CS 725/825 & IT 725

Lecture 22

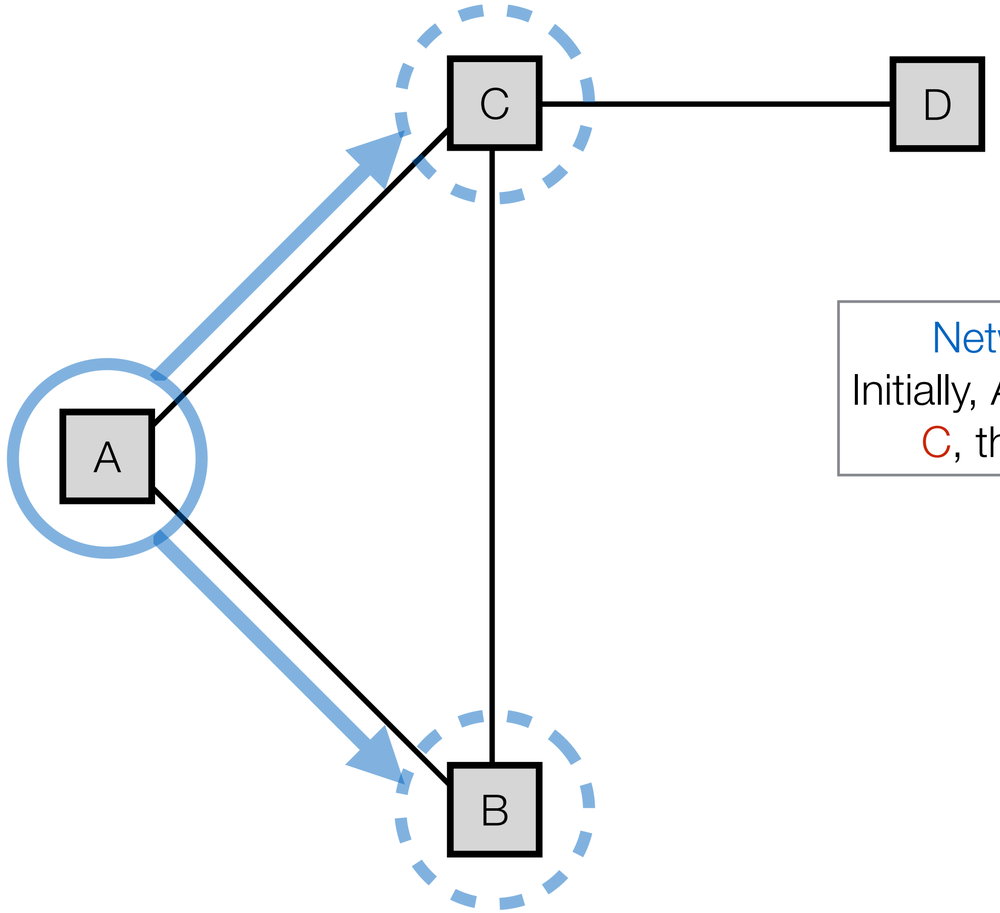
Network Layer

November 27, 2023

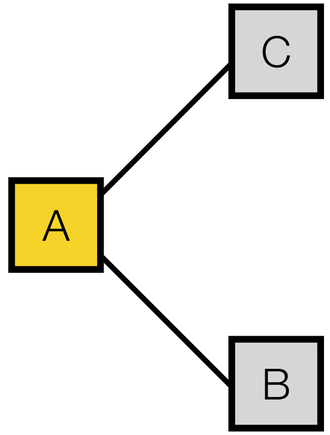
Link State (recap)

- Exact neighbor information flooded to every node on the network
- Topology of the entire networks is discovered in each node
- Shortest paths calculated and used to populate the routing tables

