MARKETING REPORT

MR-311
Overview of Fiber Infrastructure Management Systems

Issue: 1
Issue Date: July 2016

Issue History

Issue Number	Approval Date	Publication Date	Issue Editor	Changes
1	18 July 2016	5 August 2016	O.S. Gebizlioglu Huawei Technologies Y. Ren, China Telecom L. Guo, China Unicom	Original

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Executive Summary

MR-311 presents an overview of emerging Fiber Infrastructure Management Systems (FIMS) that facilitate installation, operation, management and maintenance of the physical plant (infrastructure) layer of Optical Networks, in general, and Passive Optical Networks, in particular. Optical fiber deployments in global service provider networks have been accompanied by high cost and longtime of installation and operations due to extensive use of manual labor and record keeping on paper. Thus, the FIMS product development has been aimed at reducing manual labor and transforming record keeping from the use of paper records into all electronic resource information collection and processing, thereby enabling automation of all operations from network installation through maintenance, trouble shooting, fault locating and service provisioning.
In the emerging FIMS, this transformation has been achieved with the use of electronic ID tag technologies that enable collection, storage and use of identification data for each port and connector in the network.

Section 3 describes the major challenges faced by service providers in building, operating and maintaining their FTTx networks. This section, therefore, presents major legacy FTTx installation/operation problems that are addressed by emerging FIMS.

Section 4 presents a summary of technology progress via standardization of FIMS and passive node elements.

Section 5 presents the system architecture as described in TR-311 and definitions of key architectural components.

Section 6 provides a detailed description of deployment use cases, implementation scenarios, interoperability with service provider OSS, interoperability between FIMS from multiple suppliers, and migration strategies for service providers who plan to transition their legacy networks to networks that utilize FIMS.

Section 7 presents future outlook for FIMS development based on recent progress on expanding the scope of resource management via visual and dynamic analysis of network resources, integration of network fault identification capabilities, optical fiber diagnosis and upstream signal detection for PON components such as ONU status.

1 Introduction

As FTTx network deployments continue to grow, service providers (SPs) face numerous challenges due to the large volumes of fiber and related infrastructure components required in such deployments. Reduction of labor, time and errors in building FTTx networks, increasing fiber utilization, and enabling faster service provisioning while driving down the CapEx and OpEx and improving customer satisfaction are the critical issues to be resolved for the global communications industry.

Fiber Infrastructure Management Systems (FIMS) have been developed to address these critical issues. The FIMS are integrated systems in which information collection and processing features are added to fiber infrastructure components and equipment using electronic ID tags to enable 1) automated collection and synchronization of fiber connection resource data, and 2) accurate management and control of fiber connections in support of automated scheduling and timely provisioning of services.

TR-311 published by Broadband Forum addresses the FIMS architecture, functional requirements, use cases, and implementation and deployment scenarios. It has been playing a critical role in helping the industry understand the capabilities of FIMS products and systems.

MR-311 is intended to support the industry in the use of TR-311 in on-going and future development of FIMS products. It presents a technology overview for fiber infrastructure management systems to familiarize TR-311 users with 1) the challenges faced by SPs, 2) technical progress in FIMS development, 3) experiences and issues in FIMS deployments and 4) future outlook in the development of FIMS.

2 Terminology

2.1 References

The following references are of relevance to this Marketing Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Marketing Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	RFC 2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2]	L.64	*ID Tag Requirements for Infrastructure and Network Elements Management*	ITU-T	2012
[3]	TR-311	*Fiber Infrastructure Management System: Architecture and Requirements*	Broadband Forum	2015

2.2 Definitions

The following terminology is used throughout this Marketing Report.

Optical Distribution Network (ODN)	The physical medium that connects an OLT to its subtended ONUs. The ODN is comprised of various passive components, including the optical fiber, splitter or splitters, and optical connectors.

2.3 Abbreviations

This Marketing Report uses the following abbreviations:

BSS	Business Support Systems
FTTx	Fiber to The x (Building/Curb/Home/Premise)
LED	Light Emitting Diode
MR	Marketing Report
ODF	Optical Distribution Frame
OSS	Operation Support Systems
PDA	Personal Digital Assistant
PNE	Passive Node Element

WA	Work Area

3 Challenges for Service Providers in Fiber Network Management

The fiber infrastructure network includes the cabled optical fiber, fiber connectors and splices, branching components and equipment that house these components to implement the physical optical fiber connectivity.
Thus, fiber infrastructure networks consist of passive components which do not lend themselves to automated centralized management from service provider facilities with the following challenges and issues.

