ECE 642- Design and Analysis of Computer Networks

Lecture 14: Traffic Engineering

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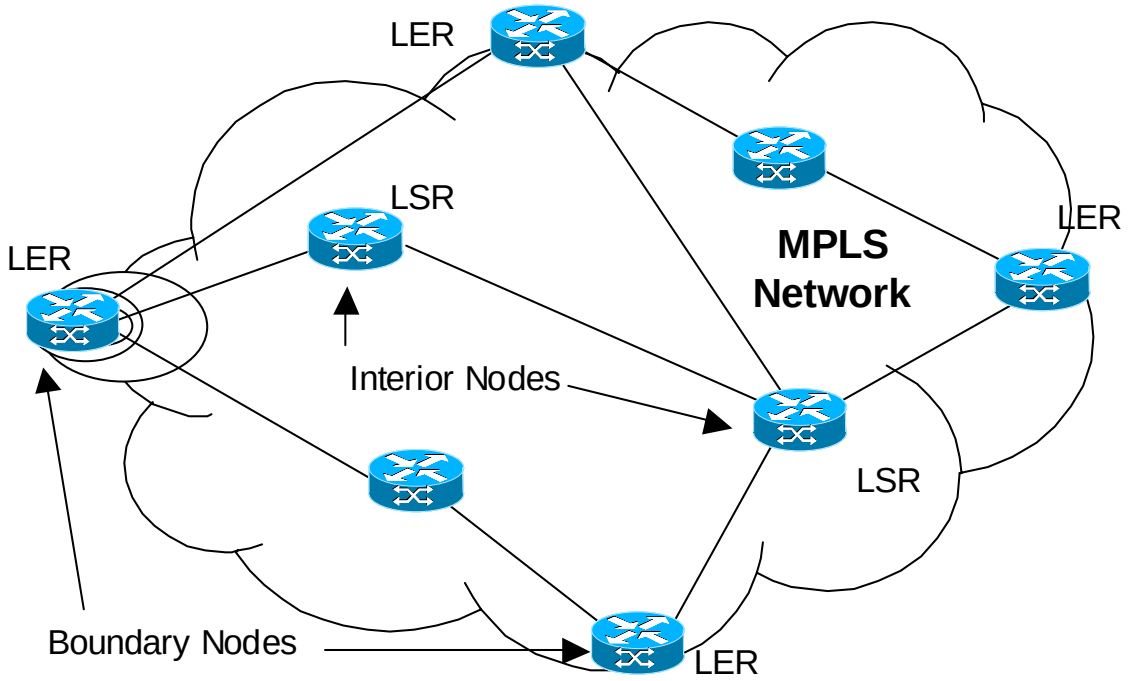
What is Traffic Engineering

- From RFC 3272
  - "Internet traffic engineering is defined as that aspect of Internet network engineering dealing with the issue of performance evaluation and performance optimization of operational IP networks. Traffic Engineering encompasses the application of technology and scientific principles to the measurement, characterization, modeling, and control of Internet traffic....."
- The ability to better control your traffic
  - It allows your IP network to route in a source-destination specific manner
    - Standard IP networks only route based on destination