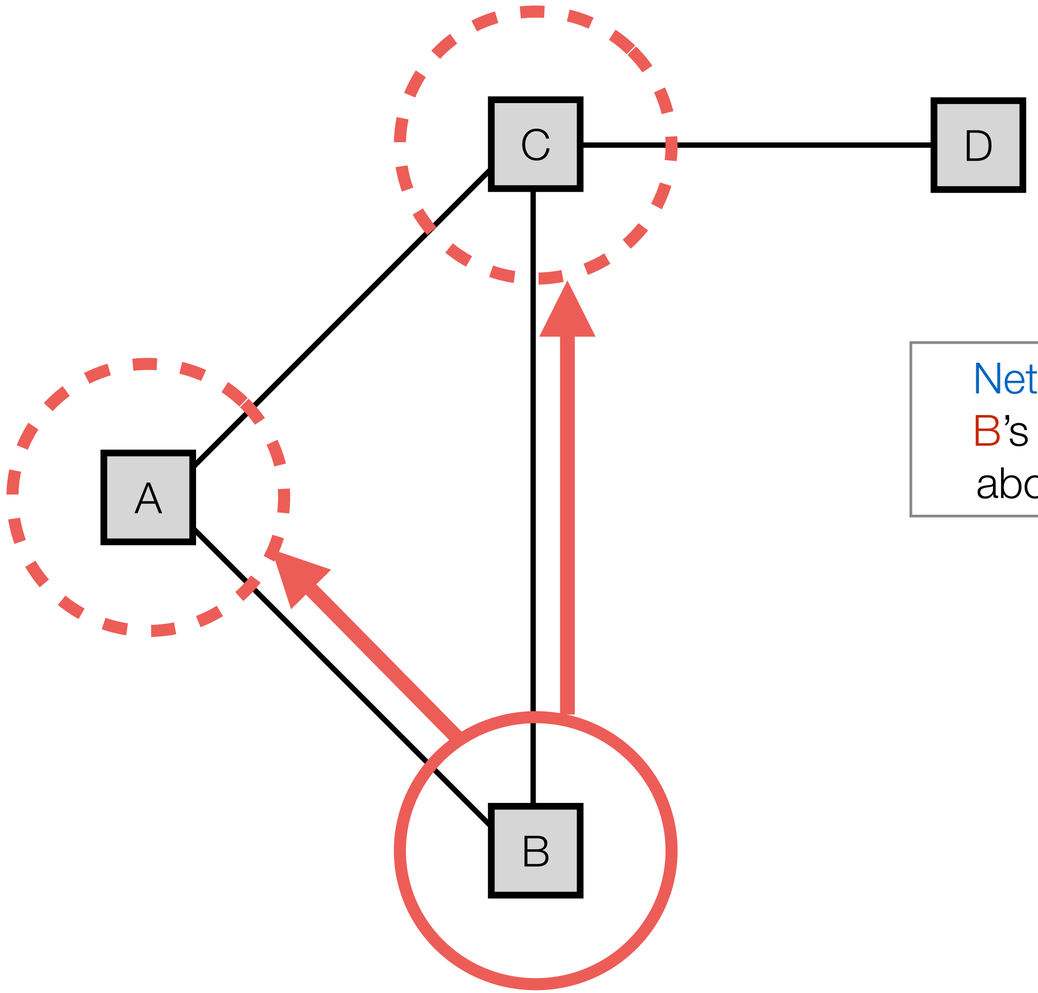
Link State routing



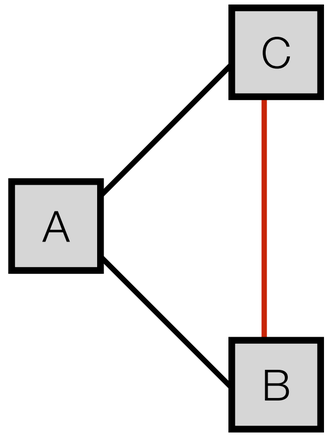
Network topology as seen by A:
Initially, A knows it is connected to B and C, this info is flooded to all nodes



