Multi Protocol Label Switching - MPLS

MPLS

- *MultiProtocol Label Switching*

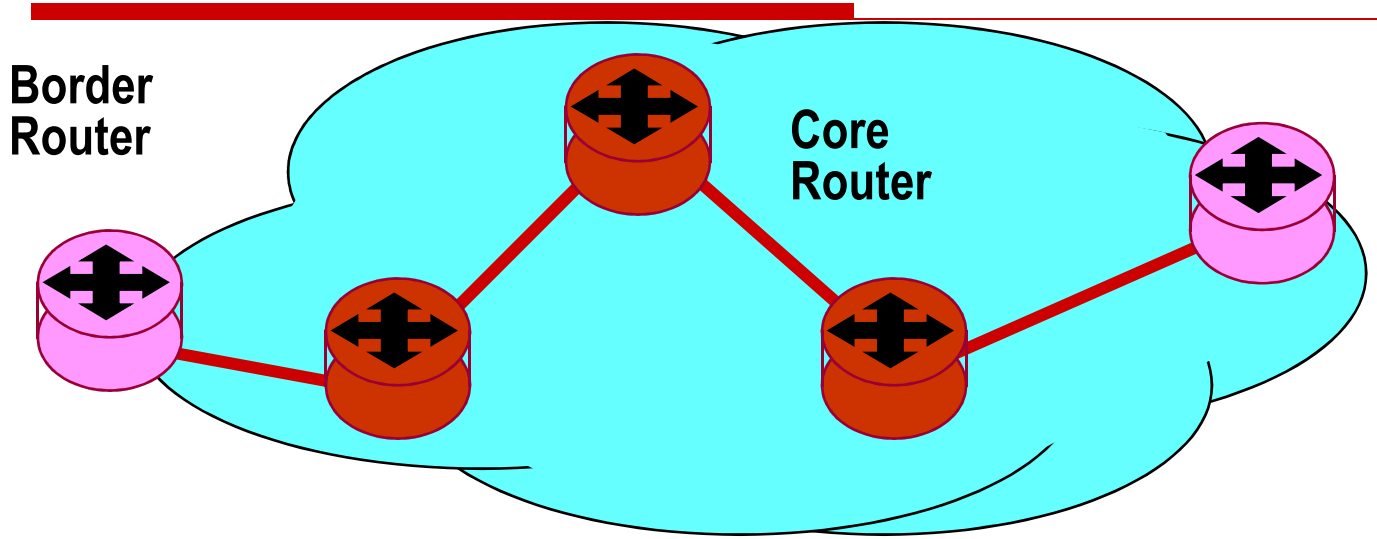
- A new layer 2 technology for taking the best features of IP and ATM in the Backbone Network
  - IP Routing
  - ATM Switching (label switching)

- ... with some enhanced features which eliminate the drawbacks of the classical IP over ATM protocols

MPLS

- Precursors (since ‘96)
  - IP Switching (Ipsilon/Nokia)
  - Tag Switching (Cisco)
  - Aggregate Route-Based IP-Switc. (IBM)
  - IP Navigator (Cascade/Ascend/Lucent)
  - Cell Switching (Toshiba)

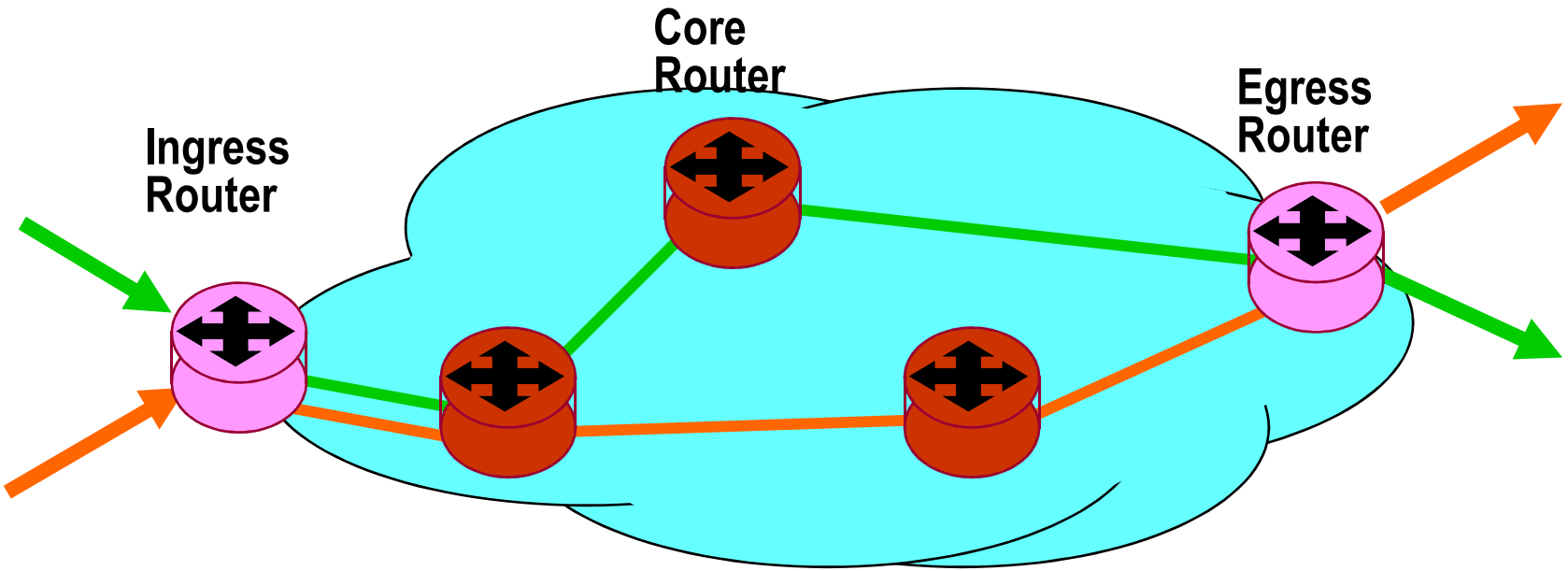
General architecture



- Flow management through **virtual circuits** (*Forward Equivalence Class*)
  - Preset by the operator
  - Set on user request
  - Set by a dynamic mechanism
  - Considering also resource reservation and Quality of Service (QoS)

