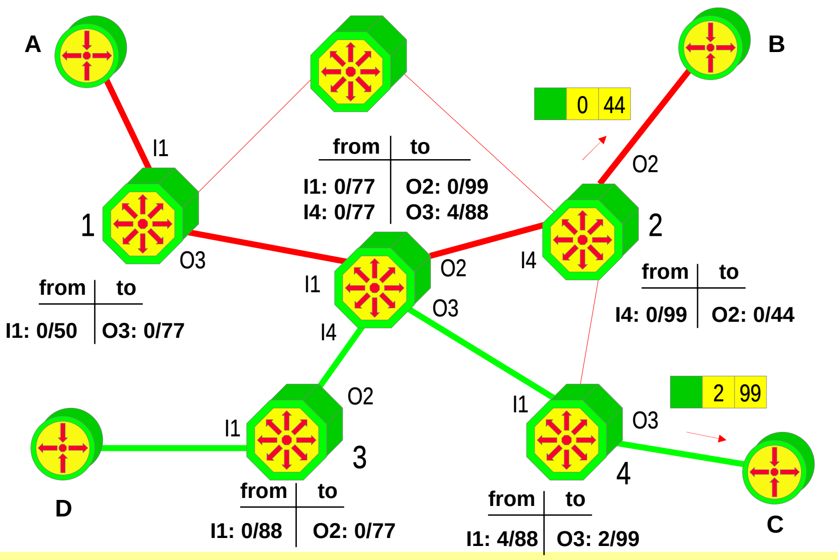
Cell Forwarding / Label Swapping 4



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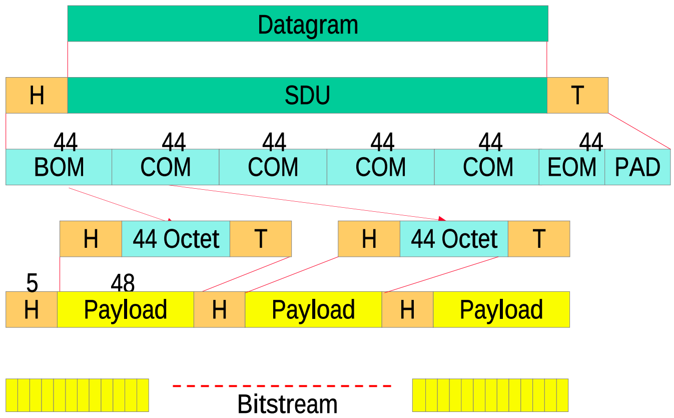
Segmentation Principle

- **Cells are much smaller than data packets**
  - Segmentation and Reassembly is necessary in ATM DTE's (!!!)
  - ATM DCE's (ATM switches) are not involved in that

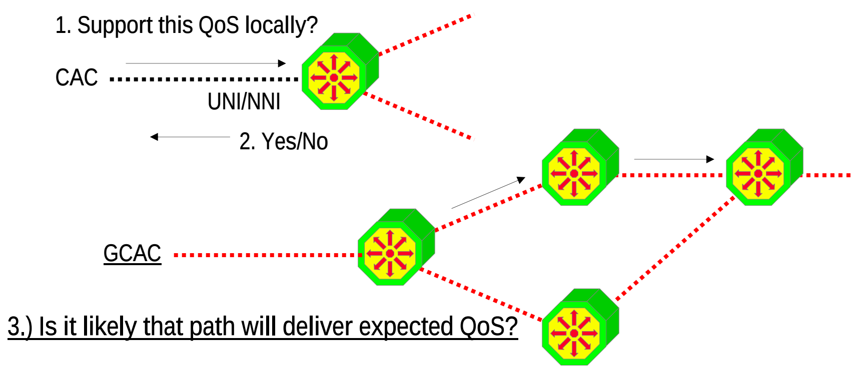


ATM Routing in Private ATM Networks

- **PNNI is based on Link-State technique**
  - like OSPF
- **Topology database**
  - Every switch maintains a database representing the states of the links and the switches
  - Extension to link state routing !!!
  - Announce <u>status of node</u> (!) as well as <u>status of links</u>
    - Contains dynamic parameters like delay, available cell rate, etc. versus static-only parameters of OSPF (link up/down, node up/down, nominal bandwidth of link)
- **Path determination based on metrics**
  - Much more complex than with standard routing protocols because of ATM-inherent QoS support

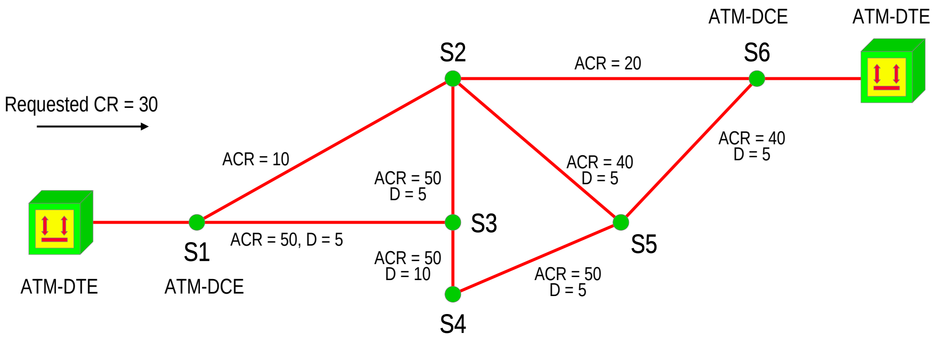
PNNI Routing

- **Generic Connection Admission Control (GCAC)**
  - Used by the source switch to select a path through the network
  - Calculates the expected CAC (Connection Admission Control) behavior of another node



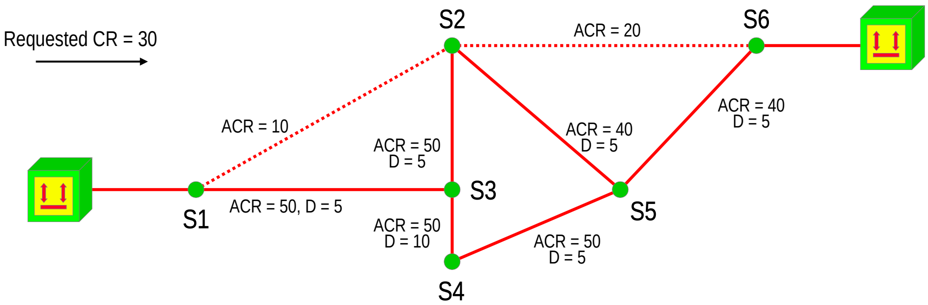
PNNI Routing (Simple QoS -> ACR only)

- **Operation of the GCAC**
  - CR … Cell Rate
  - ACR … Available Cell Rate
  - D … Distance like OSPF costs



PNNI Routing

- **Operation of the GCAC**
  - 1) Links not supporting requested CR are eliminated ->
    - Metric component -> ACR value used



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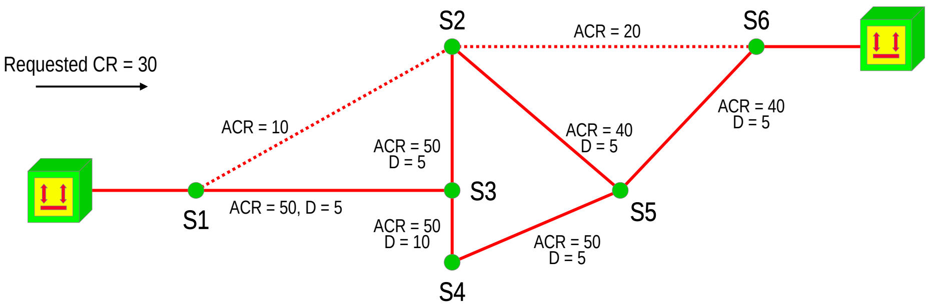
PNNI Routing

- **Operation of the GCAC**
  - 2) Next, shortest path(s) to the destination is (are) calculated
    - Metric component -> Distance value used



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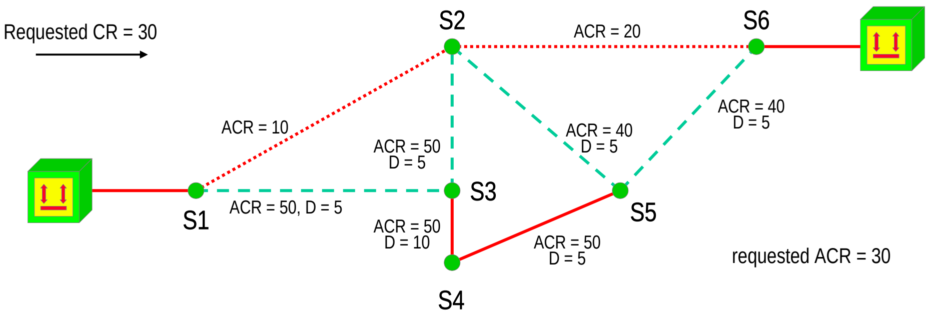
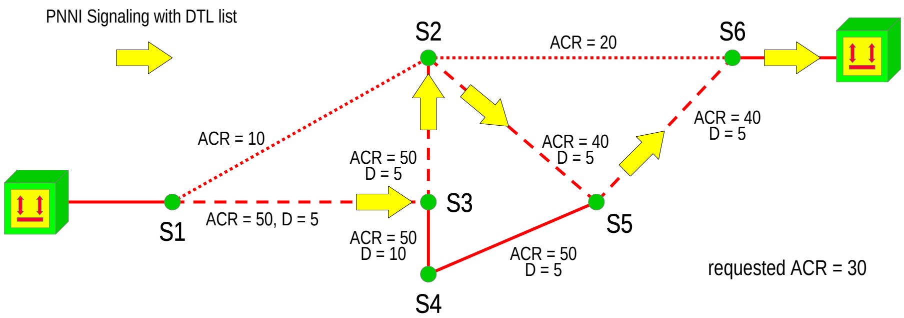
PNNI Routing

- **Operation of the GCAC**
  - 3) One path is chosen and source node S1 constructs a Designated Transit List (DTL) -> source routing -->
    - Describes the complete route to the destination



PNNI Routing - Source Routing

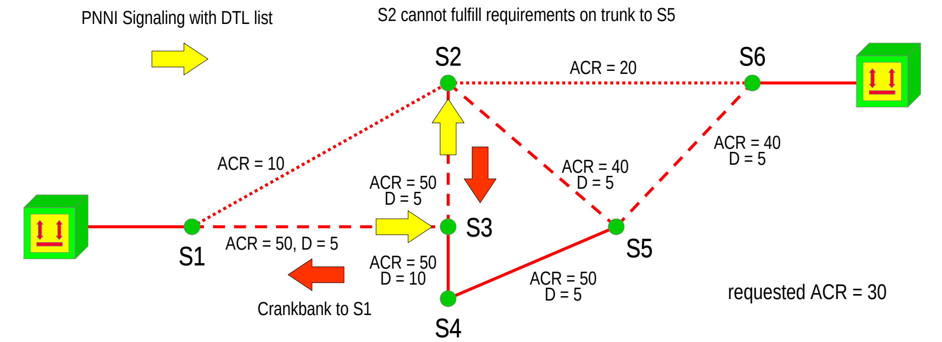
- **Operation of the GCAC**
  - 4) DTL is inserted into signaling request and moved on to next switch
  - 5) After receipt next switch perform local CAC
    - 5a) if ok -> pass PNNI signaling message on to next switch of DTL
  - 6a) finally signaling request will reach destination ATM-DTE -> VC ok



L14 - Multiprotocol Label Switching

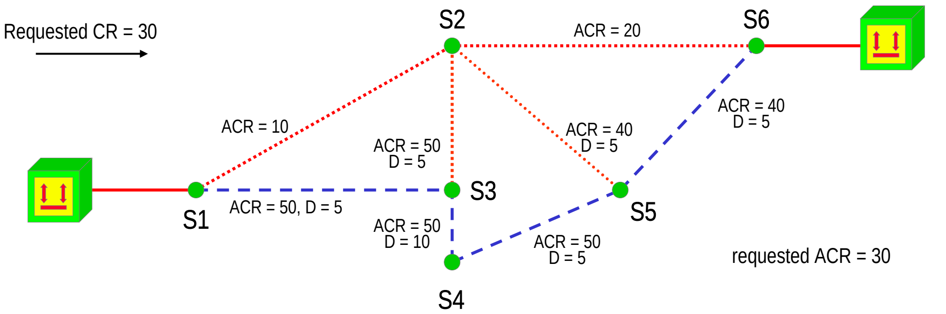
PNNI Routing - Crankbank

- **Operation of the GCAC**
  - 5) After receipt next switch (S2) perform local CAC
    - 5b) if nok -> return PNNI signaling message to originator of DTL
  - 6b) S1 will construct alternate source route