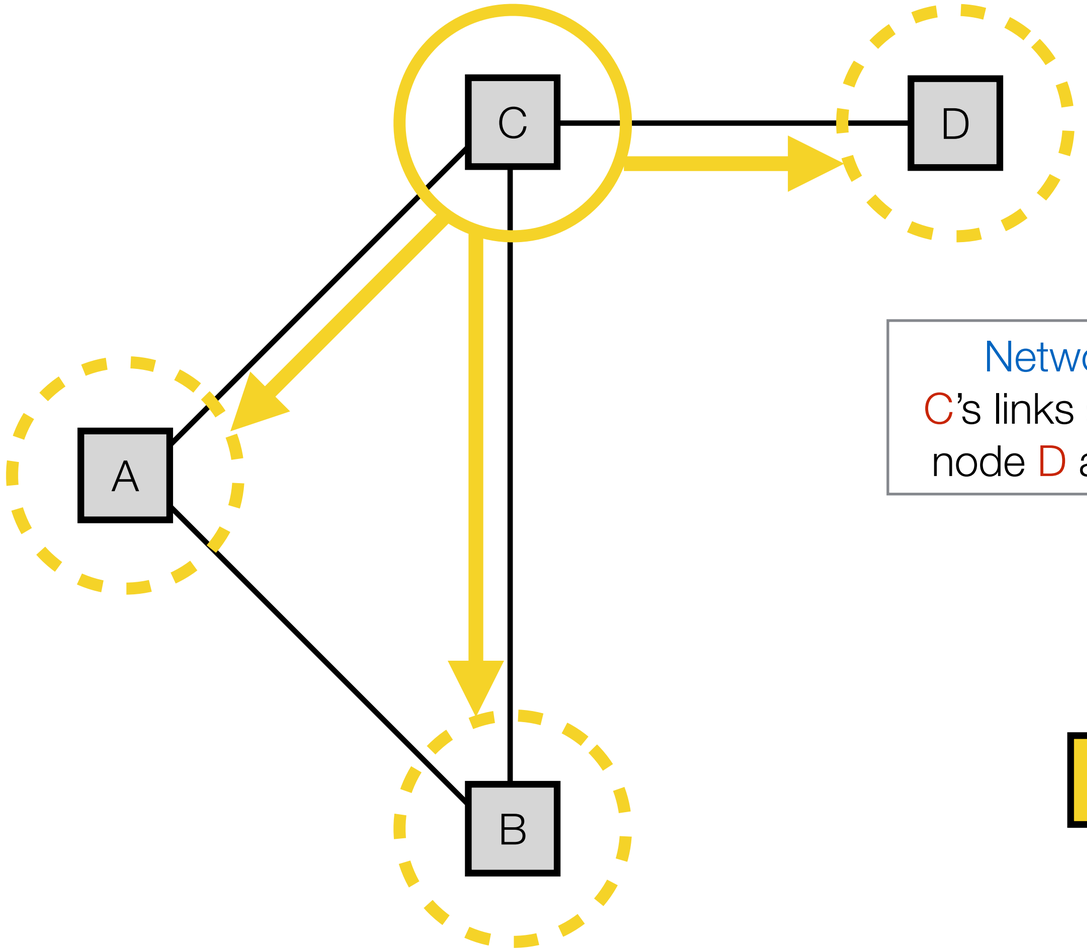
Link State routing



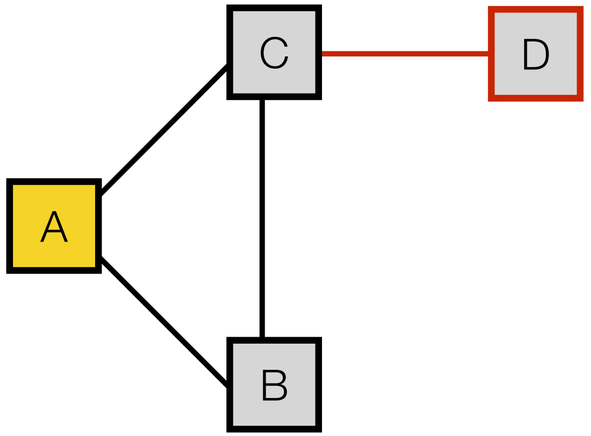
Network topology as seen by A:
B's links state received, A learns about the link between B and C



