Monitoring Burst (M-Burst) - A Novel Framework of Failure Localization in All-Optical Mesh Networks

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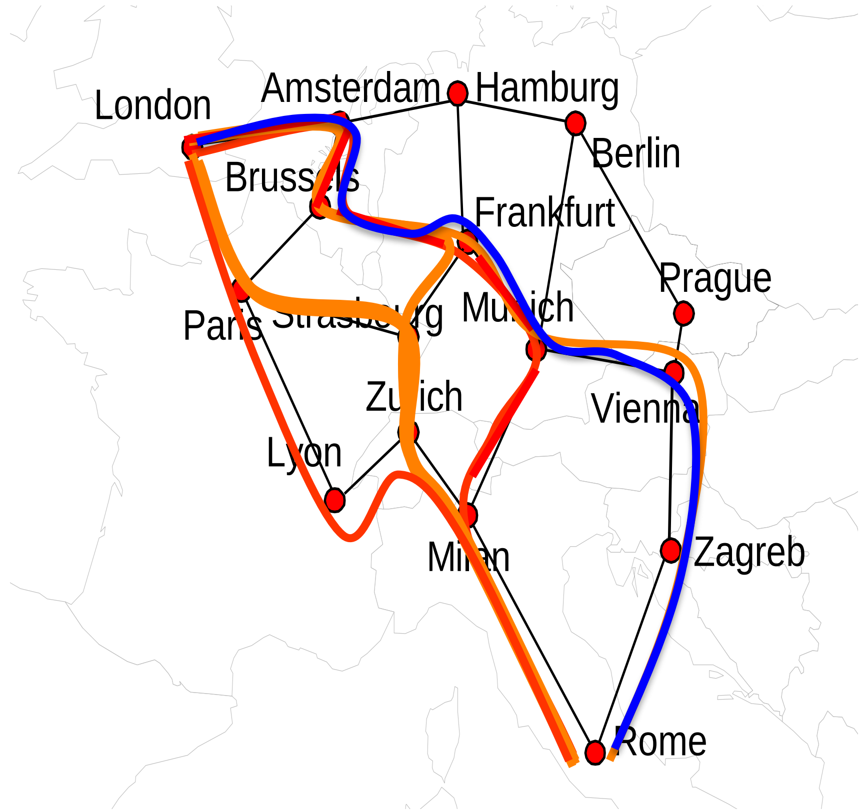
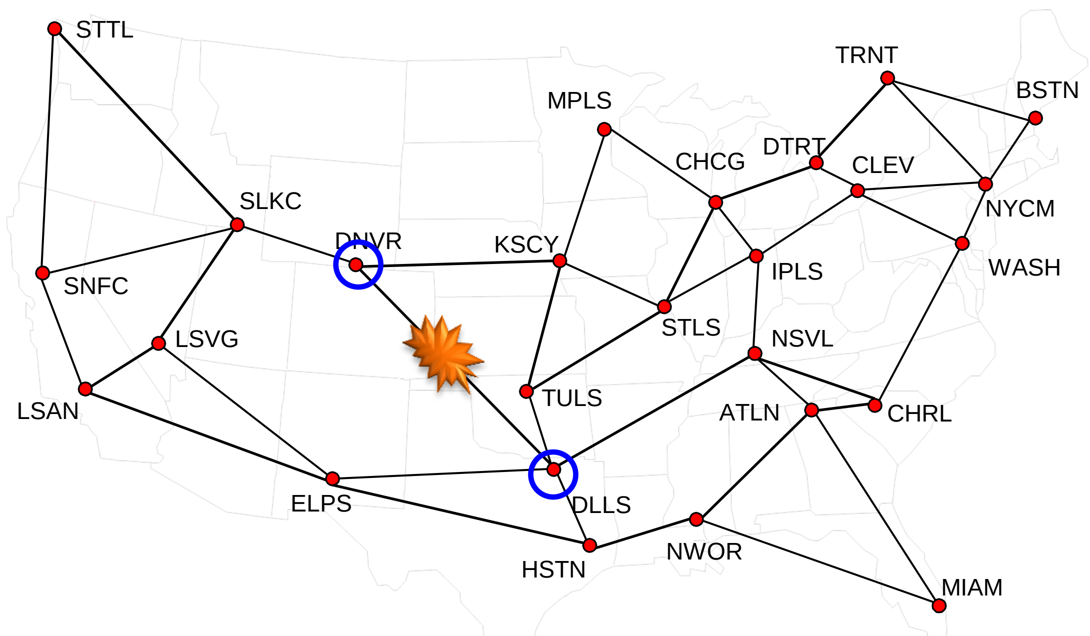
Survivabile Optical Networks

