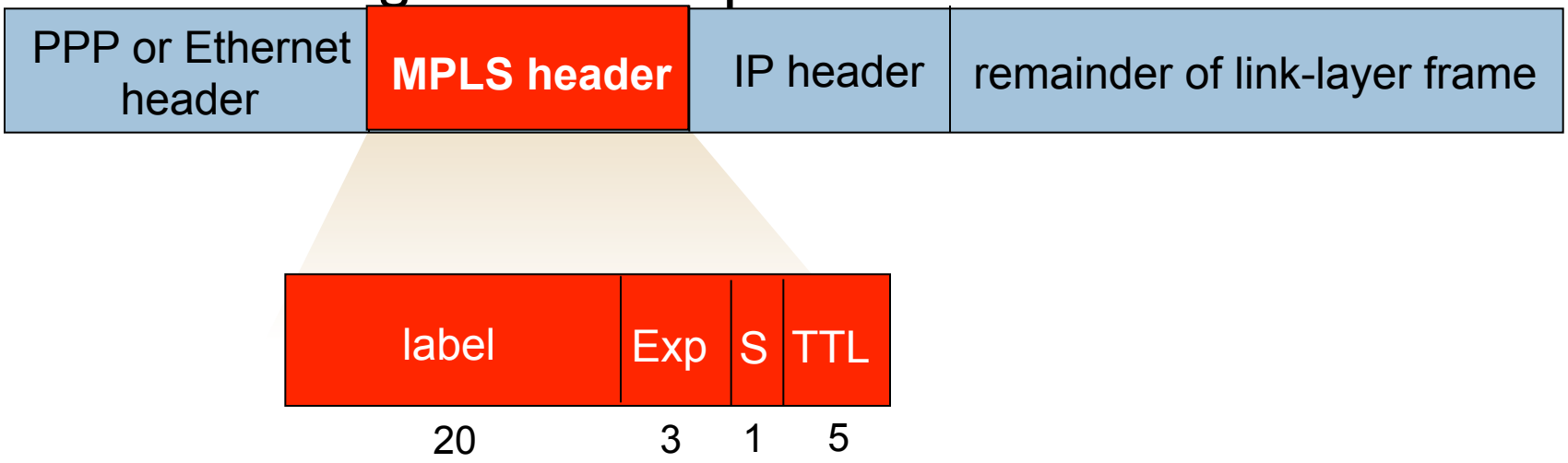
DATA LINK LAYER

MPLS

Multiprotocol label switching (MPLS)

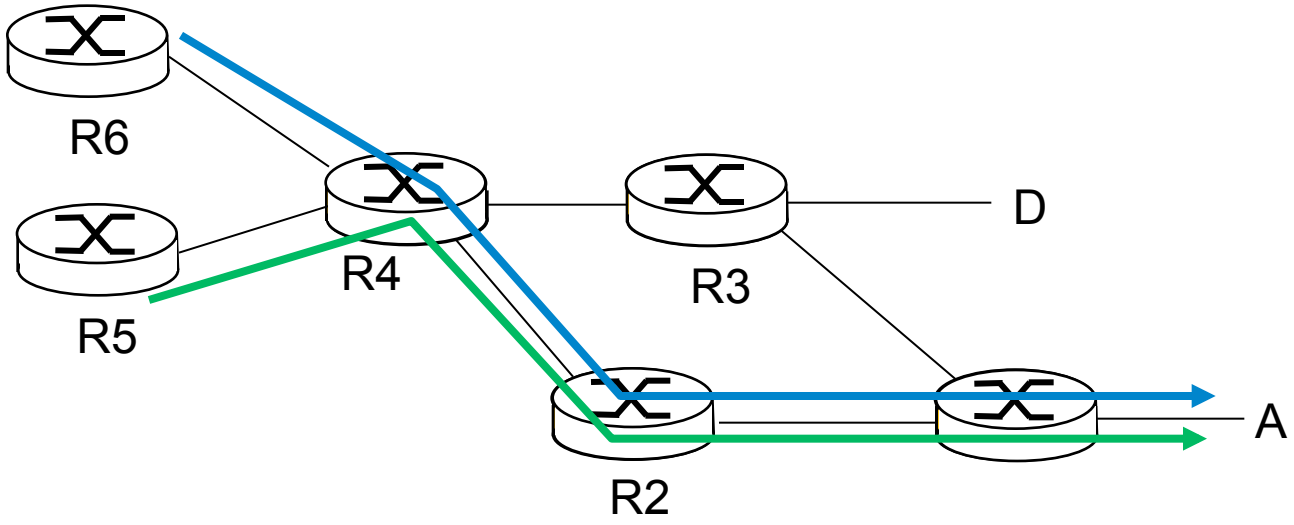
- initial goal: high-speed IP forwarding using fixed length label (instead of IP address)
  - fast lookup using fixed length identifier (rather than shortest prefix matching)
  - borrowing ideas from Virtual Circuit (VC) approach
  - but IP datagram still keeps IP address!