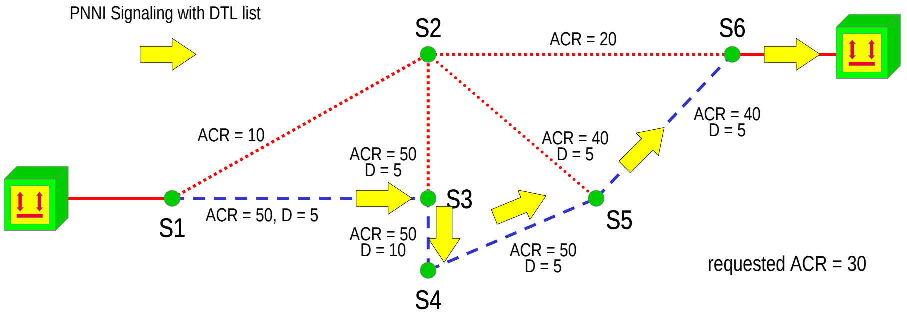
PNNI Routing - New Trial

- **Operation after Crankbank**
  - 7b) The other possible path is chosen - source node constructs again a new Designated Transit List (DTL)



PNNI Routing - Source Routing

- **Operation of the GCAC**
  - 8b) DTL is inserted into signaling request
  - 9b) After receipt next switch perform local CAC
    - if ok -> pass PNNI signaling message on to next switch of DTL
  - 10b) finally signaling request will reach destination ATM-DTE -> VC ok



Agenda

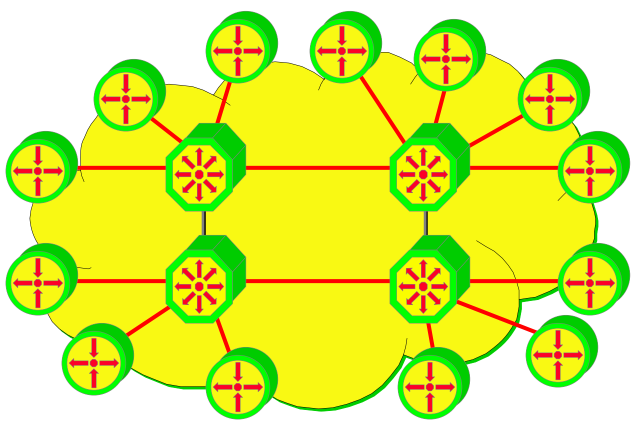
- **Review ATM**
- **<u>IP over WAN Problems (Traditional Approach)</u>**
- **MPLS Principles**
- **Label Distribution Methods**
- **RFC's**

IP Overlay Model - Scalability

- **Base problem Nr.1**
  - IP routing separated from ATM routing because of the normal IP overlay model
  - no exchange of routing information between IP and ATM world
  - leads to scalability and performance problems
    - many peers, configuration overhead, duplicate broadcasts
  - note:
    - IP system requests virtual circuits from the ATM network
    - ATM virtual circuits are established according to PNNI routing
    - virtual circuits are treated by IP as normal point-to-point links
    - IP routing messages are transported via this point-to-point links to discover IP neighbors and IP network topology

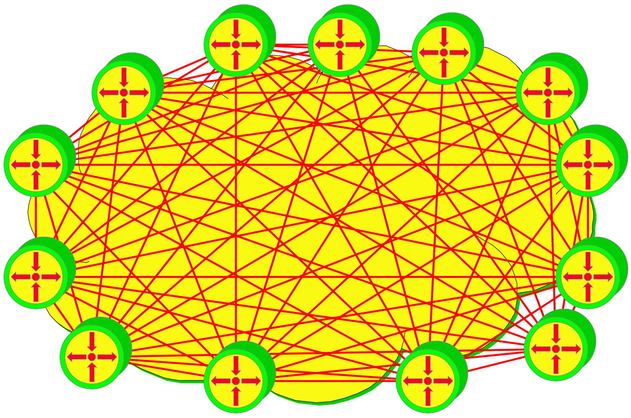
A Simple Physical Network ...

Physical wiring

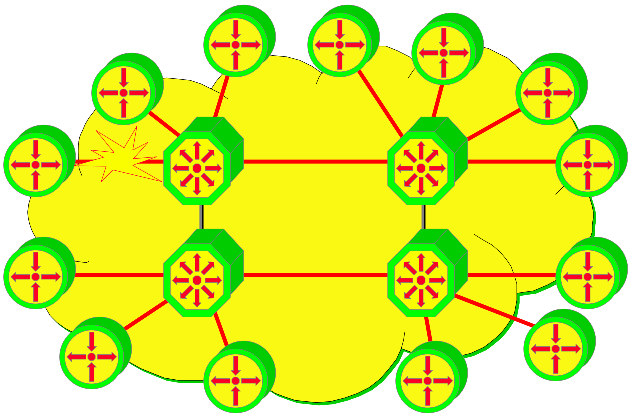


IP Data Link View (Non-NBMA)

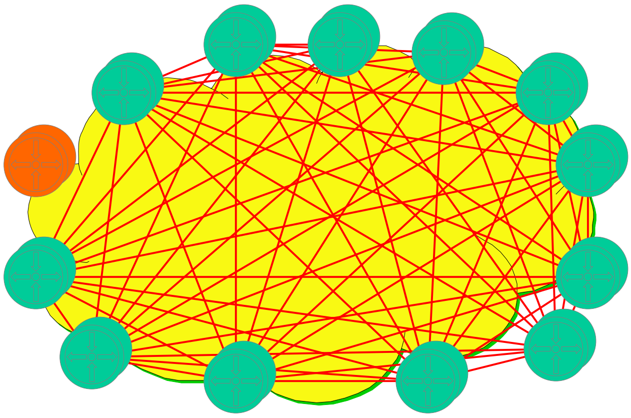
Every virtual circuit has its own IP Net-ID (subinterface technique)



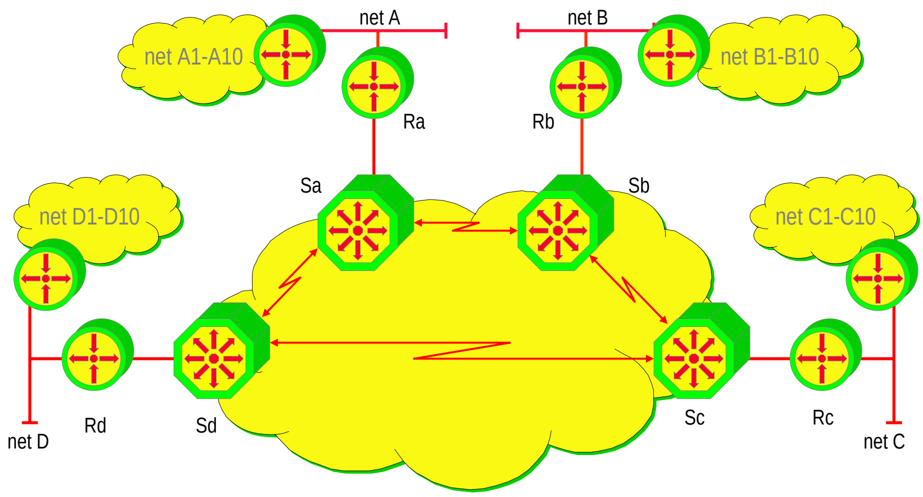
A Single Network Failure ...



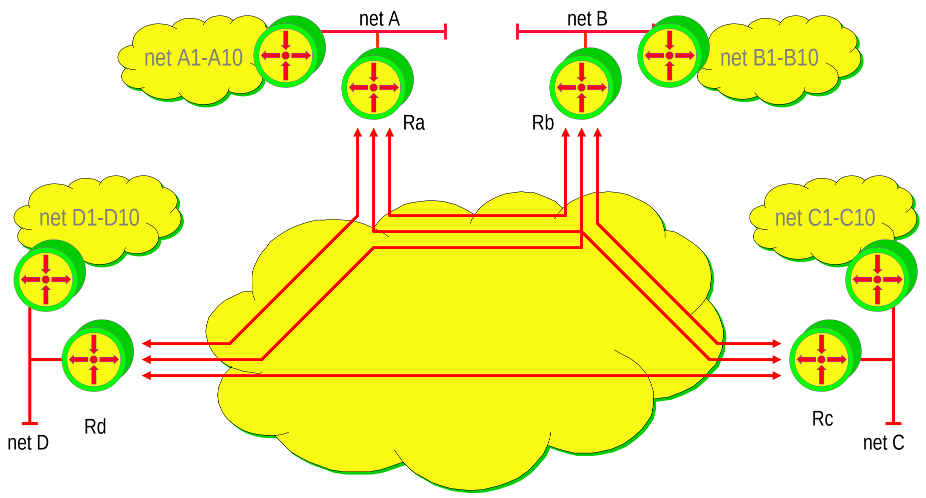
Causes Loss of Multiple IP Router Peers !!!



Example - Physical Topology



IP Connectivity through Full-mesh VC´s



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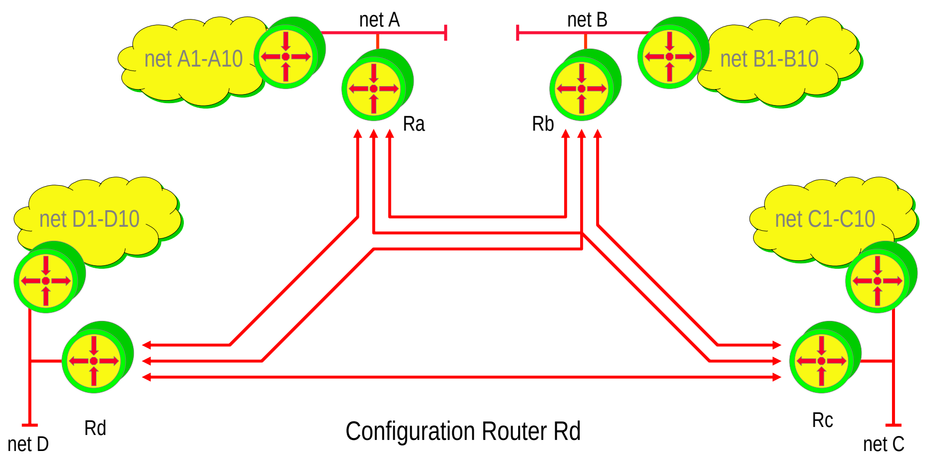
Static Routing/No Routing Broadcasts



Configuration Router Rd

static routing
net A via next hopRa
net B via next hopRb
net C via next hopRc
every remote network listed here!

address resolution PVC
Ra map VPI/VCI Rd ⇨ Ra
Rb map VPI/VCI Rd ⇨ Rb
Rc map VPI/VCI Rd ⇨ Rc

address resolution SVC
Ra map ATM addr. Ra
Rb map ATM addr. Rb
Rc map ATM addr. Rc

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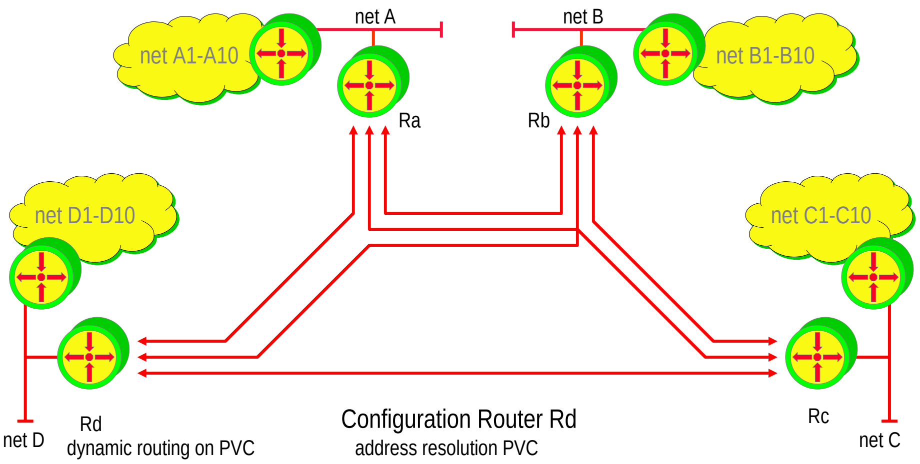
Dynamic Routing/Routing Broadcasts



