Experimental Demonstration of Suppression of Cascaded Performance Degradation in Multi-core Fiber Networks with Burst-mode EDFA

Yusuke Hirota[1*], Masaki Shiraiwa[1], Sugang Xu[1], Massimo Tornatore[2,3], Biswanath Mukherjee[2], and Yoshinari Awaji[1]

[1]National Institute of Information and Communications Technology, 4-2-1 Nukui-Kitamachi, Koganei, Tokyo 14-8795, Japan
[2] University of California, Davis, 3037 Kemper Hall, CA 95616, USA
[3]Politecnico di Milano, Piazza Leonardo da Vinci, 32, 20133, Milano, Italy
**hirota.yusuke@nict.go.jp*

Abstract: We experimentally demonstrate cascaded performance degradation caused by increased inter-core crosstalk due to optical power fluctuation of adjacent core in multi-core fiber networks, and we show that a burst-mode EDFA is a candidate solution.

1. Introduction

As network traffic keeps on increasing, spatial division multiplexing (SDM) technologies are intensively studied for expanding transmission capacity [1]. In coupled multi-core fibers (MCFs), it is important to consider inter-core crosstalk (XT) because the optical signals propagated in different cores interfere with each other. On the other hand, failure management is also an important research topic in future optical networks [2]. In MCF networks, cascaded optical power fluctuation among different cores, caused by a hard failure etc., have negative impact on lightpaths of adjacent cores due to increased XT. This performance degradation, which is classified into soft failure, may cause link disconnection or low throughput because optical signal to noise ratio (OSNR) changes over time. In this preliminary study, we focus on the cascaded performance degradation of existing lightpaths in adjacent cores. We demonstrate the potential cascaded performance degradation caused by a hard failure. Furthermore, we show the effect of burst-mode EDFA (erbium doped fiber amplifier) for suppressing the cascaded optical power fluctuation in MCF networks, which avoids the increase of XT and cascade performance degradation.

2. Cascaded Performance Degradation Problem in MCF Networks

When optical path operation (e.g., setup/release) or link failure occurs, the input optical power to EDFAs suddenly changes. The gain transient of conventional EDFA causes optical power fluctuation for multiple wavelengths [3]. The setting of EDFAs and variable optical attenuators (VOA) is readjusted as needed. This operation takes long time and therefore, it is insufficient for path provisioning especially when lightpath restoration is performed. During readjustment, the optical power fluctuation worsens quality of transmission (QoT) of optical signals of the existing provisioned paths. Especially, optical paths with minimum margin of acceptable QoT can be greatly affected [4]. Furthermore, in MCF networks, if the optical power fluctuation occurs in one core, lightpaths in an adjacent core would be indirectly affected owing to the XT between cores (Fig. 1). This may cause a cascaded degradation of OSNR of the optical paths in different cores, which seems to be irrelevant to the root-cause hard failure. To prevent this cascade performance degradation or failure, one candidate approach is to suppress optical power fluctuation. We previously developed burst-mode EDFA (BM-EDFA), which is tolerable to burst signals with short gain transient [3, 5]. The BM-EDFA are also considered to be effective for this type of cascaded performance degradation or failure.

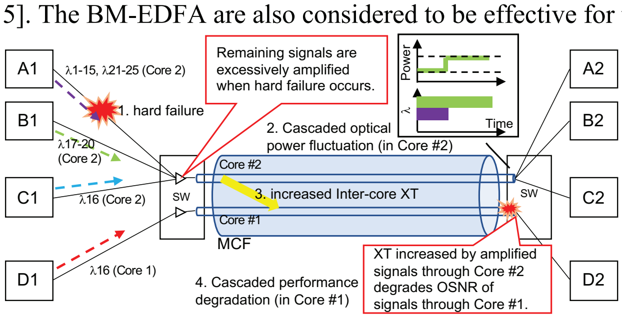

Fig. 1: QoT degradation by XT from excessively amplified lightpaths through adjacent core.

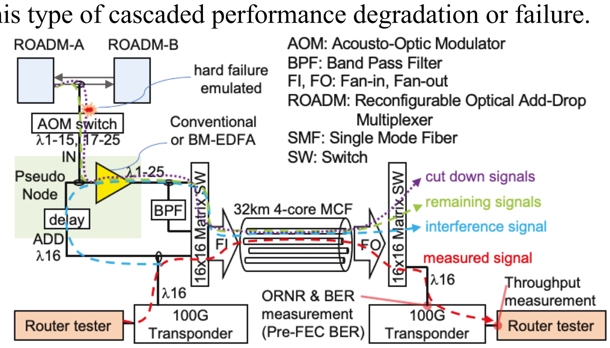

Fig. 2: Experimental setup.