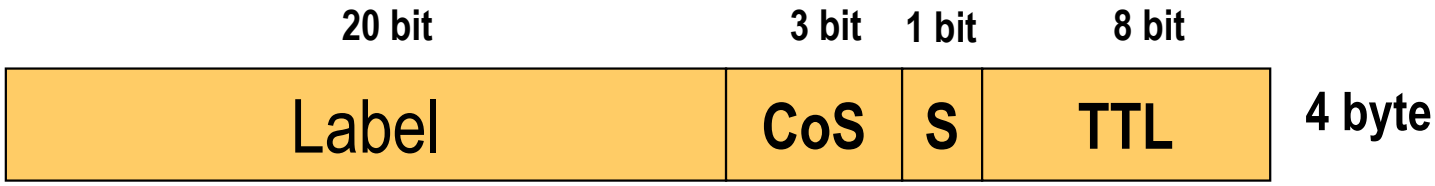
General architecture

- It is possible to optimize the routing based on *static* or *dynamic* mechanisms
- It is possible to classify traffic (flow definition) based on a rich set of parameters (including source address, ports, application, etc.).



LS Forwarding

- A LS header is added to the IP datagram



- *CoS: Class of Service*
- *S: Stack*
- *TTL: Time To Live*

- The 20 bit label is compatible with the ATM VC identifier

LS Forwarding

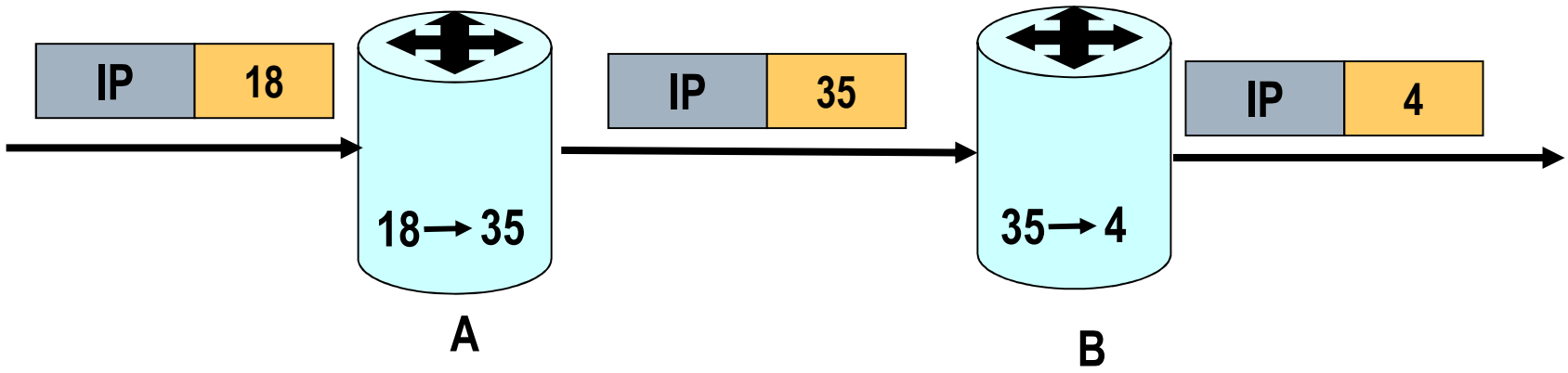
- The new Label is used for the Virtual Circuit based forwarding mechanism - Label Swapping

In Interface	In Label	Out Interface	Out Label
.....	.....	.....	.....
3	21	4	18
3	56	6	135
.....	.....	.....	.....

- The label has a *local* definition based on the link (exactly like with ATM and FR)

