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Minimal monitor activation and fault localization in optical networks

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ABSTRACT

The scheme for efficient, accurate and scalable monitoring and localizing faults is necessary for transparent optical networks. Optical transparency makes the monitoring and localization process difficult in the optical layer as failures in physical layer propagate and subsequently generate multiple alarms throughout the network. Moreover, failures in physical layer could be detected and located in optical layer before they are propagated to the upper layer. So, a fast and scalable monitoring and fault localization scheme are required to offer a secure and resilient network. In this paper we propose a fault management scheme that handles multiple failures in the optical network using wavelength-division multiplexing (WDM) technology. It consists of a two-phase scheme, namely (a) fault *detection* which detects faults by raising alarms of the monitoring devices and (b) fault *localization* that subsequently localizes these faults by invoking an algorithm. The latter phase obtains a set of potential faulty nodes (links). Next, we locate the exact position of faulty node (link) by transmitting the signal through it. We demonstrate the performance of this proposed scheme on a 28-node EuroNet.

1. Introduction

High capacity optical network is immensely used in industries due to its large transmission bandwidth and low cost. But these networks are also vulnerable to failures (such as malfunctioning of optical devices, fibre cuts, soft failures, i.e., the impairment due to subtle changes in signal power like degrading signal-to-noise ratio (SNR), etc.). One of the most important requirements to ensure survivable high speed optical network is to manage fault detection and its localization. A single failure can cause millions of dollars of revenue loss right from corporate users to service providers. Consequently, fault management is essential to ensure uninterrupted services to users. Faults (like link and/or node failures, etc.) occur mainly due to natural fatigue and ageing of optical devices and components (i.e., transmitters, receivers or controllers). Besides failures there are different types of disruptions (i.e., impairment, attack, etc.) that degrade and disrupt the performance of the network. If a fault occurs in a device it remains disabled until it is repaired again.

The management system involves in detecting faults in the network and alerting 'manager' through alarms triggered by monitoring devices when fault happens. If a certain parameter is being monitored and its value falls outside a preset range, the network equipment and/or monitoring device generates an alarm. Again, monitoring devices raise alarm if a link (e.g., fibre cut) gets damaged. When the power level of an incoming signal drops below a certain range it causes a loss of signal (LOS) and monitoring equipments raise alarms. Fault management is an important management function that is responsible for fault detection, localization and recovery. In this work we discuss only detection of faults and their localization. The block diagram of the proposed scheme is shown in Fig. 1.

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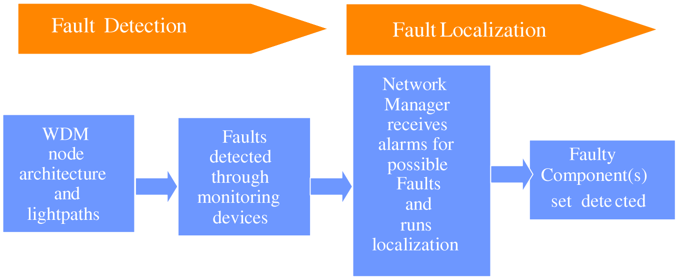

Fig. 1. Proposed fault detection and localization scheme.

Whenever there is a failure in a node, all the lightpaths passing through that node get disrupted and monitoring elements (monitoring devices and/or self-alarmed optical devices e.g., transmitter, receiver, etc.) placed in the path triggered alarms. Thus, a single failure may generate multiple alarms. In the case of multiple failures occurred in a number of nodes or in links simultaneously the raised alarms are intermingled and thus make the detection and subsequent localization process complex. Both single and multiple failures are detected through monitoring devices by triggering alarms. In order to develop fault detection and localization mechanism to be fast and effective, it is important to reduce the number of redundant alarms received to the smallest possible number. This will reduce alarm processing time as well as ambiguity in fault localization. Thus in our work we assume that monitors are placed at all nodes. During runtime, as the traffic changes, it is necessary to identify the minimum number of monitors to be turned ON so that failures can be localized using the currently established lightpaths.

The first phase of our proposed scheme is thus to select the monitoring devices that should be turned ON, and detects the failure(s) in the network components. As mentioned earlier this selective monitor activation has the advantages of reduced alarms processing time and thus has enhanced fault localization capability in a shorter time. In the second phase, the localization algorithm is invoked to locate faults and gives a set of apparent faulty components. In real scenario corrupted alarms (false alarms and miss alarms) may be triggered in the network to make the localization process more difficult. The false alarms and miss alarms are controlled by tuning the threshold values of the monitoring equipments. Lastly, the network manager sends test signals to the apparent faulty components and will locate the exact faulty components based on the acknowledgements. In this paper, we interchangeably use monitor and monitoring device.

1.1. Motivation

For critical business application running on optical networks, the 99.999% uptime of services is a critical requirement. This requirement corresponds to the connection downtime of less than five minutes per year. Hence, alerting manager appropriately through alarms triggered from upcoming faults and consequently detecting and localizing faults are prime activities in the network management. Fault diagnosis and localization is an interesting problem and hence it is an active field of research. Stanic et al. [1,2] used approximation method to reduce the number of monitors and thus make the system cost effective. Another approximation algorithm was shown in [3] to reduce the number of monitoring elements. A number of approaches based on graph theory were investigated in the context of fault diagnosis. In [4,5], authors proposed a parallel approach based on zero-time and nonzero-time systems and discussed an approach for single fault diagnosis. In [4], author showed that the optimal placement of monitors is an NP-hard problem. Several authors considered different assumptions for solving the fault localization problem. In [5,6] only single failure was assumed while in [7–9] multiple simultaneous faults were considered. In [6], fault manager checked periodically powers of all source and destination nodes by using the routing table information. If power level of some of nodes was out of expected bounds, that node was identified as a possible faulty node. In [10], the authors proposed fault identification algorithm through filtering alarms. The authors used the fault identification tree of depth equal to the number of alarming components to narrow down the potential faulty sources. In [11,12], a fault detection scheme was presented which is based on decomposition of network topology into monitoring cycles. The authors used a heuristic scheme for constructing of monitoring cycle cover that minimized cycle overlap for a given network topology. In [13], a hierarchically distributed monitoring model was proposed where the network topology is logically partitioned into monitoring domains, each of which is assigned a hierarchy level. Every monitoring domain is assigned a local fault manager responsible for computing the optimal set of activated monitors and performing the fault localization for all components within its domain, which enables distributed optimization of monitor activation and fault localization. In [14], an adaptive technique for fault diagnosis using "probes" was presented in which probes are established sequentially, each time using information about already established probes. While the sequential probing helps to achieve adaptive it also increases the fault localization time. In [7,15,16] false alarms and miss alarms were considered. In [15], authors showed that false alarms could be corrected in polynomial time but the correction of miss alarms is NP-hard. In [17], the authors propose an approach that equips only a few nodes with monitors and then based on the locations of monitors a heuristic approach is proposed for constructing monitoring cycles.

In our approach (follows our previous work described in [18–20]) we assume that all nodes are equipped with