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(Important Papers)

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Code	Title	Person
OWAA3	A Novel Two Step Approach to Surviving Facility Failures	Farhan, Uttam
OWAA5	A Network Design Technique for Selective Restoration	Chaitanya, Ferhat, Menglin
NTuA2	Benefits of Closer and Methods for Automatic Cooperation between Packet and Transport Networks	Menglin, Chaitanya
OThAA2	Wavelength Aware Translucent Network Design	Haydar
OThAA	Optical Impairments Session	MLR folks
OThAA6	Impairment Aware RWA based on K-Shuffle Edge-Disjoint Path Solution	MLR folks, Haydar, Avishek
OThI7	Heuristic Resource Provisioning for Dynamic Wavelength Services with Access Port Constraints	Richard
OThAA4	Efficient Regenerator Placement and Wavelength Assignment in Optical Networks	Avishek

A Network Design Technique for Selective Restoration

- Restoration:
  - Sufficient capacity/links in the network so that we can re-route flows in the event of failures.
- Restoration capacity/service capacity can be as high as 100%.
- Not practically feasible to ensure survivability against all failures.
  - Tradeoff between network cost, network performance, and availability.
- Common strategy: Protect against all single link failures.

A Network Design Technique for Selective Restoration

- By judiciously placing capacity one can do a good network design.
  - Network equipment have different failure rates.
    - 500-mile fiber span’s failure probability is two orders of magnitude larger than 5-mile span.
    - Long span failure – capacity for full protection.
    - Short span failure – capacity only for partial protection.
  - Each failure has different impact
    - Optical transponder affects a single circuit.
    - ROADM or router fails entire set of circuits.

A Network Design Technique for Selective Restoration

- By judiciously placing capacity one can do a good network design.
  - Cost of additional links and capacities needed to protect against failures varies widely among failures.
    - If many different failure need extra capacity on the same link, it is cost-effective to add capacity to this link in shared mesh restoration scheme.
  - Provide different levels of service to different traffic classes.

Network Model

- IP links are single circuits, e.g, OC-192, OC-768, or aggregate of many circuits.
- OSPF routing protocol
  - Each link has a weight.
  - Flows are routed over links of least weight.
  - OSPF may route flows over links of insufficient capacity, losses may occur.
  - Losses are estimated as a function of highest link utilization in the network.
    - Often proves faulty.

Identical Highest Link Utilizations, Different Packet Loss

Fig. 1. Identical highest link utilizations, but very different packet losses.

New Metric for Packet Loss

- CLPM Metric:
  - Bandwidth loss for a failure as the difference between the total offered traffic and the maximum traffic that can be routed without over-utilizing any links, computed using max-flow formulation.
- Expected CLPM over all failure states
  - $(10^6/\text{total traffic})\sum_s$ Pr(network is in state s) x (bandwidth loss in state s).
  - State s can be no failure, single failure, multiple failure, of router components (complete router, route line card, port, planned router upgrades), or layer-2 and layer-1 equipment (ROADMs, OTs, regenerators, amplifiers, fiber cuts).

New Metric for Packet Loss

- Each failure affects one or more links and is characterized by a mean time between failures (MTBF) and a mean time to restore (MTTR).
  - Its probability is MTTR/(MTBF+MTTR)
- Availability in terms of number of 9's = 1-CLPM/10^6.

Where to Add Capacity

- Given a network N with a set of links and their capacities.
- B(*l*, N): Benefit of adding unit capacity to *l* with out changing capacity of any other link.
- B(*l*, N): CLPM(N) – CLPM(N'), N' is N with extra unit of capacity added to *l*.
- Added capacity
  - Adding new link.
  - Adding extra circuit on an aggregated link.
  - Adding a new parallel link.

Heuristic

Input: (1) A base design of links and associated capacities such that in the absence of failures all demands can be routed with no congestion on any link. (2) CLPM threshold t. (3) Costs of adding unit capacities to links.

Set N to the current network

repeat

  for *every link* ℓ **do**

    $d_\ell = B(\ell, N)/(\text{cost of adding a unit of capacity to } \ell)$

  end

  Add a unit of capacity to the link with largest d_ℓ

  Set N to the new network

until $CLPM(N) \leq t$

Algorithm 1: Algorithm for deciding where to add capacity.

Simulation Experiments

- Tier-1 inter city backbone network of approximately 50 backbone routers (BRs).
- Access topology of 300 access routers (ARs).
- 1200 possible single failures from routers, router ports, ROADMs, OTs, OAs, fiber cuts etc.
- MTBFs and MTTRs are based on vendor provided information.
- Tested over 100,000 most probable failures.

Simulation Experiments

- Base design with all link-utilizations under 100% under any single failure
- Good performance with CLPM of 6.
- Two designs with
  - 21.1% cost savings over base with a CLPM of 155.
  - 26.3% cost savings over base with a CLPM of 165.
- 50% premium traffic, 50% non-premium traffic
  - CLPM for premium traffic is 8
  - CLPM for non-premium traffic is 323

Simulation Experiments

Design	traffic classes	Savings over base	CLPM	availability
1	none	21.1% inter-city	155	0.999845
2	none	26.3% inter-city	165	0.999835
2	two	26.3% inter-city	8, 323	0.999992, 0.99968
3	two	26.3% inter-city, 28% access ports	8, 1180	0.999992, 0.9988