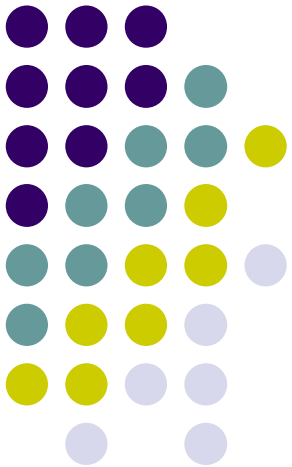
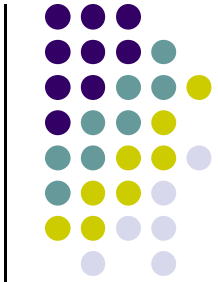
MPLS - MultiProtocol Label Switching



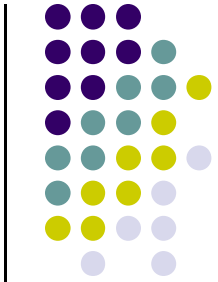
Curs in colaborare cu
Ramona Marfievici

Agenda



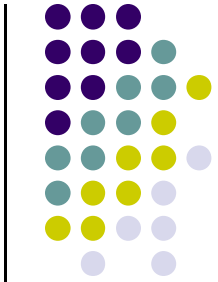
- De ce MPLS
- Conceptul si terminologia MPLS
- Operatii MPLS
- Concluzii

Agenda



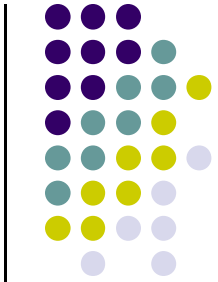
- De ce MPLS?
- Conceptul si terminologia MPLS
- Operatii MPLS
- Concluzii

De ce MPLS



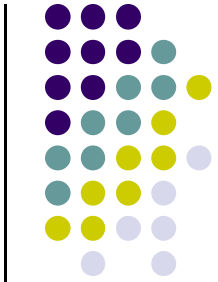
- Cerintele utilizatorilor
  - calitatea serviciilor
  - securitate, robustete
  - clase de servicii, servicii ieftine
  - trafic any-to-any
  - optiuni pentru servicii
    - ATM, FR, IP, Ethernet
    - optiuni multiple pentru VPN
  - any service, any time, anywhere

De ce MPLS (cont.)



- Solutii:
  - IP
  - ATM, Frame Relay
  - IP over ATM
  - LANE (LAN Emulation)
  - IP switching (Tag switching, ARIS)

IP, ATM, Frame Relay

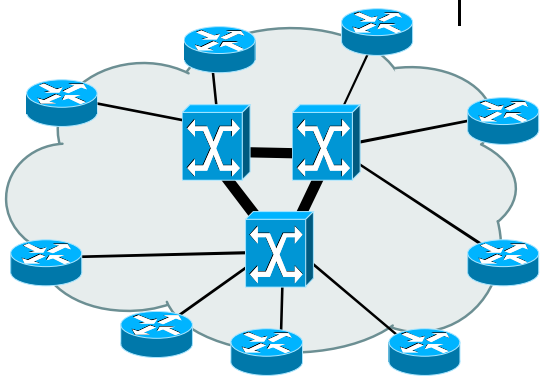


- IP
  - flexibilitate, scalabilitate
  - conectivitate infinita
  - best-effort
  - serviciu neorientat pe conexiune
- ATM, Frame Relay
  - QoS, management de trafic
  - nu au conectivitate any-to-any
- diferite dar bune

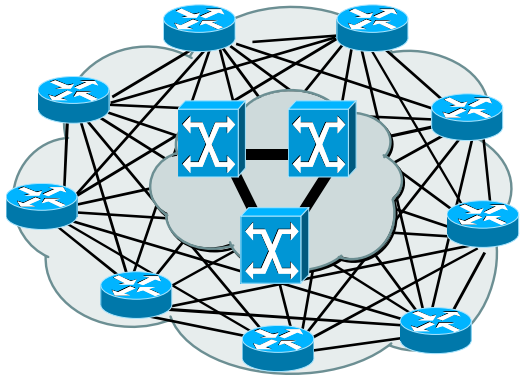
IP-over-ATM

- IP peste circuite virtuale
- Traficul IP transformat in trafic ATM
- Topologie, trafic : ATM
- Topologie logica complicata (mesh de circuite virtuale)
- Lipsa topologie de nivel 3
  - toate ruterele sint vecine
- Problema fundamentala: nu se stie de existenta IP

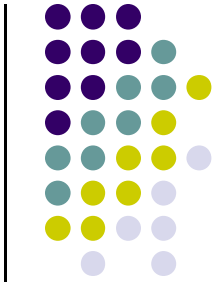
Topologia fizica



Topologia logica

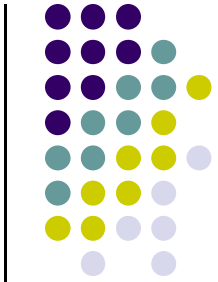


IP + ATM, MPLS: o noua paradigma



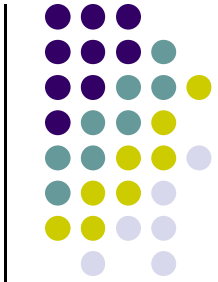
- Combina ce e mai bun din cele doua lumi:
  - QoS din ATM, Frame Relay
  - flexibilitate si scalabilitate din IP

Avantaje MPLS



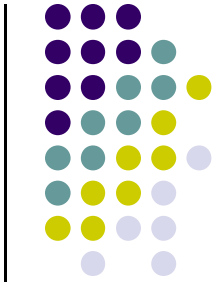
- **Simplified forwarding**: Packet forwarding is based on exact match for a short label, rather than a longest match applied to a longer address as required by datagram forwarding. Also, the label headers are simpler, resulting in a simpler forwarding paradigm.
- **Efficient explicit Routing**: Overhead of Source Routing in the case of pure datagram routing is prohibitive, since the entire explicit route (ER) is carried in each packet. In MPLS, the explicit route is carried only once, when the label switched path is being set up. Thus ER is more practical in MPLS (see next slides).
- **Traffic Engineering** is the process of selecting the paths chosen by data traffic in order to balance the traffic load on the various links, routers and switches in the network.

Avantaje MPLS



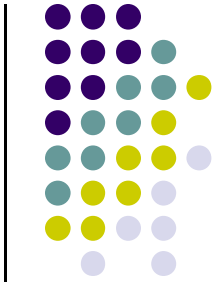
- MPLS allows data streams from any particular ingress to any particular egress to be individually identified, thereby providing a straight-forward mechanism to measure the traffic associated with each ingress-egress node pair. In addition, efficient ER ensures that any particular stream of data takes the preferred path.
- Since MPLS allows efficient ER, it follows that MPLS also facilitates **QoS routing**.
- **Complex Mappings from IP packet to FEC** at the ingress node of an MPLS domain offers an efficient method to support provisioned QoS for data traffic. ISPs can offer differentiated services to preferred customers, by providing filtering, based on src and dest address, incoming interface, etc. and then labeling the packet in some way in the MPLS domain.

Avantaje MPLS



- **Partitioning of Functionality**: it is possible to hierarchically partition the processing functionality to the different network elements. More heavy processing takes place on the edges of the network, near the customers, and on the core network, the processing is as simple as possible, eg. pure label based forwarding.
- Common Operation over Packet and Cell media

Alegerea caii (rutei) MPLS



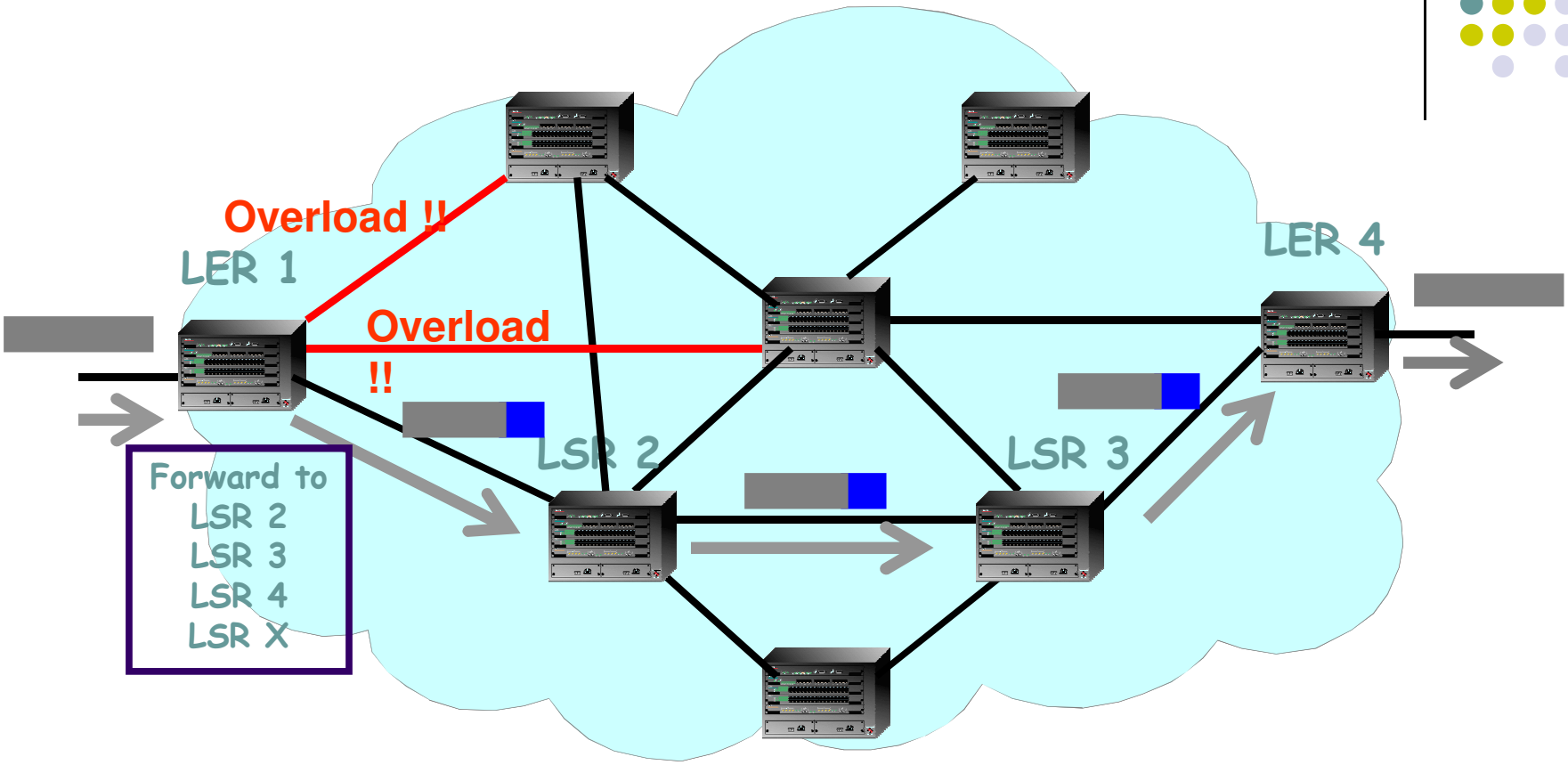
- alegerea unei cai pentru un flux de date

OBS: in cale, pachetele sunt comutate pe baza de etichete

- **hop-by-hop sau rutare explicita**
- hop-by-hop
  - fiecare LSR alege independent urmatorul hop
  - protocoalele existente sunt bazate pe prefixul adresei destinatiei

- rutare explicita
  - toate sau o parte din LSR dintr-o cale sunt specificate
  - pre-configuare sau dinamic
  - ideal, dinamic => traffic enginnering dar trebuie cunoscuta topologia domeniului si param QoS ai domeniului
  - se pot defini cai de backup => scade timpul de convergenta
- caile LSP sunt unidirectionale