- Failure Independent Protection
  - Dedicated 1+1 protetion
  - Shared Backup Path Protection
  - ✗ For each connections disjoint paths are needed
- Failure Dependent Protection
  - Path Restoration
  - Re-route
  - ☑ Better flexibility to topology limitation
  - ☑ Better capacity efficiency
  - ✗ The failure must be localized in few tens of ms



Motivation

- The goal is to provide fast SRLG failure (cable cuts) localization in All-Optical Networks
  - Link monitoring
    - a naive solution by having an active alarm for each link
    - the number of monitors is $|E|$



How to localize failures?

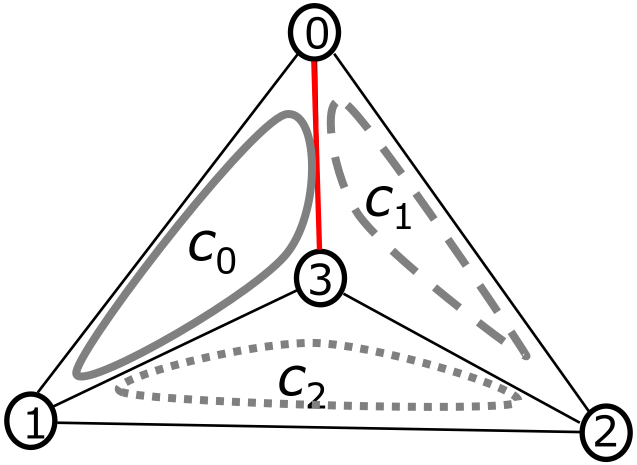
- Out-of-the band monitoring
  - Using dedicated supervisory lightpath
    - Monitoring-cycle/trails
  - ☑ Simpler and more reliable implementation
  - ☑ Fast failure localization
  - × Bandwidth requirements

- In-band-monitoring
  - ☑ Minimal bandwidth requirements
    - Taping operating connections only
  - × Less precision on failure localization
    - Combining with out-of-band monitoring
    - Dealing with imprecision of failure localization

Localizing Single Link Failure with Monitoring Cycles

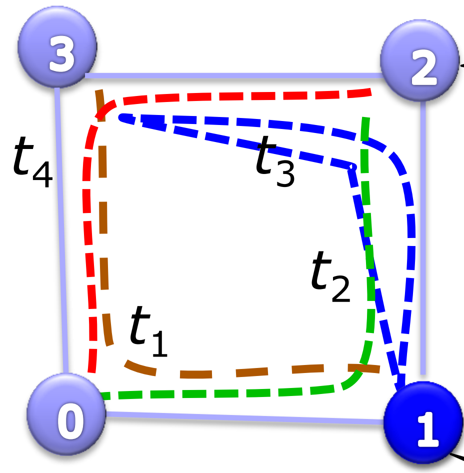
Alarm code table

	c_2	c_1	c_0
0–1	0	0	1
0–2	0	1	0
0–3	0	1	1
1–2	1	0	0
1–3	1	0	1
2–3	1	1	0



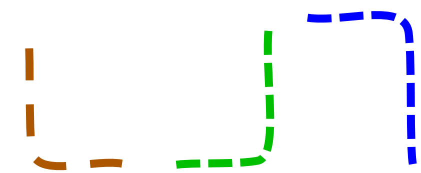
- A supervisory path (SP) is used to probe status of a group of fibre segments and components
- Each SP corresponds to a monitor which may alarm when any irregularity is identified
- By collecting all the flooded alarms in a failure event, the network controller can identify the failed SRLG instantly
- Achieve fast **unambiguous failure localization (UFL)**