Configuration Router Rd

dynamic routing on PVC
VPI/VCI Rd ⇨ Ra broadcast
VPI/VCI Rd ⇨ Rb broadcast
VPI/VCI Rd ⇨ Rc broadcast

address resolution PVC
Ra map VPI/VCI Rd ⇨ Ra
Rb map VPI/VCI Rd ⇨ Rb
Rc map VPI/VCI Rd ⇨ Rc

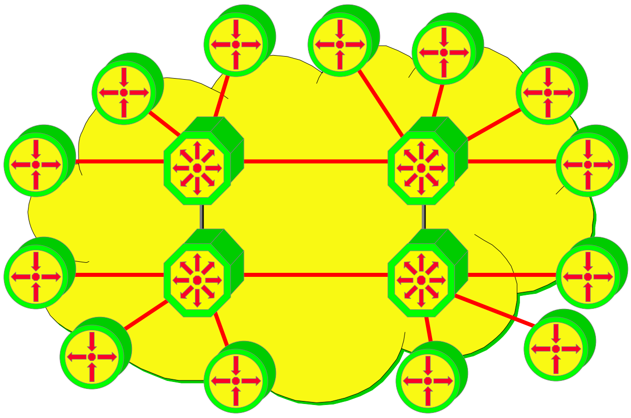
note: SVCs may be possible if Cisco neighbor command is specified for Cisco routing process because no automatic neighbor discovery is possible in this case

Observations

- **This clearly does not scale**
- **Switch/router interaction needed**
  - peering model
- **Without MPLS**
  - Only outside routers are layer 3 neighbors
  - one ATM link failure causes multiple peer failures
  - routing traffic does not scale (number of peers)
- **With MPLS**
  - Inside MPLS switch is the layer 3 routing peer of an outside router
  - one ATM link failure causes one peer failure
  - highly improved routing traffic scalability

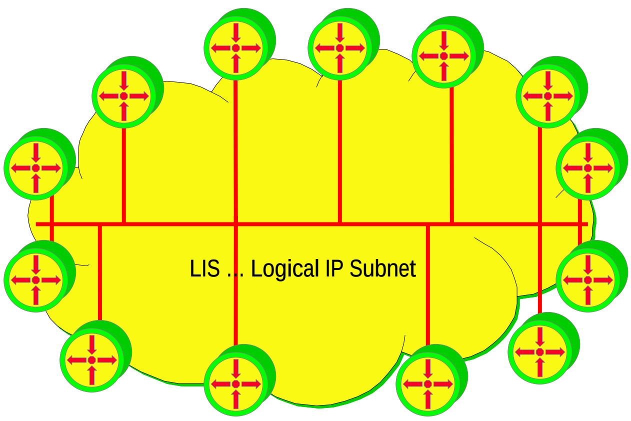
A Simple Physical Network ...

Physical wiring and NBMA behavior



IP Data Link View (NBMA)

Routers assume a LAN behavior because all interfaces have the same IP Net-ID but LAN broadcasting to reach all others is not possible

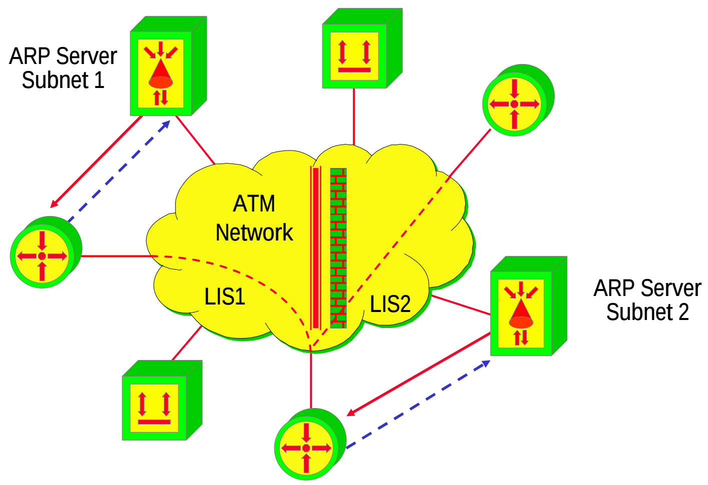


Some Solutions for the NBMA Problem

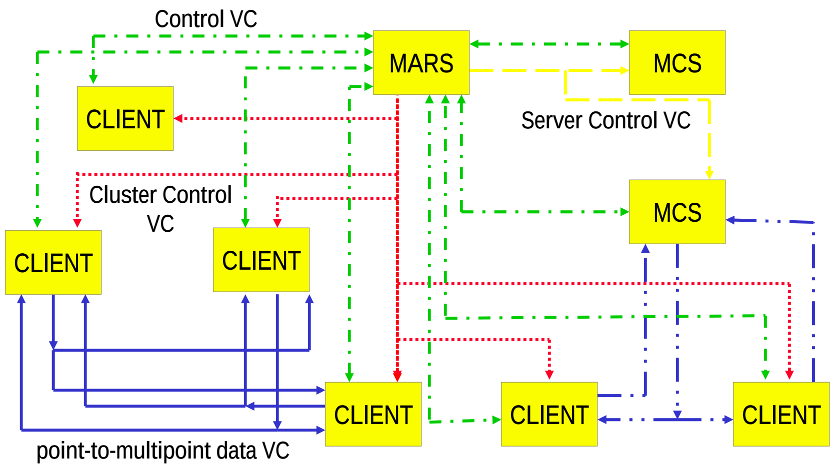
- ARP (Address Resolution Protocol) Server
  - keeps configuration overhead for address resolution small
  - but does not solve the routing issue (neighbor discovery and duplicate routing broadcasts on a single wire)
- MARS/MCS (Multicast Address Resolution Server / Multicast Server)
  - additional keeps configuration overhead for routing small
  - but does not solve the duplicate broadcast problem
- LANE (LAN Emulation = ATM VLAN´s)
  - simulates LAN behavior where address resolution and routing broadcasts are not a problem
- All of them
  - require a lot of control virtual circuits (p-t-p and p-t-m) and SVC support of the underlying ATM network

RFC 2225 Operation (Classical IP over ATM)

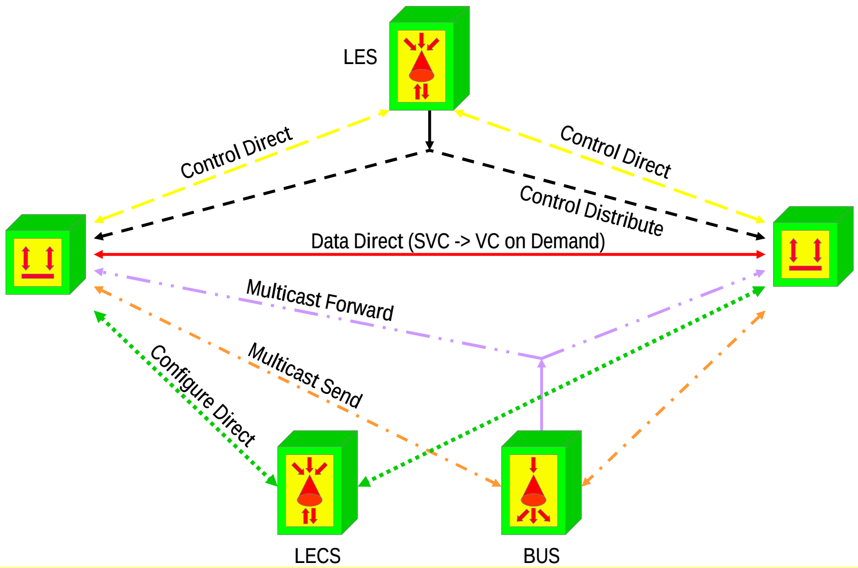
- **ARP server for every LIS**
  - multiple hops for communication between Logical IP Subnets



MARS/MCS Architecture



LANE Connections

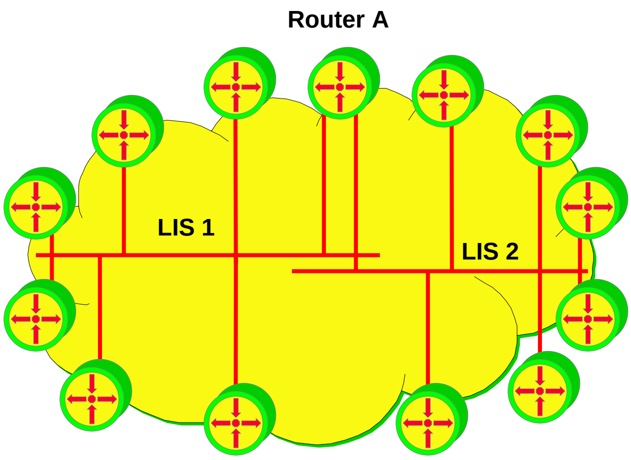


Scalability Aspects

- **Number of IP peers determines**
  - number of data virtual circuits
  - number of control virtual circuits
  - number of duplicate broadcasts on a single wire
- **Method to solve the duplicate broadcast problem**
  - split the network in several LIS (logical IP subnets)
  - connect LIS's by normal IP router (ATM-DCE) which is of course outside the ATM network
- **But then another problem arise**
  - traffic between to two systems which both are attached to the ATM network but belong to different LIS´s must leave the ATM network and enter it again at the connecting IP router (-> SAR delay)

IP Multiple LIS´s in case of ROLC (Routing over Large Clouds)

IP router A connects LIS1 and LIS2

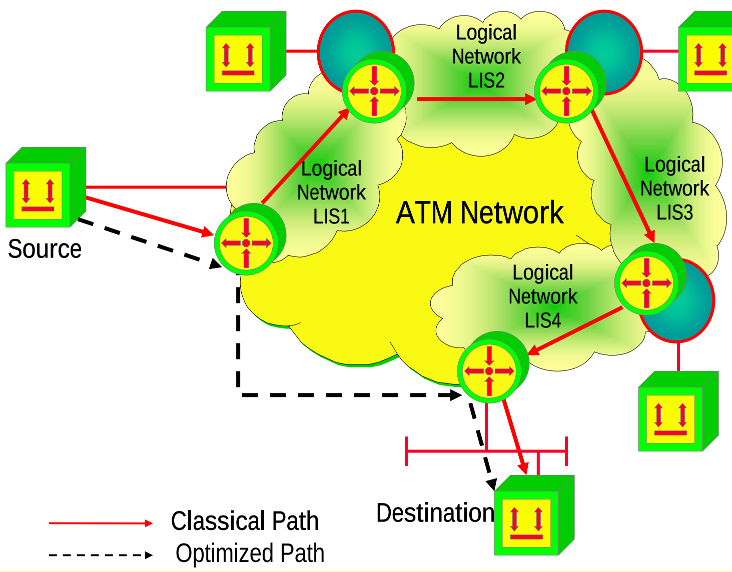


L14 - Multiprotocol Label Switching

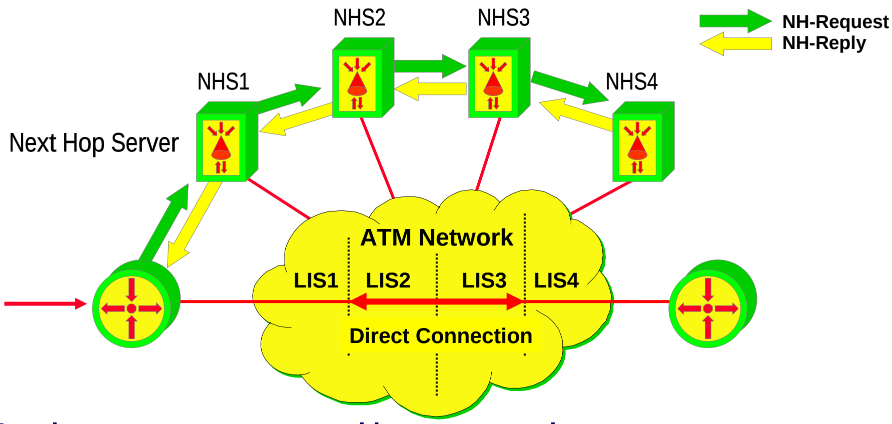
Some Solutions for the ROLC Problem

- **NHRP (Next Hop Resolution Protocol)**
  - creates an ATM shortcut between two systems of different LIS´s
- **MPOA (Multi Protocol Over ATM)**
  - LANE + NHRP combined
  - creates an ATM shortcut between two systems of different LIS´s
- **In both methods**
  - the ATM shortcut is created if traffic between the two systems exceeds a certain threshold -> data-flow driven
  - a lot of control virtual circuits (p-t-p and p-t-m) is required

