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

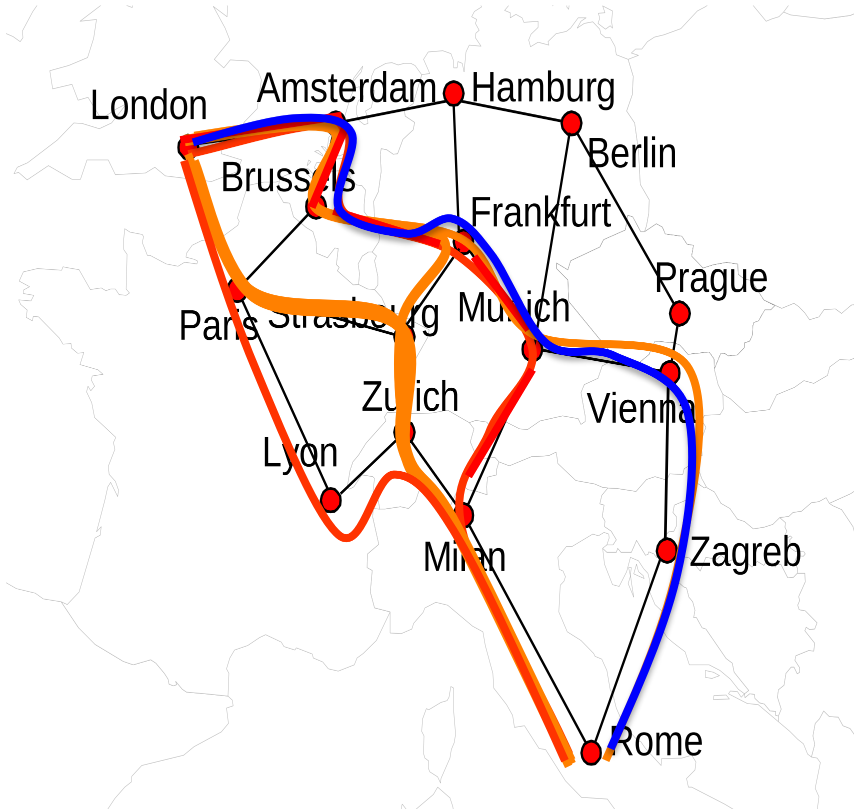
Mohammed L. Ali, Pin-Han Ho, Bin Wu, János Tapolcai, Basem Shihada

High Speed Networks Laboratory

University of Waterloo, Canada
Budapest University of Technology and Economics, Hungary
King Abdullah University of Science and Technology, Saudi Arabia