Local-UFL solution



	t_2	t_3	t_4
0–1	1	1	0
1–2	0	1	1
2–3	0	0	1
3–0	1	0	0

ACT at node 2



	t_1	t_2	t_3
0–1	1	1	0
1–2	0	1	1
2–3	0	0	1
3–0	1	0	0

Alarm code table at node 1

- Monitoring Nodes (MN)
  - It can obtain the on-off status of the m-trails passing through via optical signal tapping
  - Alarm dissemination is no longer needed
  - For simplicity: 1 MN
- The number of alarms is no longer a concern
  - Minimize the cover length

Monitoring Resources Consumption

- In our experiments it may require 10 or even more WL per link

How to reduce the monitoring cost?

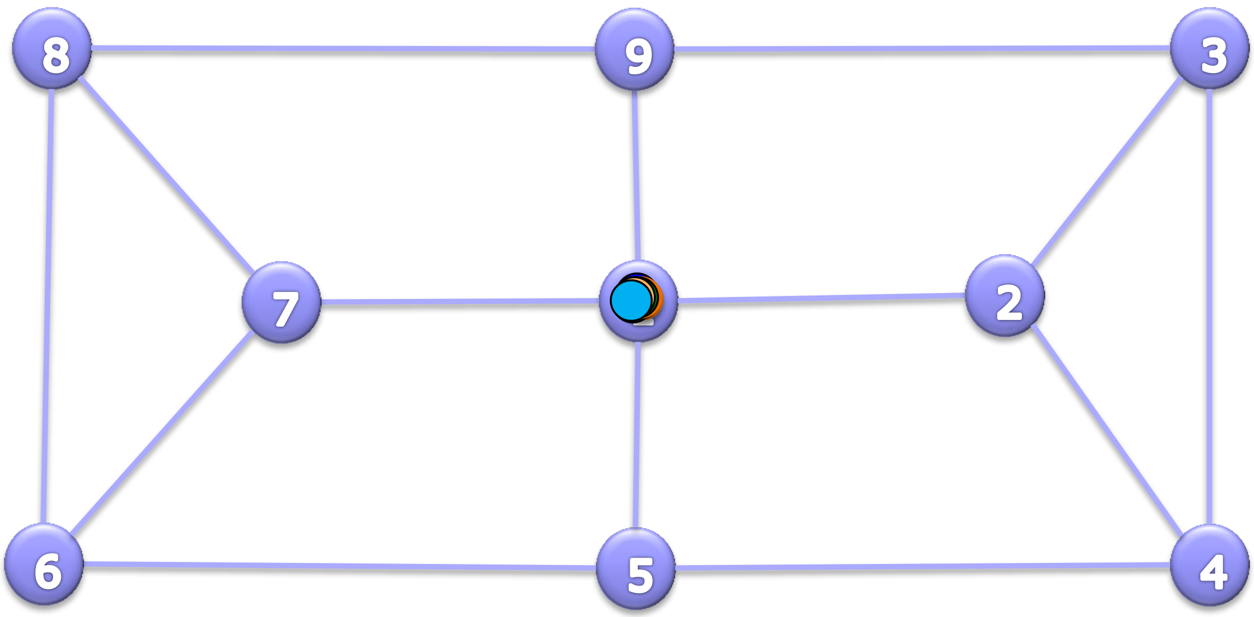
- **Time division multiplexing (TDM)** could be used to reduce monitoring resource consumption which require O/E/O conversion at intermediate nodes
- We use short duration optical burst along each m-cycle from a single MN called **monitoring burst (m-burst)**
  - To avoid collision, m-bursts are kept non-overlapping throughout the network by scheduling starting time of each m-burst

Architecture description

- The framework has **one MN**
- A set of **m-cycles** are identified for unambiguous single link SRLG failure localization
  - M-burst **routing** problem
- **Starting time** of short duration m-burst from the MN along each m-cycle is schedule to avoid burst collision
  - M-burst **scheduling** problem
- Just-Enough-Time (**JET**) [6] is suggested as resource reservation scheme
  - Tell-and-go signaling and delayed reservation scheme
  - A control packet first
  - Optical burst is sent with an offset time
    - Very short just to inspect the on-off status of the netwok equipment