MPLS - Introduction

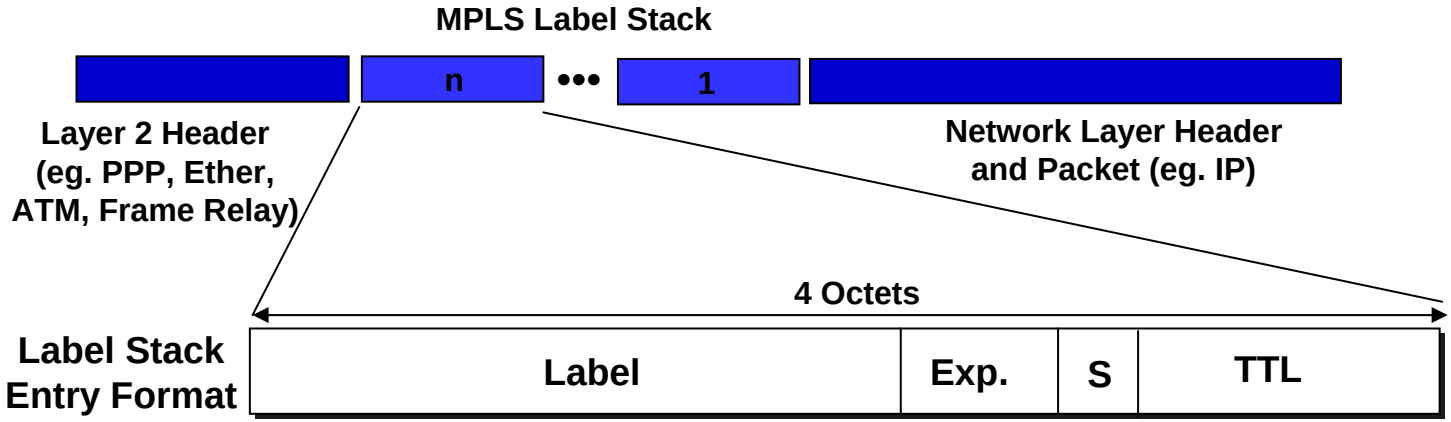
- MPLS (and GMPLS) manage data paths within transport networks using IP based control mechanisms
- Data paths are identified using a label
- MPLS was conceived as a packet-based technology
  - The payload originally focused IP
  - Forwarding is packet or cell-based
    - Each packet, or cell, is labeled
    - Forwarding involves label look-up and swap
- GMPLS adds support for
  - SONET/SDH (TDM), Optical (Lambdas), and Ports
  - Includes packet support
- Provide a foundation for data transport applications