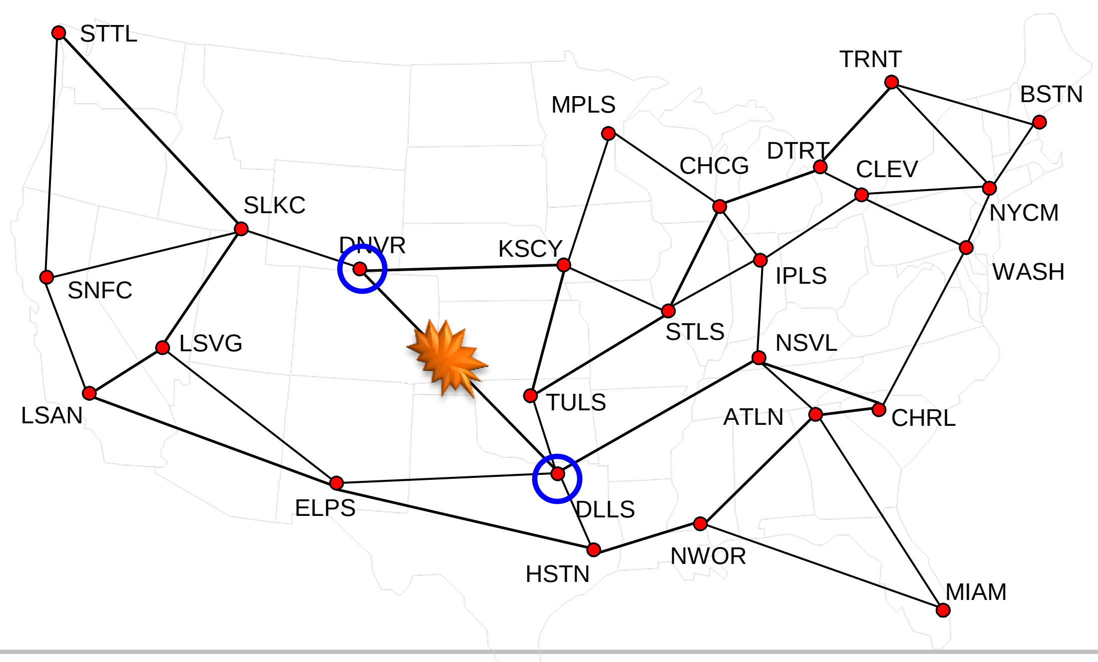
Survivabile Optical Networks

- 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 $|E|$



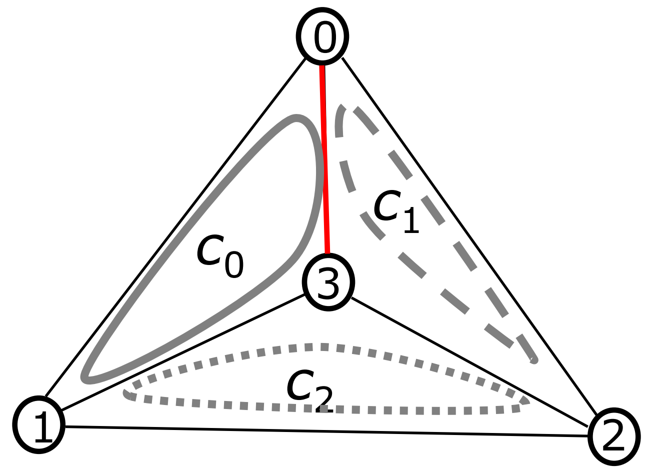
How to localize failures?

- 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

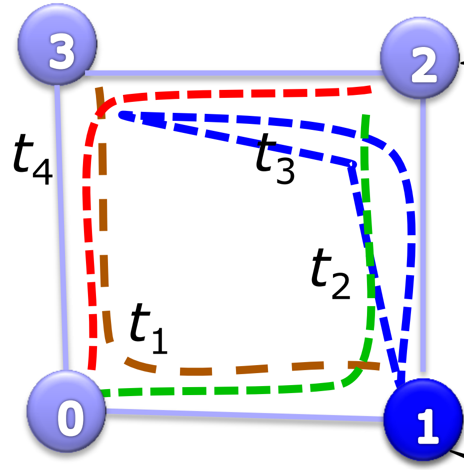
Localizing Single Link Failure with Monitoring Cycles

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



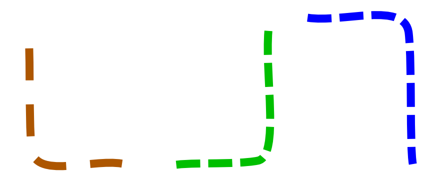
- A supervisory path (SP) is used to probe status of a group of fibre segments and components
- Each SP corresponds to a monitor which may alarm when any irregularity is identified
- By collecting all the flooded alarms in a failure event, the network controller can identify the failed SRLG instantly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

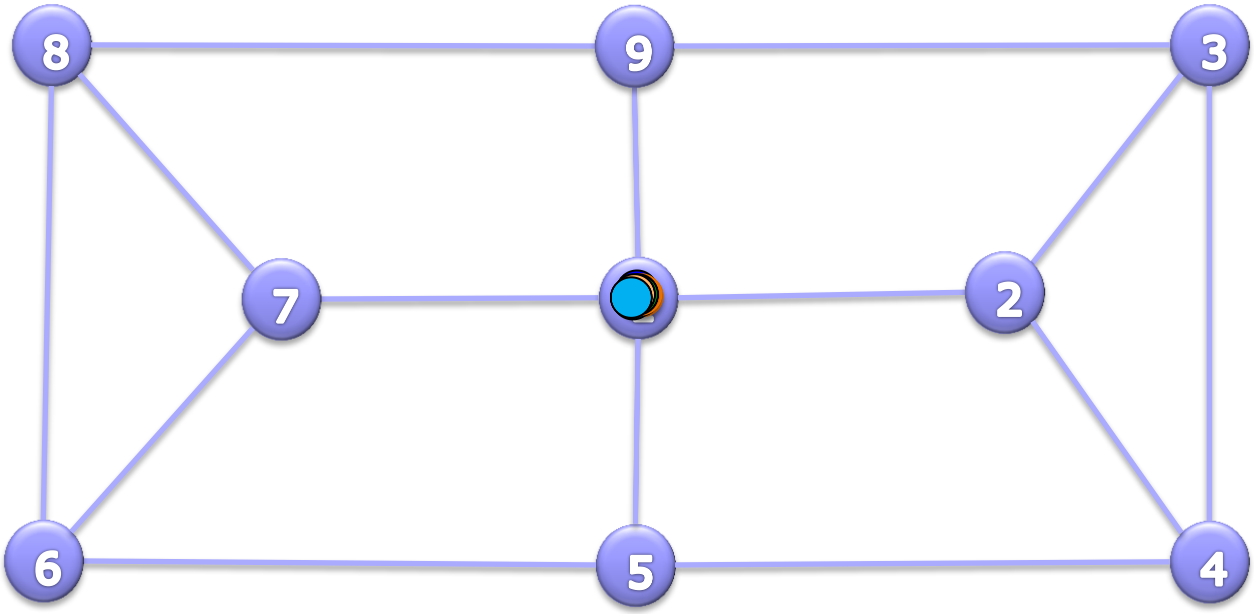
- **Time division multiplexing (TDM)** could be used to reduce monitoring resource consumption which require O/E/O conversion at intermediate nodes
- We use short duration optical burst along each m-cycle from a single MN called **monitoring burst (m-burst)**
  - To avoid collision, m-bursts are kept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

