Network vs. Traffic Engineering

- **Network engineering**
  - **Build your network to carry your predicted traffic**
- **Traffic engineering**
  - **Manipulate your traffic to fit your network**
- **Traffic patterns are impossible to accurately predict**
- **Symmetric bandwidths/topologies, asymmetric load**
- **TE can be done with IGP costs, ATM/FR, or MPLS**

Motivation for Traffic Engineering

- **Increase efficiency of bandwidth resources**

  Prevent over-utilized (congested) links whilst other links are under-utilized

- **Ensure the most desirable/appropriate path for some/all traffic**

  Override the shortest path selected by the IGP

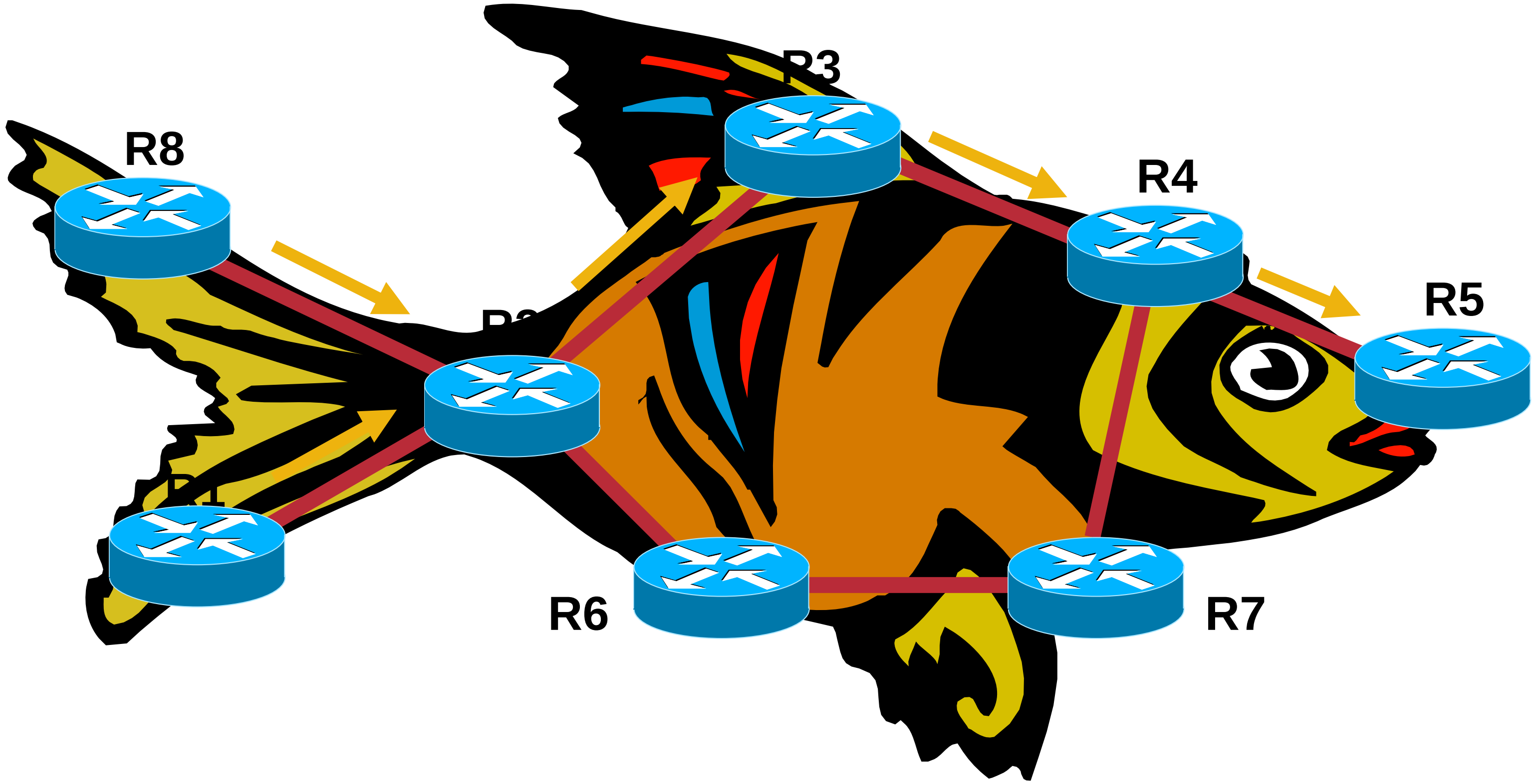
- **Replace ATM/FR cores**

  PVC-like traffic placement without IGP full mesh and associated O(N^2) flooding

- **The ultimate goal is COST SAVING**

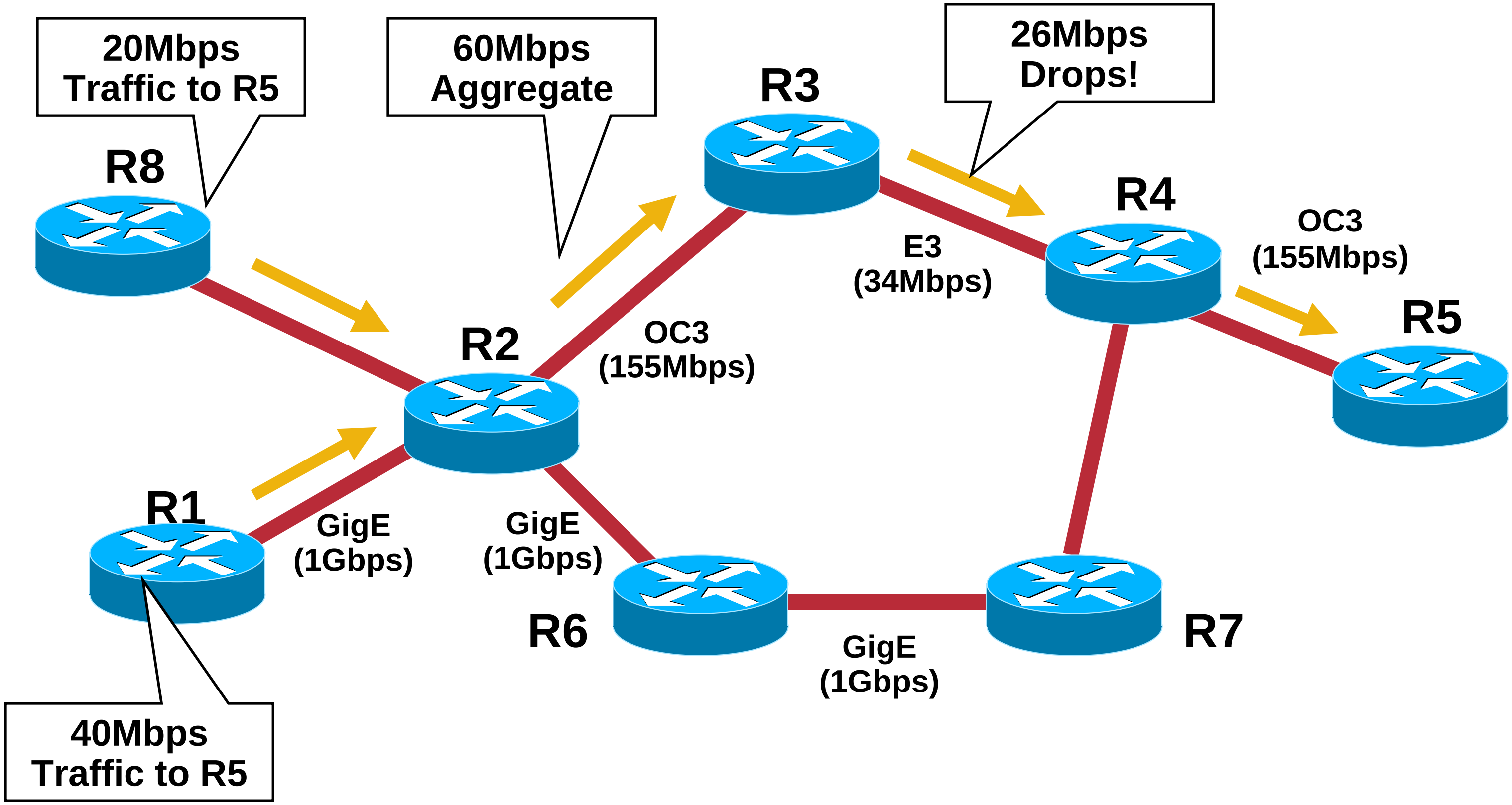
  Service development also progressing

The “Fish” Problem (Shortest Path)