Wish for Optimized Connectivity



Next Hop Resolution Protocol (RFC 2332)



- **Next hop requests are passed between next hop servers**
  - Next hop servers do not forward data
- **NHS that knows about the destination sends back a NH-reply**
  - Allows direct connection between logical IP subnets across the ATM cloud
  - Separates data forwarding path from reachability information

IP Performance

- **Base problem Nr.2**
  - IP forwarding is slow compared to ATM cell forwarding
    - IP routing paradigm
    - hop-by-hop routing with (recursive) IP routing table lookup, IP TTL decrement and IP checksum computing
    - destination based routing (large tables in the core of the Internet)
  - Load balancing
    - in a stable network all IP datagram's will follow the same path (least cost routing versus ATM´s QoS routing)
  - QoS (Quality of Service)
    - IP is connectionless packet switching (best-effort delivery versus ATM´s guarantees)
  - VPN (Virtual Private Networks)
    - ATM VC´s have a natural closed user group (=VPN) behavior

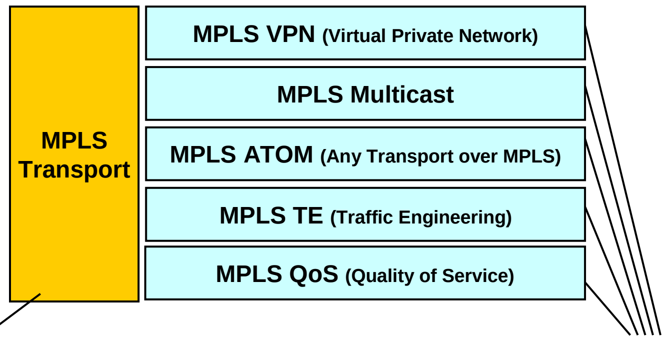
Basic Ideas to Solve the Problems

- **Make ATM topology visible to IP routing**
  - to solve the scalability problems
  - an ATM switch gets IP router functionality
- **Divide IP routing from IP forwarding**
  - to solve the performance problems
  - IP forwarding based on ATM´s label swapping paradigm (connection-oriented packet switching)
- **Combine best of both**
  - forwarding based on ATM label swapping paradigm
  - routing done by traditional IP routing protocols

MPLS

- **Several similar technologies were invented in the mid-1990s**
  - IP Switching (Ipsilon)
  - Cell Switching Router (CSR, Toshiba)
  - Tag Switching (Cisco)
  - Aggregated Route-Based IP Switching (ARIS, IBM)
- **IETF merges these technologies**
  - MPLS (Multi Protocol Label Switching)
    - note: multiprotocol means that IP is just one possible protocol to be transported by a MPLS switched network
  - RFC 3031

MPLS Building Blocks



You always need this!
MPLS Transport solves most of the mentioned problems (scalability / performance)

If you need "Advanced Features" like VPN or Multicast support you optionally may choose from these building blocks riding on top of a MPLS Transport network

Agenda

- **Review ATM**
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- **MPLS Principles**
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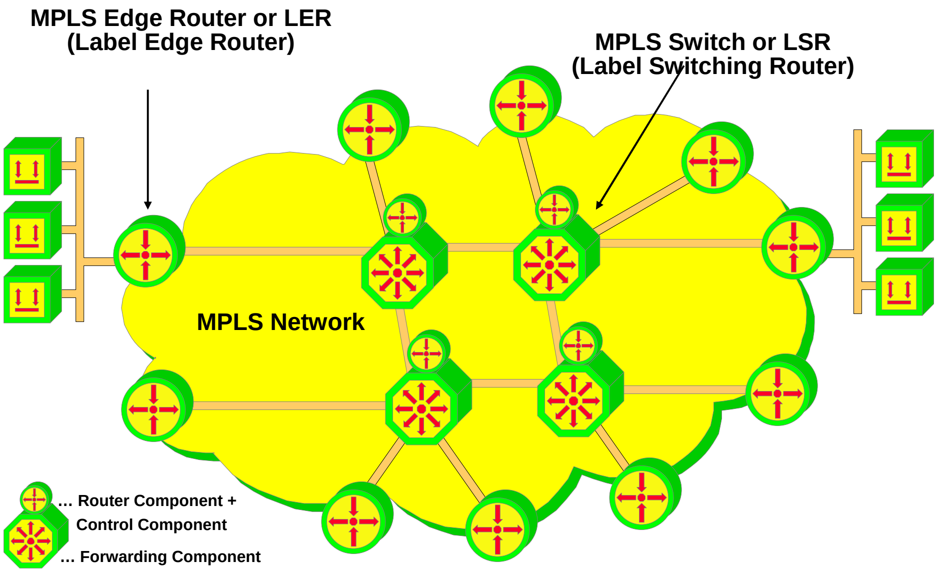
L14 - Multiprotocol Label Switching

MPLS Approach

- **Traditional IP uses the same information for**
  - path determination (routing)
  - packet forwarding (switching)
- **MPLS separates the tasks**
  - L3 addresses used for path determination
  - labels used for switching
- **MPLS Network consists of**
  - MPLS Edge Routers and MPLS Switches
- **Edge Routers and Switches**
  - exchange routing information about L3 IP networks
  - exchange forwarding information about the actual usage of labels

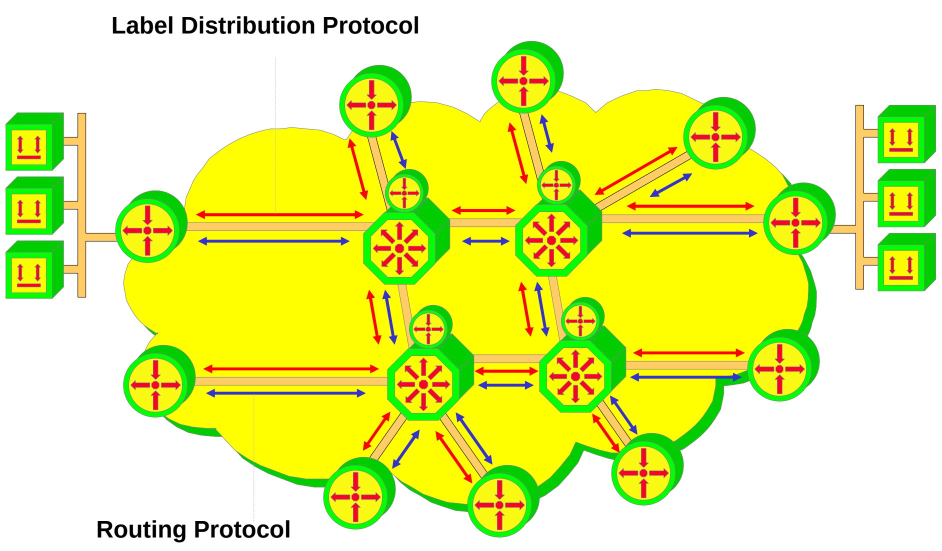
MPLS Network



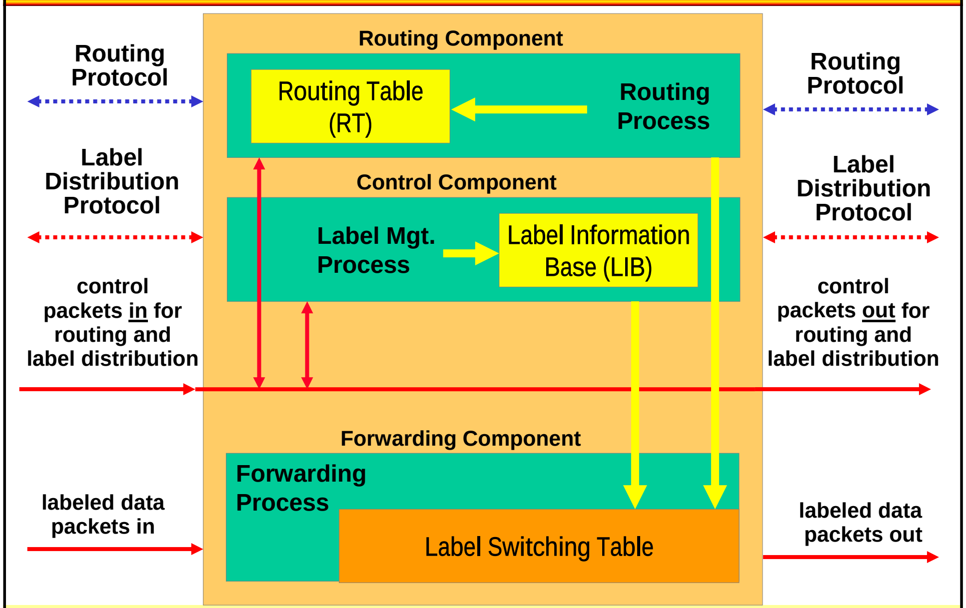
MPLS LSR Internal Components

- **Routing Component**
  - still accomplished by using standard IP routing protocols creating routing table
- **Control Component**
  - maintains correct label distribution among a group of label switches
  - Label Distribution Protocol for communication
    - between MPLS Switches
    - between MPLS Switch and MPLS Edge Router
- **Forwarding Component**
  - uses labels carried by packets plus label information maintained by a label switch (switching table) to perform packet forwarding -> “label swapping”

MPLS Control Communication



Generic Overview of MPLS LSR Internal Processes and Communication



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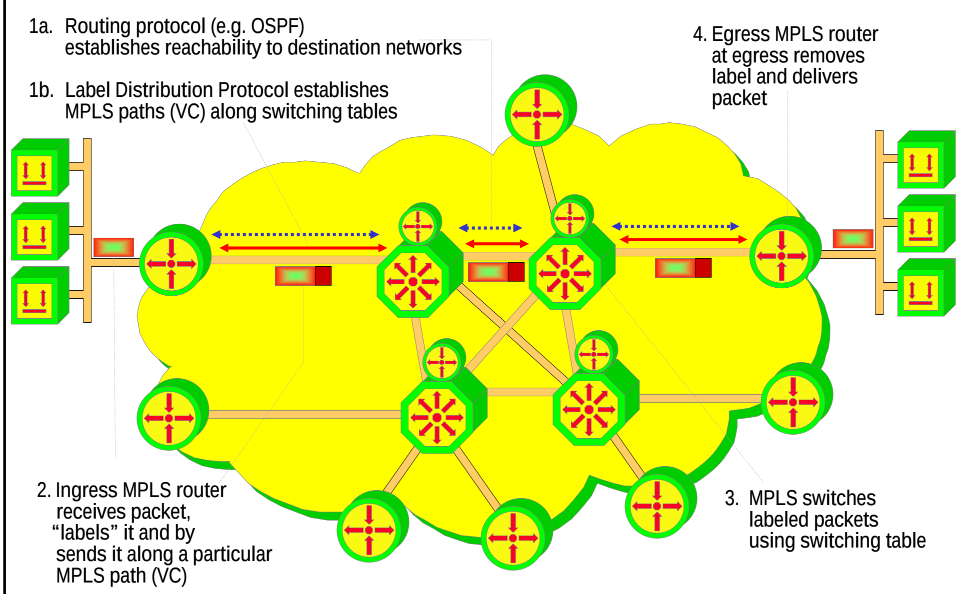
MPLS Basic Operations