Explicitly Routed LSP

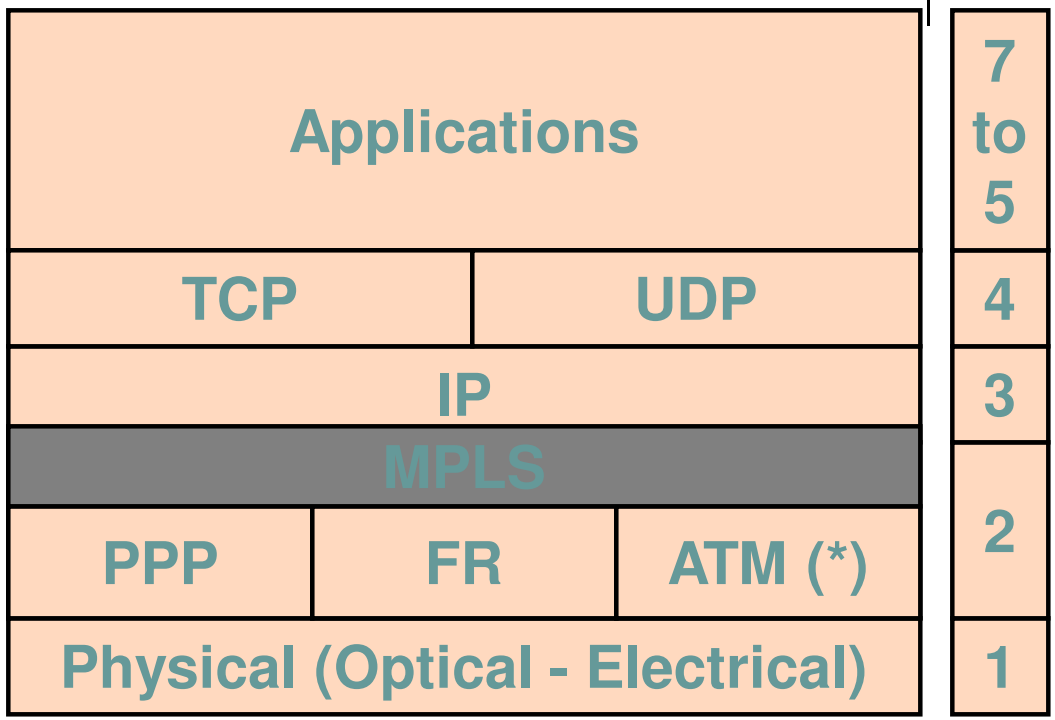


- End-to-End forwarding decision determined by ingress node.
- Enables Traffic Engineering

MPLS si ISO model

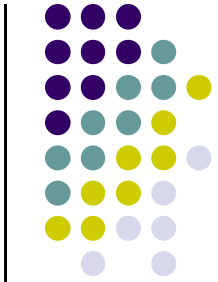
IETF proiecteaza un nou protocol, fara a fi afectate cele anterioare (backward compatible)

MPLS – ofera servicii la nivel 2+



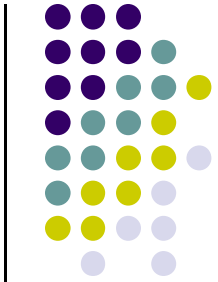
(*) ATM overlay model (fara adresare si P-NNI) – considerat ca un ISO layer 2 protocol.

Agenda



- De ce MPLS
- Conceptul si terminologia MPLS
- Operatii MPLS
- Concluzii

Conceptul MPLS

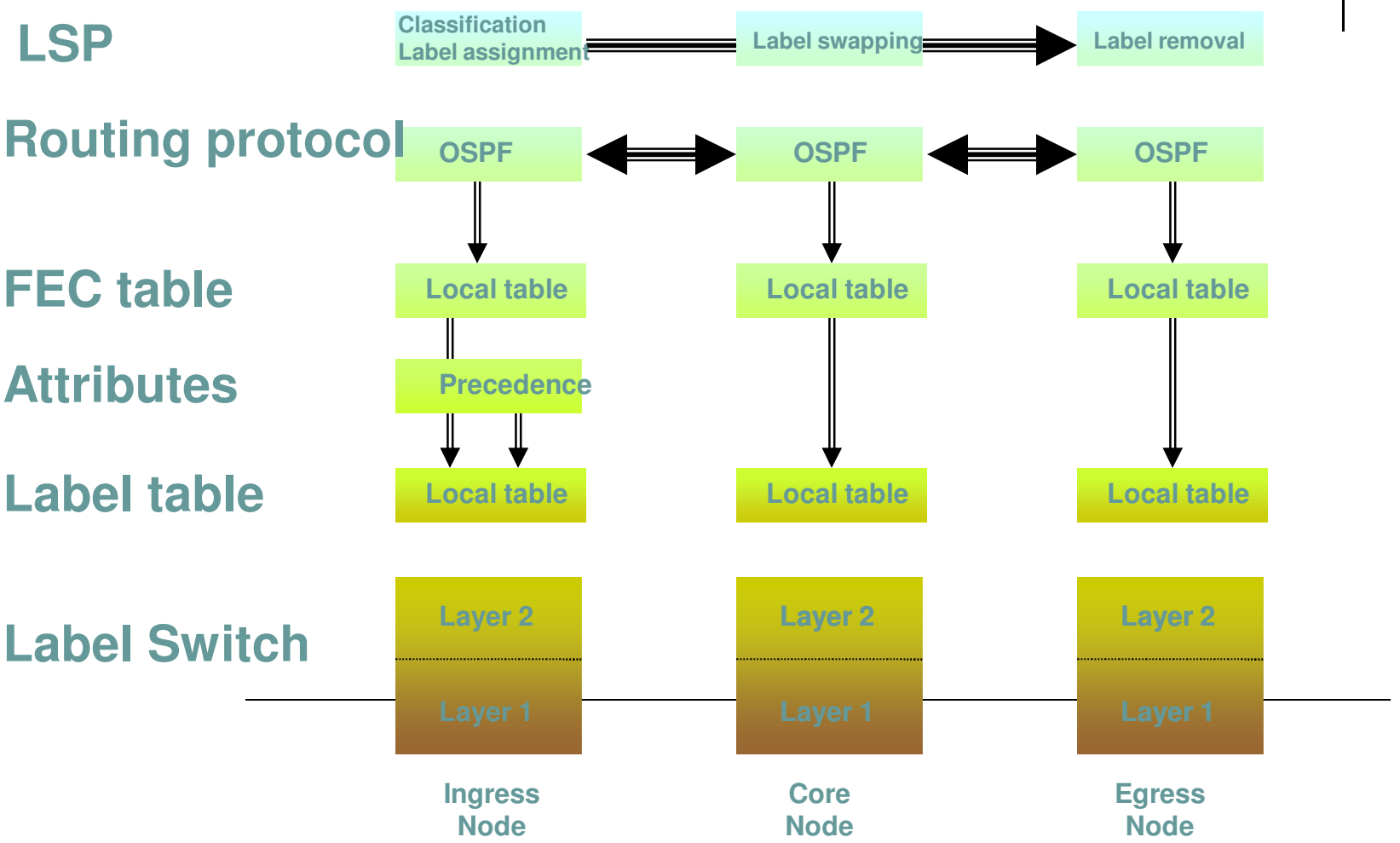


- Switching de nivel 2+
- Datagrama “intilneste” circuitul
- Decupleaza rutarea de forwardare
- Dezvoltat in cadrul IETF - fast-forwarding

http://www.ietf.org/html.charters/mpls-charter.html

- Independent de tehnologie
- Forward pe baza etichetei

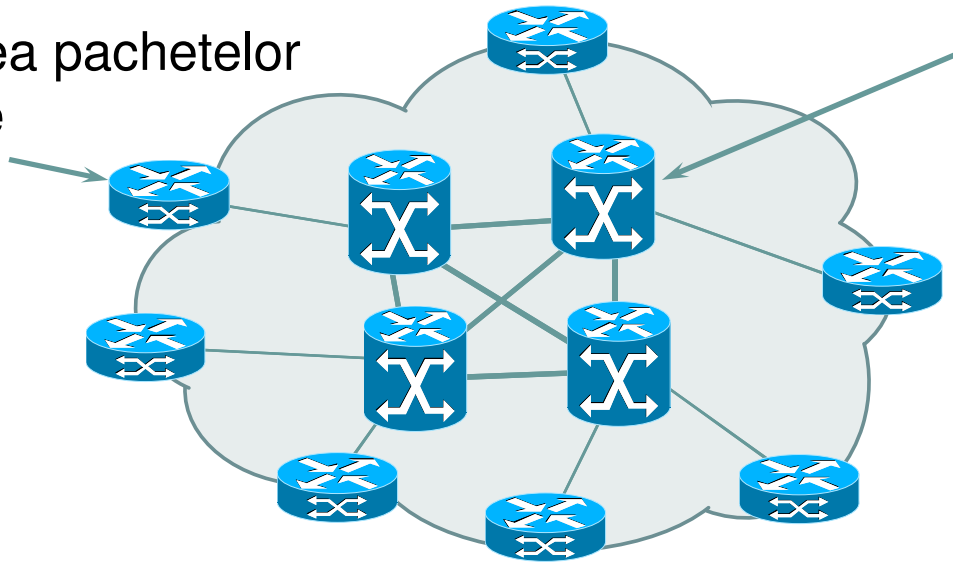
Conceptul MPLS: Arhitectura MPLS



Conceptul MPLS (cont.)

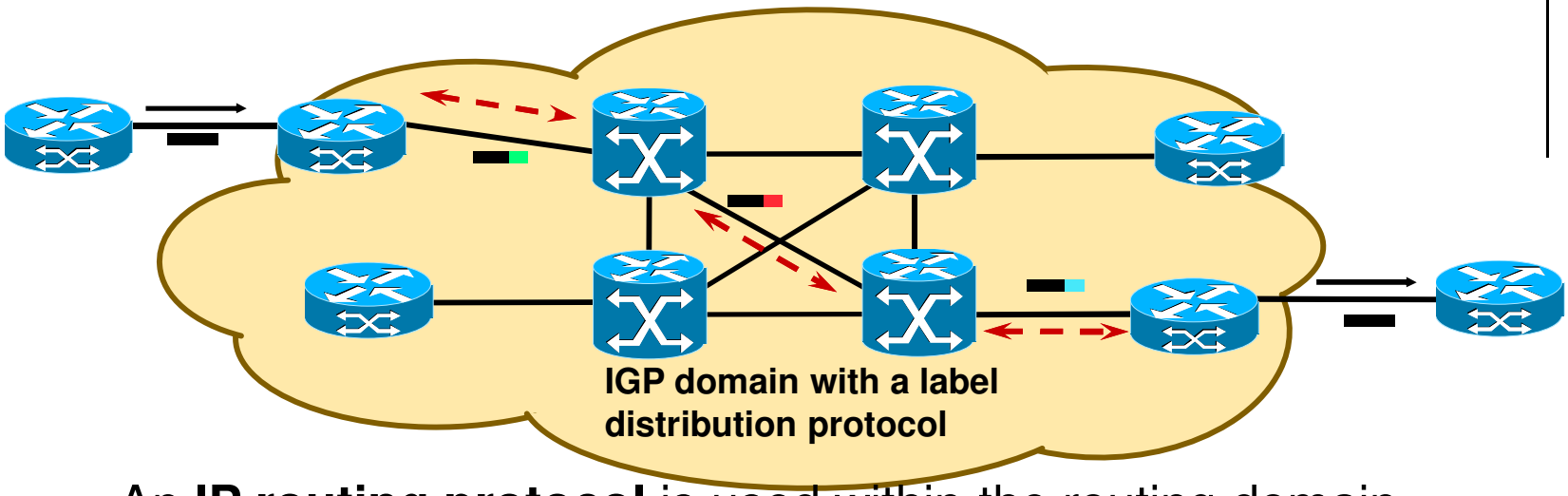
La intrare:
- clasificarea pachetelor
- etichetare

In retea:
- comutare cu etichete
- eticheta indica serviciul si destinatia



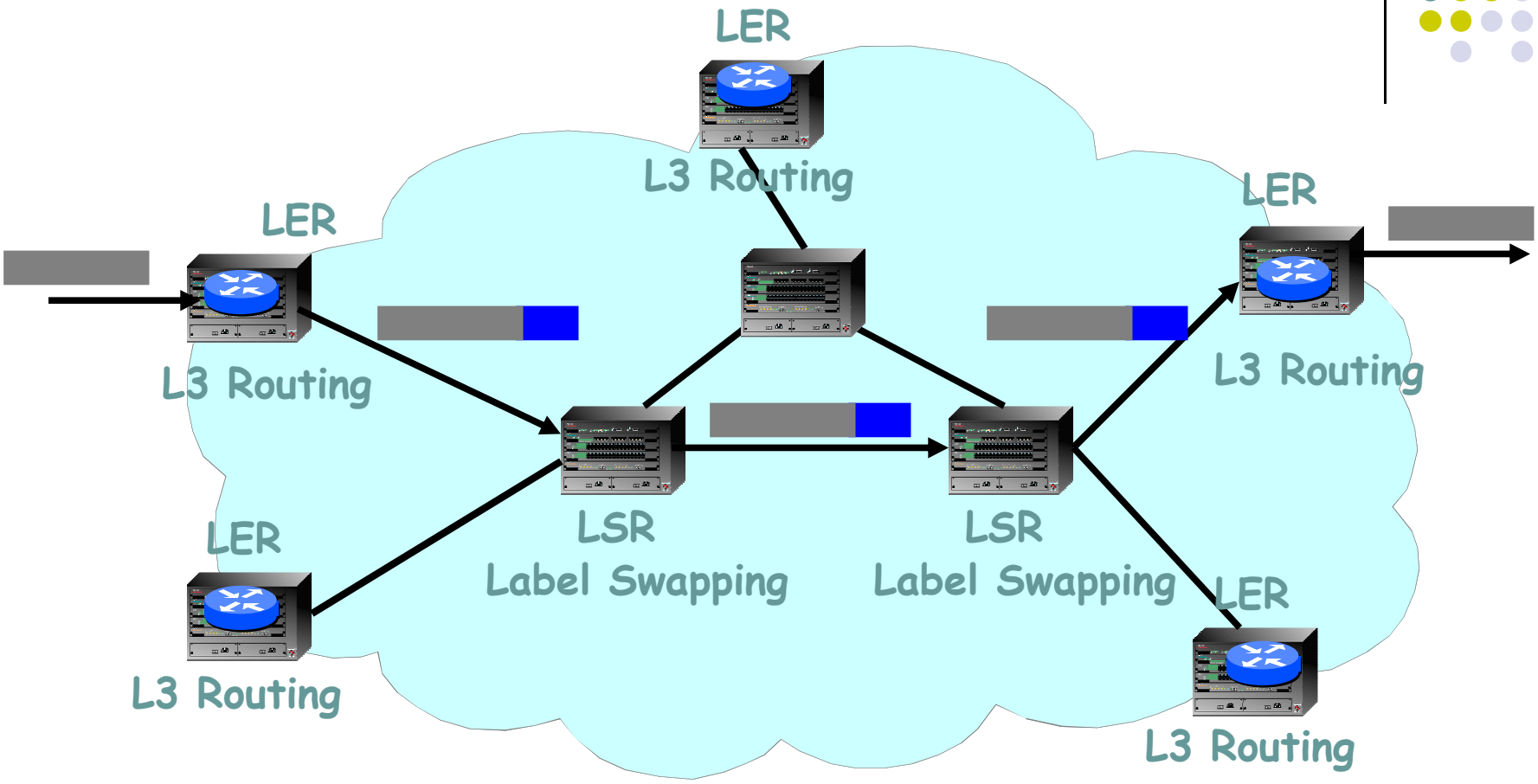
- comutarea cu etichete
- protocoale de nivel retea: IP, IPX, AppleTalk
- eticheta: unde si cum sa transmit pachetul