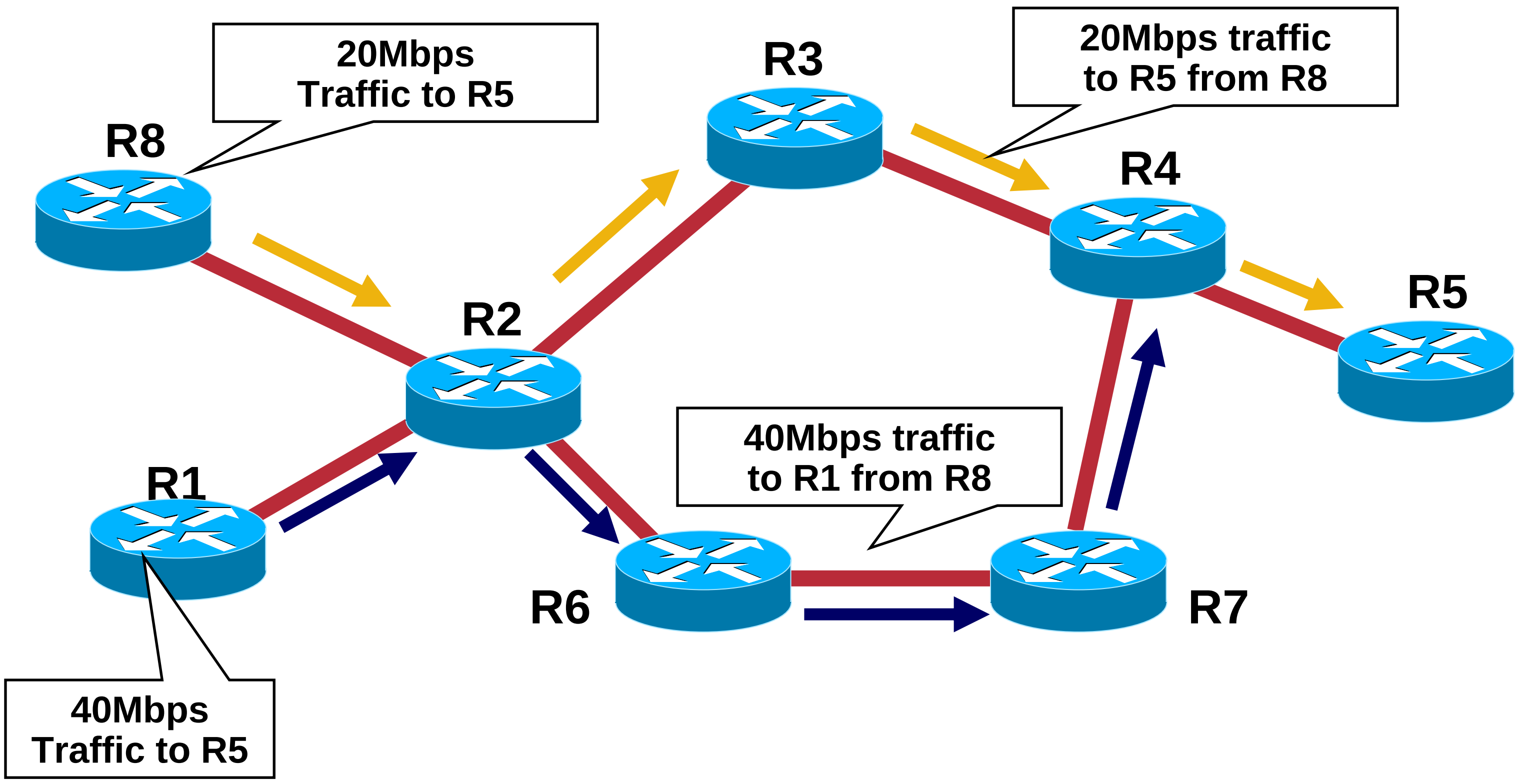


- IP uses shortest path destination-based routing
- Shortest path may not be the only path
- Alternate paths may be under-utilized
- Whilst the shortest path is over-utilized

