Managment and monitoring layer of optical network for time and frequency transfer

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Abstract — Continues operation of ultra-precise time and frequency transmission requires special monitoring, calibration and management procedures to ensure high functionality, safety, and quality of the time and the frequency dissemination. The system must deliver information to administrators, end-users, and equipment manufacturer about current state of the fiber link. In the paper a description of the essential elements of the management system and data transmission methods, based on the Internet standard protocols and preliminary test results, are presented.

Atomic clock, fiber optical network, management and monitoring, high precision dissemination of time and frequency reference signals, network management system.

I. Introduction

The idea of design the management layer came into sight as effect of the experience carried out during an over-a-year operation of 421,4 km-long fiber-optic connection between Central Office of Measures (GUM) in Warsaw and the Astrogeodynamic Observatory (AOS) in Borowiec near Poznan. The concept of the active propagation delay in the fiber optic link used to joint time and frequency transfer was widely discussed in [1,2,3,4,5]. This optical link consists of many programmable elements (amplifiers, endpoints) and classical optical fibers belonging to PIONIER backbone and spread over many kilometers. This paper focuses on out-of-band in-fiber management of EDFA (Erbium Doped Fiber Amplifier), normally installed in locations without reliable and stabile network access. Activation and a further system monitoring require robust and safety methods of management, which are based on the telecommunication standards.

A typical network management system covers the activities, methods, procedures, and tools that assure realization of special function. It is possible to find several way of their characterization. The most common is operation, administration, maintenance, and provisioning of networked systems [6].

In the Network and Management System (NMS) the operation means all activities to improve the efficiency of network and to provide defined net services. It includes monitoring, used to remark problems as soon as possible, preferably before end users are affected. The next is *administration*, which deals with tracking of resources in the network. It uses dedicated protocols and tools to keep the network under control. The *maintenance* guarantee repairs and upgrades mechanism, when equipment must be replaced. It also involves corrective and preventive measures increasing the quality of services provided by managed network, such as adjusting device configuration parameters. The last one is *provisioning*, concerned with configuring network resources to support a given service.

Network management system collects data using several mechanisms:

- agents running in infrastructure,
- logs of activity,
- sniffers,
- monitoring on demand, executed by users.

Formerly network management was worked as network status monitor, because devices were characterized only by two states: up or down. Now a crucial part of the IT team's role is delivering services on defined level, so the performance management has become a great challenges - especially for organizations of national or international range. Several access methods supporting network and network device management exist. The well-known are CLIs (Command-Line Interface), SNMP (Simple Network Management Protocol), NETCONF (Network Configuration Protocol), custom XML (Extensible Markup Language), CMIP (Common Management Information Protocol), WMI (Windows Management Instrumentation), CORBA (Common Object Request Broker Architecture) and JMX (Java Management Extensions).

The next important thing in management is an organization of a data channel for devices maintenance. Out-of-band management (OOB), called also lights-out management (LOM), needs to use a dedicated transmission channel, what makes it robust and efficient. On the contrary, in-band management is based on software and must be a part of managed system, so it is installed on the remote sites and can work transmission device operates. This solution is simply, but it does not allow access to deep system settings (system updating, reinstallation, or fix problems that prevent the system failure during booting).

In the following paragraph standard network management system (NMS) implementation, dedicated to Optical Network for Time and Frequency Transfer is presented.

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II. Optical Network Management Architecutre for Time and Frequency Transfer

A complete remote management system of ONMTFT (stand for Optical Network Management for Time and Frequency Transfer) should manage EDFA amplifiers, reference clock transmitter and receiver from remote server (Fig.1.). Requirements for monitoring, calibration and management of the transmission line, to ensure high functionality, safety, and quality, make possible the ONMTFT functions defining:

- safe access to all active system nodes;
- reading the unit status (e.g.: name, programmable parameters);
- remote reprogramming the unit parameters (e.g.: gain)
- continues/real time and on demand monitoring node performance parameters (e.g.: temperature TEMP, input power of direction West-East P_{IW}, output power of direction West-East P_{OE}, input power of direction E-W P_{IE}, output power of direction E-W P_{OW}) (Fig. 3) [1] ;
- communication with end user (e.g.: information about system status).

Delivering necessary management data is organized by CLI protocol and out-of-band technique.