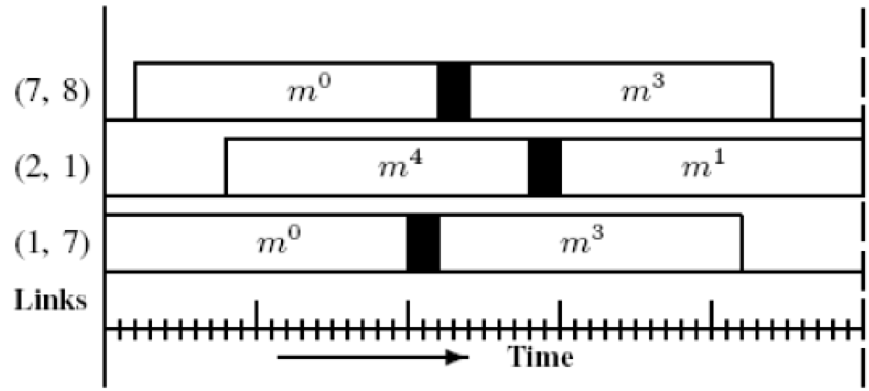
1. Constraints (2) - (15) are to identify a set of **m-cycles**
2. Constraint (16) is to find the maximum **number** of m-cycles traversing through any link in a single direction
3. Constraints (17) - (19) are to find **maximum delay** of m-bursts
4. Constraints (20) - (33) are to find burst **propagation 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

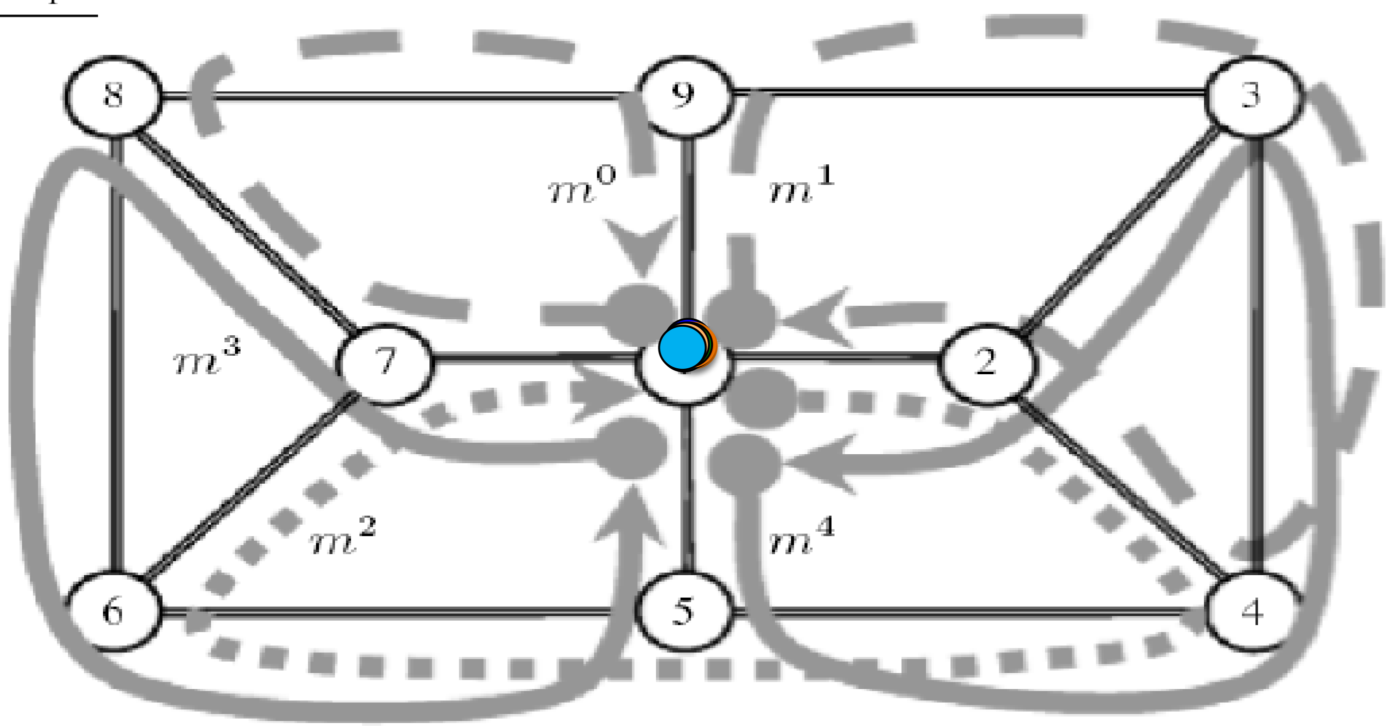
Data and Results

- 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

Solution

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





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