3.1 Planning Challenges

For service providers, fiber infrastructure network planning and design are the responsibility of a network planning and engineering or design department or a dedicated organization / subsidiary. Planning and design tools are commonly used to generate network design information and documentation for field engineers to use in the construction of the network. This information is handed over to network management and maintenance teams for their input, manually, to the service provider OSS. Manual operations with paper records present a high risk of errors and potential inaccuracies in the inventory information. Thus, for service providers, their inability to guarantee the accuracy of resource information has been a major challenge in planning, design, installation and operation of their networks.

There is no guarantee for accuracy of resource information for fiber infrastructure in the existing systems of SPs. Most SPs record their resource data in Excel spreadsheets or most frequently on paper records. This situation results in several challenges in network planning.

First challenge is that it is hard to evaluate the existing resource and to give an accurate input to the planning projects. Second challenge is that the planning work is based on potentially inaccurate information, which leads to high CapEx and/or low utilization of existing resources. Third challenge is that data sharing is difficult among different departments or different professional teams, leading to low efficiency of cooperation. Forth challenge is that the data has inadequate graphical/visualization capability since all the information is usually presented in the form of text instead of tables or figures.

After all, there are no appropriate systems with high efficiency for planning of fiber infrastructure networks.

3.2 Installation Challenges

Within an SP’s fiber network, paper labels are commonly used to record and identify optical fiber connectivity and fiber routes. However, the paper labeling makes it difficult to find a specific fiber and its fiber routing as shown in Figure 1. Accordingly, field technicians may update spreadsheet-based files manually, and these files may not be copied or transferred accurately to SP administration offices automatically for further processing in a timely manner. In addition, paper labeling and recording processes are time-intensive. In the worst known cases, more than 70 -80 % of a field technician’s time is spent on paper work for service provisioning and maintenance.

An important additional challenge is that paper labels can fall off or become difficult to identify over time. Moreover, field technicians may forget to add, remove, and/or update paper labels in a timely manner, and these errors may lead to costly operational and maintenance problems and customer dissatisfaction. One major result of the potential difficulties described above is underutilization of optical fiber network resources. According to one SP's estimate, 20-30% of optical fibers installed are not utilized since the SP does not know if they are in good working order or whether they are associated with live traffic. Secondly, there is no complete record of optical fiber connectivity to customer or group of customers. This lack of accurate records leads to delays in network service provisioning and maintenance activity when a problem is detected.

Figure 1 Paper labeling of optical fibers

3.3 Operations and Maintenance Challenges

For many SPs, service provisioning is always driven by work order on hard-copy records. Thus, a field technician carries out the service provisioning activity such as patch cord connection according to the work order. It is difficult for the field technician to complete this task efficiently and accurately with the absence of information regarding specific optical fiber and port availability along with end-to-end routing information. Also, after field operation is completed, verification and resource data updating are conducted manually with low efficiency and high risk of inaccuracy.

4 Technology Progress in the Management of Fiber Infrastructure

4.1 Standardization

As a new technology, a series of FIMS standards have been under development at ITU-T and BBF.

At ITU-T, Recommendation L.64 published in October 2012 addresses the key ID tag technologies used in FIMS products. In this Recommendation, electronic ID tag, which may have two implementations, contact-type ID tag and non-contact type ID tag such as RFID tag, is described, and its use to implement fiber infrastructure management is explained.

Also at ITU-T, a new Recommendation has been under development to address the detailed specifications and requirements including environmental conditions, functional requirements, performance requirements, and interface requirements, for passive node elements equipped with electronic ID tags attached to fiber connectors in FIMS.

At BBF, TR-311 published has been focused on architecture, functional requirements, use cases, and implementation and deployment scenarios of FIMS based on electronic ID tag technologies as defined in ITU-T Recommendation L.64.

According to the FIMS architecture defined in TR-311, there are still some topics that need to be addressed in future standardization projects. These include requirements for Fiber Management Platform, requirements for FIM (Fiber Infrastructure Management) tool, and interface specifications between different physical network elements, and test cases for FIMS.