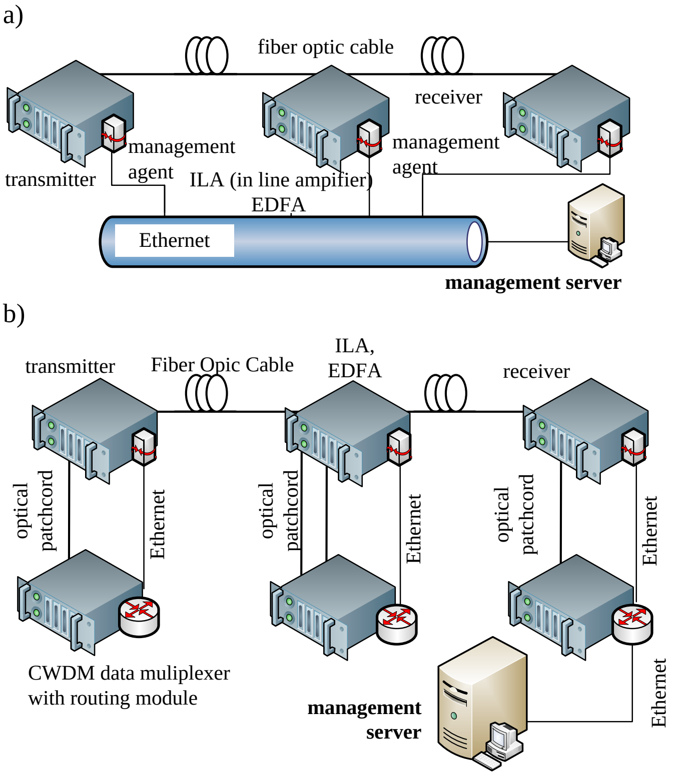

Fig. 1. Solution of out-of-band ONMTFT architecture: a) Ethernet based approach, b) "in-fiber" technique.

Implementation of the out-of-band management is usually realized, based on the Ethernet connections (Fig.1a). It is simply way of access to managed elements, but it requires additional network infrastructure. In real realization of backbone network is impossible to deliver dedicated Internet connection to ILA (In Line Amplifier) nodes. The GPRS access to network very often causes difficulties too, additionally for security reason some private network (e.g.: VLAN, VPN) is strongly recommended. Moreover management channel needs to be stable in time which is hard to achieve in GSM networks.

To eliminate this problem the remote OMTFT elements can be accessed through the time transfer link via CWDM multiplexers and routers, as shown in Fig.1b. In this case a fiber optic line is shared between time transfer link and management using in-fiber technique. A comparable solution implementing nonstandard network management procedures and dedicated to management of optical fiber link for frequency metrology was described in [8].

III. In-Fiber techniques - Nodes Arcitecture

The system of time and frequency dissemination consists of endpoints (transceiver, receiver) and regenerating nodes, included EDFA. Implementations of basic management procedures require additional management subsystem. This infrastructure (ONMTFT) contains: internal routing module (it is necessary to data exchanging between nodes and more flexible than programmable switches), Ethernet copper to fiber media converters, dedicated optical CWDM filters and optical diplexer (for physical separation of data transmission channel). The proposed hardware solution multiplexes time signal and management data using only one fiber for two functions. It is called *in-fiber* management techniques. The block diagram in Fig. 2 shows typical architecture of regenerating node. Control and status data coming from dedicated EDFA are formatted into Ethernet packet and distributed according routing table by internal routing module to media converters or local external Ethernet port. The CWDM module combines two control links (with λ_{M1} and λ_{M2} wavelengths) with time transfer carrier (λ_{C1} and λ_{C2} wavelengths) in one common fiber.

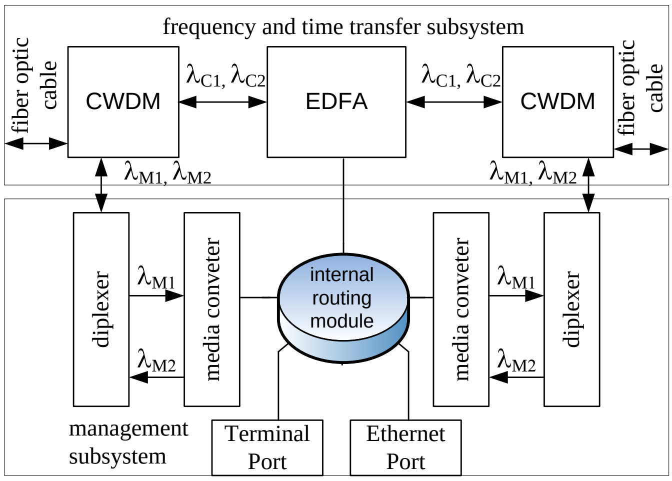

Fig. 2. Regenerating node (ILA) of fiber optic system for time and frequency transfer with management subsystem

IV. EXPERIMENTAL RESULTS

In order to verify the designed management method, presented in preceding sections, a series of measurements were arranged in the laboratory, using real telecommunication fiber link (Fig.3). The measurement results should give answer to two questions: Does a common transmission of precise time signal and management data in one optic fiber link degrade time accuracy? Does logged data of each component in the time and frequency transfer link (EDFAs, endpoints) carry information about link behavior and this information could be useful to improve time stabilization?