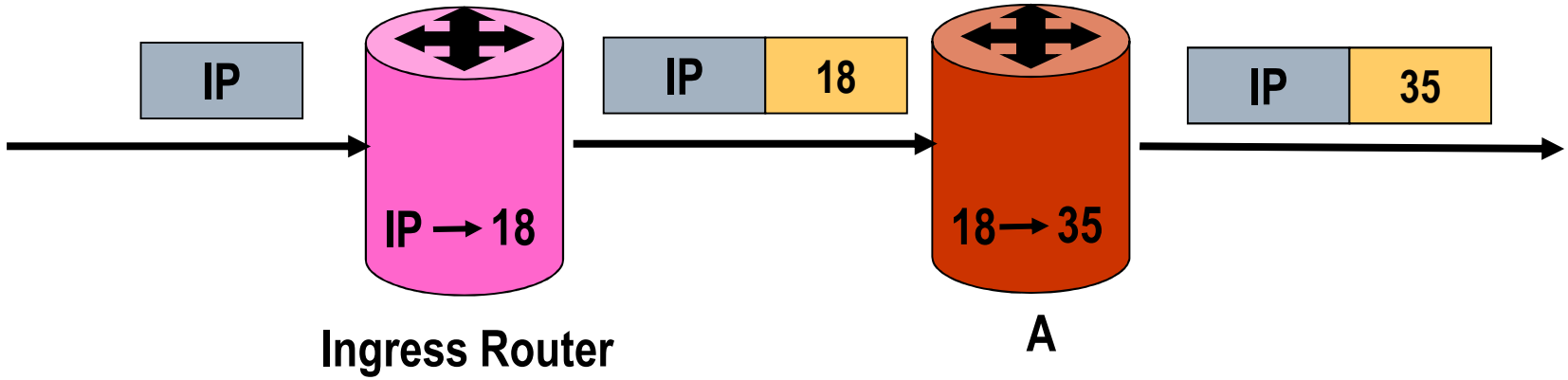
LS Forwarding

- Labels are linked together when the LS path is created

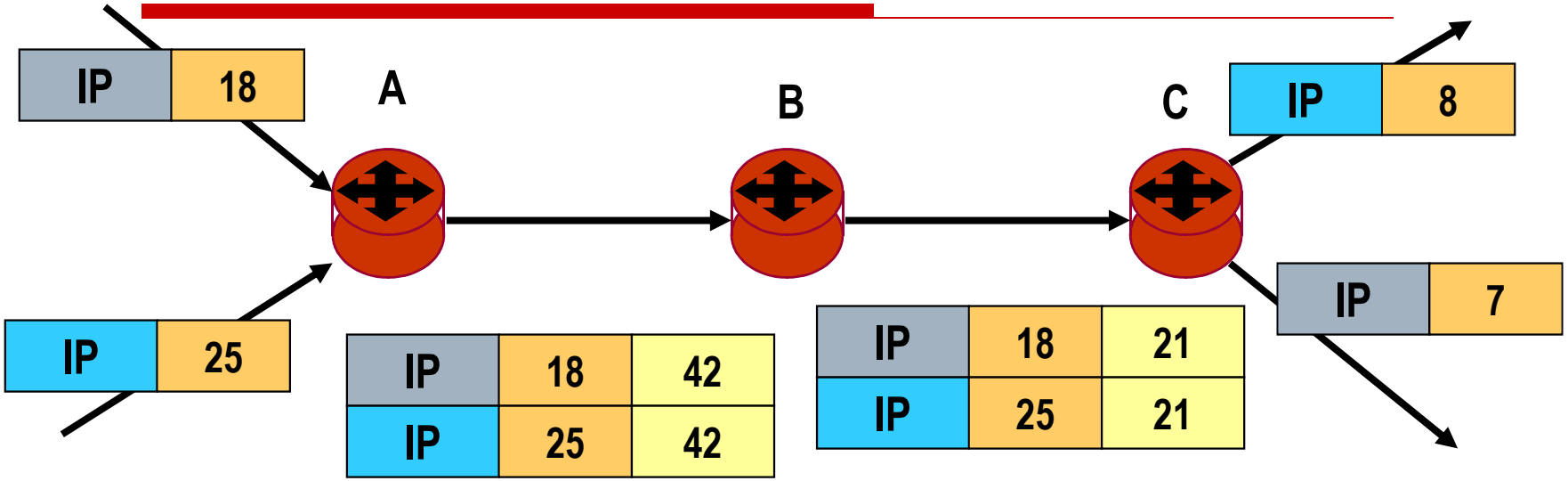


LS forwarding

- At the *Ingress Router,* each IP datagram is:
  - Classified (the simplest case is the destination-based packet classification)
  - Routed in the MPLS adding the proper label



Flow aggregation (*push* and *pop*)

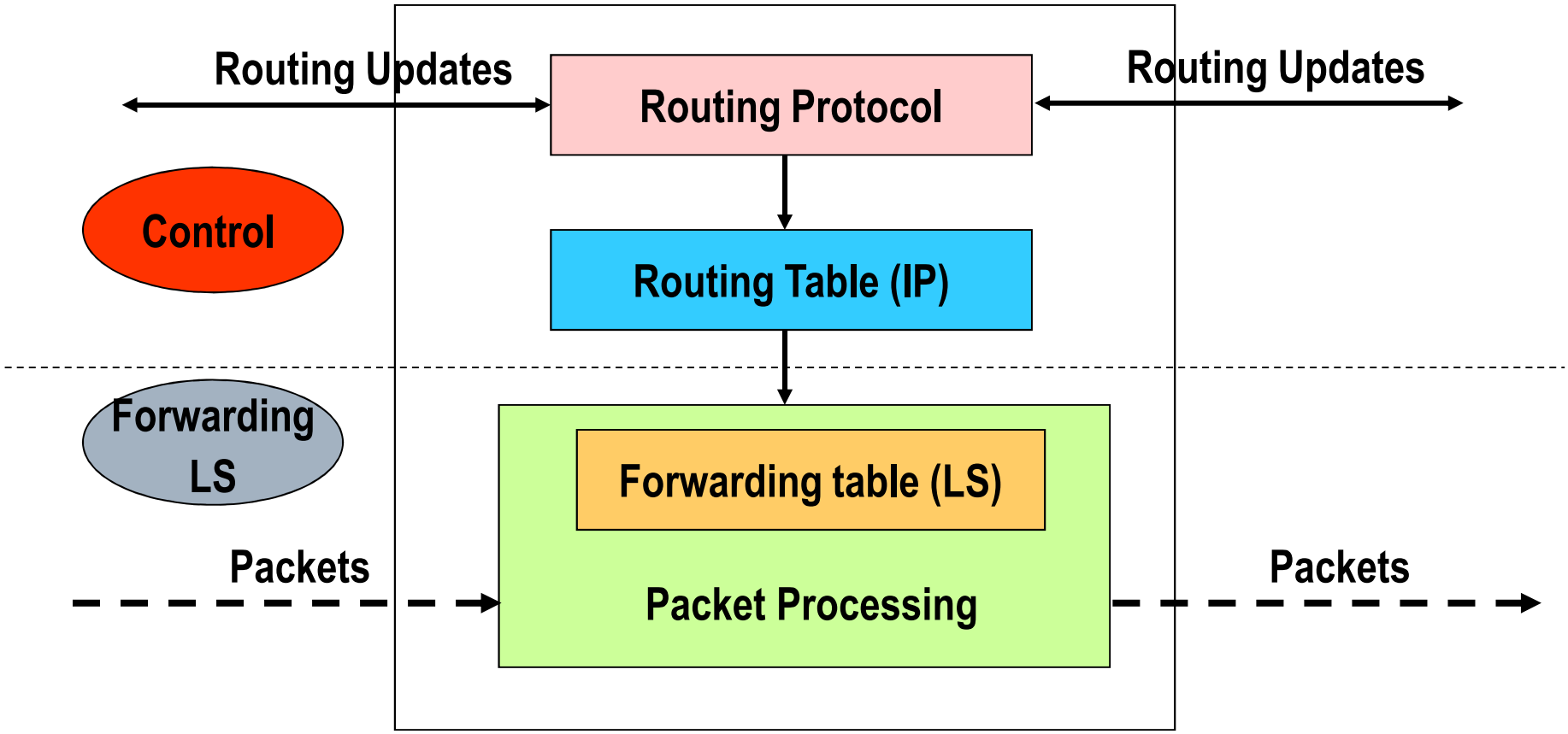


- The two flows are routed along a common path between routers A and C
- A aggregates the two flows with a common additional label (*push*)
- B forwards packets based on the outer label
- C de-aggregate flows and forwards them based on the original label (*pop*)