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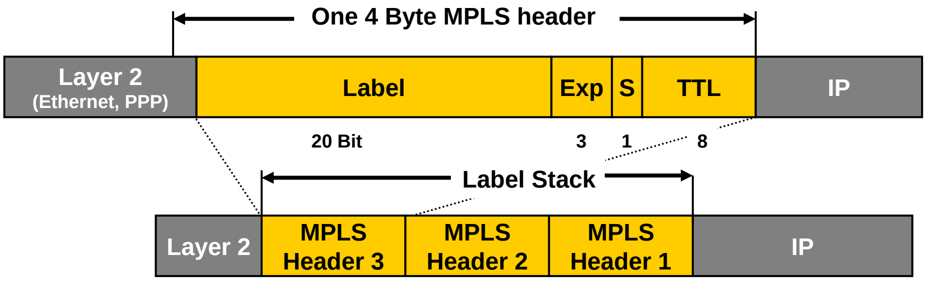
L14 - Multiprotocol Label Switching

MPLS Header: Frame Mode



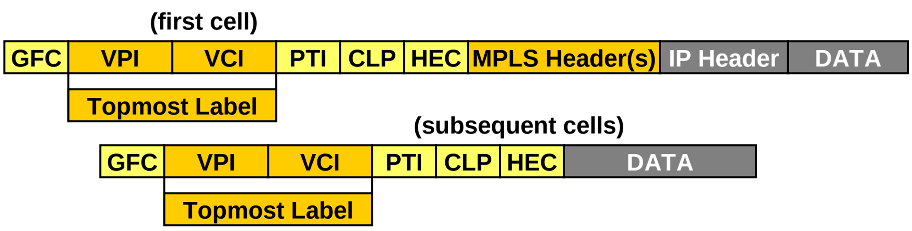
- **"Layer 2.5" can be used over Ethernet, 802.3 or PPP links**
  - note: 2.5 means 32 bit
  - 20-bit MPLS label (Label)
  - 3-bit experimental field (Exp)
    - could be copy of IP Precedence -> MPLS QoS like IP QoS with DiffServ Model based on DSCP
  - 1-bit bottom-of-stack indicator (S)
    - Labels could be stacked (Push & Pop)
    - MPLS switching performed always on the first label of the stack
  - 8-bit time-to-live field (TTL)

MPLS Header: Cell Mode

ATM Convergence Sublayer (CS):

- **ATM Switches can only switch VPI/VCI—no MPLS labels!**
  - Only the topmost label is inserted in the VPI/VCI field

ATM Segmentation and Reassembling Sublayer (SAR):



Labels and FEC

- **A label is used to identify a certain subset of packets**
  - which take the same MPLS path or which get the same forwarding treatment in the MPLS label switched network
  - The path is so called Label Switched Path (LSP)
    - “The MPLS Virtual Circuit”
- **Thus a label represents**
  - a so called Forwarding Equivalence Class (FEC)
- **The assignment of a packet to FEC**
  - is done just once by the MPLS Edge Router, as the packet enters the network
  - most commonly is based on the network layer destination address

Label Binding

- **Two neighboring LSR´s R1 and R2**
  - may agree that when R1 transmits a packet to R2, R1 will label with packet with label value L if and only if the packet is a member of a particular FEC F
- **They agree**
  - on a so called "binding" between label L and FEC F for packets moving from R1 to R2
- **As a result**
  - L becomes R1´s "outgoing label" or “remote label” representing FEC F
  - L becomes R2´s "incoming label" or “local label” representing FEC F

Creating and Destroying Label Binding 1

- **Control Driven (favored by IETF-WG)**
  - creation or deconstruction of labels is triggered by control information such as
    - OSPF routing
    - PIM Join/Prune messages in case of IP multicast routing
    - IntSrv RSVP messages in case of IP QoS IntSrv Model
    - DiffSrv Traffic Engineering in case of IP QoS DiffSrv Model
  - hence we have a pre-assignment of labels based on reachability information
    - and optionally based on QoS needs
  - also called Topology Driven

Creating and Destroying Label Binding 2

- **Data Driven**
  - creation or deconstruction of labels is triggered by data packets
    - but only if a critical threshold number of packets for a specific communication relationship is reached
    - may have a big performance impact
  - hence we have dynamic assignment of labels based on data flow detection
  - also called Traffic Driven

Some FEC Examples for Topology Driven

- **FEC´s could be for example**
  - a set of unicast packets whose network layer destination address matches a particular IP address prefix
    - MPLS application: Destination Based (Unicast) Routing
  - a set of multicast packets with the same source and destination network layer address
    - MPLS application: Multicast Routing
  - a set of unicast packets whose network layer destination address matches a particular IP address prefix and whose Type of Service (ToS) or DSCP bits are the same
    - MPLS application: Quality of Service
    - MPLS application: Traffic Engineering or Constraint Based Routing

Label Distribution

- **MPLS architecture allows an LSR to distribute bindings to LSR´s that have not explicitly requested them**
  - “Unsolicited Downstream" label distribution
  - usually used by Frame-Mode MPLS
- **MPLS architecture allows an LSR to explicitly request, from its next hop for a particular FEC, a label binding for that FEC**
  - “Downstream-On-Demand" label distribution
  - must be used by Cell-Mode MPLS

Label Binding

- **The decision to bind a particular label L to a particular FEC F**
  - is made by the LSR which is DOWNSTREAM with respect to that binding
  - the downstream LSR then informs the upstream LSR of the binding
  - thus labels are "downstream-assigned“
  - thus label bindings are distributed in the "downstream to upstream“ direction
- **Discussion were about if**
  - labels should also be “upstream-assigned“
  - not any longer part of current MPLS-RFC

Label Retention Mode 1

- **A LSR may receive a label binding**
  - for a particular FEC from another LSR, which is not next hop based on the routing table for that FEC
- **This LSR then has the choice**
  - of whether to keep track of such bindings, or whether to discard such bindings
- **A LSR supports "Liberal Label Retention Mode"**
  - if it maintains the bindings between a label and a FEC which are received from LSR´s which are not its next hop for that FEC

Label Retention Mode 2

- **A LSR supports "Conservative Label Retention mode "**
  - If it discards the bindings between a label and a FEC which are received from LSR´s which are not its next hop for that FEC
- **Liberal Label Retention mode**
  - allows for quicker adaptation to routing changes
  - LSR can switch over to next best LSP
- **Conservative Label Retention mode**
  - requires an LSR to maintain fewer labels
  - LSR has to wait for new label bindings in case of topology changes

Independent versus Ordered Control

- **Independent Control:**
  - each LSR may make an independent decision to assign a a label to a FEC and to advertise the assignment to its neighbors
  - typically used in Frame-Mode MPLS for destination based routing
  - loop prevention must be done by other means (-> MPLS TTL) but there is faster convergence
- **Ordered Control:**
  - label assignment proceeds in an orderly fashion from one end of a LSP to the other
  - under ordered control, LSP setup may be initiated by the ingress (header) or egress (tail) MPLS Edge Router

Ordered Control - Egress

- in case of egress method the only LSR which can initiate the process of label assignment is the egress LSR
- a LSR knows that it is the egress for a given FEC if its next hop for this FEC is not an LSR
- this LSR will sent a label advertisement to all neighboring LSR´s
- a neighboring LSR receiving such a label advertisement from a interface which is the next hop to a given FEC will assign its own label and advertise it to all other neighboring LSR´s
- inherent loop prevention
- slower convergence

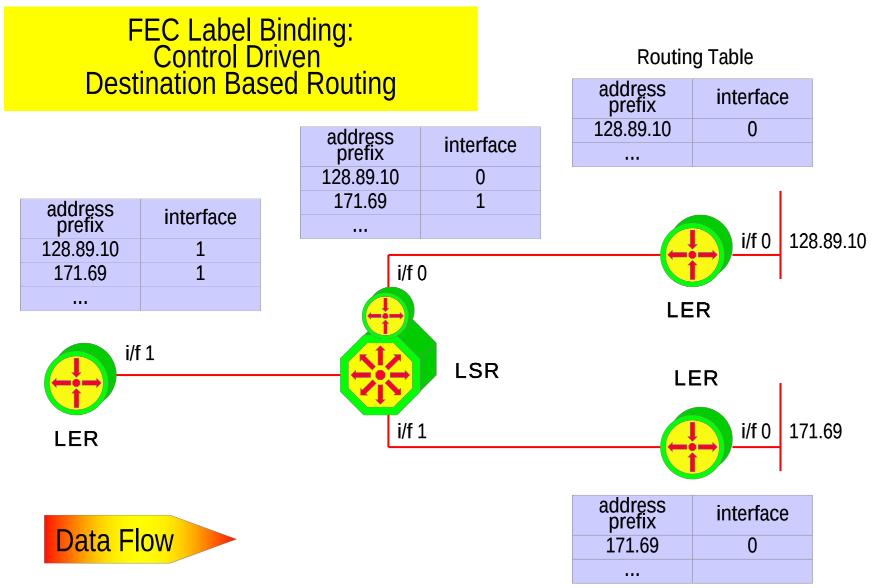
Ordered Control - Ingress

- in case of ingress method the LSR which initiates the process of label assignment is the ingress LSR
- the ingress LSR constructs a source route and pass on requests for label bindings to the next LSR
- this is done until LSR which is the end of the source route is reached
- from this LSR label bindings will flow upstream to the ingress LSR
- used for MPLS Traffic Engineering (TE)

Agenda

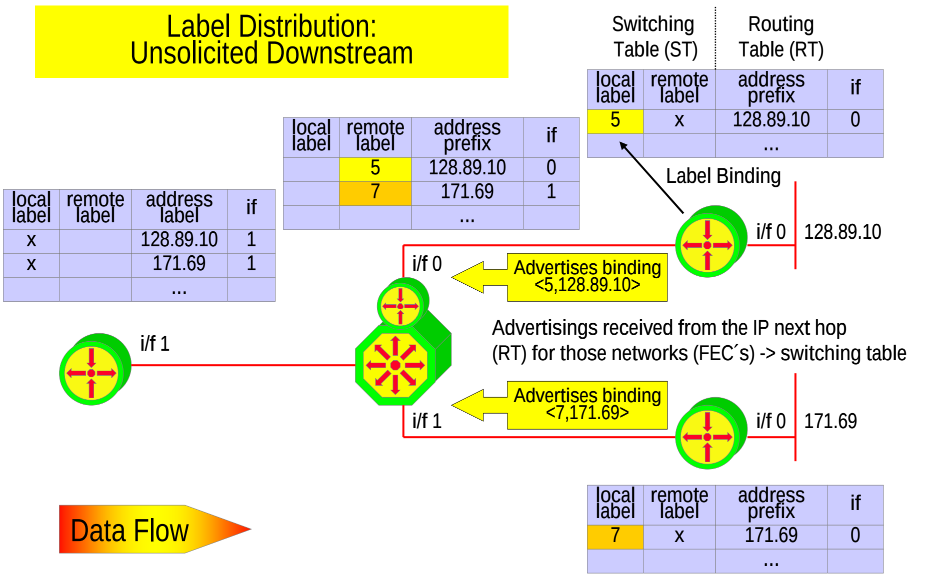
- Review ATM
- IP over WAN Problems (Traditional Approach)
- MPLS Principles
- <u>Label Distribution Methods</u>
  - <u>Unsolicited Downstream</u>
  - Downstream On Demand
- RFC's

Routing Table Created by Routing Protocol



L14 - Multiprotocol Label Switching

Labels Sent by LDP



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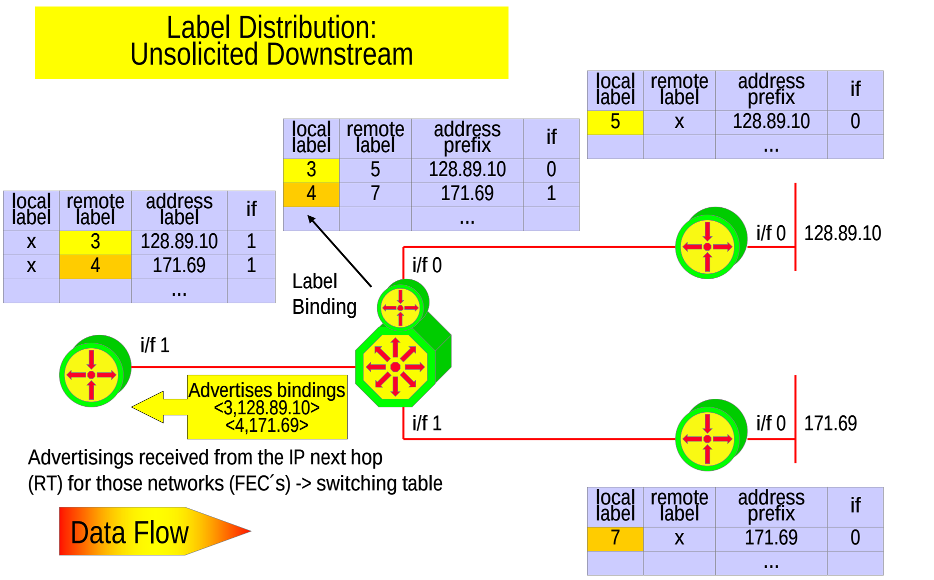
Labels Sent and Switching Table Entry Created by MPLS Switch



