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Efficient and costless monitoring mechanism in metro-access network

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ABSTRACT

Fast and unambiguous link or node failure localization is very important and necessary in optical network. But it is not always clear what constitutes a good method to monitor the whole network. In an effort to understand the benefits and drawbacks of existing methods, we empirically present two state-of-the-art methods: monitoring trails method and optical coding method for their ability of monitoring time, cost, scalability and centralized management performance. Then a new fault location method combining the advantages of two schemes in the mesh-tree network that can be used for metro-access network is introduced. At the same time, performance analysis of monitoring scheme is obtained. It can be seen that the proposed method can monitor the whole optical network effectively with low cost and good scalability. The technique can support high network capacity.

1. Introduction

With the explosive growth of internet traffic and high-bandwidth services, transmission rate of fiber channel will continue to improve, and the capacity will be gradually upgraded. In this trend, once the optical fiber link or node in the network fails, it will cause a significant loss of data and service interruptions. Thus, quickly identify faulty fiber link or node is very important. Only locating the faulty fiber segment quickly, routing protocols in each layer can be able to adjust in a timely manner. The data then can be transmitted via the failed link or node to other healthy links or nodes to recover data as soon as possible.

The mesh-tree network is popularly used in metro-access network [1]. The network consists of a feeder section in a mesh topology, a distribution section, and a drop section in a tree structure. The central office (CO) connects remote nodes (RNs) by optical fibers, forming a physical mesh topology. Mesh network has higher reliability than ring network. The distribution section is from the RN to the power splitter/combiner (PSC). The drop section runs from the PSC to the optical network units (ONUs) [2]. Mesh-tree network extends the access coverage from 20 km span to 100 km and beyond. It can support more customers by exploiting wavelength division multiplexing (WDM) technology [2].

To guarantee network services, the network must provide effective monitoring capabilities to monitor different types of network failures [3]. Network protocol model is a layered structure. In theory, faults can be monitored in any network protocol layer. Physical layer monitoring schemes are fast without complex signaling, while it needs long time for upper layer monitoring schemes, although they need less hardware [4,5]. Therefore monitoring methods in optical layer are preferred in achieving fast link failure localization [6]. Optical physical layer fault localization has been extensively studied in the past [7]. Two state-of-the-art methods are very popular. Multi-hop supervisory lightpaths, referred to as monitoring trails (m-trails), has been claimed as an effective approach [7]. M-trail is a trail-shape optical route that can cross any node several times but traverse a link only one time [3,8]. This method can help to reduce the required number of m-trail to a logarithm of the optical links number in a well-connected network [9]. However, it can't perform well in networks with poor connectivity. Also, before utilizing m-trail method, the nodes in the network should be healthy, so it cannot monitor the states of nodes in an easy way [3,10–12]. Optical coding is another effective way for monitoring the network. Every encoder at the branch termination implements a unique code to identify corresponding segment. It is scalable and is easy to monitor nodes in the network. But it needs at least the same number of links or nodes to be monitored encoders to complete unambiguous failure location. The cost is really high in some networks with large number of links and nodes.

For the mesh-tree hybrid network, there is not a single method to monitor the whole network effectively, in monitoring time, cost, scalability and centralized management performance. In this paper, an efficient monitoring mechanism combining the advantages of m-trail scheme and optical coding scheme is proposed. The rest paper is as follows. In Section 2, the network structure and the proposed monitoring algorithm is explained. In Section 3, various network fault location schemes are shown. The results and analysis of proposed scheme are displayed in Section 4. Finally, we conclude our paper in Section 5.

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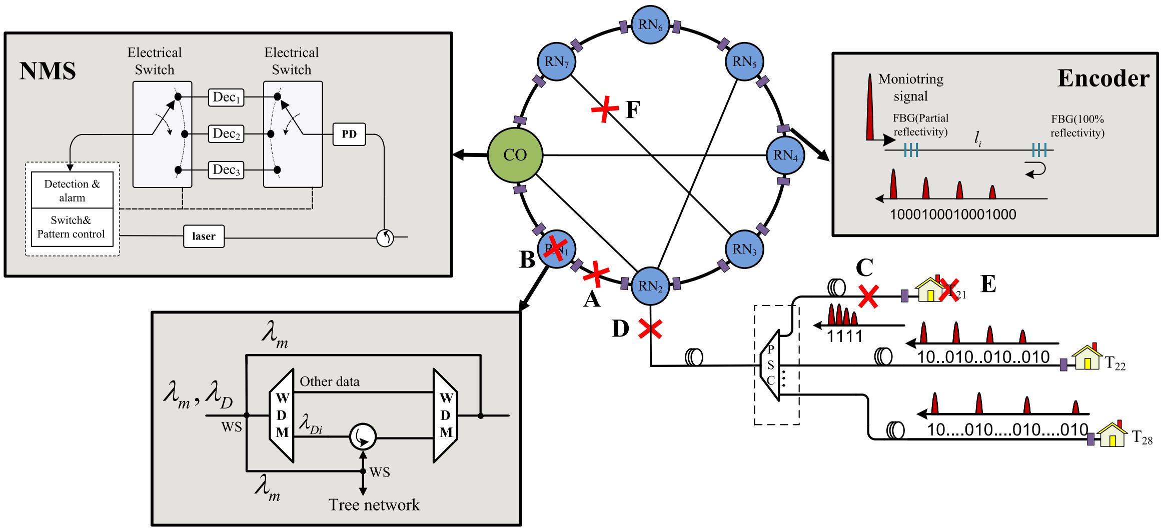

Fig. 1. The network architecture.