Flow aggregation

- Flow aggregation can be performed several times on an arbitary number of flows
- Routers forward packets based on the *outer label* only …
- … and aggregrate/de-aggregate flows based on the "push-pop" information
- The main advantage is scalability: only few flows are routed by the big routers inside backbone networks

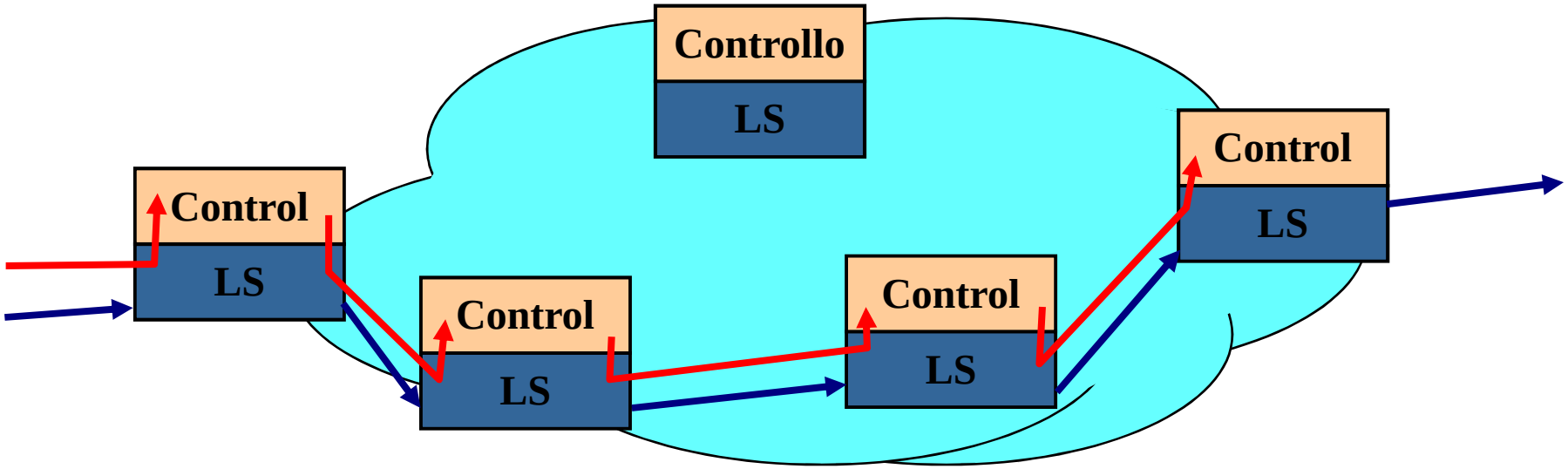
Forwarding and control



Separation between routing and forwarding

Forwarding and control

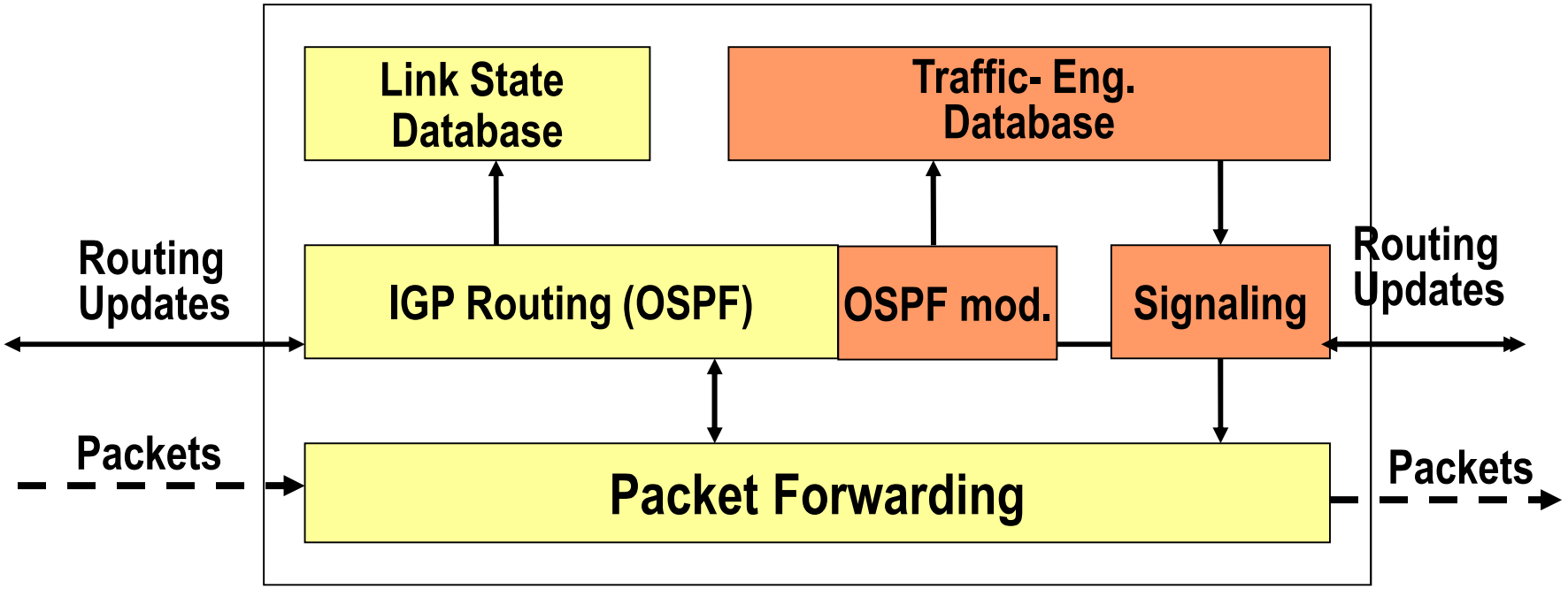
- Control packets follow an hop-by-hop forwarding like with traditional IP datagrams
- Control packets create a new label switched path (*virtual circuit*)
- Packet for which the path was created can be forwarded directly by the LS layer