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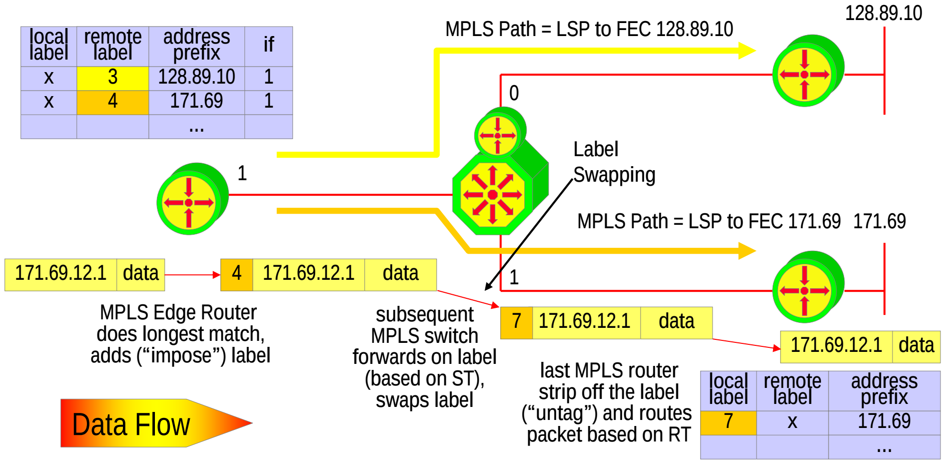
L14 - Multiprotocol Label Switching

MPLS Switched Packets

local label	remote label	address prefix	if
x	3	128.89.10	1
x	4	171.69	1
		...	

local label	remote label	address prefix	if
3	5	128.89.10	0
4	7	171.69	1
		...	

local label	remote label	address prefix
7	x	171.69
		...



Routing Table Created by Routing Protocol

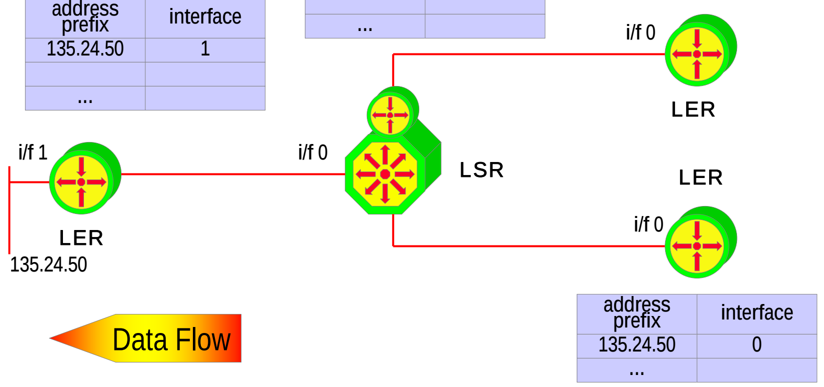
FEC Label Binding:
Control Driven
Destination Based Routing

address prefix	interface
135.24.50	1
...	

address prefix	interface
135.24.50	0
...	

address prefix	interface
135.24.50	0
...	

address prefix	interface
135.24.50	0
...	



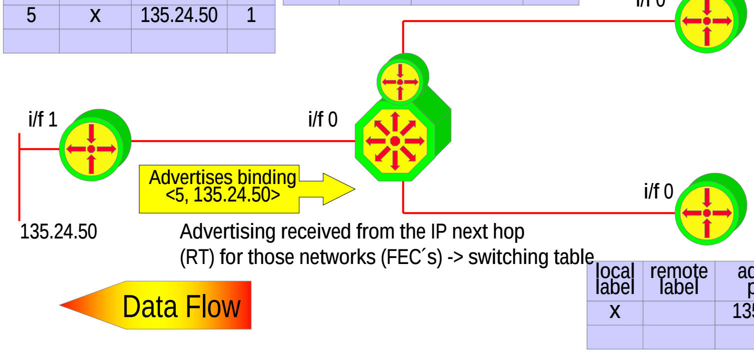
Labels Sent by LDP

Label Distribution:
Unsolicited Downstream

local label	remote label	address prefix	if
5	X	135.24.50	1

local label	remote label	address prefix	if
	5	135.24.50	0
		...	

local label	remote label	address prefix	if
X		135.24.50	0
		...	



local label	remote label	address prefix	if
X		135.24.50	0
		...	

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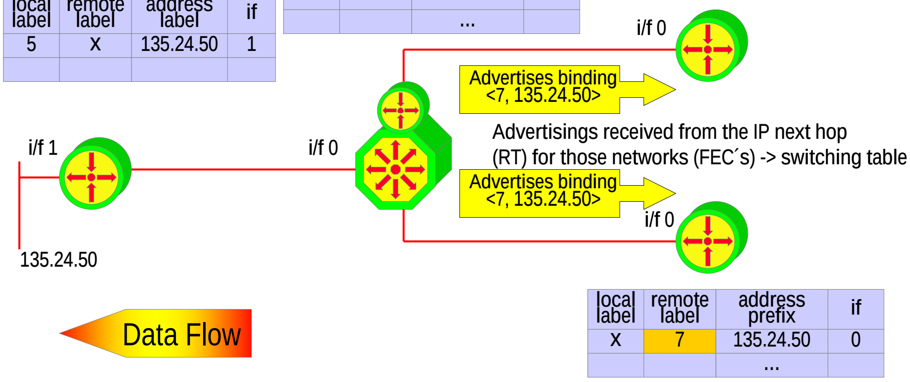
Labels Sent and Switching Table Entry Created by MPLS Switch

Label Distribution:
Unsolicited Downstream

local label	remote label	address prefix	if
5	X	135.24.50	1

local label	remote label	address prefix	if
7	5	135.24.50	0
		...	

local label	remote label	address prefix	if
X	7	135.24.50	0
		...	



local label	remote label	address prefix	if
X	7	135.24.50	0
		...	

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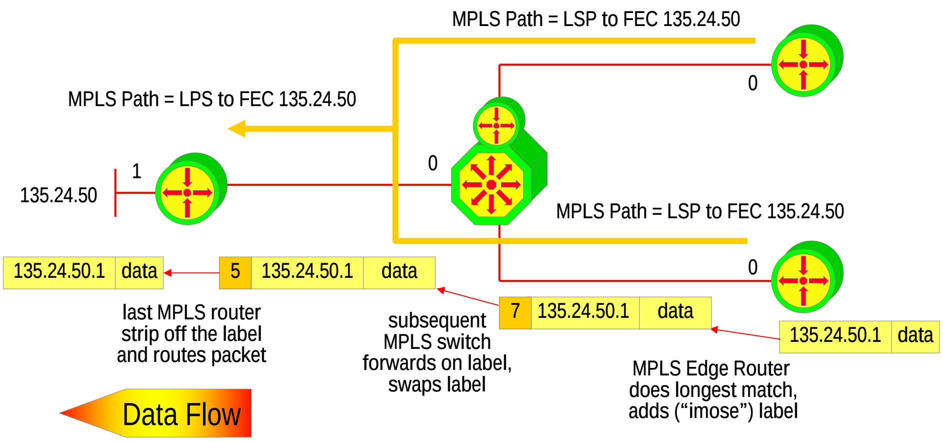
L14 - Multiprotocol Label Switching

Label Merging - LSP Merging

local label	remote label	address label	if
5	x	135.24.50	1

local label	remote label	address prefix	if
7	5	135.24.50	0
		...	

local label	remote label	address prefix	if
x	7	135.24.50	0
		...	



Agenda

- **Review ATM**
- **IP over WAN Problems (Traditional Approach)**
- **MPLS Principles**
- **Label Distribution Methods**
  - Unsolicited Downstream
  - Downstream On Demand
- **RFC’s**

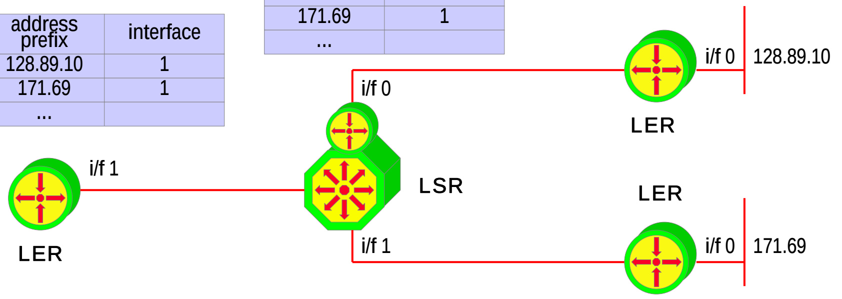
Routing Table Created by Routing Protocol

FEC Label Binding:
Control Driven
Destination Based Routing

address prefix	interface
128.89.10	1
171.69	1
...	

address prefix	interface
128.89.10	0
171.69	1
...	

address prefix	interface
128.89.10	0
...	



address prefix	interface
171.69	0
...	

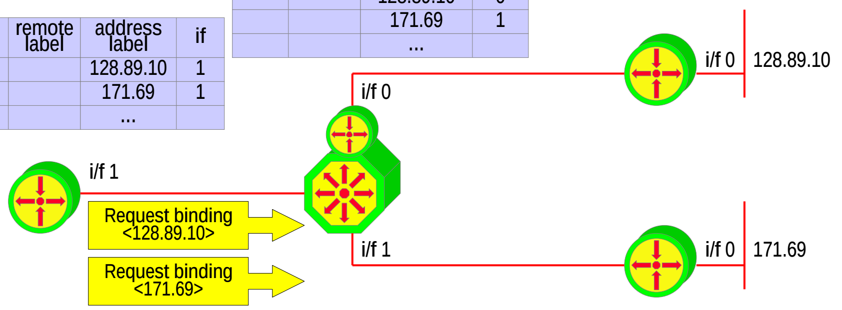
Labels Requested by MPLS Edge Routers

Label Distribution:
Downstream-On-Demand

local label	remote label	address label	if
x		128.89.10	1
x		171.69	1
		...	

local label	remote label	address prefix	if
		128.89.10	0
		171.69	1
		...	

local label	remote label	address prefix	if
	x	128.89.10	0
		...	



Request binding are sent in direction of the IP next hop (RT) for these networks (FEC´s)

local label	remote label	address prefix	if
	x	171.69	0
		...	

Labels Requested by MPLS Switch

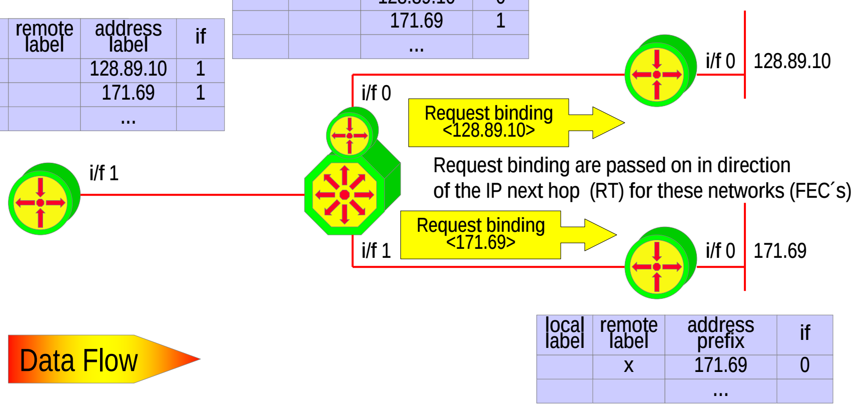
Label Distribution:
Downstream-On-Demand

local label	remote label	address label	if
x		128.89.10	1
x		171.69	1
		...	

local label	remote label	address prefix	if
		128.89.10	0
		171.69	1
		...	

local label	remote label	address prefix	if
	x	128.89.10	0
		...	

local label	remote label	address prefix	if
	x	171.69	0
		...	