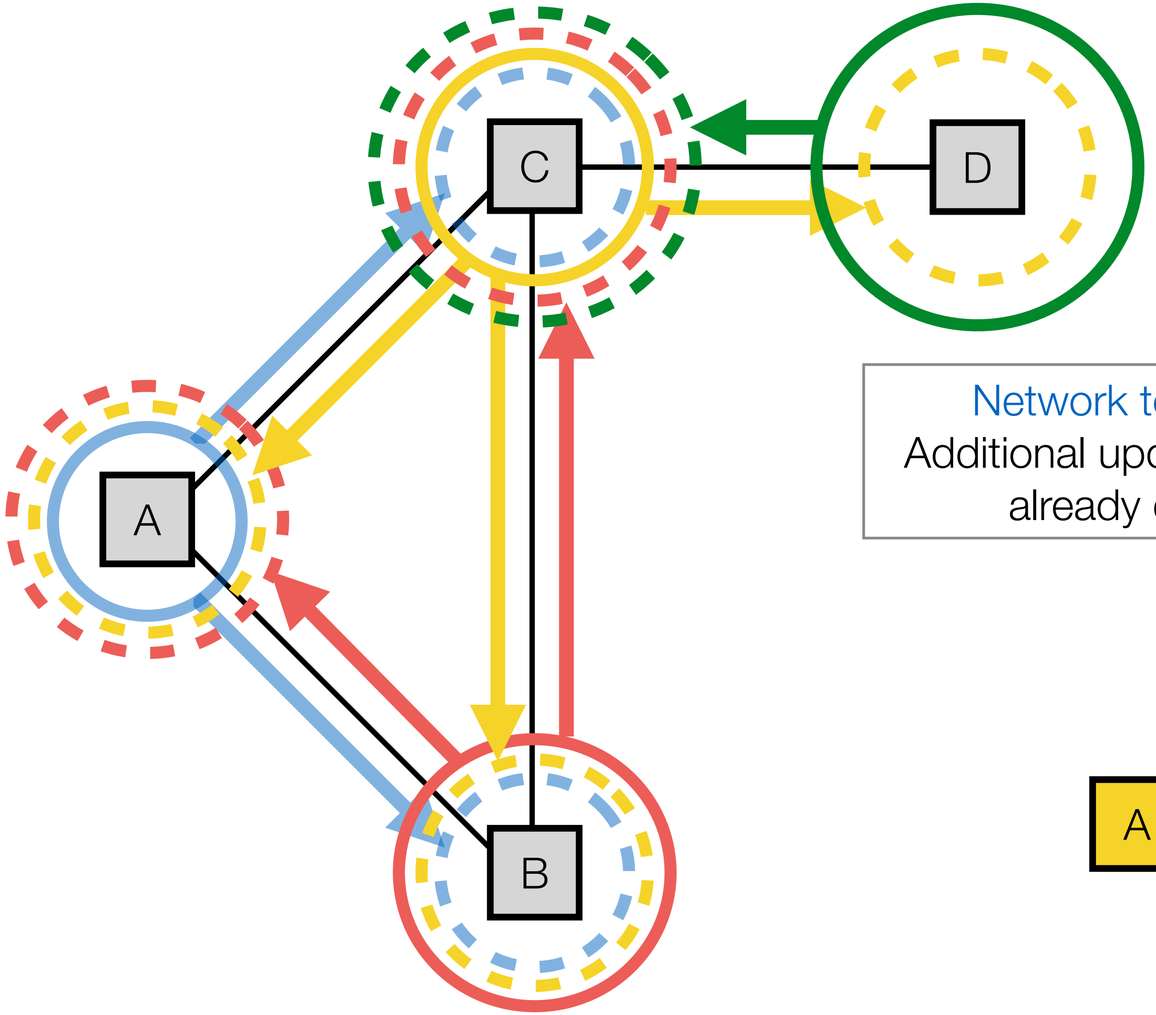
Link State routing



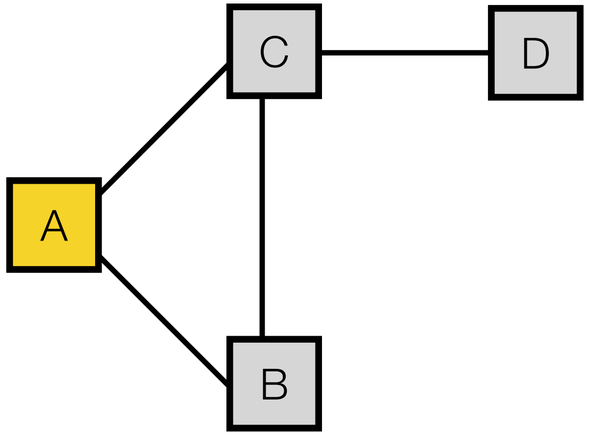
Network topology as seen by A:
C's links state received, A learns about node D and the link between C and D



Link State routing



Network topology as seen by A:
Additional updates received, confirming already discovered topology



Scalability of Routing Protocols

- Internet is large...
- Need to introduce hierarchy
  - ... into something that naturally does not have one
  - divide and conquer, abandoning hope for optimality
  - based on ownership - Autonomous System (AS)
- Different routing problems:
  - Intra AS routing - interior gateway routing (IGP)
  - Inter AS routing - exterior gateway routing (EGP)

Examples of Routing Protocols

	Distance Vector	**Link State**
IGP	RIP	OSPF
EGP	BGP-4*	

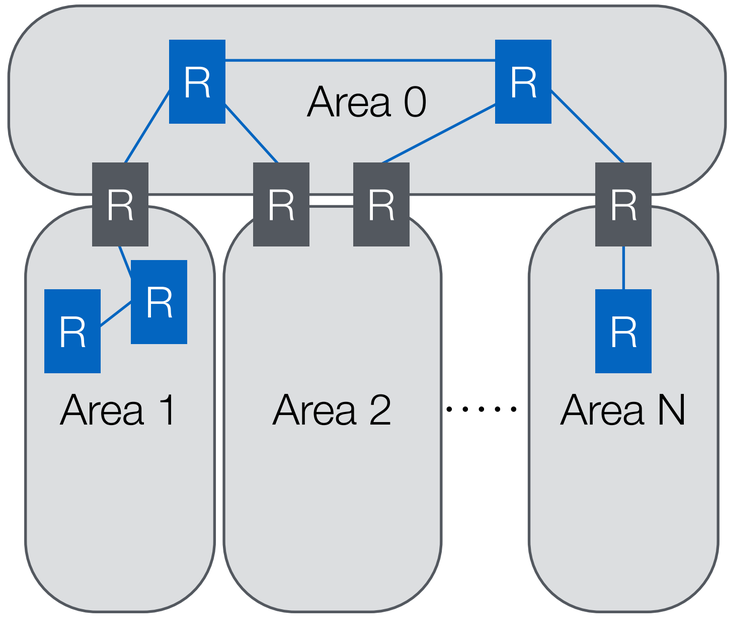
* BGP-4 extends the concept of *Distance Vector* routing to include the path information and is typically referred to as a ***Path Vector*** routing protocol

RIP

- Routing Information Protocol
  - a distance vector routing protocol
  - hops used as a measure of distance
  - 30 second update interval
- Version history
  - RIPv1 - 1988
  - RIPv2 - 1993 (includes CIDR, authentication)
  - RIPng - 1997 (IPv6 support)