MPLS capable routers

- a.k.a. label-switched router
- forward packets to outgoing interface based only on label value (*don't inspect IP address*)
  - MPLS forwarding table distinct from IP forwarding tables
- *flexibility:* MPLS forwarding decisions can *differ* from those of IP
  - use destination *and* source addresses to route flows to same destination differently (traffic engineering)
  - re-route flows quickly if link fails: pre-computed backup paths (useful for VoIP)

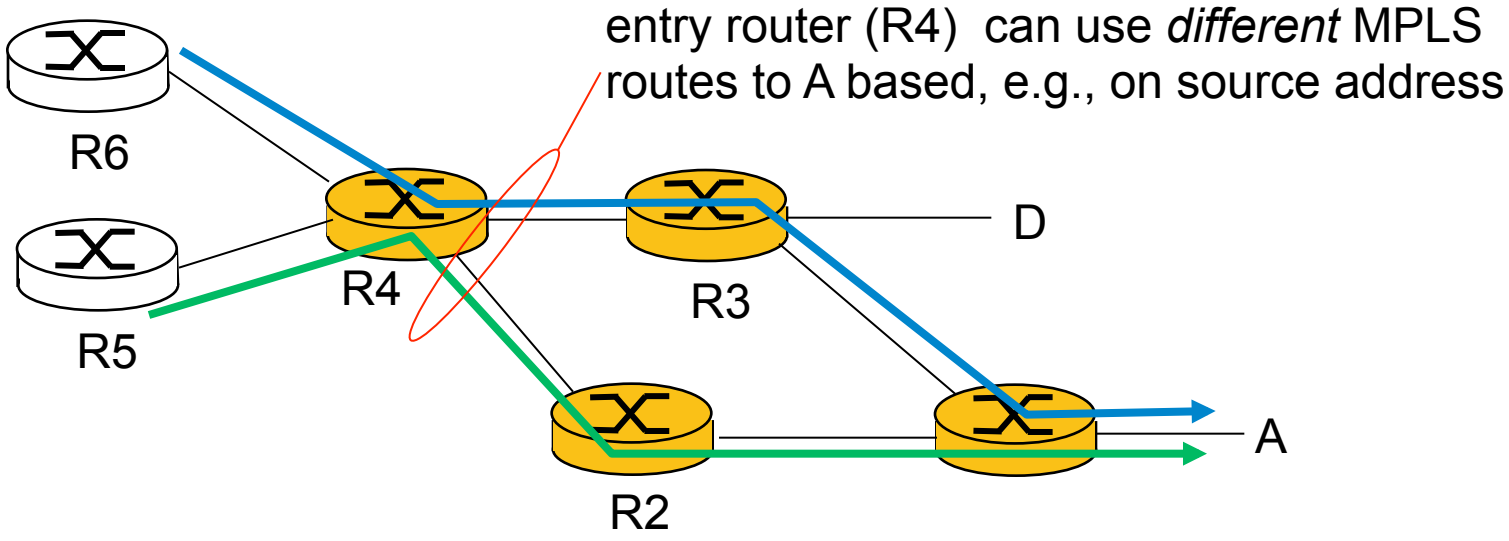
MPLS versus IP paths



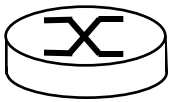
- *IP routing: path to destination determined by destination address alone*