Forwarding and control

- Obviously, label switched paths can be configured *manually* with no signalling exchange
- The separation between routing and forwarding permits to consider enhanced routing techniques considering quality parameters
- Flow aggregation allows to consider a huge number of flows with limited computation efforts
- The virtual circuit forwarding allows resource reservation and traffic engineering

Control



- New Traffic Engineering Database (TED)
- New signaling procedures

TED

- Includes information on:
  - Topology (exactly like link state protocols)
    - Obtained by classical routing protocols (e.g. OSPF)
  - Network available resources (bandwidth on links, reserved bandwidth, etc.)
    - Obtained by extended versions of routing protocols
  - Administrative data
    - Obtained from user-specific parameters
- It allows border routers to select the best path according to specific routing constraints

Path set-up

- Paths can be built-up:
  - "off line"
    - Global optimization based on the information on all flows and network resources
  - "on line" (Constrained based routing)
    - Considering user/flow specific constraints:
      - bandwidth
      - inclusion/exclusion of links/nodes
      - administrative specific requiremens
      - possibility to re-arrange previously routed flows
      - …

Signalling

A signalling mechanism is required for

- Coordinating label distribution
- Setting up the virtual circuit on the selected path (Explicit Route)
- Resource reservation
- Resource re-assignment
- Loops avoidance

Signalling

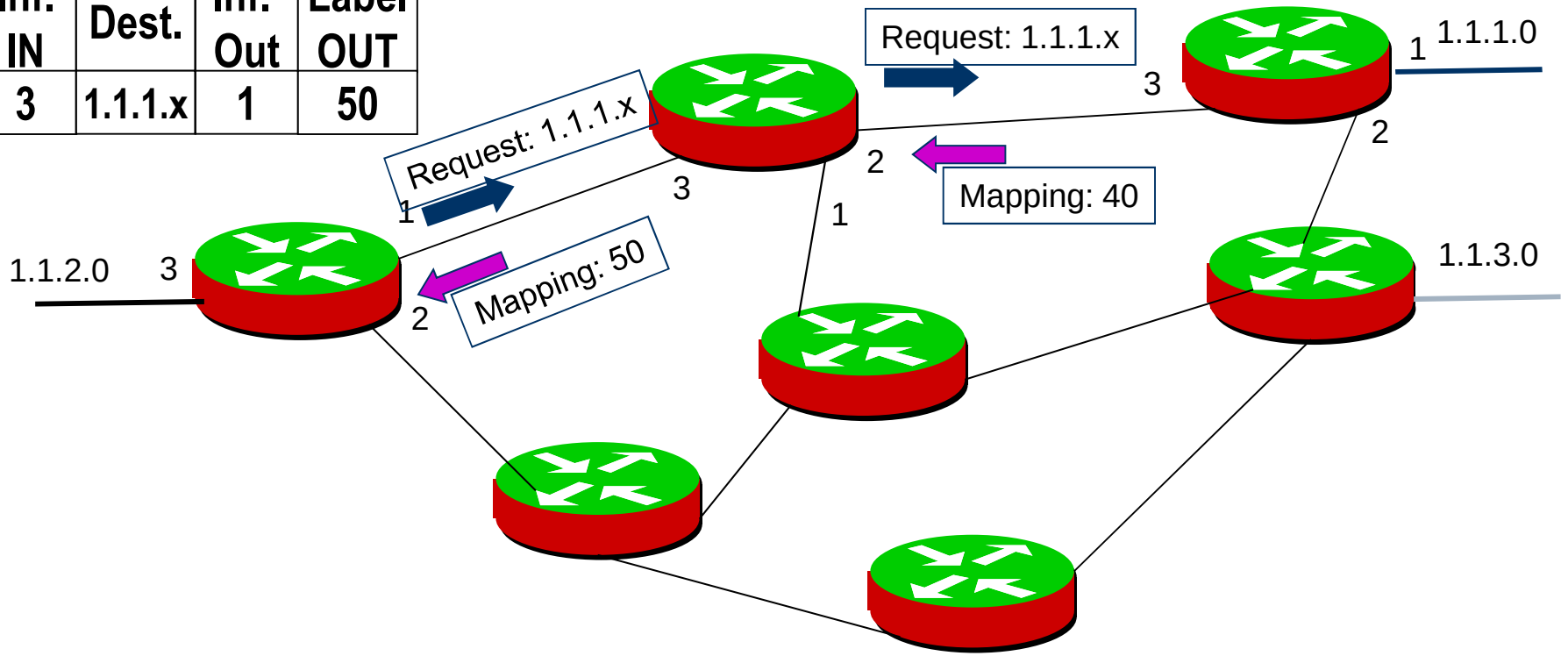
- Three protocols have been defined so far:
  - *Label Distribution Protocol* (LDP)
    - Hop-by-Hop
    - follows IGP paths
    - Traffic Engineering is not supported
  - ReSerVation Protocol (RSVP)
    - Managed by border Routers
    - Explicit routes supported
  - Constrained Routing LDP (Label Distribution Protocol)
    - Estended version of LDP with explicit route support

Label Distribution Protocol (LDP)