Monitoring Burst (M-burst) scheduling problem

- The MN is the only sender and receiver of the bursts for all the m-cycles
- Goal is to determine starting times of the m-bursts in order to avoid burst collision
  - Minimize the monitoring delay



Goal: Minimize the monitoring delay

- Two extreme cases
  - using sufficient numbers of wavelength channels in each link for monitoring
  - using no more than one burst on-the-fly in the network
- At most a **single** wavelength channel is assigned for monitoring in each direction of a link
- Topology is known
  - Identify a set of **m-cycle** to localize single link SRLG faults unambiguously
  - Schedule the **starting time** of the m-bursts for the m-cycles from the MN
    - Keep m-bursts **non-overlapping** through any link

Min-max optimization of monitoring delay

Integer Linear Program

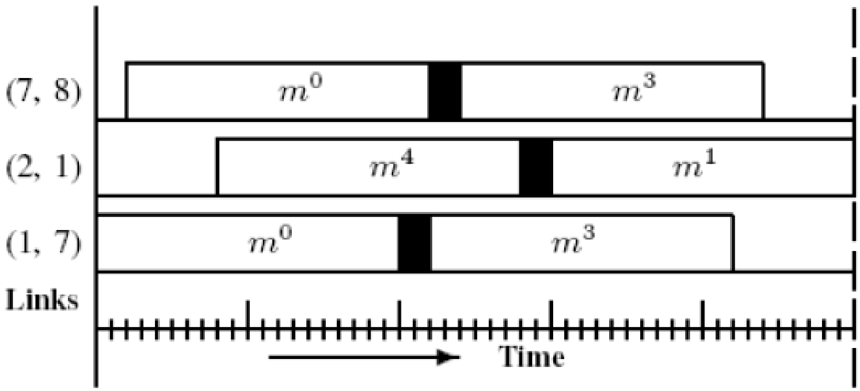
1. Constraints (2) - (15) are to identify a set of **m-cycles**
2. Constraint (16) is to find the maximum **number** of m-cycles traversing through any link in a single direction
3. Constraints (17) - (19) are to find **maximum delay** of m-bursts
4. Constraints (20) - (33) are to find burst **propagation delay** up to the sending ends of the links using recursion
5. Constraints (33) - (35) are to keep all the bursts **non-overlapping** through the links