IP router

MPLS versus IP paths



- *IP routing:* *path to destination determined by destination address alone*
- *MPLS routing:* path to destination can be based on source *and* dest. address
  - *fast reroute:* precompute backup routes in case of link failure

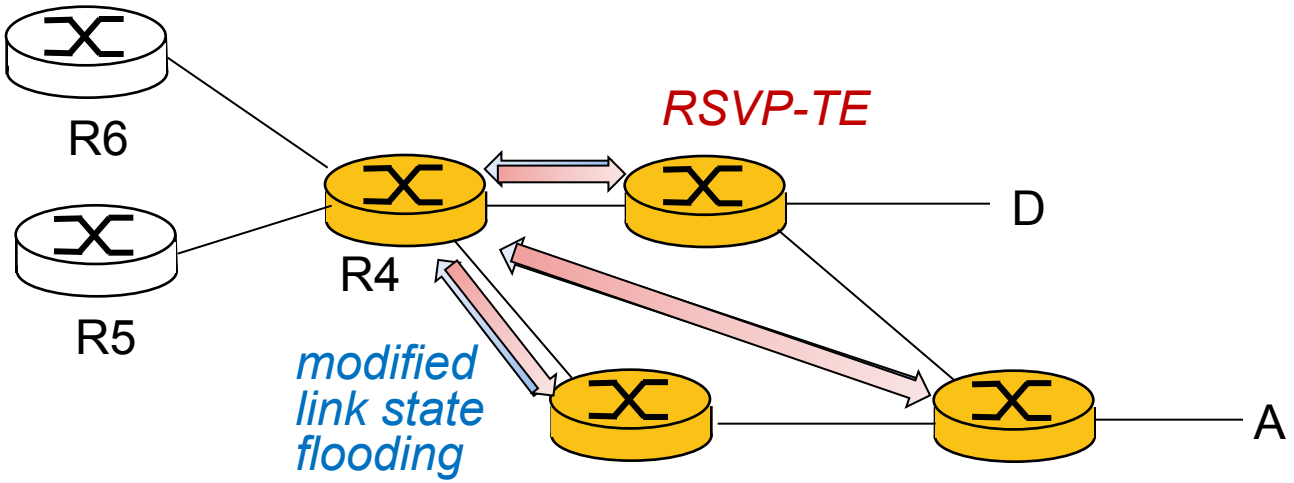


IP-only router

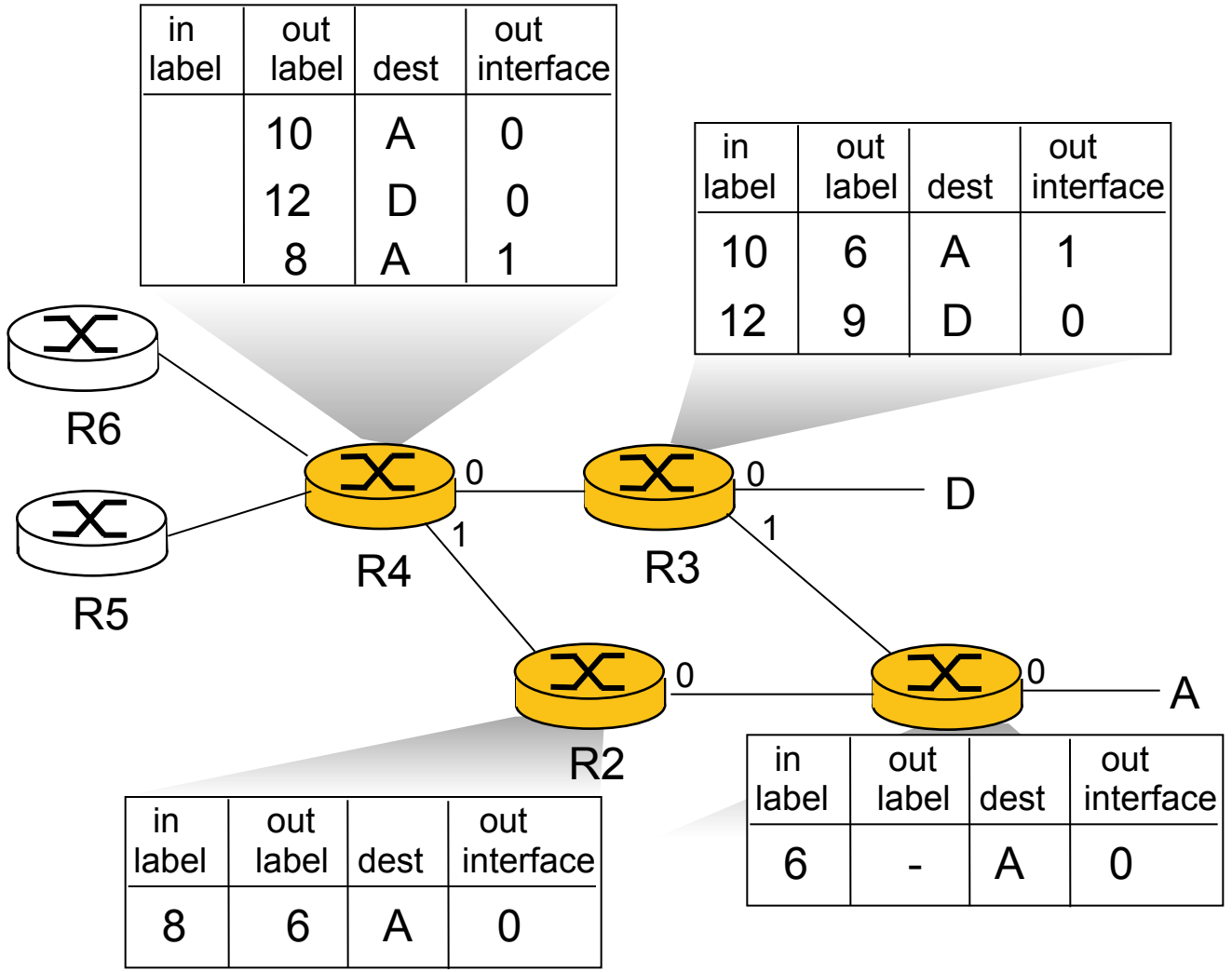
MPLS and IP router

MPLS signaling

- modify OSPF, IS-IS link-state flooding protocols to carry info used by MPLS routing,
  - e.g., link bandwidth, amount of "reserved" link bandwidth
- *entry MPLS router uses RSVP-TE signaling protocol to set up MPLS forwarding at downstream routers*



MPLS forwarding tables



Data Center Networks

- 10's to 100's of thousands of hosts, often closely coupled, in close proximity:
  - e-business (e.g. Amazon)
  - content-servers (e.g., YouTube, Akamai, Apple, Microsoft)
  - search engines, data mining (e.g., Google)