Interior and Boundary Nodes in an MPLS Network



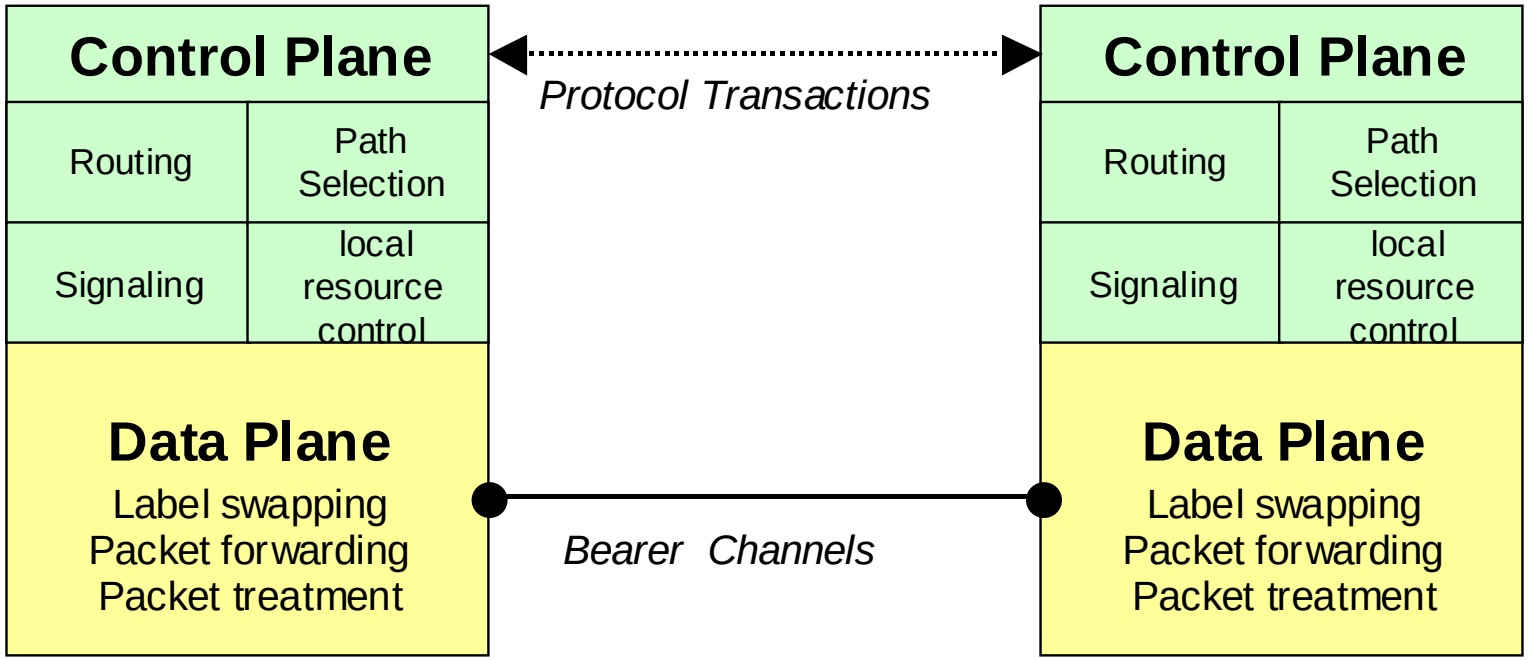
MPLS Labels

- Labels are identifiers used in forwarding
- Label values have meaning between two nodes NOT end-to-end
- There may be multiple labels stacked per packet



Label: **Label Value, 20 bits (0-16 reserved)**
Exp.: **Experimental, 3 bits (Class of Service is one use)**
S: **Bottom of Stack, 1 bit (1 = last entry in label stack)**
TTL: **Time to Live, 8 bits**

Functional View of Control and Forwarding Planes



Dichotomies in the Classification of Traffic Engineering Systems

Dynamic vs Static	Online vs Offline	Predictive vs Descriptive
Proactive vs Reactive	Time dependent vs State Dependent	Open Loop vs Closed Loop
Tactical vs Strategic	Local info vs Global info	Centralized vs Distributed

LSP Types

- Prefix based
  - LSPs created based on “route” advertisement
  - Controlled by routing or signaling
  - Some application at the edge
- Tunnel based
  - LSPs created between specific MPLS end-points
  - Controlled by signaling
  - Applicable to the core
- MPLS LSPs are always unidirectional
  - Two LSPs required to support bi-directional traffic
  - GMPLS adds bi-directional support
- Different control protocol supports different types

MPLS Evolution

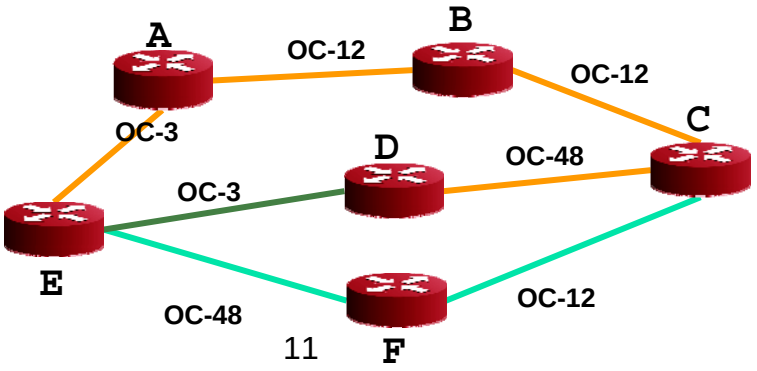
- Following Ipsilon and IP Switching cisco's Tag Switching and TDP and IBM's ARIS came about
- MPLS signaling protocol
  - LDP
  - RSVP-TE
- IP routing protocols used
  - OSPF-TE, ISIS-TE and BGP (VPNs)

A Few Standardization Drafts

- RFCs
  - RFC 2702 - Requirements for Traffic Engineering Over MPLS
  - RFC 3272 – Overview and Principles of Traffic Engineering
  - RFC 3346 - Applicability Statement for Traffic Engineering with MPLS
  - RFC 3209 - RSVP-TE: Extensions to RSVP for LSP Tunnels
  - RFC 3212 - Constraint-Based LSP Setup using LDP
  - Traffic Engineering Extensions to OSPF Version 2
  - IS-IS extensions for Traffic Engineering

Constrained SPF (CSPF)