Conceptul MPLS (cont.)



- An **IP routing protocol** is used within the routing domain (e.g.:OSPF, IS-IS)
- A **label distribution protocol** is used to distribute address/label mappings between adjacent neighbours
- The ingress LSR receives IP packets, performs packet classification, assign a label, and forward the labelled packet into the MPLS network
- Core LSRs switch packets/cells based on the label value
- The egress LSR removes the label before forwarding the IP packet outside the MPLS network

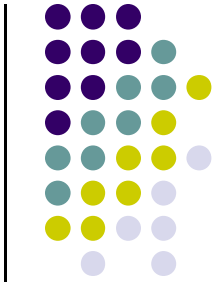
MPLS Cloud



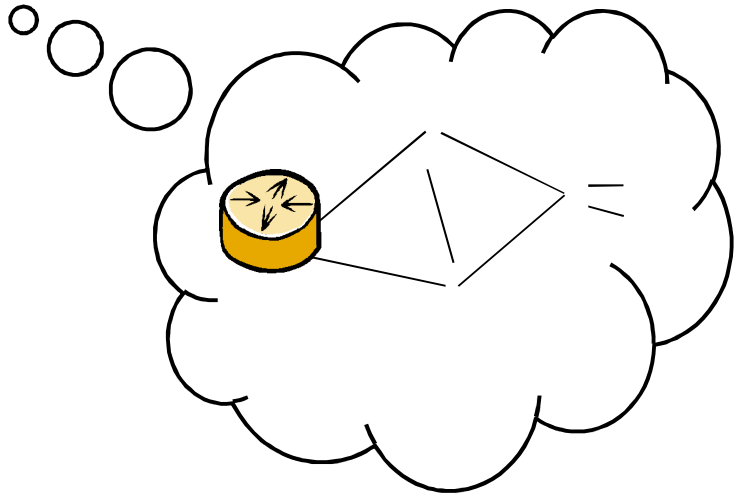
IP Packet

IP Packet w/ Label

Edge LSR Features

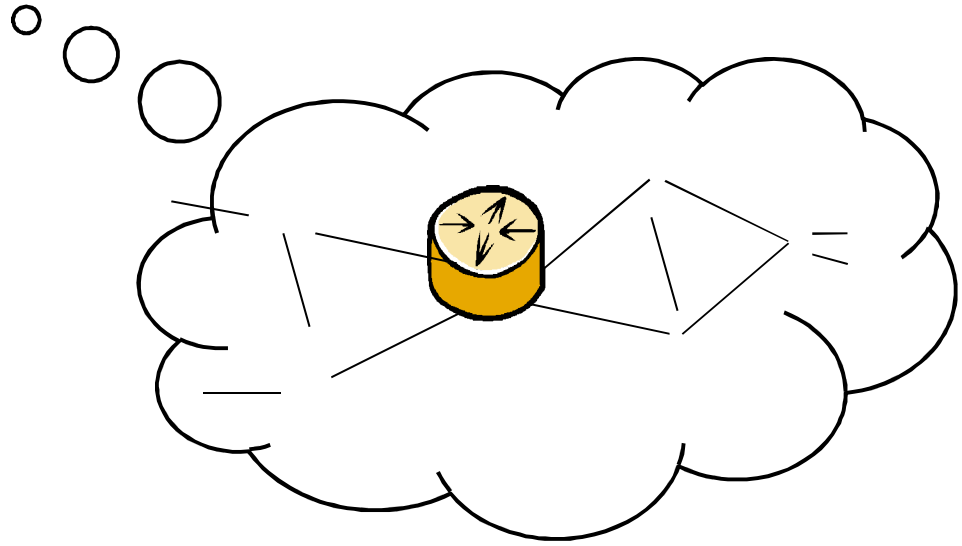


- Routing protocols
- FEC Classification
- Initiates LSP setup for Downstream On Demand method
- Adaptation of non-MPLS data to MPLS data
- Layer 2 translation for MPLS data
- Terminated MPLS-VPN
- At least one LDP protocol
- Edge LSR is counted into the TTL count as a regular router

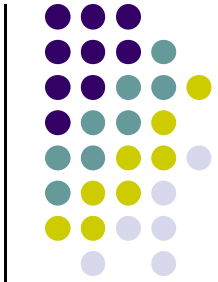


Core LSR Features

- Routing protocols
- Propagates Downstream On Demand method (request and mapping)
- Layer 2 translation
- High speed label forwarding/switching
- At least one LDP protocol

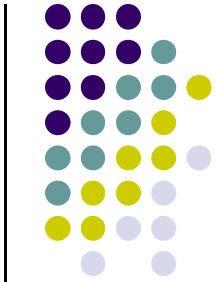


Terminologie MPLS



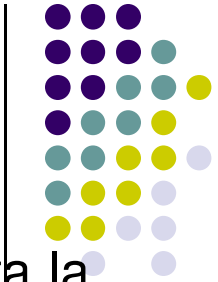
- etichete MPLS
- clase de echivalenta
- rutere MPLS
- cai comutate
- penultimate/ultimate hop popping
- protocoale de semnalizare

Some MPLS Terms...



- **LER** - Label Edge Router
- **LSR** - Label Switch Router
- **FEC** - Forward Equivalence Class
- **Label** - Associates a packet to a FEC
- **Label Stack** - Multiple labels containing information on how a packet is forwarded.
- **Shim** - Header containing a Label Stack
- **Label Switch Path** – unidirectional path that a packet follows for a specific FEC; may differ from routing protocol's shortest path
- **LDP** - Label Distribution Protocol, used to distribute Label information between MPLS-aware network devices
- **Label Swapping** - manipulation of labels to forward packets towards the destination.

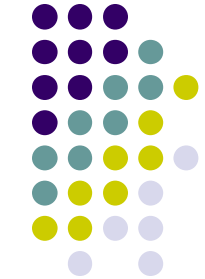
Etichete MPLS

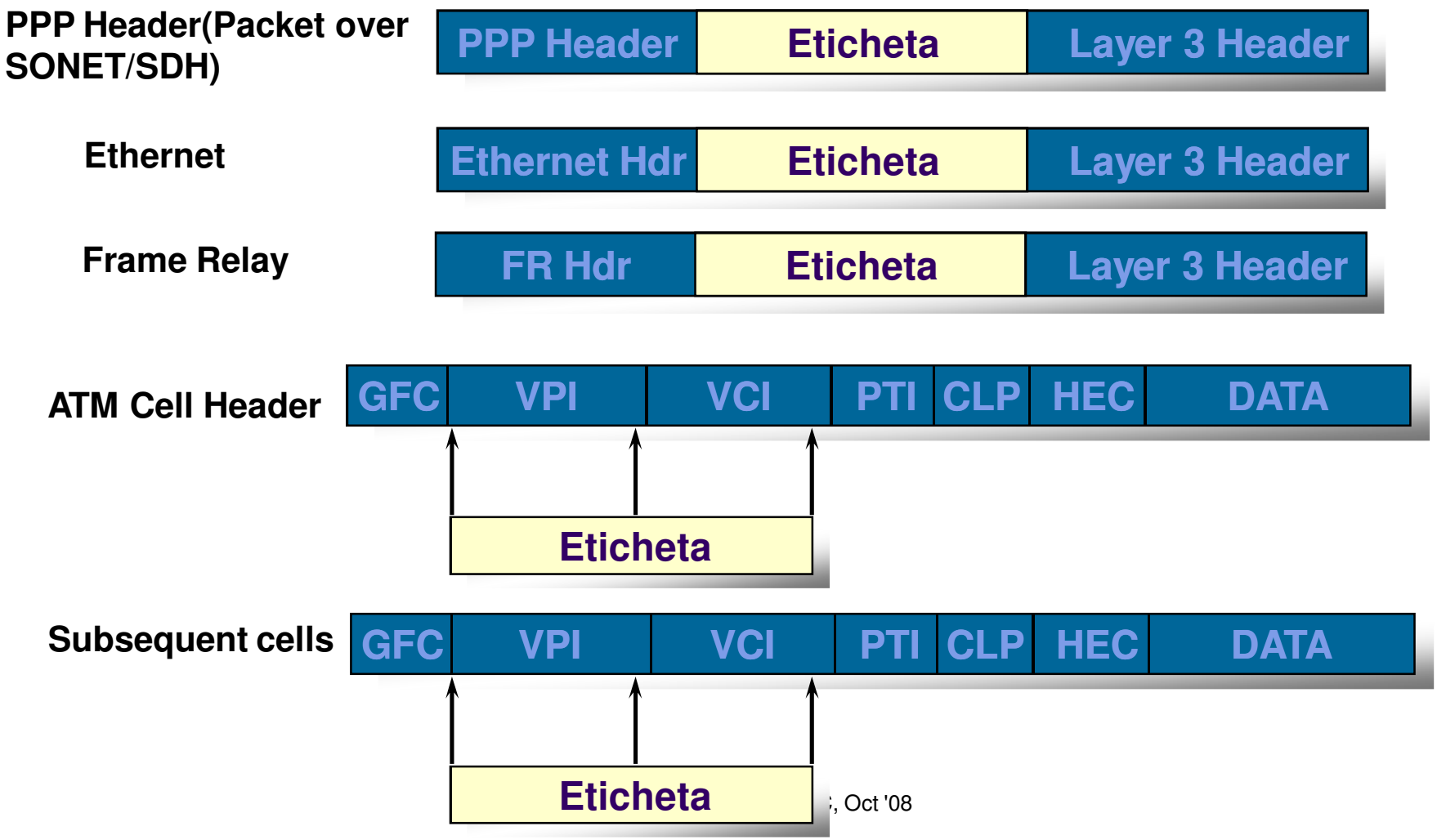


- identificator de dimensiune fixa; identifica o clasa de echivalenta la forwarding (FEC)
- semnificatie locala (ruter); semnificatia unui identificator de layer 2

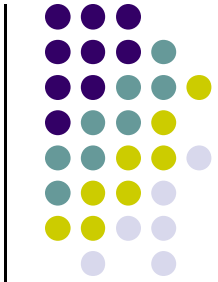
  - eticheta: 20 biti (0…1048575)
  - Exp: biti experimentali (3biti)
  - Stackbit (1bit) – stiva last-in first-out (setat indica bottom of stack)
  - Time To Live (8biti)
- etichetele 0-15 rezervate IETF
- Numita si **MPLS shim header**
- cei 32 biti formeaza **Label Stack Entry**

Eticheta MPLS - incapsulare



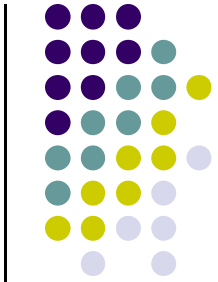


Clasele de echivalenta (FEC)



- subset de pachete comutate in aceeasi maniera (interfata, nexthop, eticheta)
- Un pachet poate fi mapat la o clasa de echivalenta (FEC particular) bazat pe criterii de:
  - **destination IP address,**
  - **source IP address,**
  - **TCP/UDP port,**
  - **in case of inter AS-MPLS: Source-AS and Dest-AS,**
  - **class of service,**
  - **application used,**
  - **…**
  - **any combination of the previous criteria.**