Shortest Path and Congestion



The TE Solution



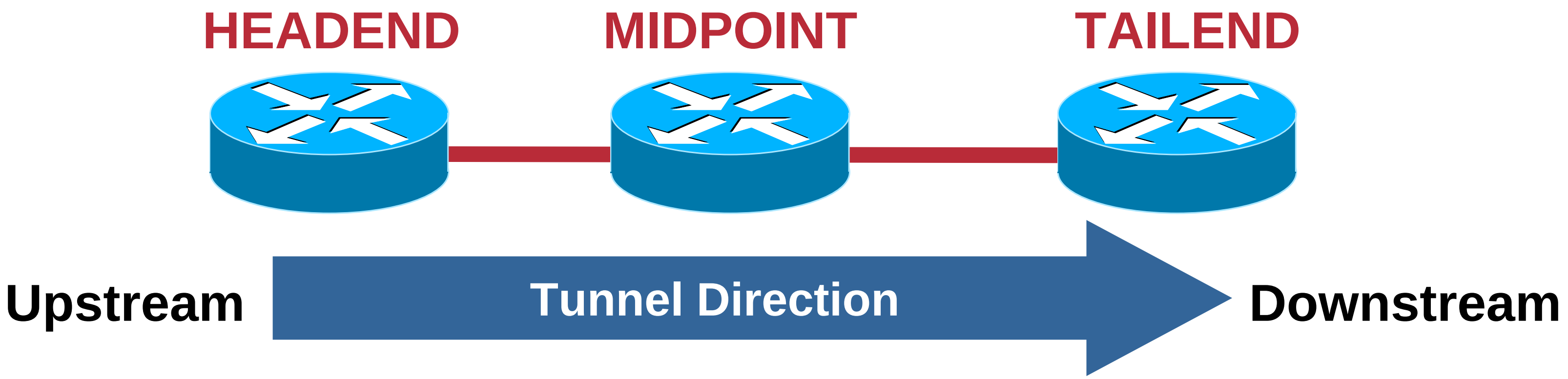
- MPLS Labels can be used to engineer explicit paths
- Tunnels are UNI-DIRECTIONAL

Normal path: R8 → R2 → R3 → R4 → R5

Tunnel path: R1 → R2 → R6 → R7 → R4

Terminology

- **Constrained-Based Shortest Path First (CSPF)**
  - **MPLS-TE uses CSPF to create a shortest path based on a series of constraints:**
    - **Bandwidth**
    - **Affinity/link attributes**
    - **…or an explicitly configured path**
- **Tunnels are UNI-DIRECTIONAL!**



TRAFFIC
ENGINEERING THEORY

Traffic Engineering Components

- **Information distribution**
- **Path selection/calculation**
- **Path setup**
- **Trunk admission control**
- **Forwarding traffic on to tunnel**
- **Path maintenance**

Information Distribution

- **Need to flood TE information (Resource Attributes) across the network**
  - **Available bandwidth per priority level, a few other things**
- **IGP extensions flood this information**
  - **OSPF uses Type 10 (area-local) Opaque LSAs**
  - **ISIS uses new TLVs**
- **Basic IGP: {self, neighbors, cost to neighbors}**
- **TE extensions: {self, neighbors, cost to neighbors, available bandwidth to neighbors}**
- **TE bandwidth is a control-plane number only**

Path Calculation

- Once available bandwidth information and attributes are flooded, router may calculate a path from head to tail
    - Path may be explicitly configured by operator
- TE Headend does a “Constrained SPF” (CSPF) calculation to find the best path
- CSPF is just like regular IGP SPF, except
    - Takes required bandwidth and attributes into account
- Looks for best path from a head to a single tail (unlike OSPF)
- Minimal impact on CPU utilization using CSPF
- Path can also be explicitly configured

Path Setup

- **Once the path is calculated, it must be signaled across the network**
  - **Reserve any bandwidth to avoid "double booking" from other TE reservations**
  - **Priority can be used to pre-empt low priority existing tunnels**
- **RSVP used to set up TE LSP**
  - **PATH messages (from head to tail) carries LABEL_REQUEST**
  - **RESV messages (from tail to head) carries LABEL**
- **When RESV reaches headend, tunnel interface = UP**
- **RSVP messages exist for LSP teardown and error sig**

Trunk Admission Control

- **On receipt of PATH message**
  - **Router will check there is bandwidth available to honour the reservation**
  - **If bandwidth available then RSVP accepted**
- **On receipt of a RESV message**
  - **Router actually reserves the bandwidth for the TE LSP**
  - **If pre-emption is required lower priority LSP are torn down**
- **OSPF/ISIS updates are triggered**