Session 2:

MPLS Traffic Engineering and Constraint-Based Routing (CR)

MPLS Routing

- The need for Traffic Engineering extensions
  - ✓ Constraint-based Routing (CR)
- OSPF Traffic Engineering (OSPF-TE)
  - ✓ TE link characteristics
  - ✓ OSPF-TE LSA (Link State Advertisements)
- IS-IS Traffic Engineering (ISIS-TE) in comparison with OSPF-TE

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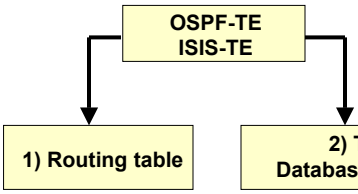
Limitations of Current IGP Control Mechanisms

- Interior Gateway Protocol (IGP) control capabilities are not adequate for Traffic Engineering (TE)
- IGPs based on shortest path algorithms significantly contribute to congestion problems in Autonomous Systems (AS) within the Internet
  - ✓ protocols are topology driven
  - ✓ Shortest Path First (SPF) algorithms generally optimize based on a simple additive metric
  - ✓ bandwidth availability and traffic characteristics are not considered in routing decisions

Open Shortest Path First (OSPF)

- OSPFv2
  - ✓ Interior Gateway Protocol (IGP)
  - ✓ link-state protocol
    - ➢ neighbour discovery and maintenance
    - ➢ Link State Advertisements (LSA)
      - link-state database
      - link state database distribution (reliable flooding)
    - ➢ routing calculations
      - Dijkstra's Shortest Path First (SPF) algorithm
- TE extensions
  - ✓ extended link attributes
  - ✓ extended database

Constraint-based Routing
Operational Model



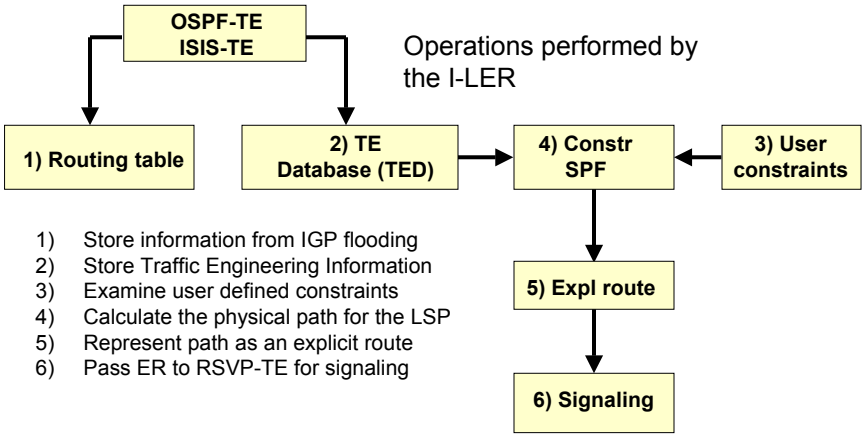
Operations performed by the I-LER

1) Store information from IGP flooding in a routing table
2) Store Traffic Engineering Information in a TED

OSPF and IS-IS - **TE** extensions

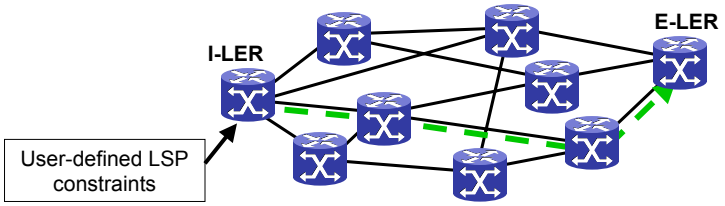
- Distributed (piggybacked) on Opaque Link State Advertisements (LSA)
- Encoded as new "Type-Length-Values" (TLV) objects
- New parameters: TE metric (e.g., delay, loss, cost), max BW, max reservable BW, unreserved BW, administrative group ("color")

Constraint-based Routing
Operational Model



1) Store information from IGP flooding
2) Store Traffic Engineering Information
3) Examine user defined constraints
4) Calculate the physical path for the LSP
5) Represent path as an explicit route
6) Pass ER to RSVP-TE for signaling