Answering to those problems, the test system of Time and Frequency Dissemination System with Optical Network Management for Time and Frequency Transfer, according block diagram in Fig.3, was arranged. To take closer real application of designed system, in the experiment the fibers deployed in optical cable and located in the field running along the motorway near Krakow and being the part of the TP S.A. telecommunication infrastructure, was used.

The fibers were looped-back, thus both ends of each line were accessible in the Optical Network Laboratory at AGH University of Science and Technology in Krakow. In whole line SC/APC (Angled Physical Connector) mechanical connectors were used.

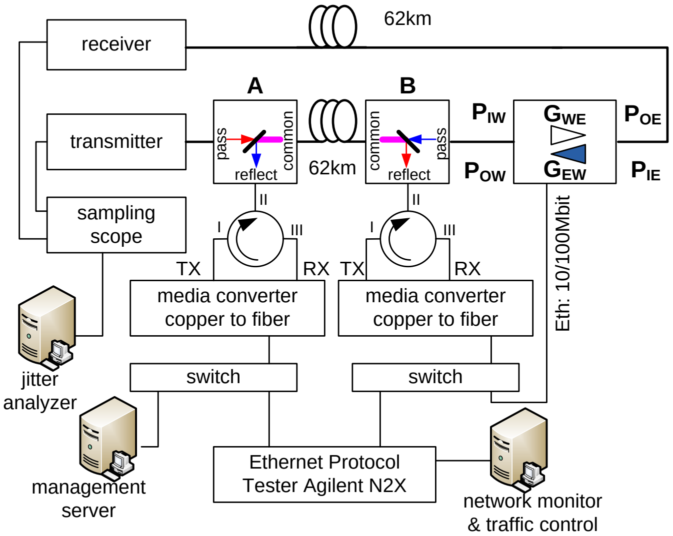

Fig. 3. Test system of Optical Network Management for Time and Frequency Transfer

In the experiments, EDFA amplifier was continuously controlled and data was recorded to the server. Managed amplifier was inserted between two 62 km long fiber spans (referred as B on Fig.3) with total attenuation equal 19.2 dB and 19.5 dB respectively. A control and status data coming from EDFA is formatted into Ethernet packets and then are transmitted over fiber by media converter. The standard small form-factor pluggable module of 1510 nm (λ_{M1}) and link budget 20 dB was applied. The optical circulator separate TX and RX signals transmitted together in circulator port II. Optic filter allows combining management wavelengths λ_{M1} and λ_{M2} (near 1510nm) with time transfer carrier (λ_{C1} and λ_{C2} wavelengths close to 1549ns) in one common fiber.

The EDFA remote pooling was executing concurrently with simulation of background 50Mbit/s network traffic, generated and measured by AGILENT N2X Network Protocol Analyzer (see Fig. 4). The maximum measured throughput between point A and B was 80Mbit/s, and this boundary is consequence of switches limitations.

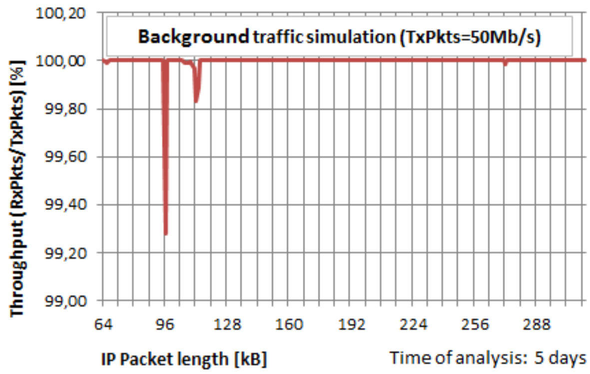

Fig. 4. Packets size test used as background traffic simulation

A set of EDFA parameters: the temperature TEMP, input power of direction West-East P_{IW}, output power of direction West-East P_{OE}, input power of direction E-W P_{IE}, output power of direction E-W P_{OW}, have been logged for 5 days, with 1 minute resolution. The behavior of EDFA gain stabilization reports graphs in Fig. 6 and in Fig.7.

