Research Problems in Dynamic Traffic Grooming
A Position

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Outline

- Context
- Static traffic grooming
- Dynamic traffic grooming
- Example - recent results
Context - Static Traffic Grooming
The Different Faces of Grooming

- Multiplexing
  - Single wavelength bandwidth quite large
  - Need to multiplex lower speed data streams

- Termination cost
  - Optical signal terminated by wavelength
  - Terminating one wavelength terminates all subwavelength
  - Other streams have to be electronically forwarded
  - Cost – amount of electronic routing, or equipment
  - At a node or total

- Cost could be other equipment (OTDM, tuning lasers?)

- We would like to tailor the multiplexing to minimize such network equipment cost
  - “Groom” traffic, in other words
Dynamic Traffic Grooming

- Recent growing interest in this area
  - Generalization
  - ROADMs
  - Grooming point moving in the network

- Literature starting to appear
  - Mukherjee et al, Perros et al, Qiao et al, Ramamurthy et al, Sasaki et al, Somani et al, Xin et al …
  - Others have bearing, Modiano et al, Sivarajan et al, …
Design and Analysis

Design problem
- Given certain network conditions, obtain network design/strategy (perhaps partial), usually to optimize some benefit
- By and large the focus of STG

Analysis problem
- Given network condition and strategy, model/analyze to determine the quantity of some performance metric
- DTG has till date focused on this, specifically blocking probability
Traffic Grooming Arenas - Simplistic View

1. $t << C$, $\Delta t << C$
   - Packet switching

2. $t < C$, $0 < \Delta t < t$
   - DTG?

3. $t \sim C$, $0 < \Delta t < C$
   - DTG?

4. $t >\sim C$, $\Delta t \sim 0$
   - SLE, VTOP

Bandwidth

Peakedness / Burstiness
Variation Models

- Different models may be appropriate for different kinds of traffic / places in the network
  - Scheduled traffic - Mohan et al
  - Sliding scheduled traffic - Wang et al
  - Max envelope - Sasaki et al, Modiano et al
  - Min-max bounds? Matrix sets? With probability? Sequences?

- Two broad categories
  - Entirely predetermined - time can be folded out in a static model - formulate as ILP
  - Some uncertainty/unpredictability - formulate MDP
    - Expressible as exponential or otherwise
The Cost Function

- STG - all traffic usually assumed carried
- DTG - some may not be admitted - blocking probability (subwavelength calls)
- Network equipment cost
  - Might be handled as constraint, or
  - Could continue to be part of the objective
- Other considerations
  - Schedule length, delay, simplicity …
Design Approaches

- Virtual topology provides dynamic mediation
  - Traffic is definitely time-varying
  - Physical topology is definitely not
  - Lightpaths may or may not vary - network control
- May choose to install static virtual topology, and control grooming
- May choose to design strategy for translating traffic variation to (optional) lightpath additions or deletions
Model: traffic components are relatively static, but may change somewhat over time (LCAS)
- For revenue, increases are desirable to serve, decreases are desirable to leverage
- For resilience, need to react fast to opportunities

Over-provisioning at traffic demand level: use extra capacity, otherwise unutilized
- OXCs and DXCs configured to carry over-provisioned traffic

Family of traffic matrices supported
- All new traffic matrices that are subset of the over-provisioned traffic matrix

Lightpath slack limits over-provisioning
- Equal allocation
- Prorated allocation
- Inverse allocation
Over-provisioning Approaches

Different Methods of Over-Provisioning

- Equal over-provisioning method
  - Pick minimum over-provision over all traffic elements

- Selective over-provisioning method
  - Pick minimum over-provision for each individual traffic element

- Iterative over-provisioning method
  - Iteratively over-provision some traffic elements with any extra capacity, if available
  - Iterative-Min
  - Iterative-Max
  - Iterative-Ratio
  - Iterative-Max-lightpath
  - Iterative-Min-Max
Over-provisioning Example

\[ C = 15 \]

3,7,2
Over-provision
1,1,1

\[ T = \begin{pmatrix} 0 & 3 & 4 & 0 \\ 7 & 0 & 5 & 0 \\ 2 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \end{pmatrix} \]

\[ T_{prov}(Selective) = \begin{pmatrix} 0 & 7 & 7 & 0 \\ 8 & 0 & 8 & 0 \\ 3 & 0 & 0 & 0 \\ 4 & 0 & 0 & 0 \end{pmatrix} \]
Knowledge of Traffic Variation

- What if upper and lower bounds for traffic are known?
  - Allows smarter over-provisioning
  - Also possible to take current traffic state into account at each over-provisioning

- Assuming Poisson processes for increase and decrease, possible to model with a Markov Chain
Division of Slack

- Slack for each traffic component determines MTTF
- On a lightpath, individual traffic component slacks独立
- Over several lightpaths, over several traffic components, some correlation must be accounted for
- Finally, an over-provisioning method for the whole network
Summary

- DTG - a new arena for traffic grooming
- Different modes of traffic variation - driven by realistic network operation considerations
- Network equipment cost probably continues to be a significant consideration
- Design and analysis complement each other