Clase de echivalenta



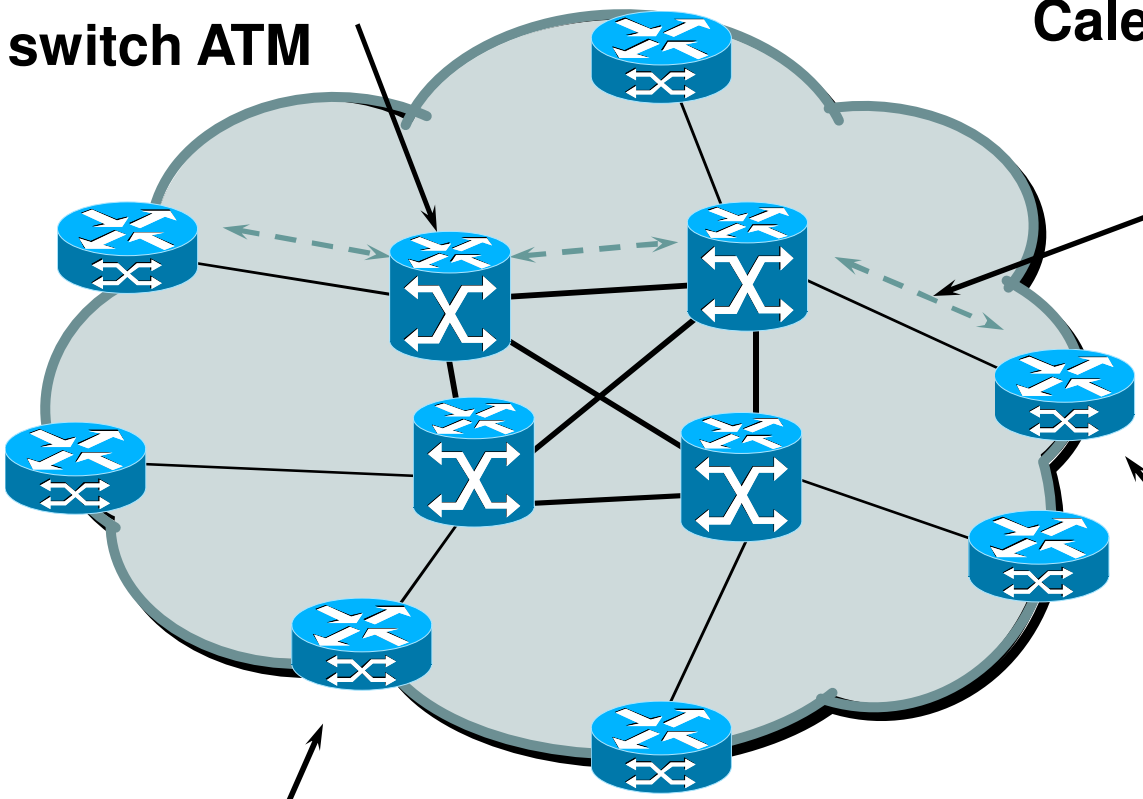
- tabela de rutare extinsa la ruterul de intrare (ingress)
- un FEC este asociat cu cel putin o eticheta
- nod de intrare (ingress): mapare FEC
  - prefix adresa IP destinatie
  - identificator ruter
  - flux (SA/DA)
  - QoS

Ingress Label	FEC	Egress Label
6	138.120.6/24 - xxxx	9

Ingress Label	FEC	Attribute	Egress Label
6	138.120.6/24 - xxxx	A	9
6	138.120.6/24 - xxxx	B	12

Rutere MPLS

Ruter tranzit
- ruter
- switch ATM



Cale comutata (LSP)

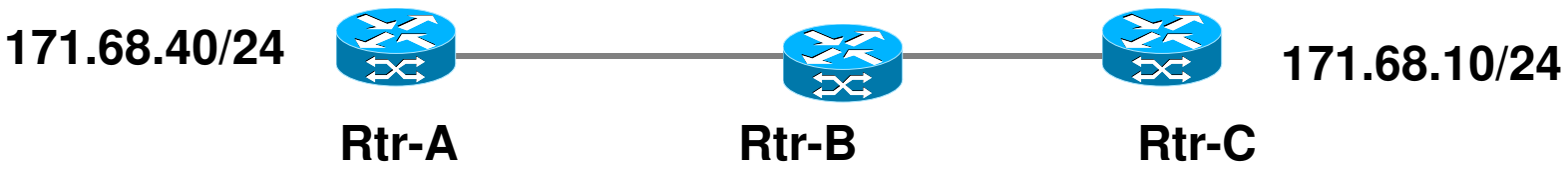
Ruter ingress - de intrare
- switch ATM sau ruter

Ruter egress – de iesire

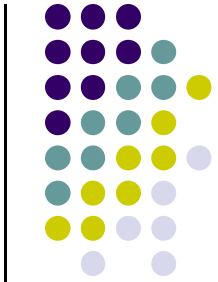
Asignarea etichetelor

- Etichetele - semnificatie locala
- LSR asigneaza etichete pentru FEC
- Etichete asignate local si transmise intre vecini
- LIB (label information base): interface in, label in, interface out, label out
- LSR isi cunosc vecinii, prin protocoalele de rutare

Exemplu: Rtr-C este vecin in aval (downstream) pentru Rtr-B pentru adresa 171.68.10/24

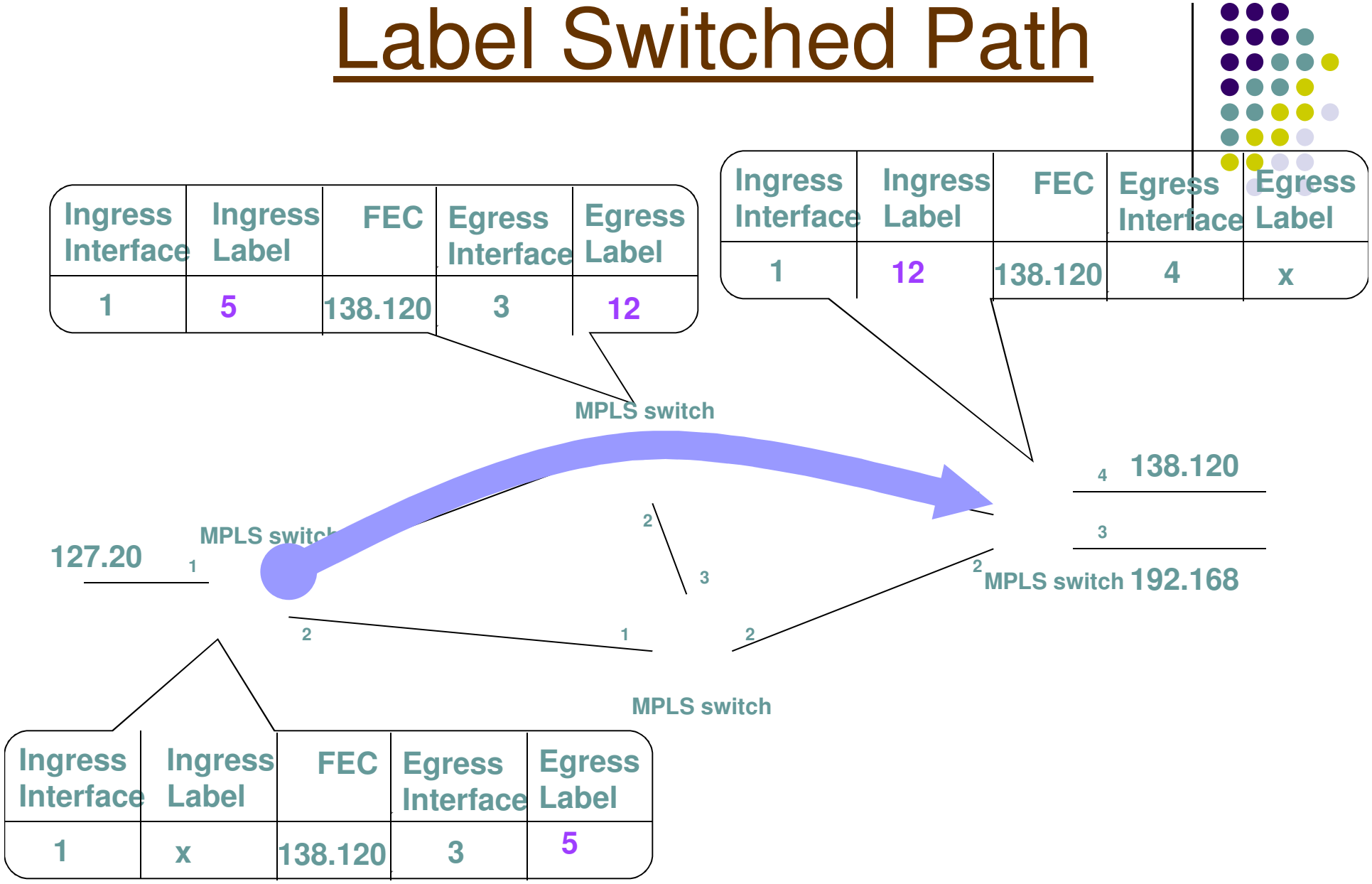


Scheme de asignare etichete

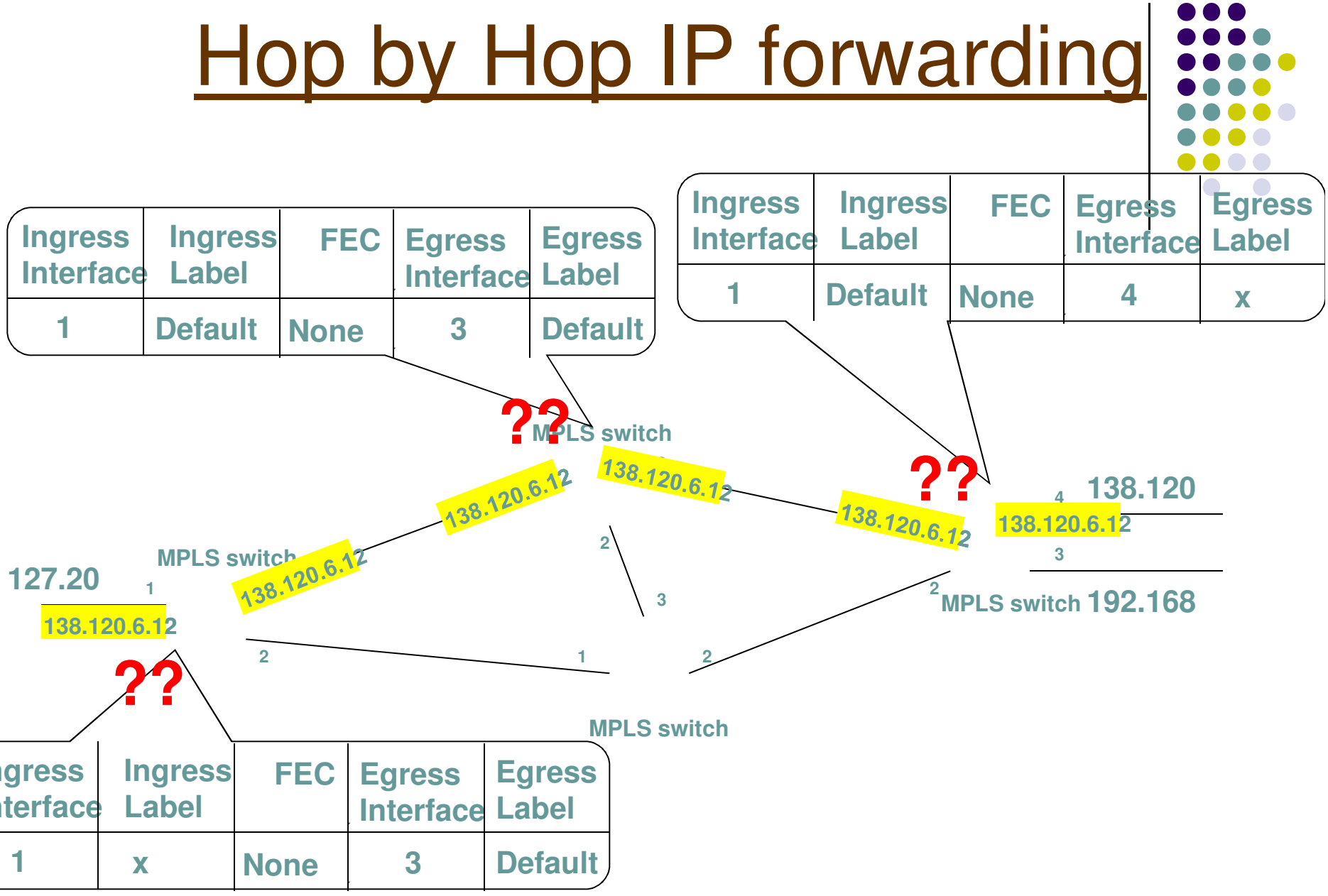


- Topology Driven
  - Label assignment in response to routing protocols (OSPF and BGP) updates
- Control Driven
  - Label assignment in response to RSVP, CR-LDP requests
- Traffic Driven
  - Label assignment in response to flow detection & triggering