3. Experimental Demonstration

First, we verified the potential performance degradation and failure by increased crosstalk from excessively amplified lightpaths in MCF networks. Figure 2 shows the experimental setup. We connected two commercial 100G transponders with 32 km of coupled 4-core MCF. Two router testers, which generated 1 Gbps traffic, were connected to 100G transponders and used to measure end-to-end throughput performance. After 100G transponder at sender side, the optical signal was branched by a coupler as the measured signal (red line in Fig. 2) and the interference signal (blue line in Fig. 2). We emulated a hard failure by cutting down the background lightpaths at the AOM switch. ROADM A generated 24 lightpaths for background signal, which were 20 lightpaths for cut down (purple line in Fig. 2) and 4 lightpaths for remaining signals (green line in Fig. 2). Figures 3 shows the results of OSNR and pre-FEC BER measured at the 100G transponder and received bit rate measured at the router tester in cases of conventional EDFA. In the conventional EDFA case, after a hard failure (around 90,000 s), the OSNR immediately decreased as shown in Fig. 3(a) and the pre-FEC BER increased around FEC limit. Even if the pre-FEC BER satisfies the FEC limit at a certain point, the end-to-end performance was temporary degraded as shown in Fig. 3(c) because BER changes over time (see Fig. 3(b)).

Second, we verified the effect of burst-mode EDFA for suppressing the cascaded optical power fluctuation in MCF networks in Fig. 4. In the case of BM-EDFA, remaining signals through adjacent cores were not excessively amplified and therefore, the OSNR and the pre-FEC BER kept the same level as shown in Figs. 4(a) and 4(b). Hence, the received bit rate did not change after the failure (see Fig. 4(c)). From these results, we verified that even if the excessively amplified signals can be decoded with no errors after FEC process, unintentionally increased XT degrades the end-to-end performance and BM-EDFA can avoid this indirect and cascaded performance degradation and failure.

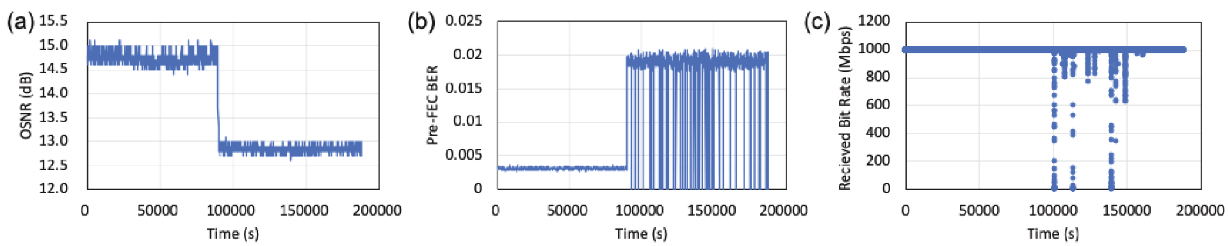

Fig. 3: Conventional EDFA case; (a) OSNR, (b) pre-FEC BER, (c) received bit rate.

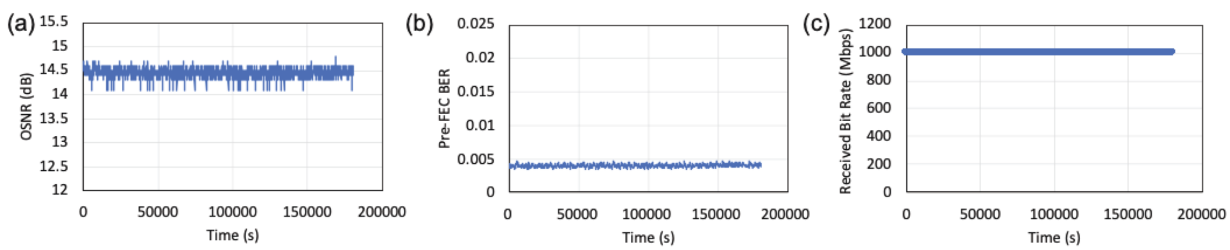

Fig. 4: Burst-mode EDFA case; (a) OSNR, (b) pre-FEC BER, (c) received bit rate.

4. Conclusions

We verified that an unintentionally increased XT temporally degrades the end-to-end performance even if the excessively amplified signals can be decoded with no errors after FEC process, and our BM-EDFA can avoid this indirect failure and keeps end-to-end throughput performances without time-consuming process of EDFA gain controls.

Acknowledgement

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