Constraint-based Routing



- LSP constraints are configured at the Ingress LER
  - ✓ bandwidth requirement
  - ✓ inclusion or exclusion of specific links
  - ✓ Inclusion of specific nodes traversal
  - ✓ QoS and/or CoS parameters
- Control mechanisms select an LSP path that meets the constraints

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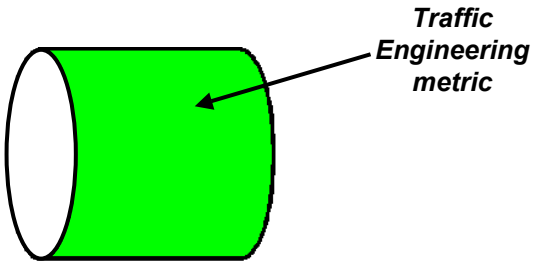
OSPF-TE

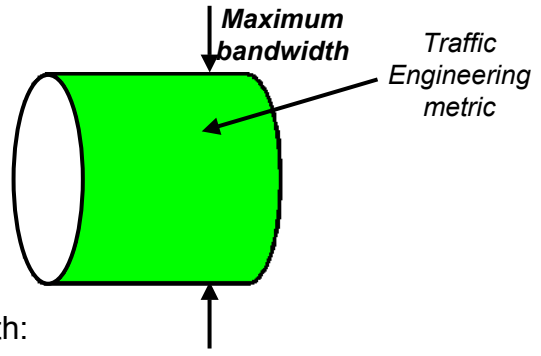
- TE-enabling link characteristics
  - ✓ traffic engineering metric, e.g.:
    - ➢ delay, delay variation, loss
  - ✓ maximum bandwidth, i.e.:
    - ➢ nominal bandwidth of a link
  - ✓ maximum reservable bandwidth; allows to specify:
    - ➢ over-provisioning
    - ➢ over-subscription
  - ✓ unreserved bandwidth
    - ➢ for each of eight classes
  - ✓ resource class/color
    - ➢ a bit mask that determines to which class(es) a link belongs (e.g., satellite link, link that can be used only by selected users, link with special pricing)

TE Link Characteristics
Traffic Engineering Metric



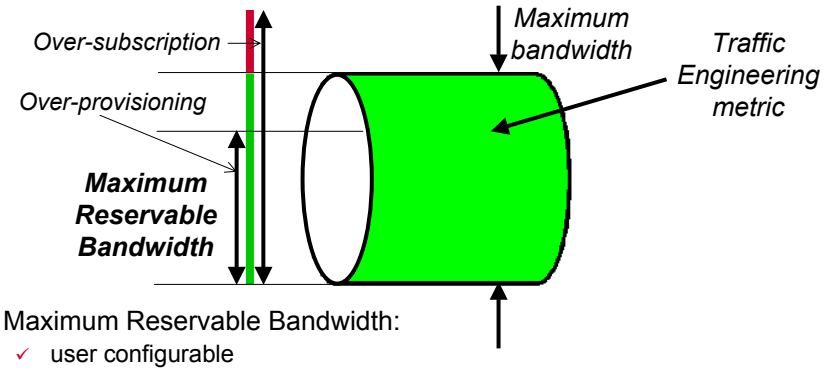
- Traffic Engineering metric
  - ✓ link metric (e.g., delay, delay variation)
  - ✓ may be different than the standard OSPF link metric

TE Link Characteristics
Maximum Bandwidth



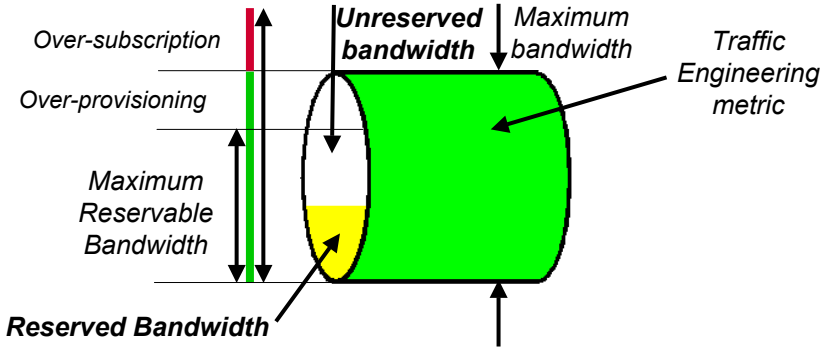
- Maximum Bandwidth:
  - ✓ true link capacity
  - ✓ units: bytes per second