Request binding are passed on in direction of the IP next hop (RT) for these networks (FEC´s)

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Labels Allocated by MPLS Edge Router

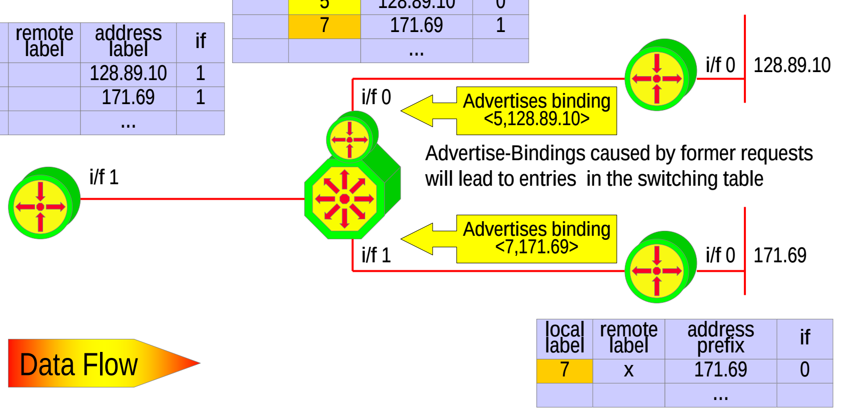
Label Distribution:
Downstream-On-Demand

local label	remote label	address label	if
x		128.89.10	1
x		171.69	1
		...	

local label	remote label	address prefix	if
	5	128.89.10	0
	7	171.69	1
		...	

local label	remote label	address prefix	if
5	x	128.89.10	0
		...	

local label	remote label	address prefix	if
7	x	171.69	0
		...	



Advertise-Bindings caused by former requests will lead to entries in the switching table

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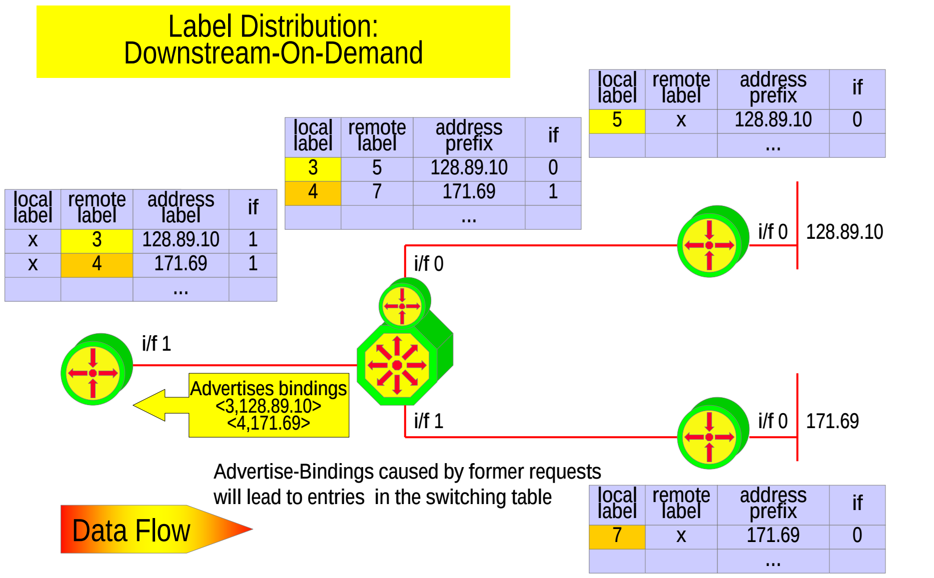
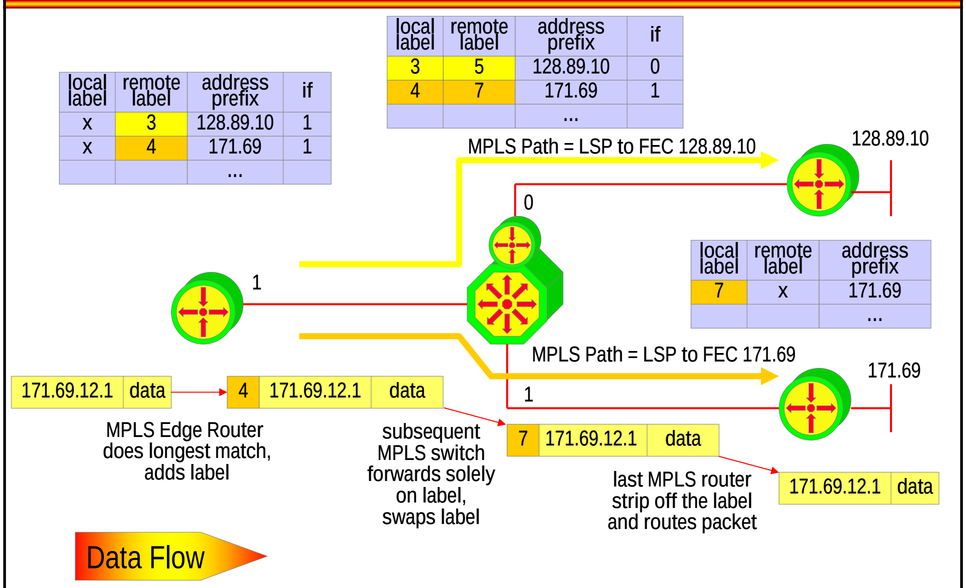
L14 - Multiprotocol Label Switching

Labels Allocated and Switching Table Built by MPLS Switch



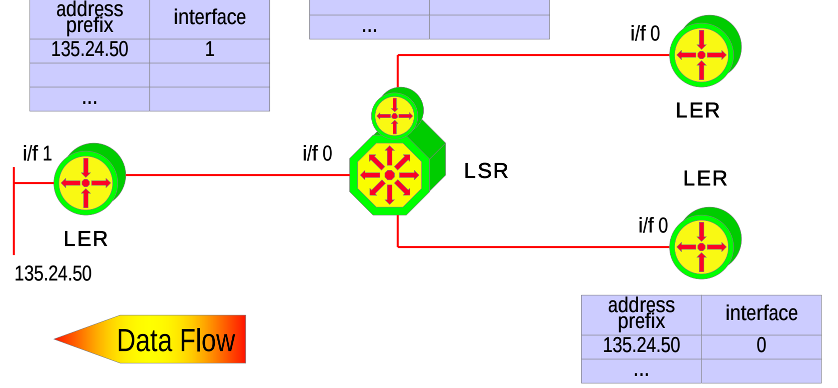
MPLS Switched Packets



L14 - Multiprotocol Label Switching

Routing Table Created by Routing Protocol

FEC Label Binding:
Control Driven
Destination Based Routing



address prefix	interface
135.24.50	1
...	

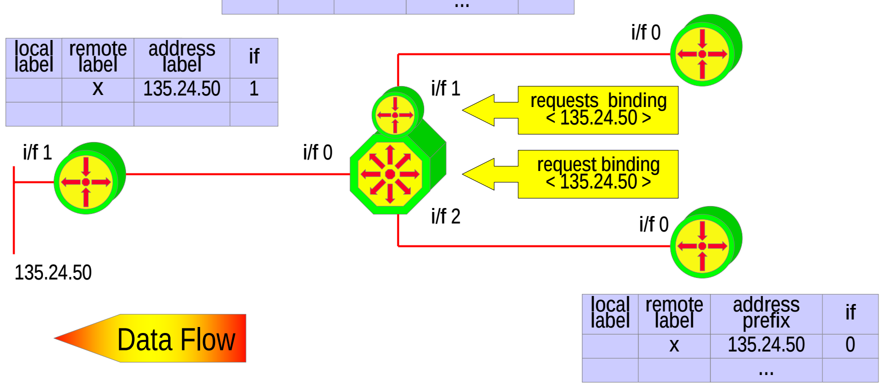
address prefix	interface
135.24.50	0
...	

address prefix	interface
135.24.50	0
...	

address prefix	interface
135.24.50	0
...	

Labels Requested by MPLS Edge Routers

Label Distribution:
Downstream-On-Demand



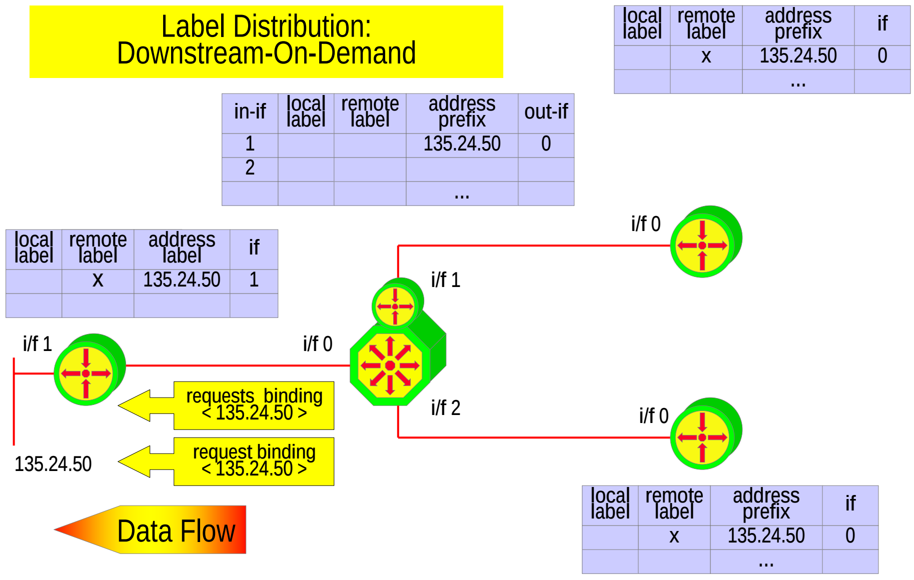
local label	remote label	address label	if
	x	135.24.50	1

in-if	local label	remote label	address prefix	out-if
1			135.24.50	0
2				
			...	

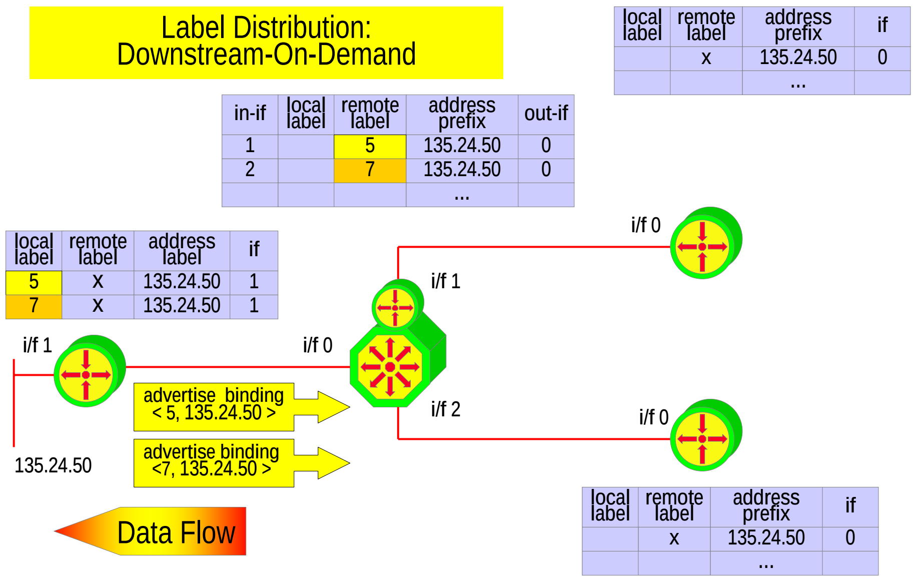
local label	remote label	address prefix	if
	x	135.24.50	0
		...	

local label	remote label	address prefix	if
	x	135.24.50	0
		...	