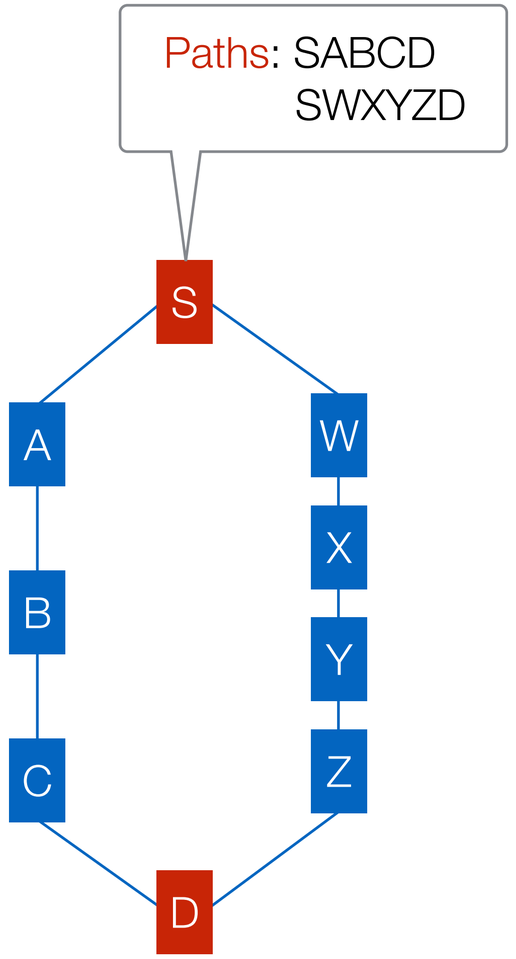
OSPF

- Open Shortest Path First
  - link state routing protocol
  - two-level hierarchy
  - user-defined link weights
- Version history:
  - OSPF (1989)
  - OSPFv2 (1998)
  - OSPFv3 (2008, IPv6)



BGP-4

- Border Gateway Protocol
  - exterior gateway routing protocol
  - *path* vector routing
  - allows policy based routing
  - AS as a routing hop
- Version history
  - Version 4 (1995)
  - Latest “version” of version 4 (2006)



QoS Measures

- Throughput
  - bits, bytes, packets per second
- Latency
  - one way or round trip
- Latency variation (jitter)
  - average, max, etc.
- Probability of successful delivery
  - packet loss rate
  - bit error rate