2. Proposed monitoring method in mesh-tree network

The network architecture is shown as Fig. 1. The mesh network is a WDM network and the tree network is a TDM one. There are 7 RNs on the ring and every RN supports 8 terminals. There are some other links between nodes to strength the network. When the network works healthy, the downstream data signals transmit in counterclockwise direction from CO. Each RN selects the wavelength it needs and transmits other waveband. The upstream data signals from the tree network transmit counterclockwise on the ring. For such a widely used network structure, previous monitoring methods can't be effectively addressed to detect fault for the whole network. In this paper a mechanism combining m-trails scheme and optical coding scheme is proposed to monitor the links and nodes in the network effectively and reliably.

2.1. Optical coding scheme

A modified direct-sequence (DS) optical code-division multiplexing (OCDM) technology can be used for monitoring the network [13]. First, it is based on optical encoders (square boxes in Fig. 1) as identification for the nodes, fiber links on the ring and tree branches. Optical encoders are installed before terminals on the tree branches and on both sides of the nodes on the ring [14]. The CO sends a monitoring pulse transmitting counterclockwise on the ring and each encoder couples part of the pulse, generate a code and reflects it back clockwise to CO. The CO collects the reflected optical encoder pulses in a clockwise direction for both the nodes monitoring and the tree terminals monitoring. Every encoder is different from each other. Once a fault occurs in specific segment, the corresponding optical code signal is missed and the CO will detect and locate the fault in the network. The structures of encoder and node on the ring are introduced in Fig. 1. λ_m is monitoring wavelength in U-band, λ_D is for data signals, and λ_{Di} is the data wavelength that i^{th} RN transmits to corresponding tree network.

Suitable code family is selected to reduce mutual interference among these codes. Optical orthogonal periodic codes are simple and easy to produce. The code weight of each code is ω. Each encoder has the same reflection coefficient R_1 and R_2, and the same center wavelength. It must ensure the level of correlation values among all codes should lower than R_2. The flow chart of producing these codes is shown in Fig. 2.

The codes can be produced by many ways in practice. A fiber bragg grating (FBG) based encoder shows an obvious advantage, compared to

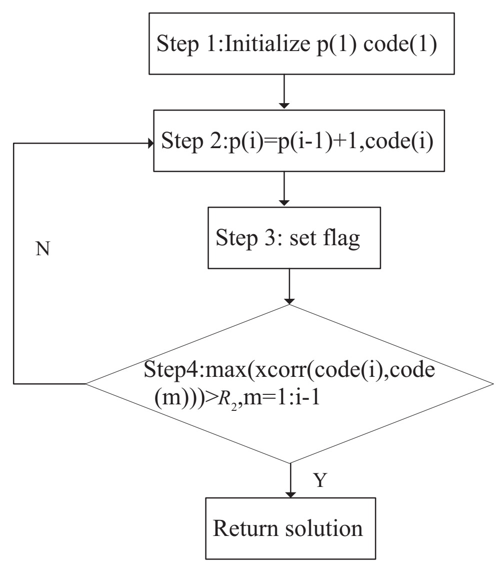

Fig. 2. The flow chart of producing orthogonal periodic codes.

PSC based encoder structures, in terms of simplicity, component count, and power and loss budget [15]. Encoder is shown in an inset of Fig. 1, and decoder is same as encoder. Let ρ_j be the level of the j^{th} pulse generated by the cavity. It can know:

$$\rho_j = \begin{cases} R, j = 1 \\ (1-R)^2 R^{j-2}, j \ge 2 \end{cases} \tag{1}$$

However, to make the total optical power concentrate into the first ω pulses, suitable reflection coefficients R in encoders are chosen. Only a unique physical separation of the grating l_i distinguishes one encoder from the next. It can produce multilevel periodic code (ML-PC). The cavity length l_i is related to period of the i–th code p_i as Eq. (2).

$$l_i = \frac{p_i c_1 T}{2} \tag{2}$$

c_1 is the speed of monitoring pulse in the fiber, T_s is pulse duration [16]. The encoder on the ring is set as an inset in Fig. 1. The structure of receiver in CO is displayed in an inset in Fig. 1. It receives the sum of reflected monitoring signals and extracts the state of a particular segment by matching its unique decoder cyclically to the received signal. The values of auto-correlation peak of decoded signals are used to assess the quality of the individual fiber link or node [17]. There will