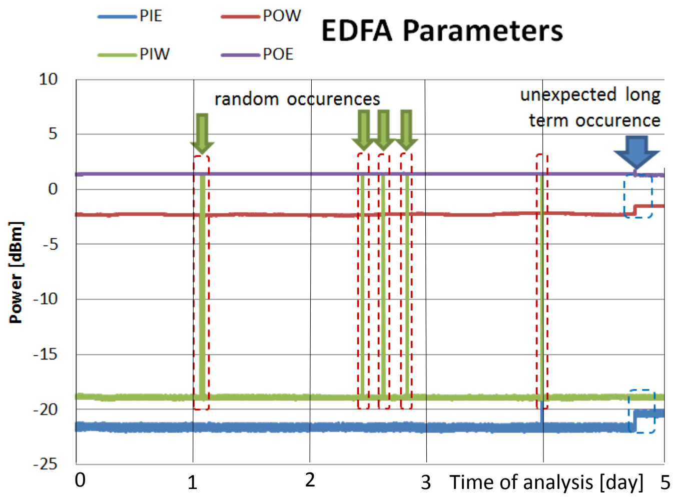

Fig. 5. Power changes in input and output of EDFA during test experiments

A short random occurrence of P_{IW} fluctuation and changes of P_{OW} and P_{IE} was observed, but its nature and its influence to time stability have not be well characterized yet.

In Fig. 7 the strong correlation between temperature and output power can be observed, however analyzes in [5] suggest that it is possible to compensate influence of temperature variance to output power. This discovery should be better investigated in future, because is related to transmitted time stability.

The time transfer accuracy was evaluated by means of Overlapping Allan Deviation (ADEV, measured using methods described in [3,7].

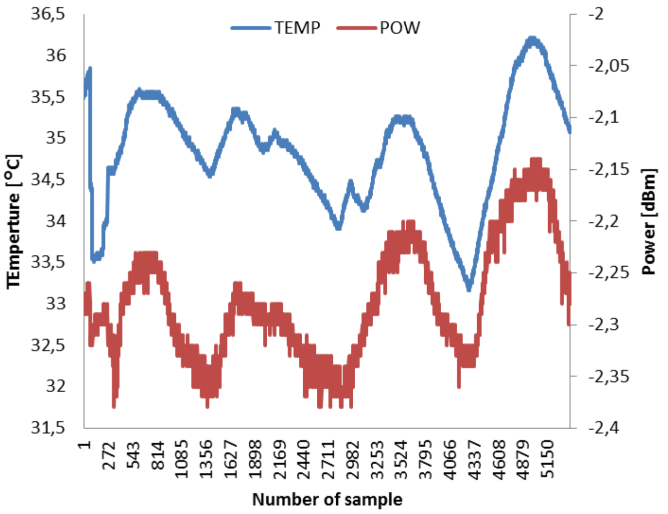

Fig. 6. Discovered correlation between output power POW and temperature TEMP

Time transfer stability with (red line) and without (blue line) management system data traffic (Fig.4.) gives similar results. It allows draw a conclusion that management facilities and in-fiber transmission do not affect time transfer accuracy.

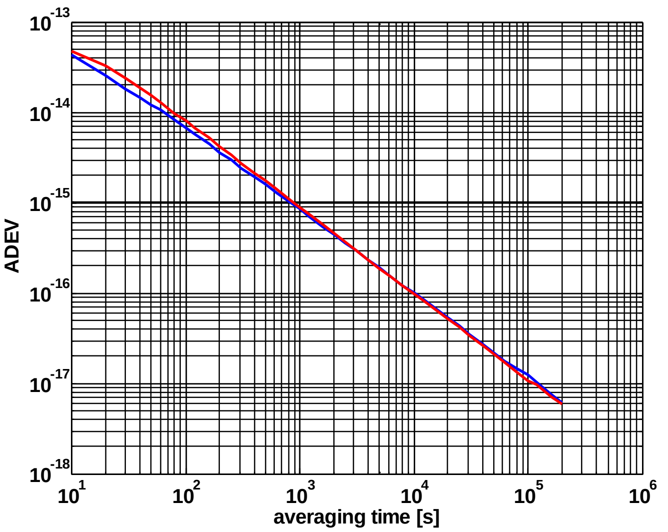

Fig. 7. Allan deviation (ADEV) with (red line) and without (blue line) running of management layer

SUMMARY

Access to ultra-precise time and frequency signals are very important for many user groups include scientific and research communities and business or government users. It requires not only infrastructure for time transfer, management layer is important too. An activating the link spread over many kilometers and keeping on its high accuracy of time transfer is impossible without reliable management system. Presented out of band in-fiber solution fulfill user expectation and could be developed in the future. The management system doesn't change *Allan deviation* of transmitted clock and allows provide additional analysis to improve performances of time transfer.

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