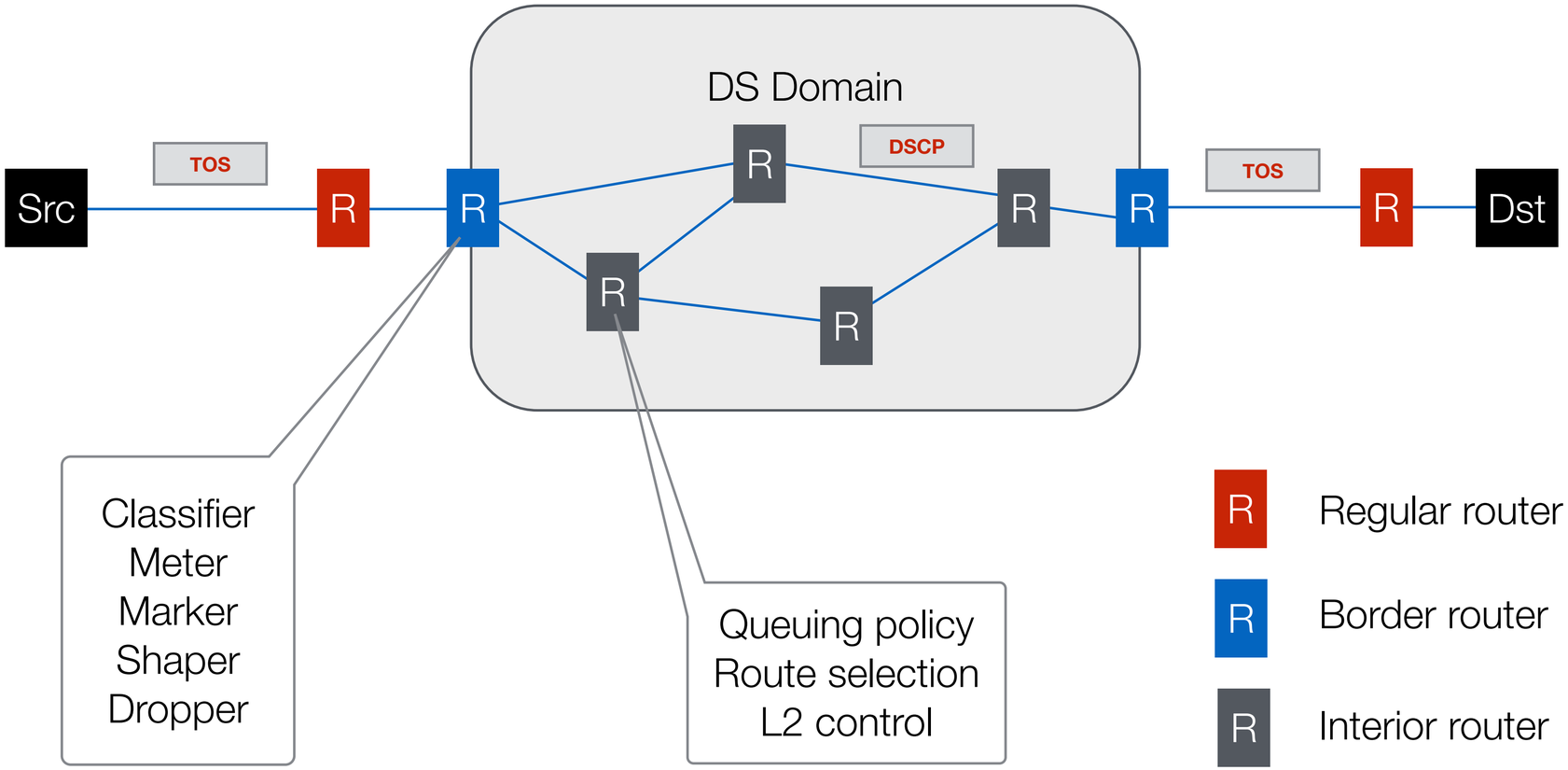
Quality of Service in IP

- Type of Service (TOS) field in IPv4, Traffic Class in IPv6
  - 8 bits
  - priority (3 bits)
  - bits to request high throughput, low latency, low loss, and low monetary cost
  - set by traffic generating applications
- For most parts, this attempt has failed:
  - no cost for requesting higher category of service
  - no broad agreement on how to handle the different categories

Differentiated Services

- Domain-based solution
- Relative guarantees
- Few classes of service
- Framework rather than a complete and prescriptive solution
- Reuses TOS field (called DSCP - Differentiated Services Code Point)

Differentiated Services



Categories of Networks

- Compromise: virtual packet switched

Circuit switched

Packet switched

Images from Wikimedia Commons

Virtual Circuits

- Problems with packet-switched networks:
  - no connection between packets
  - difficult to provide QoS
  - difficult to provision resources
  - difficult to control routes the packets take
  - reactive fault-tolerance
- All these problems can be addressed in circuit-switched networks

Circuits vs Virtual Circuits

- Virtual Circuit Switched Networks
  - an overlay on top of a packet switched network that provides a circuit-based service
  - “most of the benefits at a fraction of the cost”
  - trading ability to control for loss of simplicity
- Always the next big thing
  - OSI - Open System Interconnect (R.I.P.)
  - ATM - Asynchronous Transfer Mode (R.I.P.)
  - MPLS - MultiProtocol Label Switching (alive and well)

Virtual Circuit Switching

- Virtual Circuit (VC)
  - separation of routing and forwarding
- Circuit Switching Table
  - state-full forwarding
- Virtual Circuit Identifier (VC id)
  - global circuit vs locally significant circuit identifier

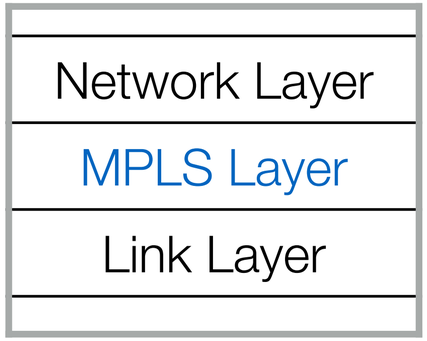
MPLS

- MultiProtocol Label Switching
  - a protocol providing virtual circuit service
  - designed to coexist and complement existing protocols, not to replace them
- One protocol, many uses:
  - simplification of forwarding
  - traffic engineering
  - protection and restoration
  - support for legacy services
  - VPNs, ...

MPLS Terminology

- Label Switched Path (LSP): a VC
- Label: VC id
- Label Switch Router (LSR): a switch
- Forwarding Equivalence Class (FEC)

Typically:



MPLS packet