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
MPLS Routing

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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

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

OSPF-TE
ISIS-TE

Operations performed by the I-LER

1) Routing table
2) TE Database (TED)
4) Constr SPF
5) Expl route
6) Signaling

- 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

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**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

**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

Standard LSA Header
- Advertising Router
- Link 1
- ...
- Link n

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**

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

### MPLS Routing

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### ISIS-TE vs. OSPF-TE

<table>
<thead>
<tr>
<th>TE Extension</th>
<th>OSPF</th>
<th>ISIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Engineering metric</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Maximum bandwidth</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Maximum reservable bandwidth</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Unreserved bandwidth</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Resource class/color</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

### Path Computation Using Estimated Bandwidth for Best Effort Traffic

**BEFORE**
- 25Mbps @ 30%
- 100Mbps @ 50%
- 400Mbps @ 60%

**AFTER ADDING 10Mbps**
- 25Mbps @ 70%
- 100Mbps @ 60%
- 400Mbps @ 62.5%

**SELECTED PATH**
- 25Mbps @ 30%
- 100Mbps @ 60%
- 400Mbps @ 60%
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

• IS-IS-TE reference:
End of Session 2

Thank You