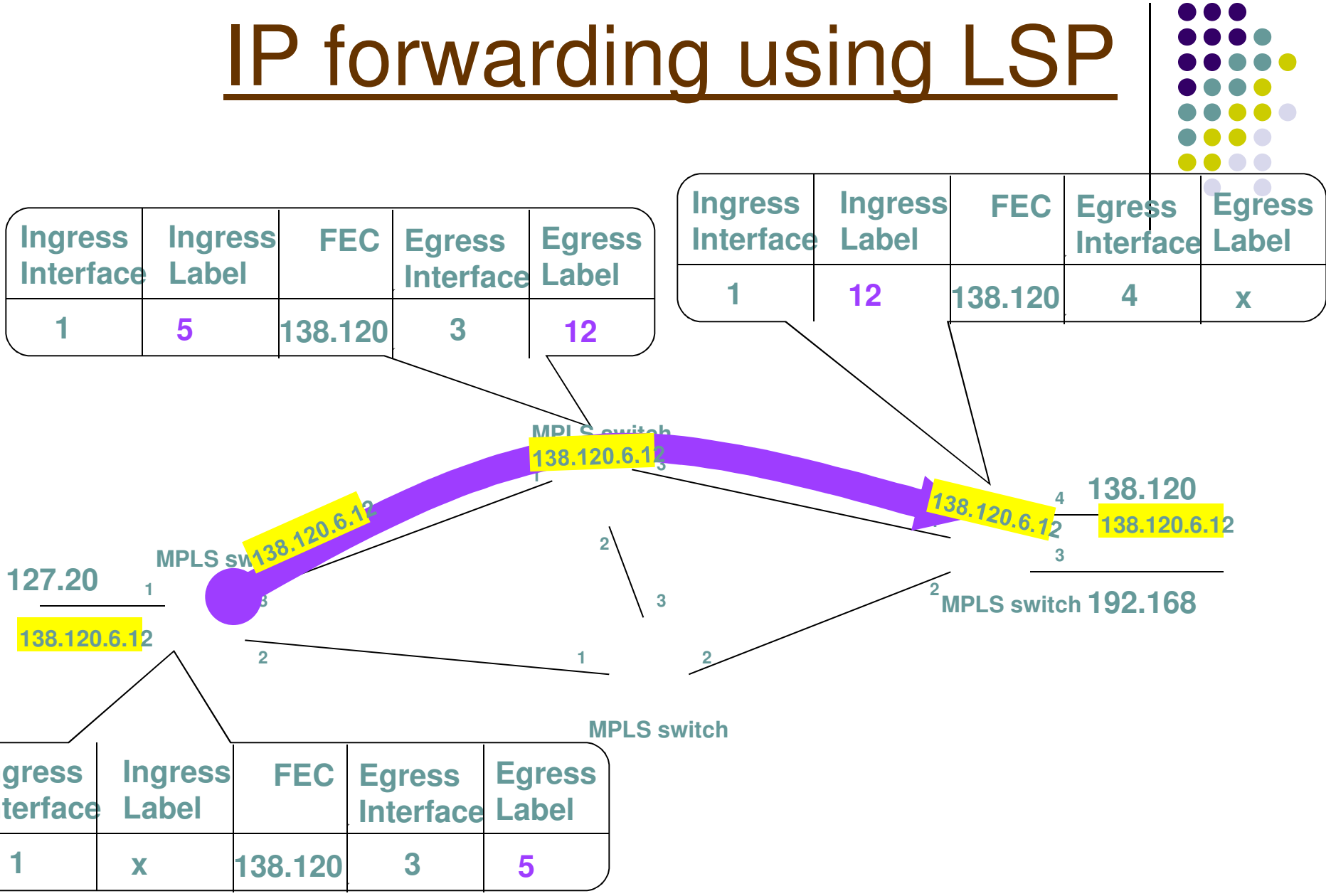
Label Switched Path



Hop by Hop IP forwarding

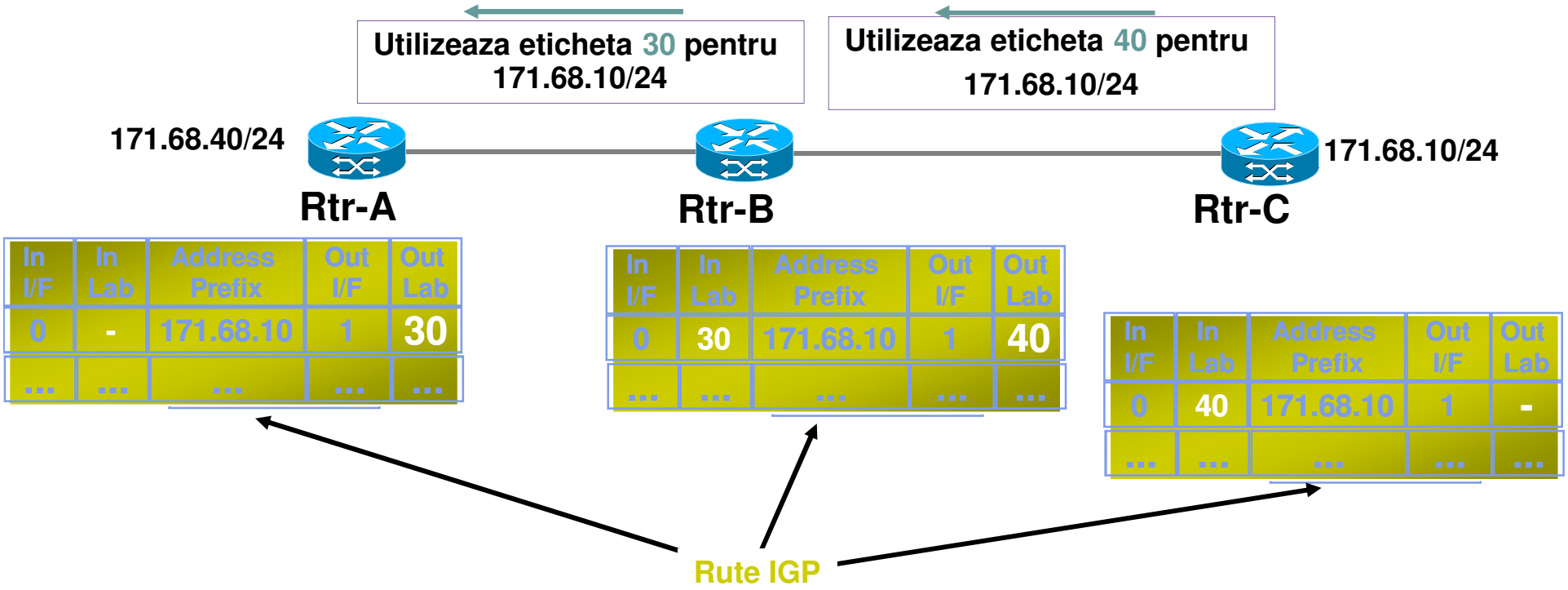


IP forwarding using LSP



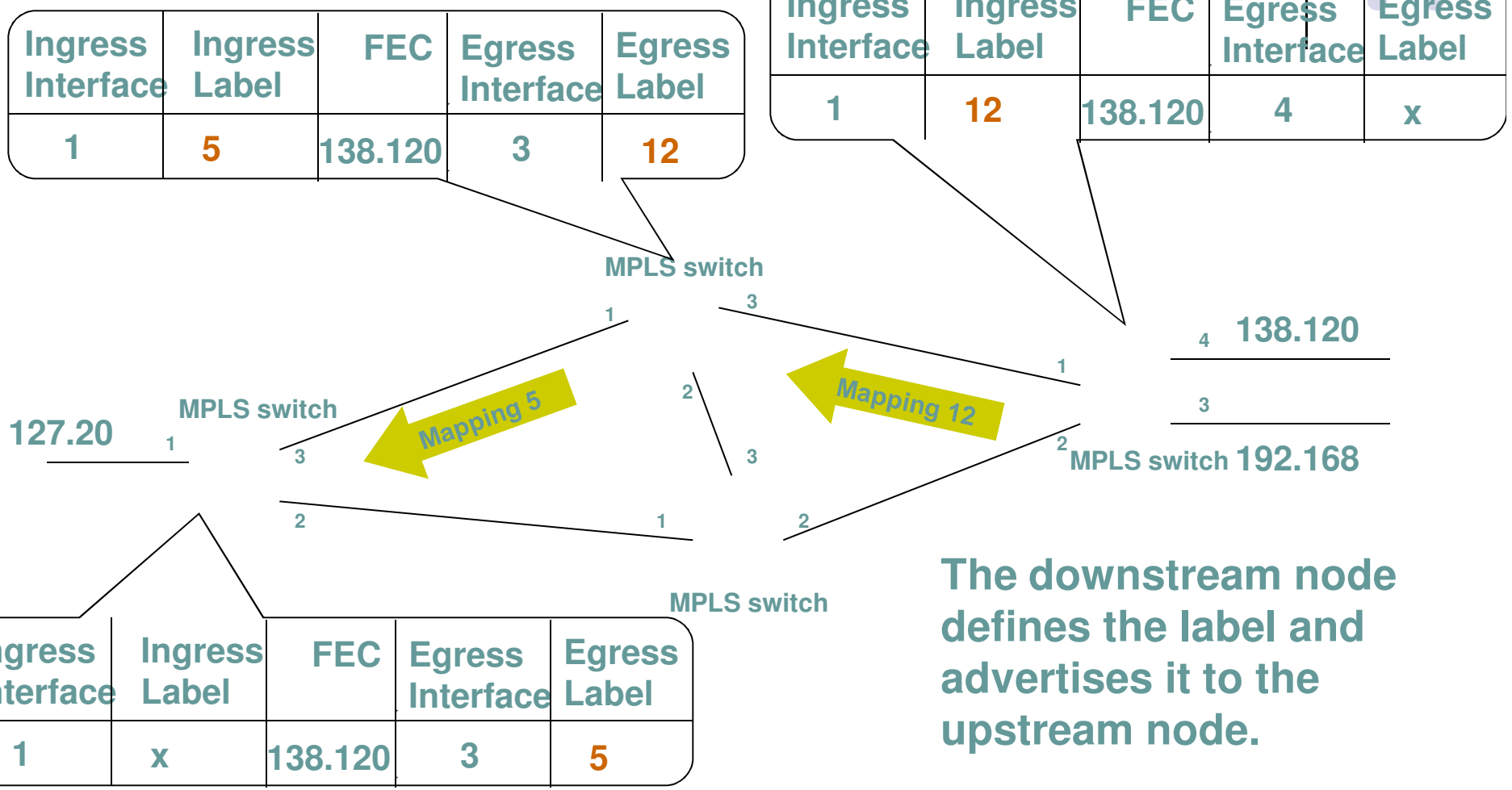
Distributia etichetelor

Distributie nesolicitata



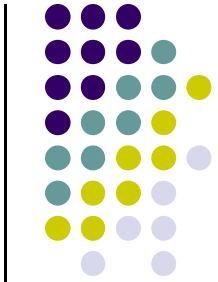
- LSR distribuie etichete vecinilor (upstream)

Unsolicited Downstream

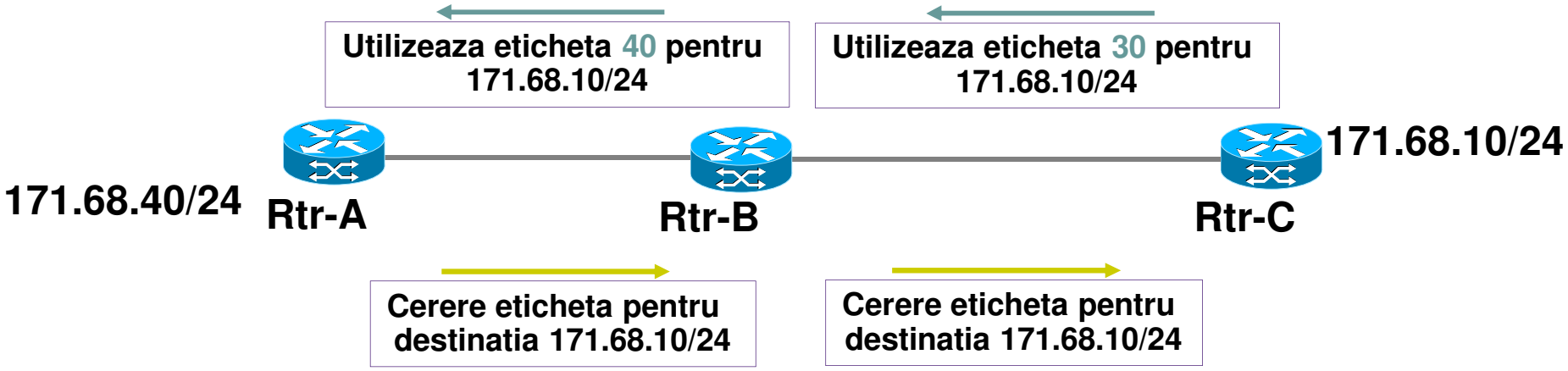


The downstream node defines the label and advertises it to the upstream node.