Inf. IN	Label IN	Dest.	Inf. Out	Label OUT
3	50	1.1.1.x	2	40

Inf. IN	Label IN	Dest.	Inf. Out
3	40	1.1.1.x	1

Inf. IN	Dest.	Inf. Out	Label OUT
3	1.1.1.x	1	50

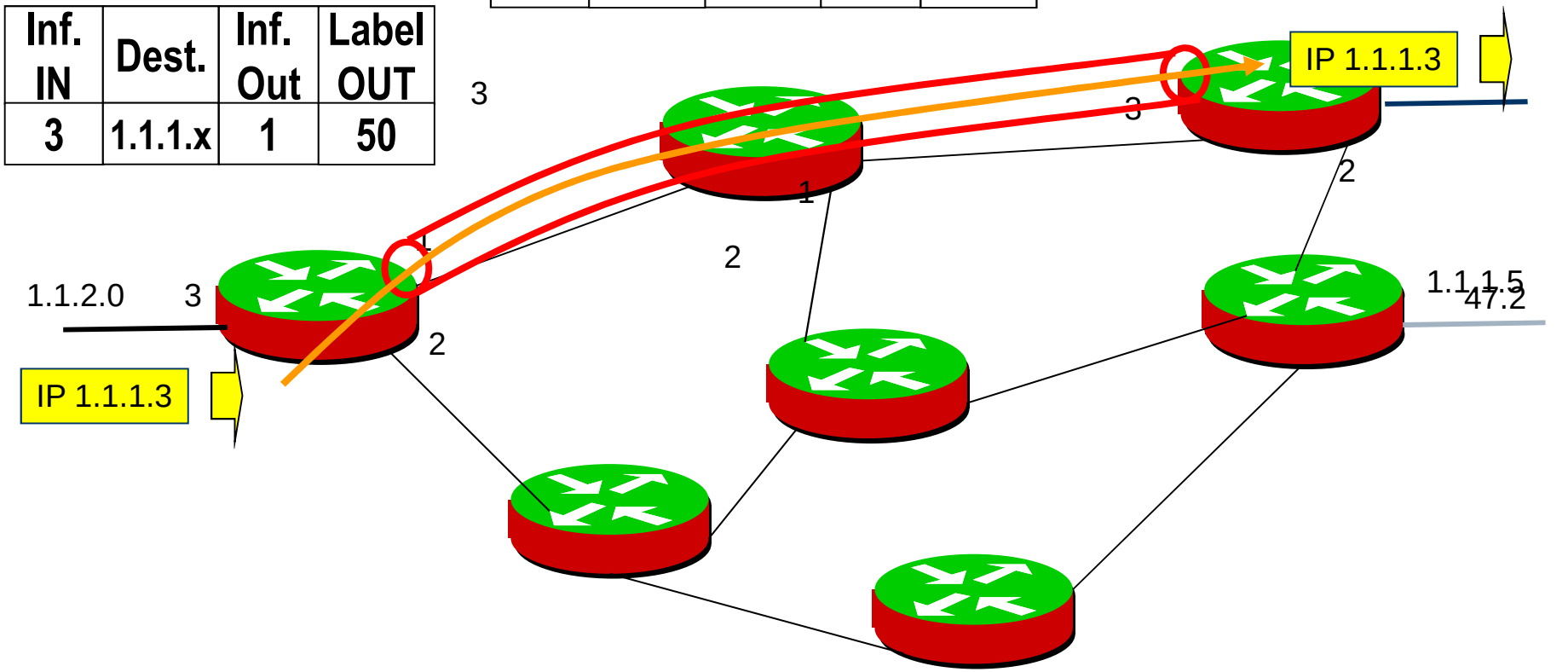


Label Switched Path (LSP)

Inf. IN	Label IN	Dest.	Inf. Out	Label OUT
3	50	1.1.1.x	2	40

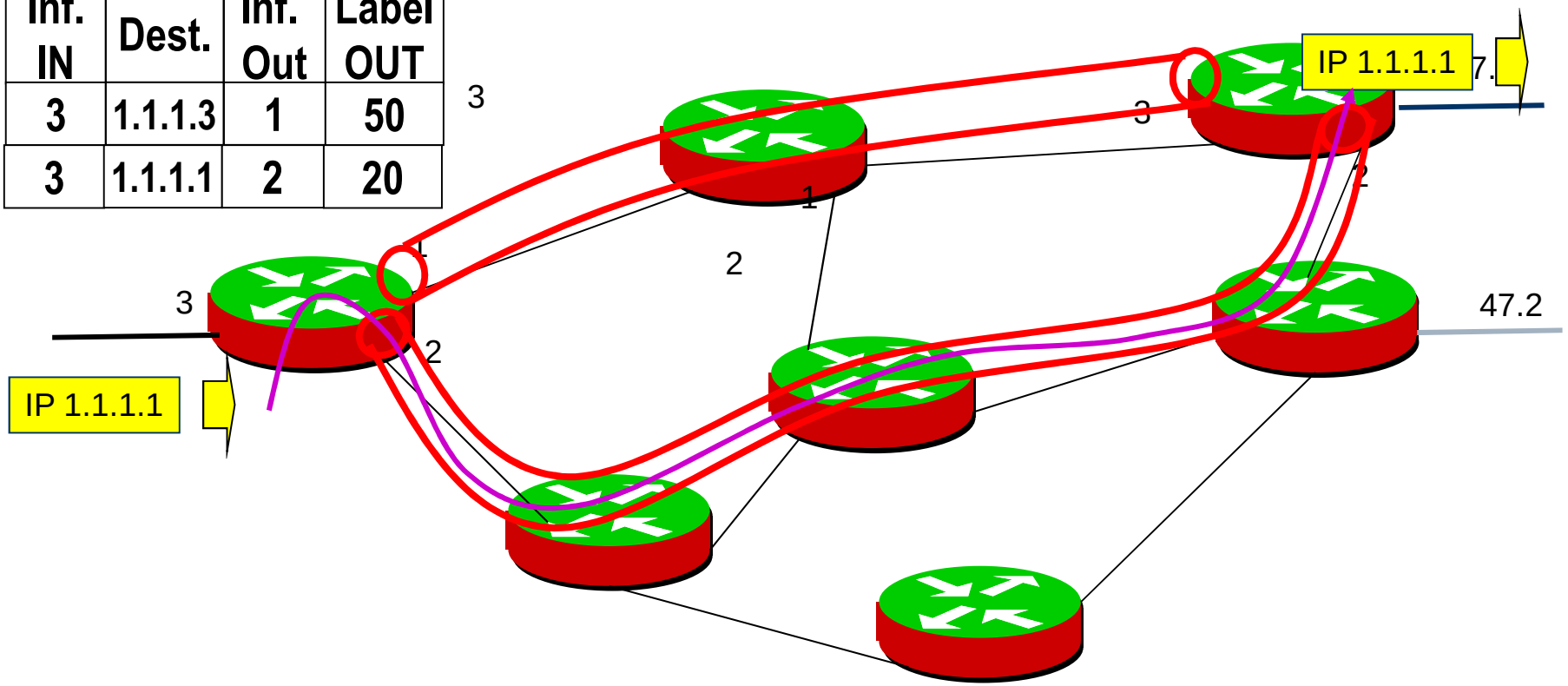
Inf. IN	Label IN	Dest.	Inf. Out
3	40	1.1.1.x	1

