# Theoretic study on Network Cost for Link Failure Detection in Optical Networks using Monitoring paths and cycles

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## ABSTRACT

Network management and control contribute to at least half of the operating cost of current optical networks. All optical networks with end-to-end transparent lightpaths promise significant cost savings using optical switching at network nodes. However, this cost saving cannot be realized unless the cost of network management is also reduced. In this paper we explore some technique towards that goal.

We consider the fault diagnosis problem in all optical networks, focusing on probing schemes to detect faults. Our work concentrates cost deduction on single link failure and multiple link failure in order to meet the stringent time requirements for fault recovery. The efficiency of often depends on the network topology.

## 1. INTRODUCTION

With the emerging deployment of all-optical networks, broadband network services have the potential to become available to the mass population at much lower cost than what can be achievable today. Future all-optical networks promise significant cost savings via optical switching of high data rate lightpaths at network nodes, reducing electronic processing.

Optical networks have gained tremendous importance due to their ability to support very high data rates using the dense wavelength division multiplexing technology. With such high data rates, a brief service disruption in the operation of the network can result in the loss of a large amount of data. Commonly observed service disruptions are caused by fiber cuts, equipment failure, excessive bit errors, and human error. It is desired that these faults be uniquely identified and corrected at the physical layer before they are even noticed at higher layers. Therefore, it is critical for optical networks to employ fast and effective methods for identifying and locating network failures. Some failures, such as optical cross-connect port blocking and intrusion, can affect a single or a specific subset of wavelengths within a link. Other failures, including fiber cuts and high bit error rates (BERs), may affect all the wavelengths that pass through a fiber duct. In this work, we focus on the detection of the latter type of failures, and present a fault detection technique that can uniquely localize any single-link failure. For ease of explanation, we use the notion of "failure," although the treatment applies as well to assessing other metrics that significantly impact the link performance, such as optical power, optical signal-to-noise ratio (SNR), and BER. In order to rapidly measure the performance of a link (or a collection of links), it is essential to analyze the signal in the optical domain via optical spectrum analyzers (monitors).

## 2. NETWORK COST

From a hardware standpoint, building a monitoring system involves both operational and setup (one-time) cost. We assume that the operational cost per link is directly proportional to the number of wavelengths used for monitoring purposes over that link. Such dedicated wavelengths represent a loss of revenue for the network provider, as they would have otherwise been used to transport actual traffic. The setup cost is essentially the cost of monitors needed at the monitoring location. When monitors are dedicated to individual cycles, a wavelength is reserved over all the links in a cycle. The total operational cost is then proportional to the sum of the hop length of cycles employed in the monitoring system. The setup cost in this case is directly proportional to the number of monitoring cycles employed. If a network is heavily loaded, i.e., if the cost of reserving wavelengths over a period of time will dominate over the fixed cost associated with monitors, it is desired to minimize the sum of length of cycles employed for monitoring purpose. When monitors are time-shared, a single wavelength is reserved for monitoring purposes over each link, and only one monitor is employed at the monitoring location. In such a case, the operational cost is constant, i.e., one wavelength per link, and the setup cost is the cost of a monitor. To identify failures, cycles are sequentially scanned by the monitor. The larger the set of cycles, the higher the delay incurred in identifying a failure. Hence, when a single monitor is time-shared among a set of cycles, the objective should be to minimize the number of cycles in order to minimize the processing delay.

Theoretically, fault diagnosis can be understood from an information theoretic perspective. The network state can be viewed as a collection of binary-valued random variables; where each variable is associated with a network element, indicating failure/no-failure of that element. A fault diagnosis algorithm uses a number of tests, whose results are called the 'syndromes', to uniquely identify the network state. The objective of the fault diagnosis process is to encode the set of network states with the set of probe syndromes such that the average syndrome length (thus the operating cost of diagnosis) is minimized. The source-coding problem in Information Theory shares a similar objective, which suggests that the single-hop and the multi-hop test models can be compared using an information theoretic framework.