Distributia etichetelor (cont.)

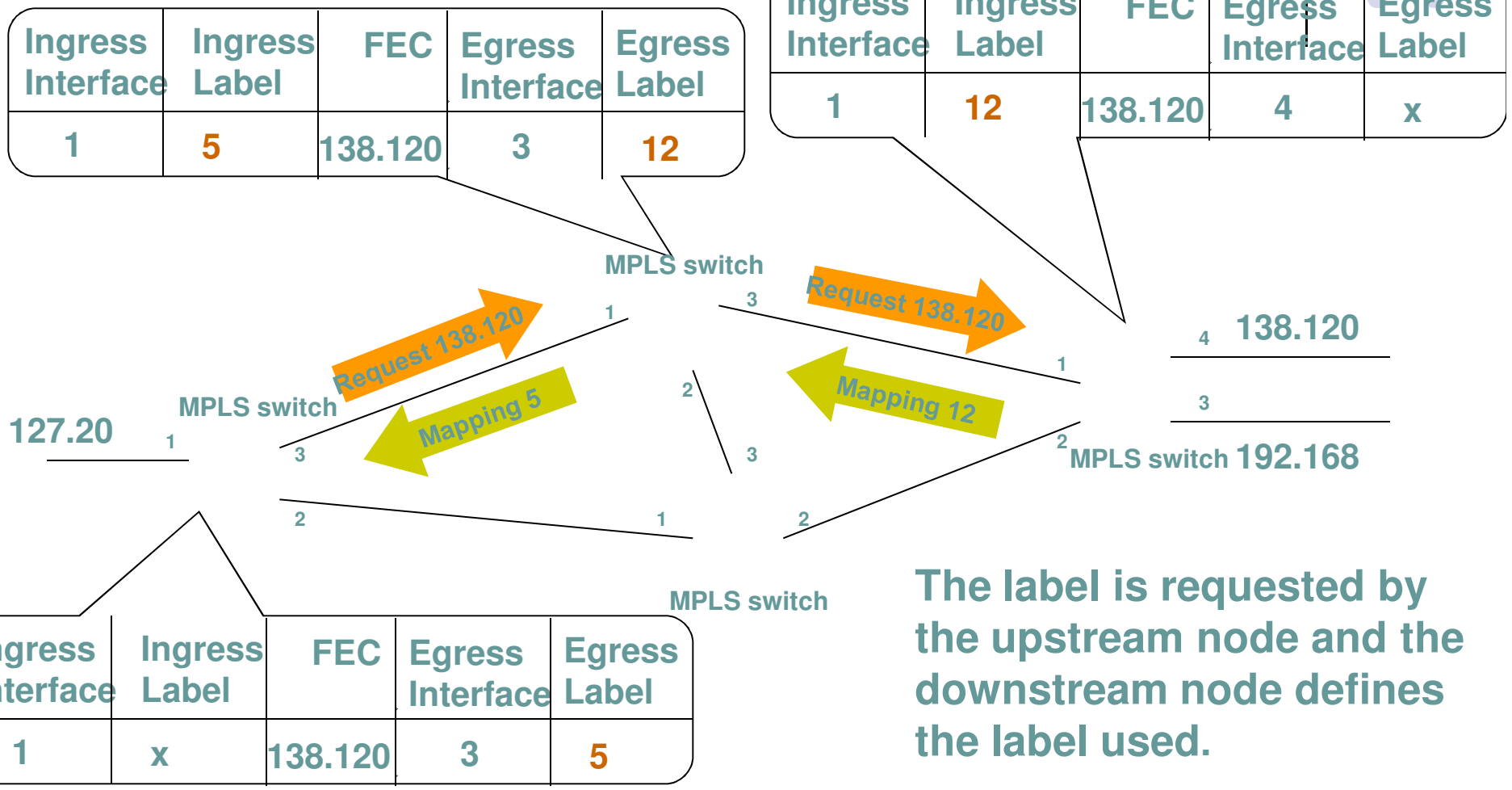


Distributie la cerere



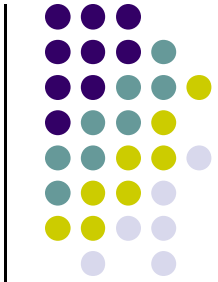
- LSR (upstream) cer etichete vecinilor (downstream)
- LSR (downstream) distribuie etichete la cerere

Downstream stream on demand



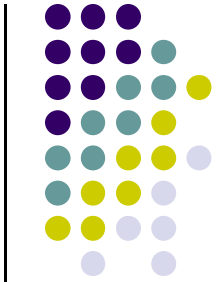
The label is requested by the upstream node and the downstream node defines the label used.

Distributia etichetelor (cont.)



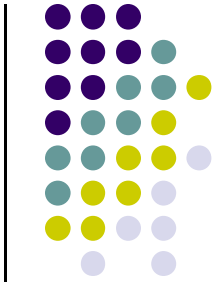
- Independent
  - LSR asigneaza eticheta-FEC independent
  - transmite eticheta vecinilor
- Ordered
  - LSR asigneaza eticheta-FEC si transmite vecinilor daca este ruter egress pentru FEC sau a primit o asignare de la un next-hop

Stocarea etichetelor



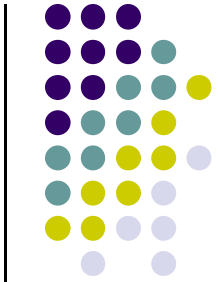
- Liberal
  - etichete de la toti vecinii
  - timp de convergenta imbunatatit
  - necesita memorie (label space)
- Conservator
  - etichete de la vecini next-hop
  - se sterg toate etichetele pentru FECs fara nexthop

Protocoale de semnalizare LSP/ distributie etichete



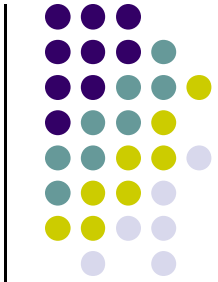
- Resource Reservation Protocol (RSVP)
- Label Distribution Protocol (LDP)
- Constrained Routing LDP (CR-LDP)
- BGP

Label Distribution Protocol



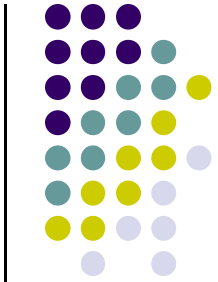
- protocol de distributie a etichetelor
- construirea cailor comutate (Label Switched Path)
- etichetele asignate FECs pentru prefix de adrese destinatie de tip unicast
- LSP sint unidirectionale
- LDP opereaza asupra **perechi rutere** adiacente sau nu
- Mecanisme:
  - “descoperirea” ruterelor
  - mesaje: Discovery, Adjacency, Label Advertisment, Notification
  - nivel transport: TCP, UDP (Discovery)

LDP Messages



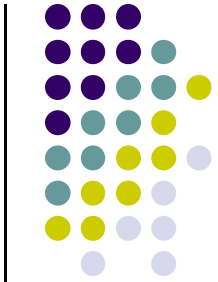
- Discovery messages
  - Used to discover and maintain the presence of new peers
  - Hello packets (tip UDP) sent to all-routers multicast address
  - Once neighbor is discovered, the LDP session is established over TCP

LDP Messages (cntd)



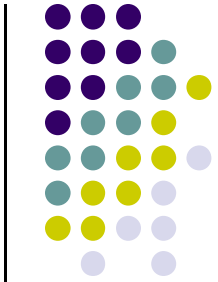
- Session messages
  - Establish, maintain and terminate LDP sessions
- Advertisement messages
  - Create, modify, delete label mappings
- Notification messages
  - Error signalling

Sesiuni LDP



- doua rutere in proxima vecinatate, cu capabilitati LDP, pot crea o sesiune LDP
  - Se foloseste UDP la nivel transport
  - periodic, mesaje Hello
  - Adr. nivel transport/sursa – identificator de sesiune
  - conexiune TCP (o singura conexiune)
  - LDP session Id

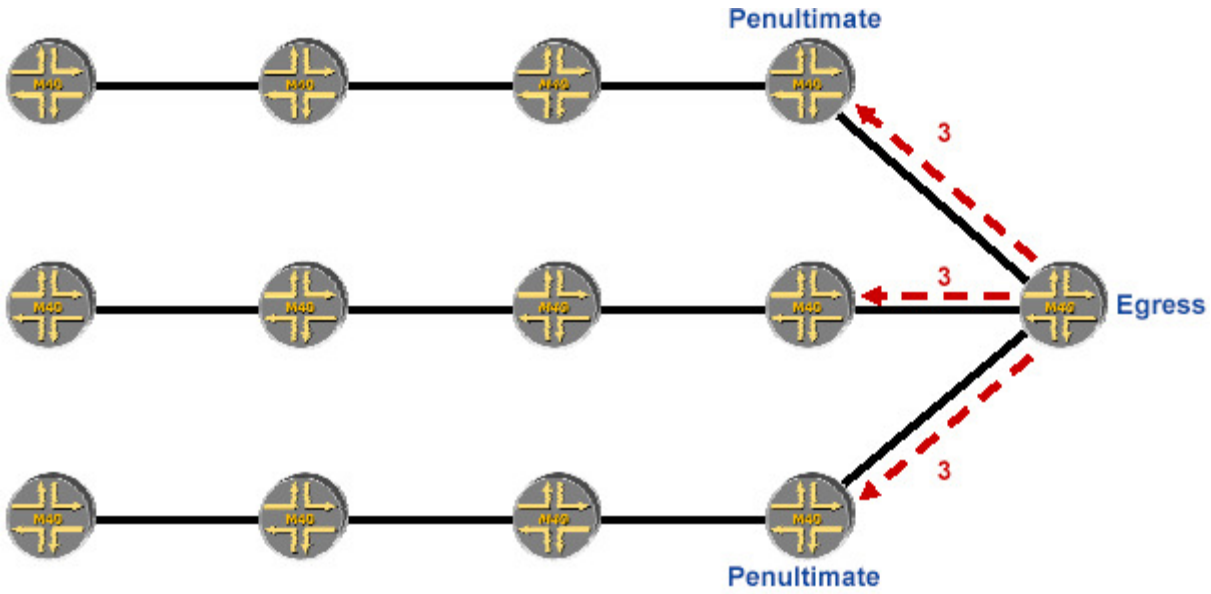
Sesiuni LDP (cont)



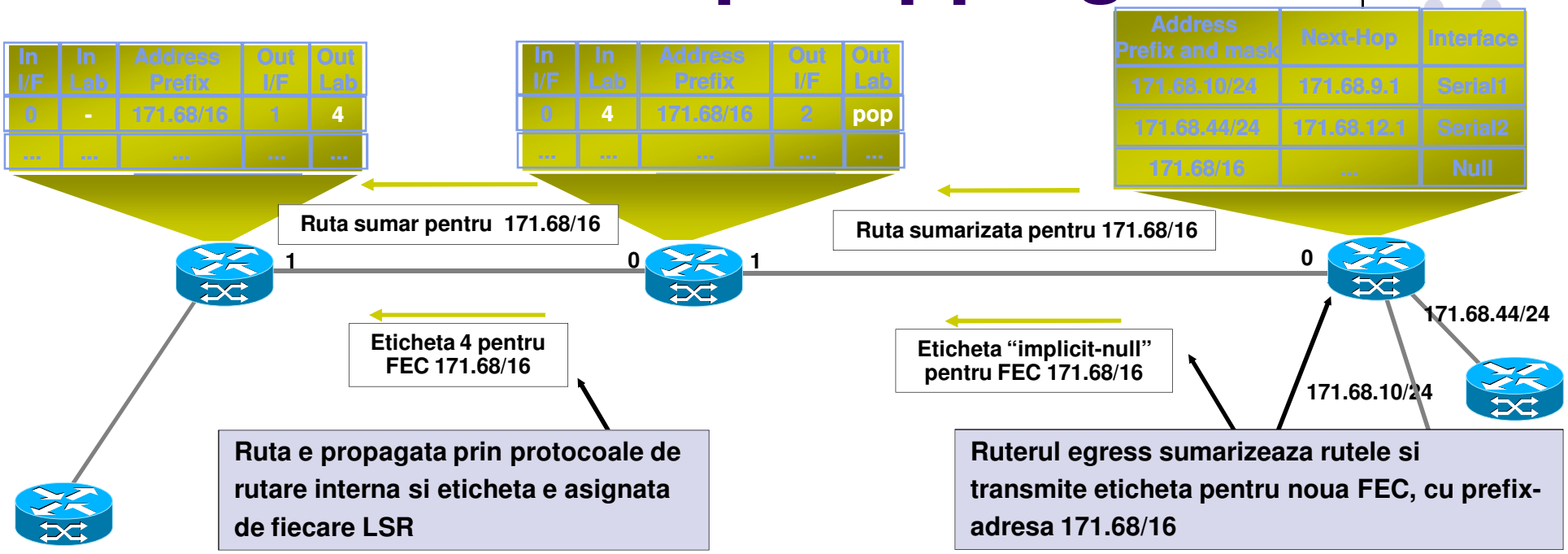
- doua rutere la distanta pot forma, de asemenea, o sesiune LDP
  - UDP la nivel transport
  - msg Hello multicast
  - vecin descoperit => sesiune TCP
- mapare FEC-eticheta
- full-mesh al informatiilor: input-output mapping (eticheta - port)

Penultimate hop popping

- eticheta stearsa in penultimul ruter
- ruterul egress semnalizeaza eticheta 3 (Implicit NULL Label)
- decongestie ruter egress



Label Switch Path (LSP) Penultimate Hop Popping



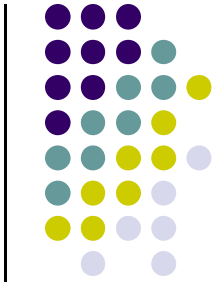
Ruterele egress executa 'IP routing table lookup' pentru a gasi rutele specifice (171.68.44/24 de ex.)