Inf. IN	Dest.	Inf. Out	Label OUT
3	1.1.1.x	1	50

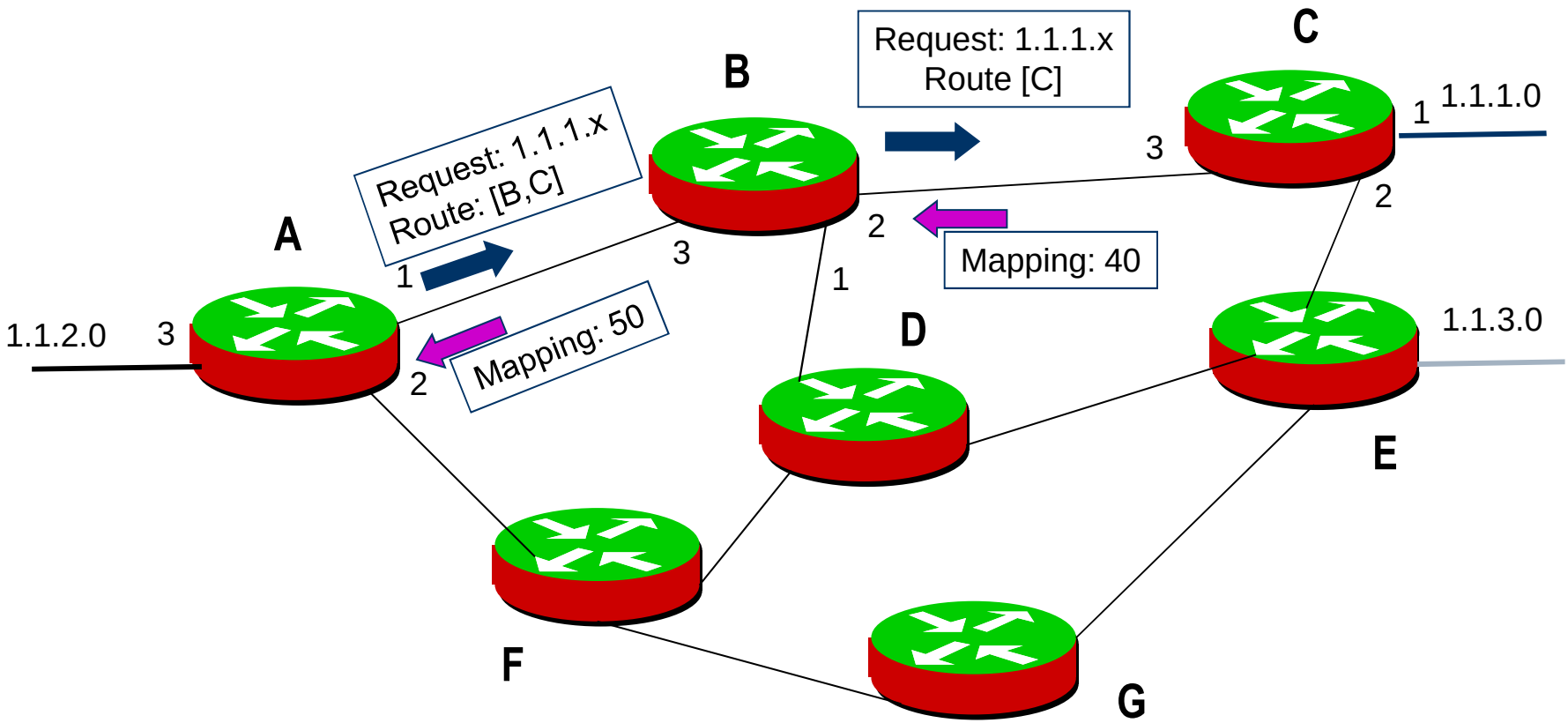


Explicitely Routed-LDP

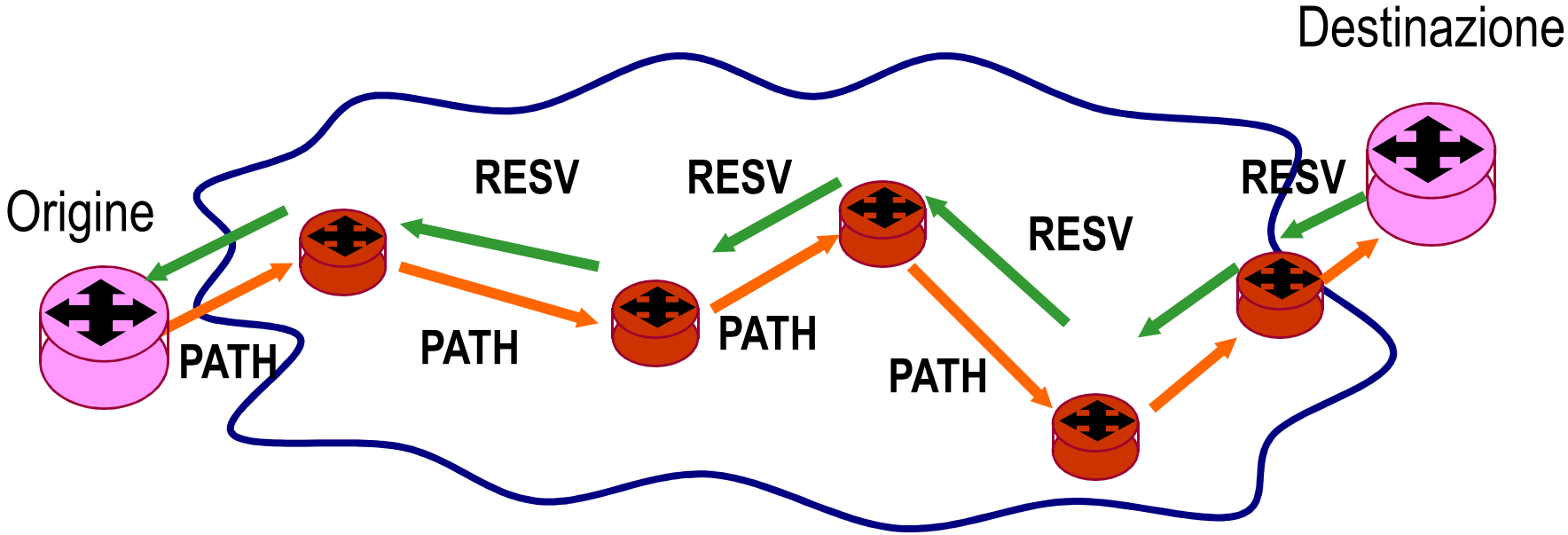
Inf. IN	Dest.	Inf. Out	Label OUT
3	1.1.1.3	1	50
3	1.1.1.1	2	20