When compared with the fault localization, fault detection is easier and faster. Fault localization is the process of finding a minimum set of potential failed network resources based on the alarms generated in the fault detection phase. Fault localization in general network has been studied exclusively for many years in various areas and thus it is not a new problem. It has been studied in the areas like power distribution systems, electrical circuits, industrial control systems, and in communication networks. On the other hand, due to the lack of electrical terminations or the excessive cost and the difficulty in implementation, the existing fault localization schemes for traditional networks cannot be applied to the WDM networks directly [3]

# 3. INTRODUCTION TO MONITORING PATHS CYCLES

We first consider the scenario when the network employs one monitoring location. Given the monitoring location, the goal is to construct a set of MCs (or simply cycles) that pass through the monitoring location. The choice of the monitoring location depends on various factors such as its geographic location, security issues, and network topology. A wavelength is reserved for each cycle, and the failure of a cycle may be detected at the monitoring location using a dedicated monitor per cycle or by time sharing the available set of monitors at the monitoring location.

Given a network graph *G (N, L)*, where *N* is the set of nodes and *L* is the set of undirected edges, and given a monitoring location *m* belongs to *N*. We get a set of Monitoring cycles(MCs) *C* such that every link in the network is present in at least one cycle and every single-link failure results in the failure of a unique subset of cycles in *C*. All MCs must pass through the given monitoring location m. Such a unique subset is called the syndrome of the link. The set *C* is called as the fault-detection (FD) set.

Consider the network given in fig.1. We consider node 1 as monitoring node cycles formed are c1={1-2-3-4-5-1} and c2={1-2-3-1} and c3={1-5-4-1} and c4={1-2-5-1}. In the above network for each link failure will give us unique combination of cycles so link failure is very easy. Table in fig.2 gives the actual fault detection set for each link.

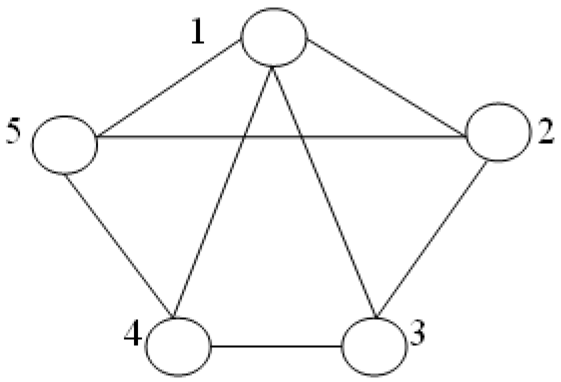


**Fig 1. Network with one monitor location**

| Links | c1 | c2 | c3 | c4 | Links | c1 | c2 | c3 | c4 |
|---|---|---|---|---|---|---|---|---|---|
| 1,2 | * | * | | * | 5,1 | * | | * | * |
| 2,3 | * | * | | | 1,3 | | * | | |
| 3,4 | * | | * | | 1,4 | | | * | |
| 4,5 | * | | | | 2,5 | | | | * |

**Fig 2. FD set for one monitoring location**

When we deal with more than one monitoring location, Depending on whether the monitoring locations share information about cycle failures or not, we define two modes of operation

- With information exchange: Monitoring locations exchange information about observed cycle failures to collaboratively localize a link failure. The information exchange process will add some delay to the failure localization time. However, as shown later, less network resources are needed for failure detection.
- Without information exchange: The monitoring locations work independently and do not share any information. Fault localization is faster but may require additional network resources. In this case, every link failure results in the failure of a combination of cycles traversing a specific monitoring location.

For a given monitoring location, we define its cloud as the set of links that this location is responsible for monitoring. We associate each link with the cloud of the monitoring location that is closest to that link. By being closer to the monitoring location, it is more likely that the monitoring cycles passing through the link will be shorter. We refer to this step as cloud formation. The use of paths along with cycles provides greater flexibility. A monitoring path (MP) originates from one monitoring location and terminates at another. The failure of a link along the path will be detected by the terminating monitoring location associated with that path.