Ruterele egress pot sa nu primeasca pachete cu etichete, pentru a salva un lookup

Ultimate hop popping

- eticheta stearsa in ultimul ruter
- ruterul egress semnalizeaza eticheta 0 (Explicit NULL)

Agenda



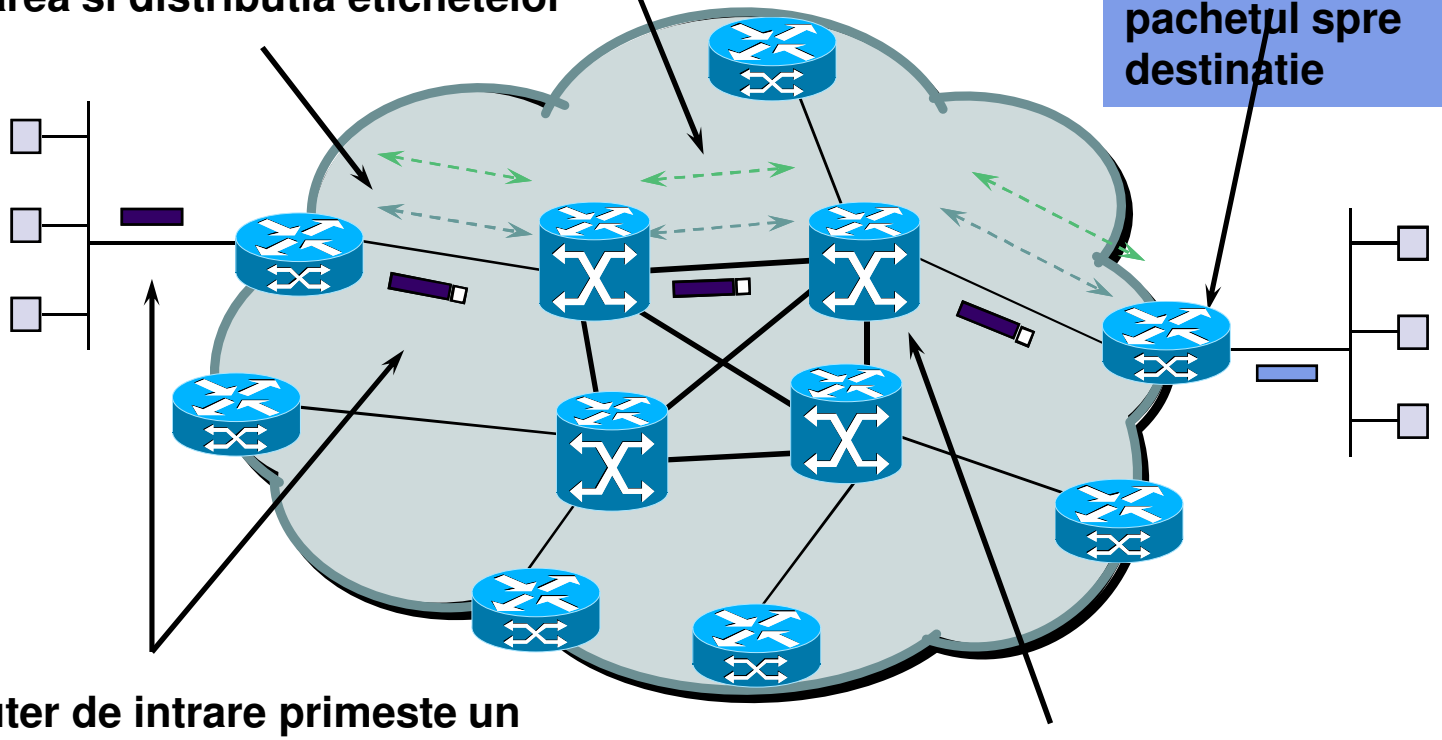
- De ce MPLS?
- Conceptul si terminologia MPLS
- Operatii MPLS
- Concluzii

Operatii MPLS

1a. Protocoale de rutare (OSPF, EIGRP) stabilesc topologia retelei

1b. Protocoale de semnalizare pentru asignarea si distributia etichetelor

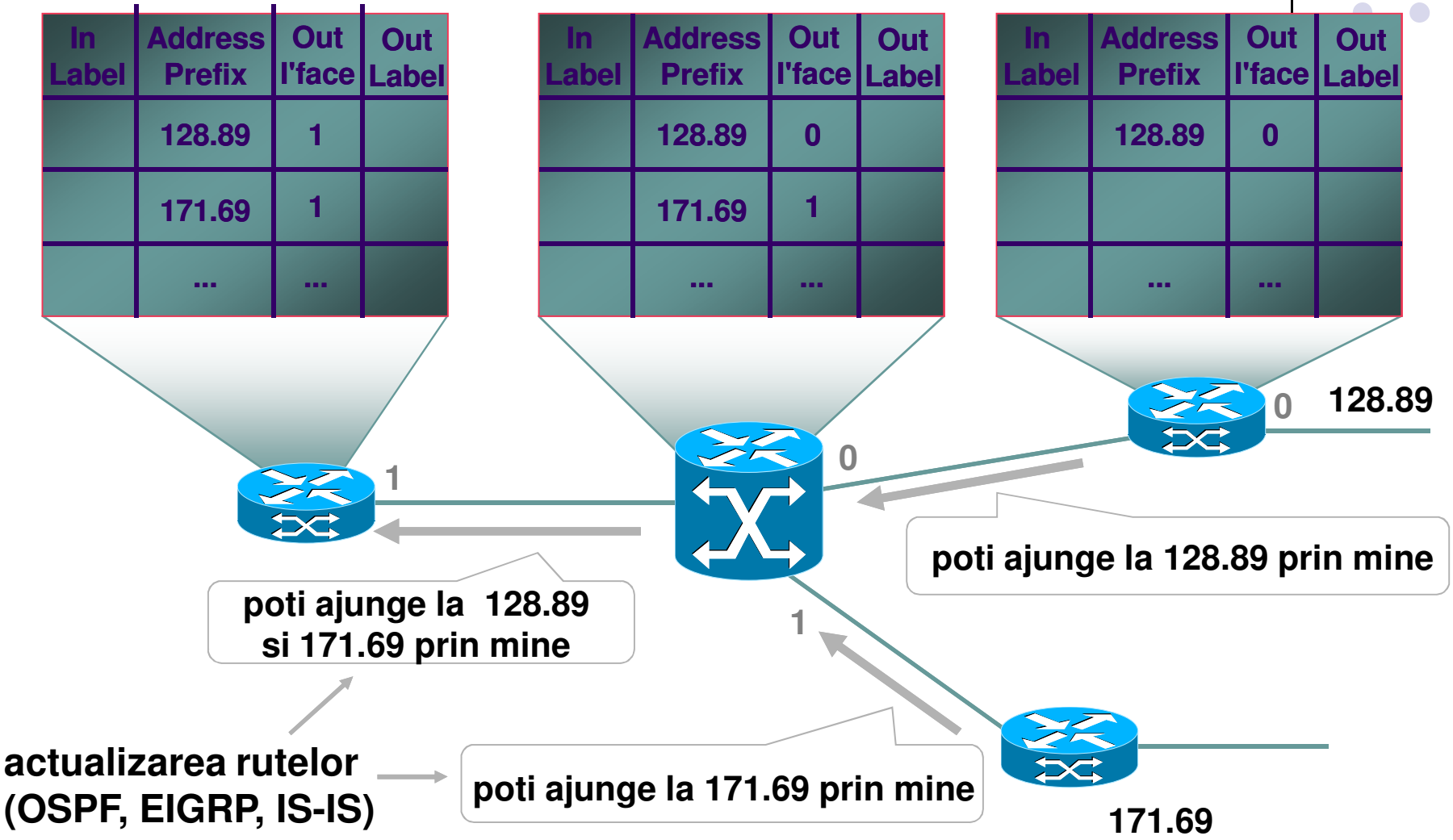
4. Ruterele de iesire sterg eticheta si ruteaza pachetul spre destinatie



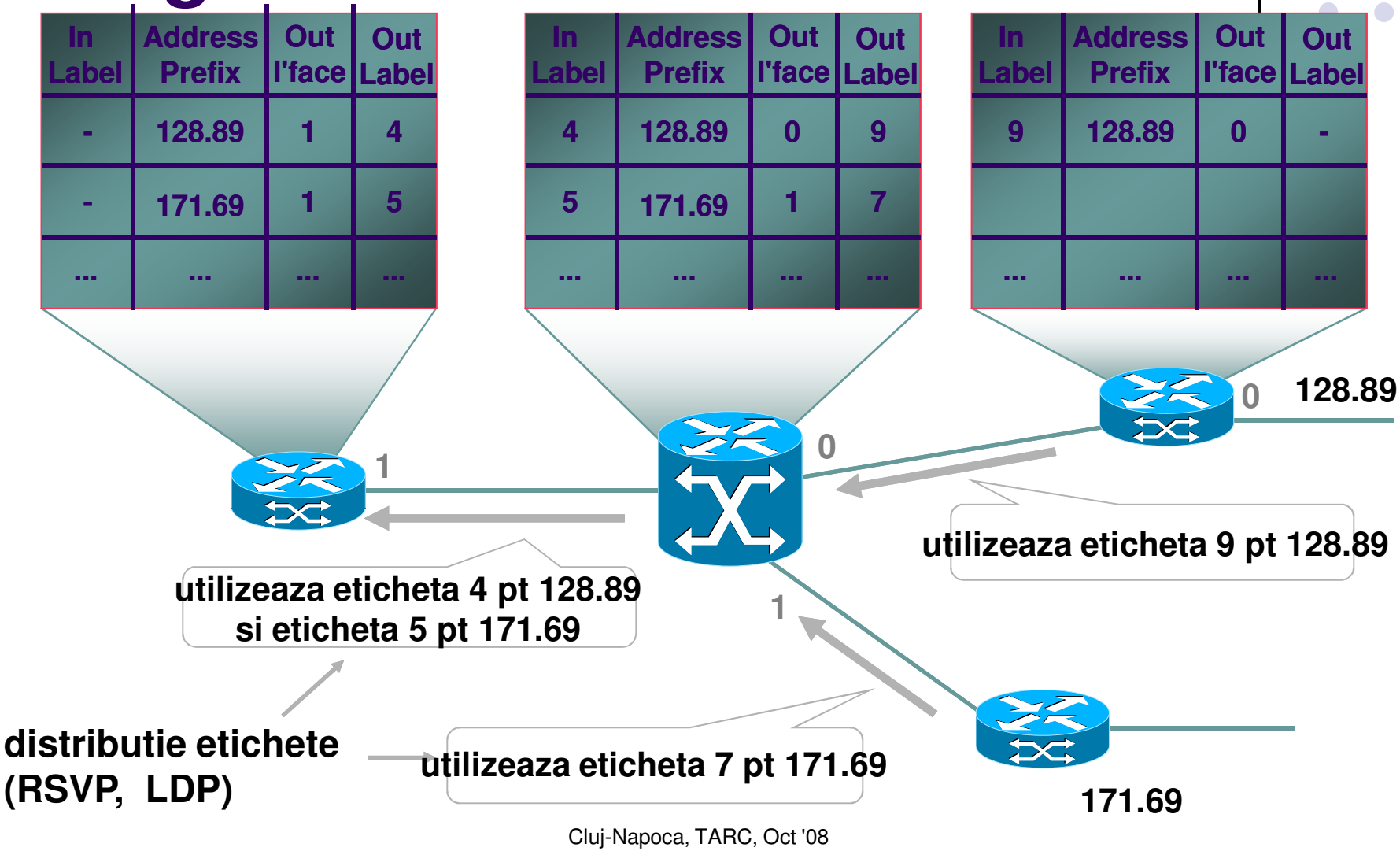
2. Un ruter de intrare primeste un pachet, evalueaza serviciile de care are nevoie, asigneaza FEC, eticheteaza pachetul

