Lecture 8

WDM Network Design

Homework #3:

8.2 Ramaswami

8.3 Ramaswami

8.4 Ramaswami

8.7 Ramaswami

LTD and RWA Problems

- Look at a design problem where
  - The underlying fiber topology does not pose any constraint
  - All lightpaths are bi-directional
  - Each node has an IP router with at most Δ ports connecting to other IP routers
  - Number of lightpaths in the network is therefore constrained on Δ

LTD and RWA Problems

- Assume a statistical model for IP traffic
  - Arrival rate for packets for source-destination (s-d) pair *(s,d)* is λ^{sd}, s,d = 1, ….m
  - b_{ij}, i,j = 1, …,n, $i \neq j$ are binary variables for each possible lightpath (i,j).
  - Solution to the lightpath design problem is to specify the set $\{b_{ij}\}$
  - a_{ij}^{sd} is the fraction of traffic between pair *(s,d)* routed over link (i,j)
  - $\lambda_{ij}^{sd} = a_{ij}^{sd} \lambda^{sd}$ is the traffic in packets/sec between pair *(s,d)* routed over link (i,j)
  - Total traffic over all pairs routed over link (i,j) is

$$\lambda = \sum_{sd} \lambda_{ij}^{sd}$$

Congestion Parameter and Queuing Delay

- Define ***congestion*** parameter $\lambda_{max} = \max_{ij}\{\lambda_{ij}\}$
- We must determine variables λ_{ij}^{sd}, λ_{max} and λ_{ij}
- The process of determining λ_{ij}^{sd}, λ_{max} and λ_{ij} is equivalent to the problem of finding a routing algorithm

- Example:
  - Packet transmission times are exponentially distributed (Poisson Process) with mean time $1/\mu$ seconds.
  - Model each link as an M/M/1 queue, where it is assumed that traffic offered to a link in the network is independent of the traffic offered to other links.
  - The average queuing delay under these assumptions is

$$d_{ij} = \frac{1}{\mu - \lambda_{ij}}$$

Throughput

- ***Throughput*** is defined as minimum value of the offered load for which any link experiences infinite delay, which happens when

$$\lambda_{\max} = \max_{ij} \lambda_{ij} = \mu$$

- Performance objective

$$\text{Minimize } \left(\lambda_{\max}\right)$$

- Subject to the following flow conservation at each node

$$\sum_j \lambda_{ij}^{sd} - \sum_j \lambda_{ji}^{sd} = \begin{cases} \lambda^{sd} & \text{if } s = i, \\ -\lambda^{sd} & \text{if } d = i, \\ 0 & \text{otherwise,} \end{cases} \qquad \text{for all } s,d,i$$

- Subject to the total flow on a logical link

$$\lambda_{ij} = \sum_{s,d} \lambda_{ij}^{sd}, \quad \text{for all } i, j,$$

$$\lambda_{ij} \le \lambda_{\max}, \quad \text{for all } i, j,$$

$$\lambda_{ij}^{sd} \le b_{ij} \lambda^{sd}, \quad \text{for all } i, j,$$

Throughput

- ⇨ Subject to degree constraints

$$\sum_i b_{ij} \le \Delta, \qquad \text{for all } j,$$

$$\sum_j b_{ij} \le \Delta, \qquad \text{for all } i.$$

- ⇨ Subject to bidirectional lightpath constraint

$$b_{ij} = b_{ji}, \qquad \text{for all i}, j.$$

- ⇨Subject to Nonnegativity and integer constraints

$$\lambda_{ij}^{sd}, \lambda_{ij}, \lambda_{\max} \ge 0, \qquad \text{for all i}, j, s, d$$

$$b_{ij} \in \{0,1\}, \qquad \text{for all i}, j.$$

Throughput

- ⇨ We associate packets routed between pair (s,d) as the ***flow*** of a commodities.
- ⇨ The flow conservation constraint at node *i* yields the net flow out of node *i* for one commodity *(s,d)*.
- ⇨ The net flow is the difference between the outgoing and ingoing flows.
- ⇨ The flow conservation is 0 if a node is neither a source or destination of that particular commodity.
- ⇨ If node *i* is the source of the flow ($i=s$) the net flow = λ^{sd}
- ⇨ If node *i* is the destination of the flow ($i=d$) the net flow = $-\lambda^{sd}$