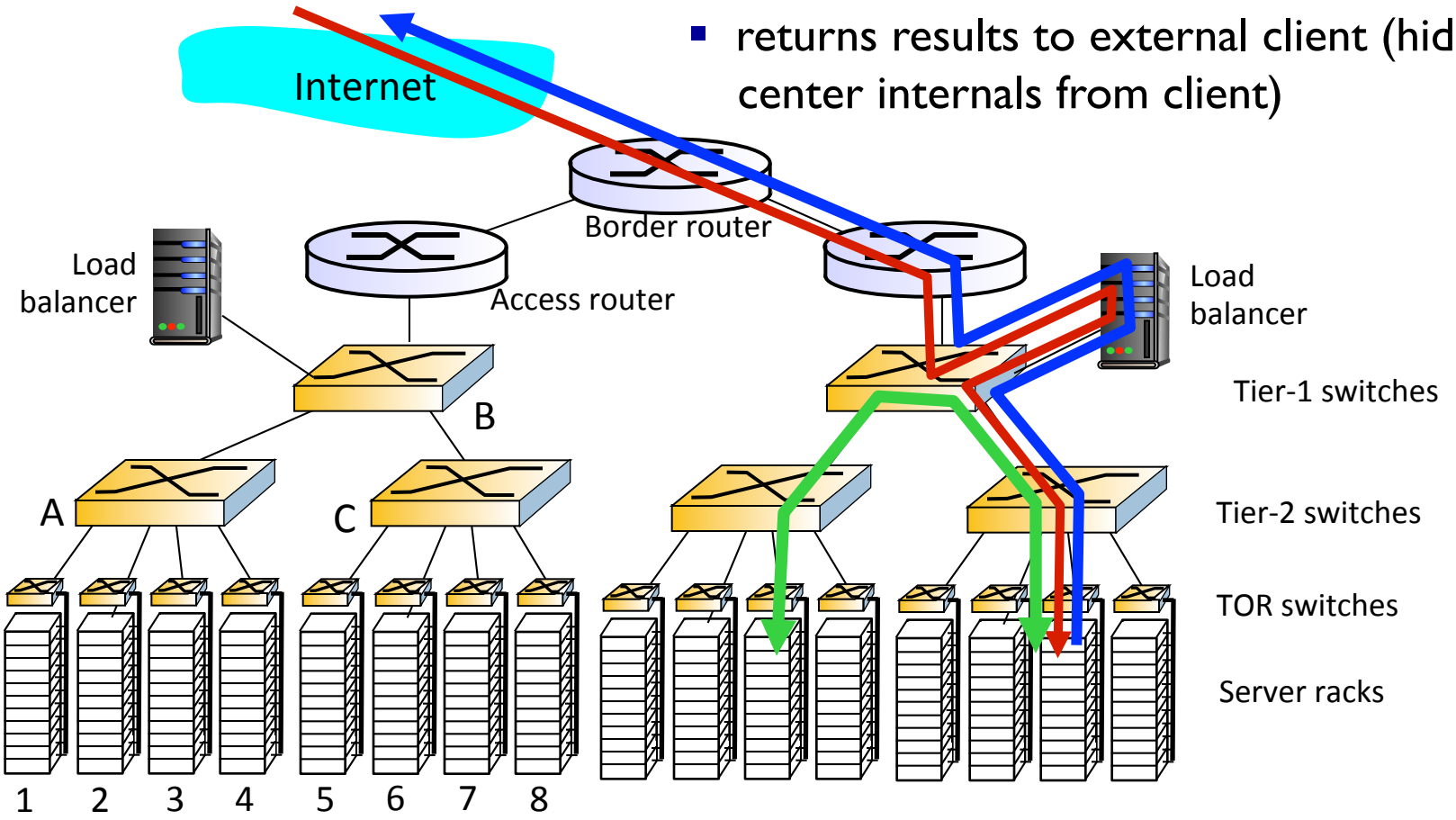
- challenges:
  - multiple applications, each serving massive numbers of clients
  - managing/balancing load, avoiding processing, networking, data bottlenecks

Inside a 40-ft Microsoft container, Chicago data center

Data Center Networks - Load

load balancer: application-layer routing

- receives external client requests
- directs workload within data center
- returns results to external client (hiding data center internals from client)



Data Center Networks - Layout

- rich interconnection among switches, racks:
  - increased throughput between racks (multiple routing paths possible)
  - increased reliability via redundancy