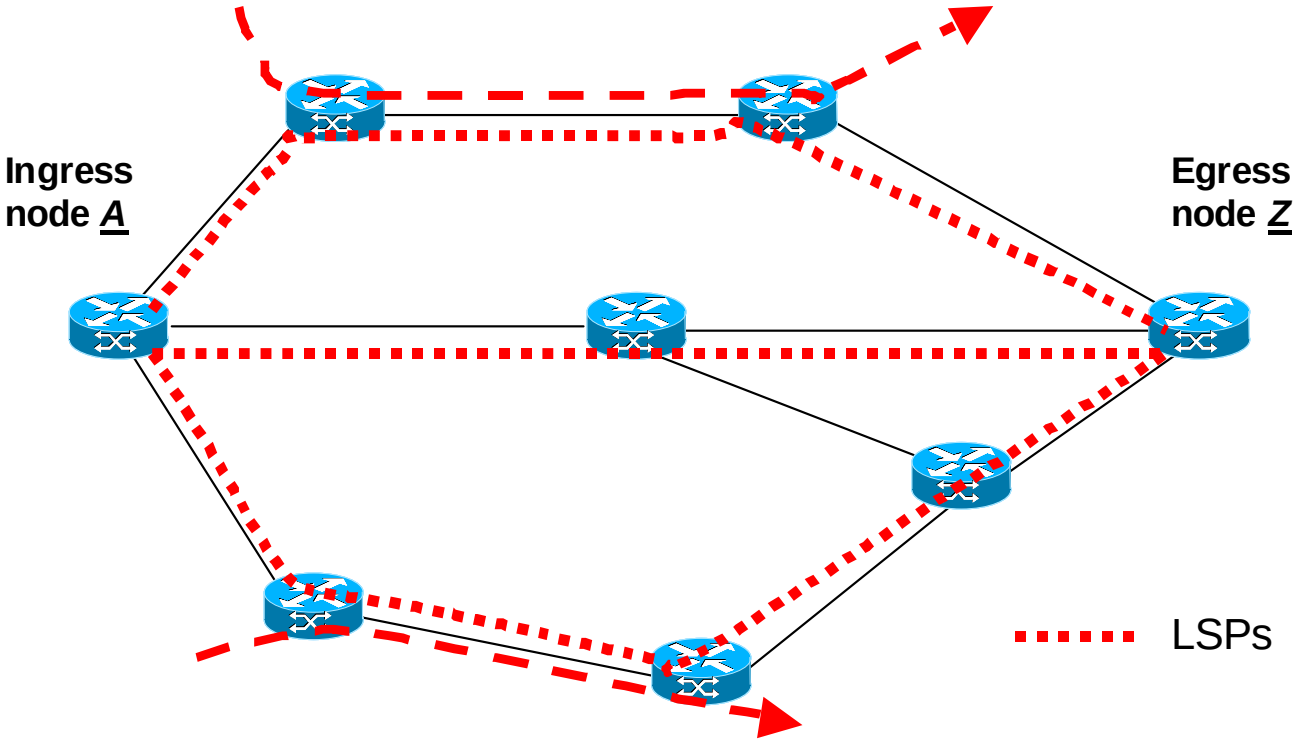
- CSPF is an advanced form of the SPF algorithm used in OSPF and IS-IS networks.
- Allows a network to use its resources at its maximum efficiency by enhancing traditional SPF implementations
- CSPF not only considers the topology of the network but the attributes of its links as well.
- A routing node running CSPF will parse its LSDB for entries matching the criteria needed. The resulting entries then form a temporary table called the Traffic Engineering Database (TEDB)
- This temporary table is used to find the traffic engineered shortest path by running the SPF algorithm against it, to create the desired LSP.



Modeling Using Queueing Networks

- Analytical modeling and mathematical formulation of the MPLS traffic engineering problem
- Traffic partitioning and assignment

Three Parallel LSPs Between Two Nodes – An Illustrative Network



Problem Definition

- MPLS TE optimization problem deals with the optimal partitioning and assignment of traffic to parallel LSPs between pairs of MPLS ingress and egress nodes
  - Dynamic control of the partitioning of traffic
  - Assignment of the partitions to parallel LSPs to optimize network performance

Mathematical formulations

- Consider three paths between ingress node ***A*** and egress node ***Z***
- The questions to be addressed is How to map the input traffic (which arrives according to a stochastic process) dynamically and efficiently onto the parallel paths.
- The approach is based on developing an analytical model to obtain the optimal partitioning of ingress traffic and the subsequent mapping of the traffic onto the parallel LSPs, taking into account the current state of the network
- Each LSP can be modeled by a network of queues
- To simplify the problem, so that each node along the LSP is represented by a queue and each queue is characterized as an M/M/1/K system.
- The model takes into account the aggregate traffic arriving at each nodal queue, some of which is contributed by traffic from the target LSP traversing the node, while the remaining traffic is contributed by all other LSPs that traverse the node.
- An iterative methodology is then applied to solve the resulting problem