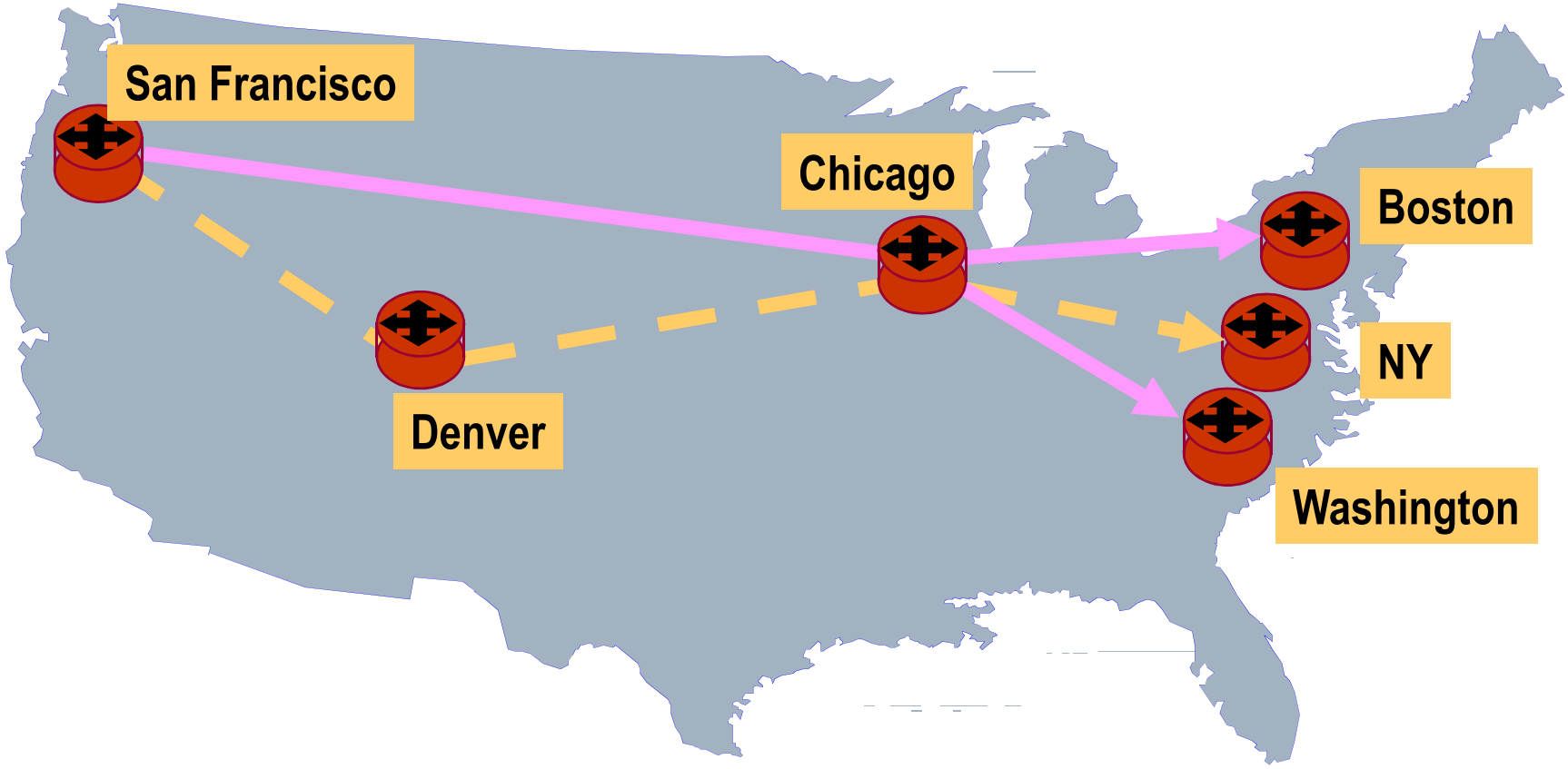
CR-LDP


Request: 1.1.1.x
Route [C]
C
B
Request: 1.1.1.x
Route: [B,C]
1.1.1.0
1
3
2
A
2
Mapping: 40
3
1
1
1.1.2.0
3
D
1.1.3.0
Mapping: 50
2
E
F
G

ReSerVation Protocol (RSVP)



Example:



For more information:

- Papers:
  - G. Armitage, "MPLS: The Magic behind the Myths", IEEE Communication Magazine, Jan. 2000, pp. 124-131.
  - D.O. Awduche, "MPLS and Traffic Engineering in IP Networks", IEEE Communication Magazine, Dic. 1999, pp. 42-47.

- Books:
  - Bruce S. Davie, Yakov Rekhter, MPLS: Technology and Applications , Morgan Kaufmann Publishers, 2000.