# 4. EFFECT OF NUMBER OF MONITORS ON NETWORK COST

Note that number decreases with M when information is exchanged among the monitoring locations. When no information exchange takes place, the average number of links per cycle is affected by two factors: the number of monitoring locations employed and the number of cycles that pass through a link that are not used to detect the failure of that link8. In this case, the number of cycles consumed per link first decreases and then increases with M. The initial decrease is due to the use of multiple monitoring locations. The subsequent increase is due to the excessive number of cycles that pass through links but do not contribute to these links failure detection. Observe that for a large number of monitoring locations, information exchange among locations can save up to 10% of network resources. The use of paths and cycles further optimizes the performance by significantly reducing the average numbers consumed wavelengths.

Number of cycles to construct the Fault detection set (FD set) is equivalent to the number of monitors required for failure detection. If the monitoring locations share information about cycle failures, then with a large number of monitoring locations, approximately 20% of the cost associated with employing monitors can be saved. Notice that by using paths and cycles for fault detection, the total number of wavelengths consumed (which is directly related to the number of monitors required) is less than the case when monitoring locations do not share information.

We consider the average detection time in the two cases.

1. The detection time when information is not exchanged depends on the delay associated with the longest cycle that passes through the link and its monitoring location. For

example t1 be the time for traversing through longest cycle then total time T for detection is

T = t1.

2. When information is exchanged between monitoring locations, the detection time of a given link is given by the sum of the delay of the longest cycle that passes through the link and the time to disseminate information among the multiple monitoring locations that are responsible for detecting the failure of that link. We assume that the processing time at a monitoring location is negligible compared with the delay associated with traversing a cycle in the network. When failure information is exchanged between monitoring locations, the detection time first increases with M and then decreases. The initial increase is due to the additional delay associated with sharing information among monitoring nodes. For example t1 be the time for traversing through longest cycle and t2 be the required to exchange the information then total time T for detection is

T = t1+t2.

Note that if a monitoring location can localize a link failure by just observing the cycles associated with it, then the information may not be shared. The subsequent decrease is due to the decrease in the average length of the longest cycle in the syndrome of a link. When information is not shared, the average detection time decreases with number of monitors.

A link-based scheme requires one monitor for each link. When a fault occurs, only one monitor will be triggered. But the number of monitors required is equal to the number of links in the network. To reduce the number of monitors, the concept of *monitoring cycle(m-cycles)* was introduced in [4]-[5].

The concept of *super monitor* for further cutting down the monitoring cost is introduced[6].Instead of having a dedicated monitor for each m-cycle, we can place a super monitor at a junction of a set of m-cycles. A super monitor only requires a single laser for simultaneously transmitting supervisory signals onto multiple m-cycles. This is achieved by splitting the power from a single laser using an inexpensive optical splitter. Note that we still require a dedicated receiver for each m-cycle, but it is less expensive than a laser. Alternatively, we can have a single receiver detecting the signals from all m-cycles in a time-multiplexed fashion. But this will slightly increase the fault detection time. The main drawback of super monitor is network monitor location must be 4-edge connected.

Constructing a set of m-cycles that not only yields the minimum localization degree, but also consumes the least amount of network resources. The amount of network resources consumed is defined as *network cost*. It consists of both monitor cost (measured by the total number of monitors required) and bandwidth cost (measured by the cover length)[7].To minimize the network cost for link failure detection, we need to consider the tradeoff between the monitor cost and the bandwidth cost. Without loss of generality, we define the cost function as a weighted sum of the two cost components[7].

Cost = monitor cost + bandwidth cost

## 5. CONCLUSION

In this paper, we address a very important cost driver for future networks by proposing a new network diagnosis technique that can substantially reduce network operating costs. We investigated the fault diagnosis problem for all optical networks with probabilistic link failures via an information theoretic approach.

In our paper we also study about monitoring paths cycles and obvious effect of the path and cycles on network cost. The important thing to note is that number of monitors has huge effect on the network.

For future work in this paper there must some threshold on number of monitors and must be the heuristic placement of monitors.

## 6. ACKNOWLEDGMENT

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