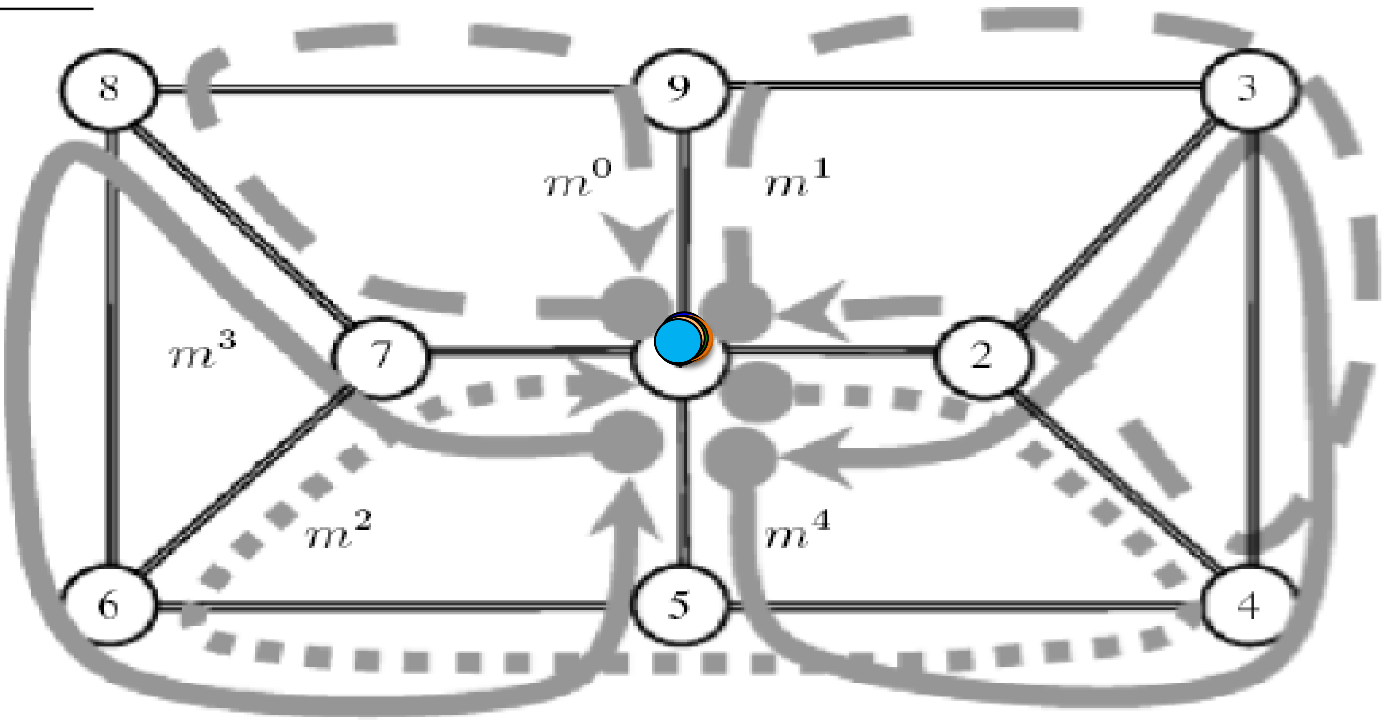
Data and Results

- Data
  - The experiment conducted on a 9 node and 14 link network
  - Node **1** is assigned as MN
  - Propagation delay through any link is **2 ms**
  - Burst length is **20 ms**
- Results
  - **Total monitoring delay** is 50 ms
  - **Maximum number** of m-cycles traversing through any link in a single direction is 2
  - **Total number** of m-cycles to localize single link SRLG failure unambiguously is 5

Link	m^4	m^3	m^2	m^1	m^0
(1, 2)	1	0	1	1	0
(1, 5)	1	1	0	0	0
(1, 7)	0	1	1	0	1
(1, 9)	0	0	0	1	1
(2, 3)	1	0	0	0	0
(2, 4)	0	0	1	1	0
(3, 4)	1	0	0	1	0
(3, 9)	0	0	0	1	0
(4, 5)	1	0	1	0	0
(5, 6)	0	1	1	0	0
(6, 7)	0	0	1	0	0
(6, 8)	0	1	0	0	0
(7, 8)	0	1	0	0	1
(8, 9)	0	0	0	0	1

Solution





Performance – More Networks

Performance metrics	Networks				
	4 nodes 6 links	5 nodes 8 links	6 nodes 9 links	7 nodes 12 links	8 nodes 12 links
$\sum_j m^j$	3	4	4	6	4
n	1	1	2	2	2
T	26	26	48	48	52

Summary

- Problem
  - Single link failure localization
  - From a single monitoring node (MN)
  - every link has at most a single dedicated wavelength channel for monitoring in each direction
- Finding m-cycles and scheduling m-burst starting time are considered as a joint optimization problem
  - A set of m-cycles is identified to achieve unambiguous failure localization (UFL) for the single-link failures
  - Starting time of the short optical bursts along each m-cycle is derived to achieve the minimum monitoring delay
  - Bursts along different m-cycles are kept non-overlapping through any link of the network

Conclusions and Future Work

- The proposed monitoring burst (m-burst) framework aims to reduce the consumed monitoring resources and signaling overhead significantly
- We conducted simple numerical experiments on small networks, and the result demonstrated feasibility and easy implementation of the framework
- Future Work
  - Investigate the effect of burst length on monitoring delay
  - Devise a heuristic algorithm to find near optimal solution of the problem
  - Investigate the scenario where more than one MN is present in the network and the MNs are either loosely synchronized or completely non-synchronized
  - Investigate the tradeoff between delay and monitoring resources