TE Link Characteristics
Maximum Reservable Bandwidth



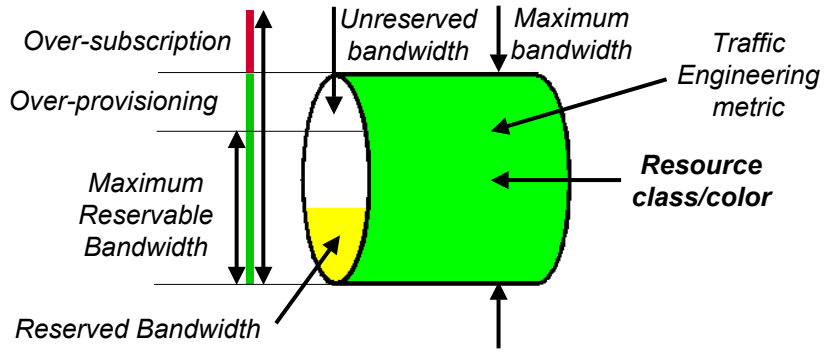
- Maximum Reservable Bandwidth:
  - ✓ user configurable
  - ✓ units = bytes per sec
    - ➢ = max BW ← default
    - ➢ < max BW ← over-provisioning
    - ➢ > max BW ← over-subscription

TE Link Characteristics
Unreserved Bandwidth



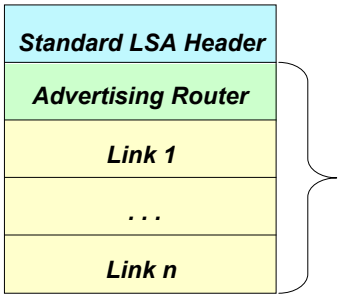
- Unreserved Bandwidth
  - ✓ bandwidth not yet reserved at each of 8 priority levels
  - ✓ initial values = Maximum Reservable Bandwidth

TE Link Characteristics
Resource Class/Color



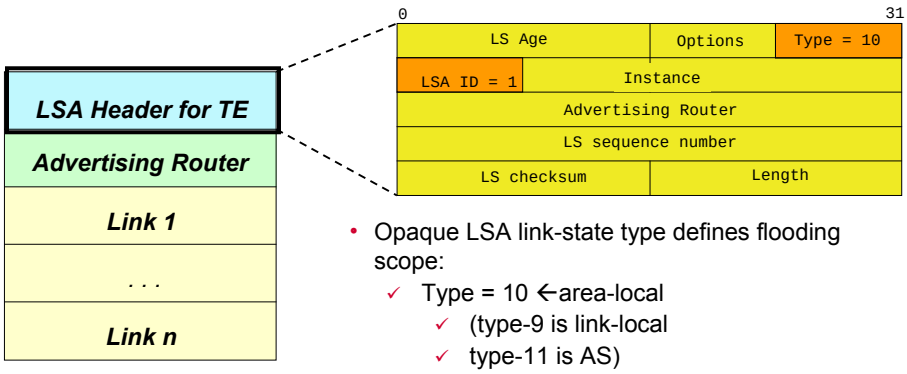
- Resource Class/Color
  - ✓ administrative group membership per link
  - ✓ bit mask

Opaque LSA Format for OSPF-TE



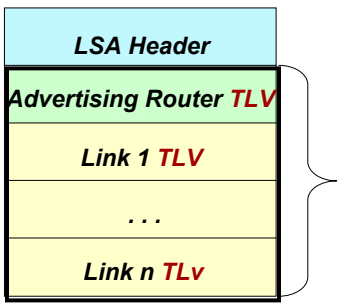
LSA Payload
- *32-bit word aligned*
- *application-specific*
- *coded as TLVs, I.e., Type-Length-Value triplets*