3. Ruterele tranzit comuta pachetele pe baza etichetelor

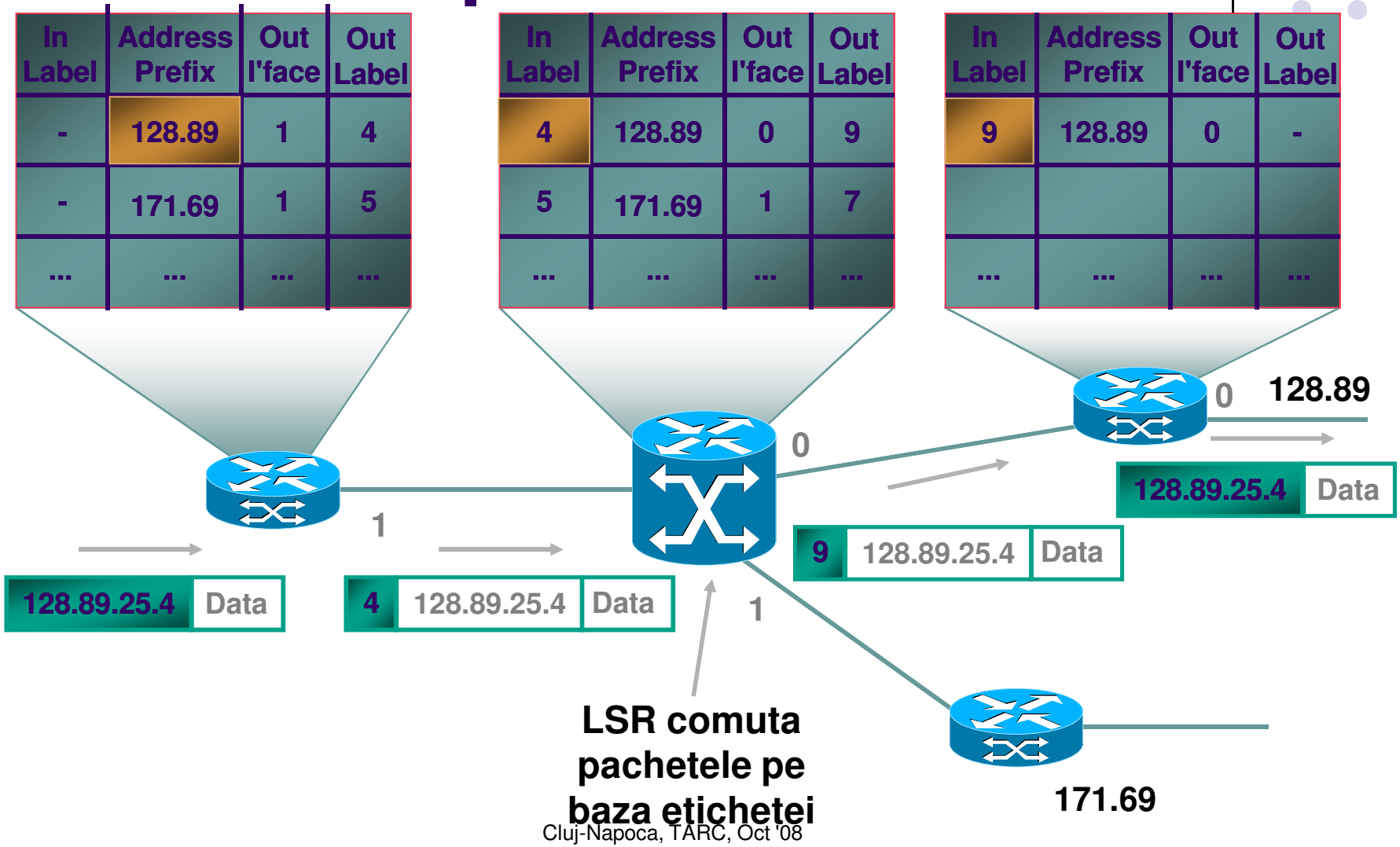
Exemplu
Informatii de rutare



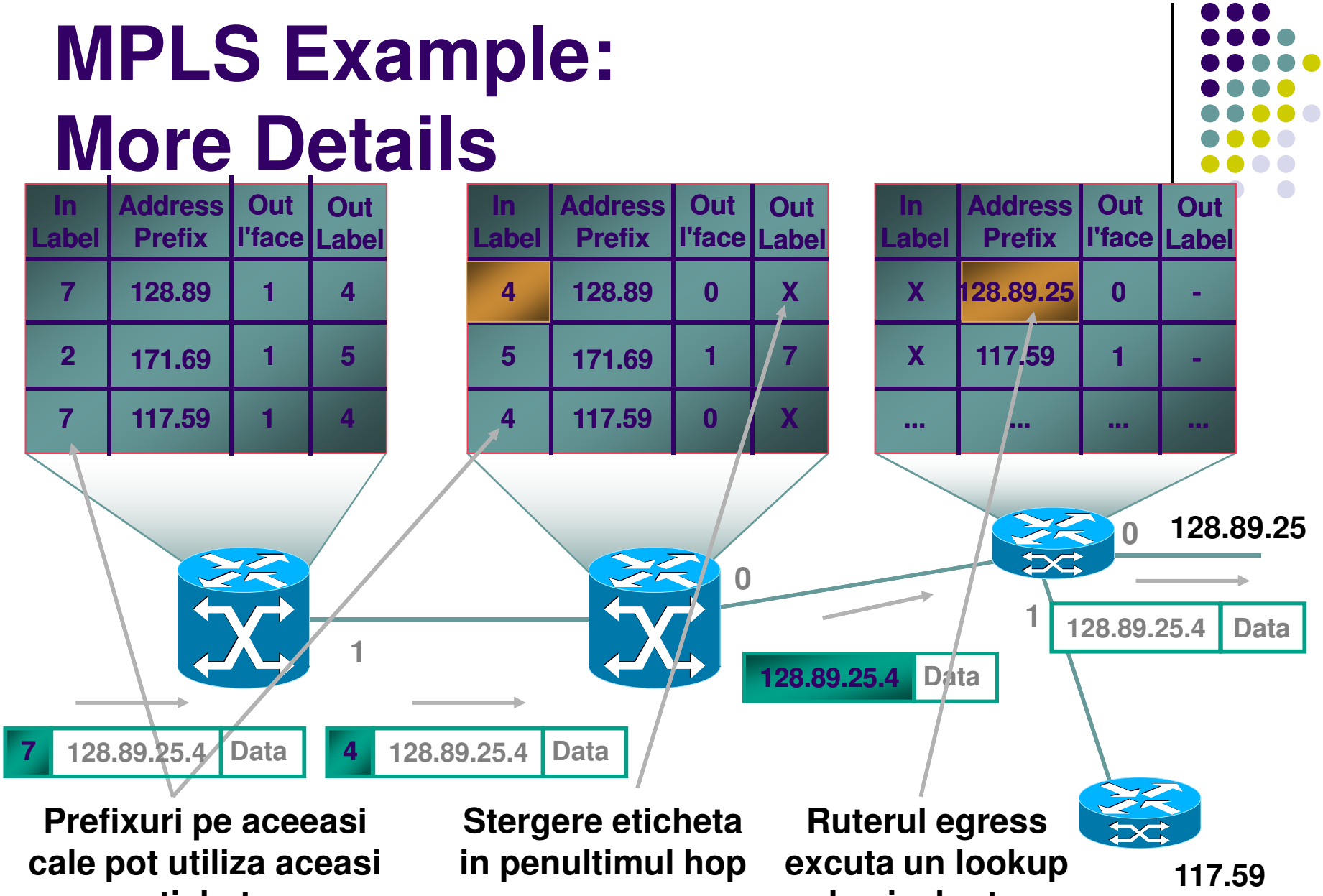
Exemplu: Asignarea etichetelor



Exemplu: Comutarea pachetelor



MPLS Example: More Details

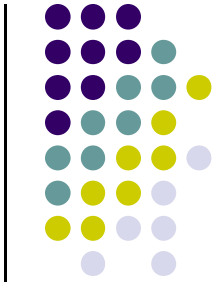


Prefixuri pe aceeasi cale pot utiliza aceasi eticheta

Stergere eticheta in penultimul hop

Ruterul egress excuta un lookup de nivel retea

Buclarea in retele MPLS

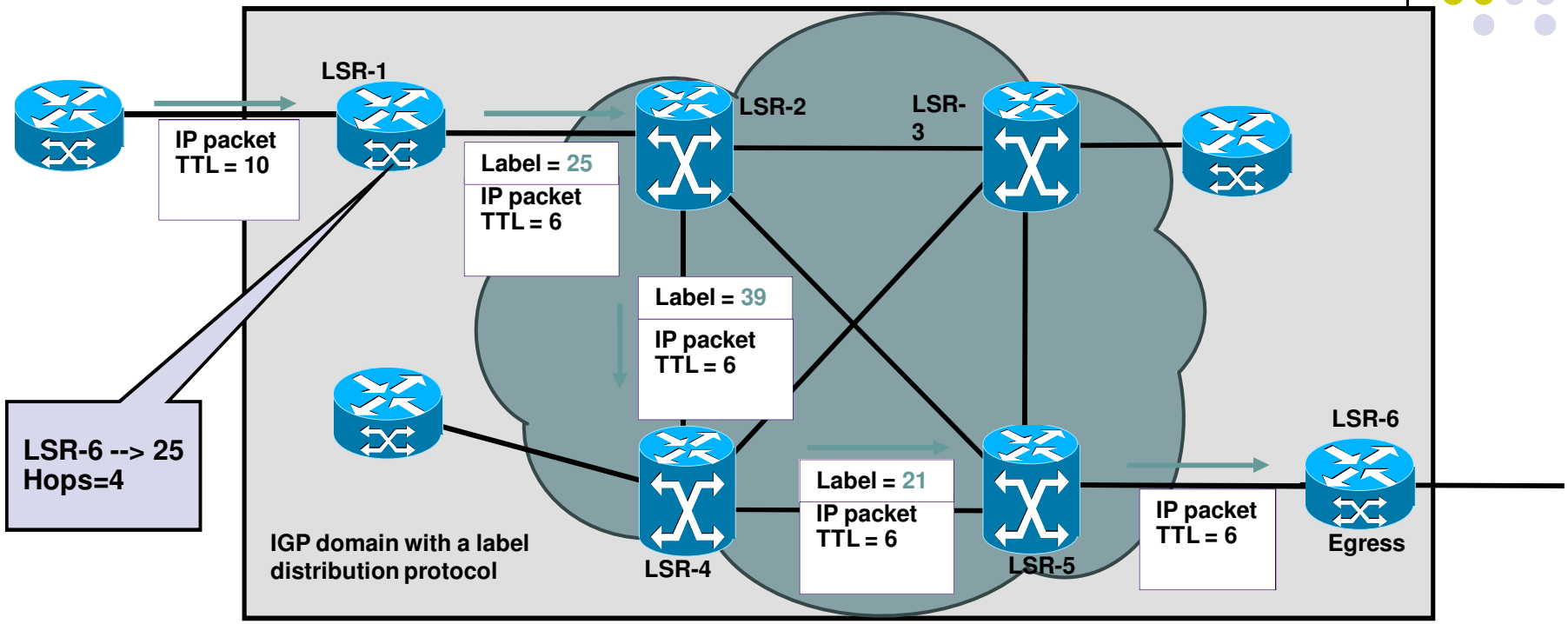


- In IP networks Time-To-Live (TTL) is used to prevent packets to travel indefinitely in the network
- MPLS ***may*** use same mechanism as IP, but not on all encapsulations
  - TTL is present in the label header for PPP and LAN headers (shim headers)
  - ATM cell header does not have TTL
- Some suggested options:

  - hop-count object in LDP

  - Path Vector object in LDP

Loops and TTL

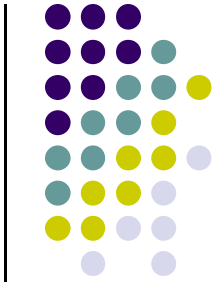


- **TTL is decremented prior to enter the non-TTL capable Label Switching Path (LSP)**

  If TTL becomes 0, the packet is discarded at the ingress point

- **TTL is examined at the LSP exit**

Concluzii



- LSR – forward pachete pe baza etichetei
- Eticheta: protocoale de rutare IP, traffic engineering, QoS, VPN
- Decupleaza rutarea de forwardare
- Clasificarea pachetelor
- Protocoale de distributie etichete: RSVP, LDP, CR-LDP pot coexista
- Etichetele au semnificatie locala