Labels Requested by MPLS Switch

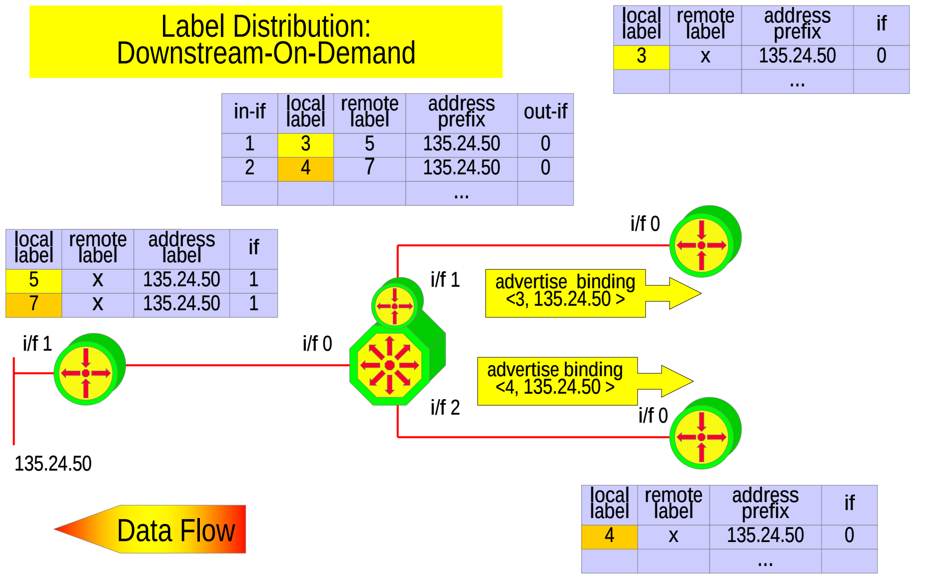


Labels Allocated by MPLS Edge Router



L14 - Multiprotocol Label Switching

Labels Allocated and Switching Table Built by MPLS Switch



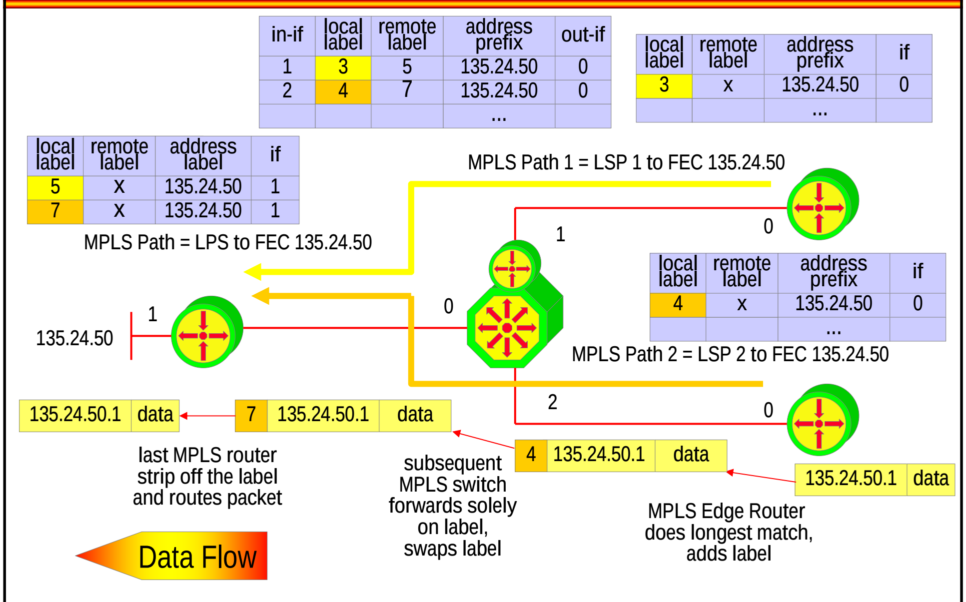
local label	remote label	address prefix	if
3	x	135.24.50	0
		...	

in-if	local label	remote label	address prefix	out-if
1	3	5	135.24.50	0
2	4	7	135.24.50	0
			...	

local label	remote label	address label	if
5	x	135.24.50	1
7	x	135.24.50	1

local label	remote label	address prefix	if
4	x	135.24.50	0
		...	

Two Separate LSP´s



in-if	local label	remote label	address prefix	out-if
1	3	5	135.24.50	0
2	4	7	135.24.50	0
			...	

local label	remote label	address prefix	if
3	x	135.24.50	0
		...	

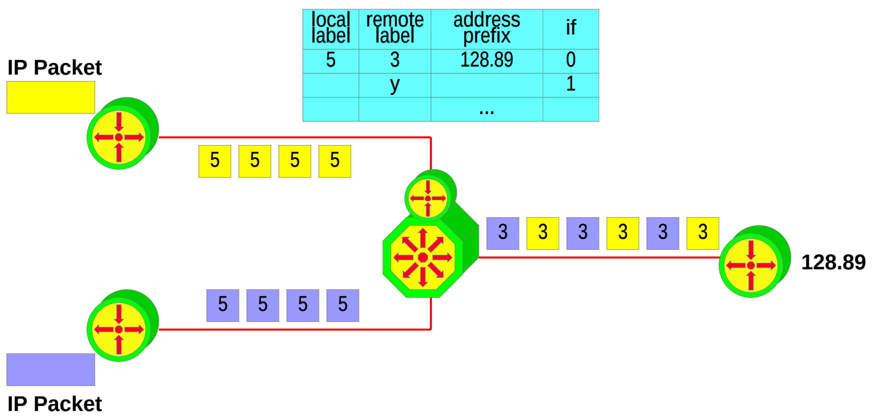
local label	remote label	address label	if
5	x	135.24.50	1
7	x	135.24.50	1

local label	remote label	address prefix	if
4	x	135.24.50	0
		...	

Label Switching and ATM

- **Can be easily deployed with ATM because ATM uses label swapping**
  - VPI/VCI is used as a label
- **ATM switches needs to implement control component of label switching**
  - ATM attached router peers with ATM switch (label switch)
    - exchange label binding information
- **Differences**
  - how labels are set up
    - label distribution -> downstream on demand allocation
  - label merging
    - in order to scale, merging of multiple streams (labels) into one stream (label) is required

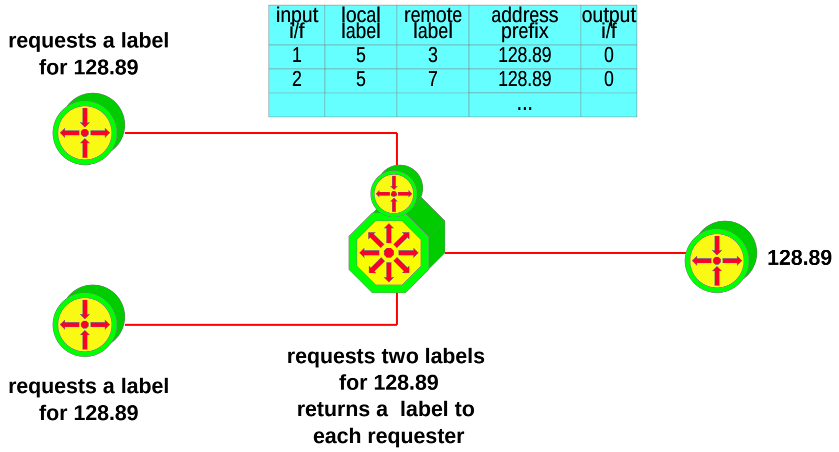
Label Switching and ATM



ATM switch interleaves cells of different packets onto same label.
That is a problem in case of AAL5 encapsulation.
No problem in case of AAL3/AAL4 encapsulation because of AAL3/AAL4´s inherent multiplexing capability.

Label Distribution Solution for ATM

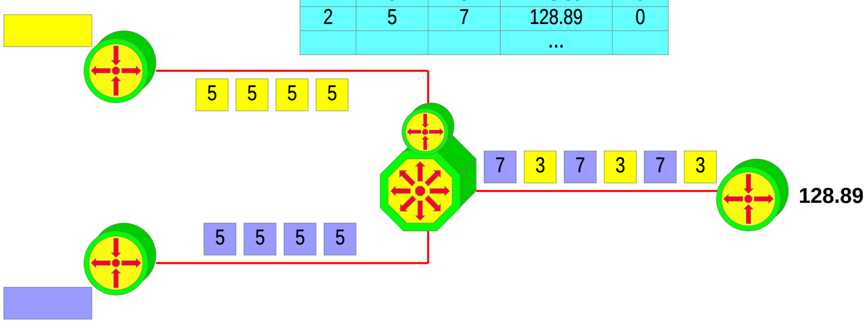
input i/f	local label	remote label	address prefix	output i/f
1	5	3	128.89	0
2	5	7	128.89	0
			...	



- **"Downstream On Demand" Label Distribution**

Label Distribution Solution for ATM

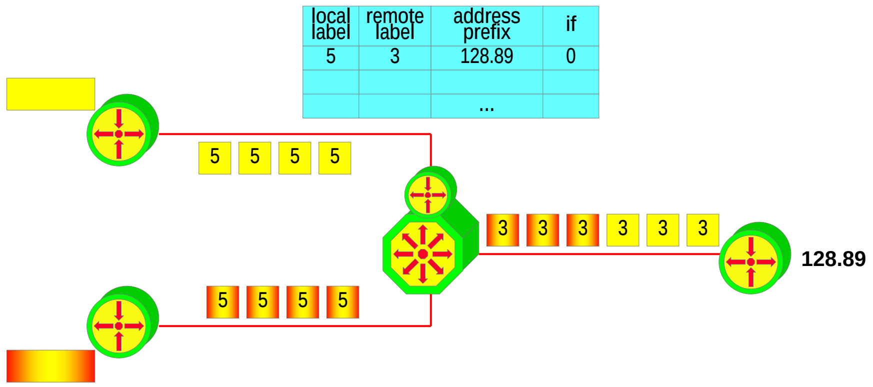
input i/f	local label	remote label	address prefix	output i/f
1	5	3	128.89	0
2	5	7	128.89	0
			...	



- **Downstream On Demand label distribution is necessary**
  - multiple labels per FEC may be assigned
  - one label per (ingress, egress) router pair
- **Label space can be reduced with VC-merge technique**

L14 - Multiprotocol Label Switching

VC Merge Technique



- **ATM switch avoids interleaving of frames**
  - VC Merge technique
  - looking for AAL5 trailers and storing corresponding cells of a frame until AAL5 trailer is seen

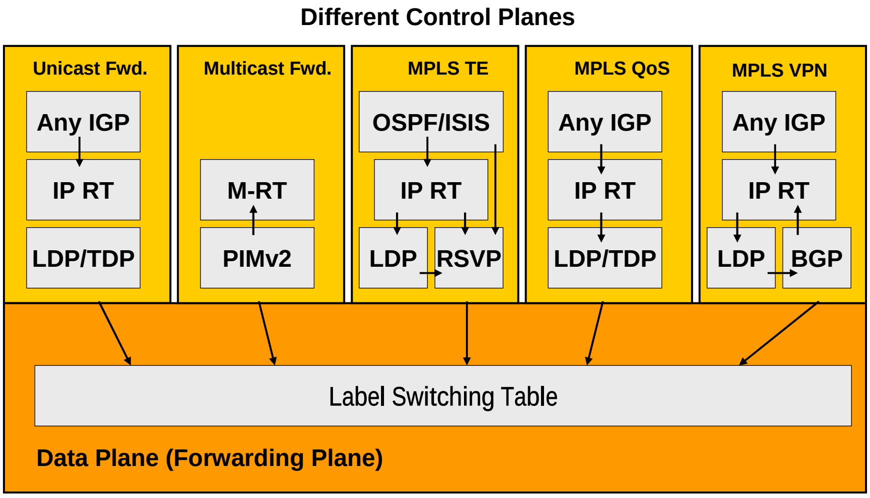
 MPLS, v4.5

Agenda

- **Review ATM**
- **IP over WAN Problems (Traditional Approach)**
- **MPLS Principles**
- **Label Distribution Methods**
- **RFC's**

 MPLS, v4.5

MPLS Applications and MPLS Control Plane



RFC References 1

- **RFC 3031**
  - Multiprotocol Label Switching Architecture
- **RFC 3032**
  - MPLS Label Stack Encoding
- **RFC 3036**
  - LDP Specification
- **RFC 3063**
  - MPLS Loop Prevention Mechanism
- **RFC 3270**
  - MPLS Support of Differentiated Services

RFC References 2

- **RFC 3443**
  - Time To Live (TTL) Processing in MPLS
- **RFC 3469**
  - Framework for Multi-Protocol Label Switching (MPLS)-based Recovery
- **RFC 3478**
  - Graceful Restart Mechanism for Label Distribution Protocol
- **RFC 3479**
  - Fault Tolerance for the Label Distribution Protocol (LDP)