OSPF-TE
Opaque LSA Header



- Opaque LSA link-state type defines flooding scope:
  - ✓ Type = 10 ←area-local
    - ✓ (type-9 is link-local
    - ✓ type-11 is AS)
- LSA ID = 1 (TE)
  - ✓ Instance – arbitrary value used to maintain multiple TE LSAs

OSPF-TE
Opaque LSA Payload



- Type
  - 1 = router address (single TLV)
  - 2 = link (nested TLVs)
- Length = number octets in the Value portion
- Value
  - depends on the type
  - 32-bit aligned
  - padding is not included in the Length count
  - nested TLVs: Value is a set of sub-TLVs

OSPF-TE
Opaque LSA - Link sub-TLVs

Link sub-TLVs	Type	Length
Link type (point-to-point or multi-access)	1	1 octet
Link ID (in pt-to-pt router ID of a neighbor)	2	4 octets
Local interface IP address (1 to N local addr)	3	4N octets
Remote interface IP address (1 to N rem addr)	4	4N octets
Traffic engineering metric	5	4 octets
Maximum bandwidth	6	4 octets
Maximum reservable bandwidth	7	4 octets
Unreserved bandwidth	8	32 octets
Administrative group ("resource class/color")	9	4 octets

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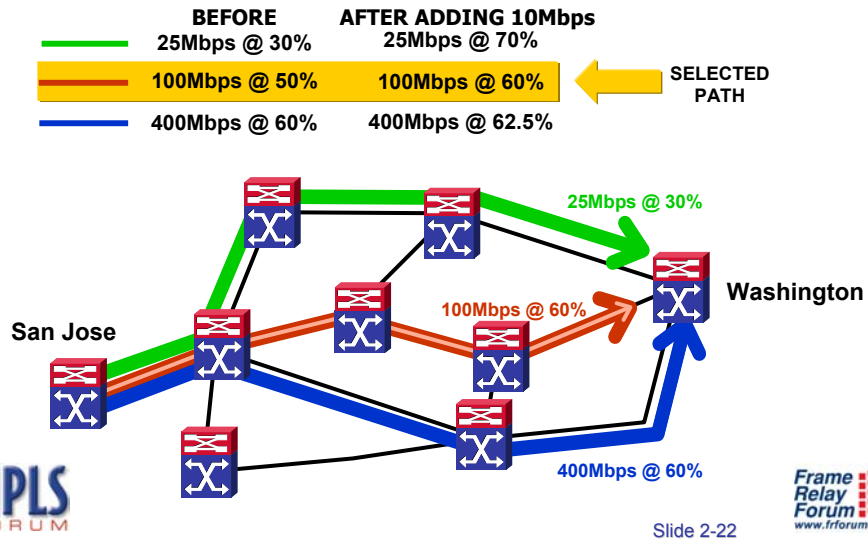
ISIS-TE vs. OSPF-TE

TE Extension	OSPF	ISIS
Traffic Engineering metric	√	√
Maximum bandwidth	√	√
Maximum reservable bandwidth	√	√
Unreserved bandwidth	√	√
Resource class/color	√	√

Path Computation Using Estimated Bandwidth for Best Effort Traffic



MPLS Routing
Summary

- Traffic Engineering extensions for OSPF and IS-IS
  - ✓ provide routers a dynamic and more exact view on network capacity, load, congestion state, and other link attributes
  - ✓ enable Constraint-based Routing (CR) through intelligent path computation/explicit route determination, and therefore MPLS Traffic Engineering

IGP-TE References

- OSPF-TE references:
  - ✓ "Traffic Engineering Extensions to OSPF version 3," draft-ietf-ospf-ospfv3-traffic-00.txt, April 2003
  - ✓ "Traffic Engineering Extensions to OSPF version 2,"draft-katz-yeung-ospf-traffic-09.txt, October 2002
- IS-IS-TE reference:
  - ✓ "IS-IS extensions for Traffic Engineering," draft-ietf-isis-traffic-04.txt, December 2002

End of Session 2

Thank You