5 Architecture of Fiber Infrastructure Management Systems

Figure 2 shows the functional block representation of FIMS architecture. It encompasses several functional modules including the following:

- **The Data Collection Function** is used to read or write ID data via I1 interface to the ID block, and to generate {port, ID} mapping. It also serves to control the port indicator to execute the field operation instructions in accordance with commands from the Management Layer.
- **The Node Management Function** is a bridge between the Data Collection and Control Layer and the Management Layer. It achieves field operation guidance by commanding the Data Collection and Control Layer functions and receiving the corresponding operational result.
- **The Fiber Network Management Function** is used to deal with resource data. It receives resource data as well as alarm and/or event via the I4 interface and synchronizes with OSS/BSS via the I7 interface. It supports resource data verification in order to maintain the consistency of the stored resource data with the actual field resource data. It manages the computing and consistency maintenance of end-to-end fiber connection.
- **The Work Order Management Function** is used to handle work orders. It receives the work order request from the OSS/BSS and sends commands to the Node Management function. When the field operation is completed, the result of work order execution is a report from the Node Management function via the Work Order Management function to the OSS/BSS. If the work order does not include fiber routing information, then, the Work Order Management function sends the work order to the Fiber Network Management function with an end-to-end fiber routing computation request.

The ID block represents resource data stored in the ODN equipment, which serves as the physical plant of a fiber infrastructure management system. The OSS/BSS and other applications related to fiber infrastructure management system provide tools to a user who wants to utilize fiber infrastructure more efficiently.

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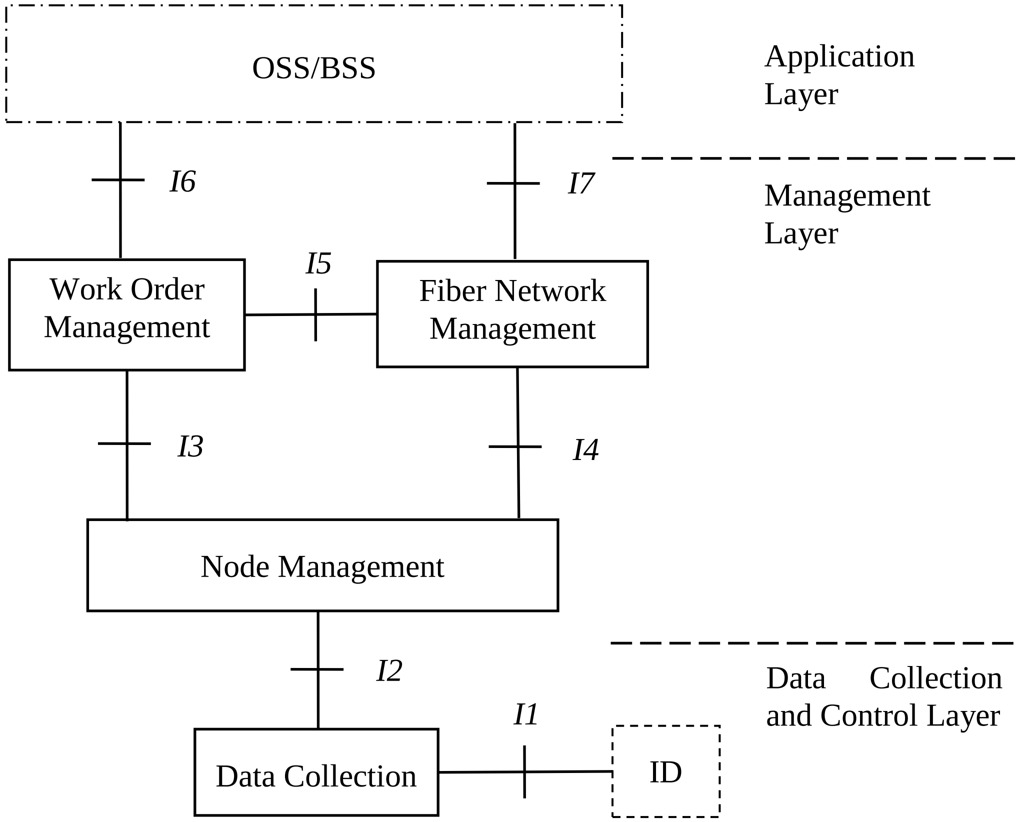

Figure 2 Architecture of fiber infrastructure management system

6 Deployment Use Cases and Implementation Scenarios

6.1 Deployment Use Cases

Here a set of deployment use cases are described. The implementation architecture includes following subsystems such as Fiber Infrastructure Equipment (also referred as Passive Node Element with ID tags), Fiber Infrastructure Management Tool, Fiber Management Platform, Inventory System and Work Order System. In this architecture, the interoperability of FIMS equipment from multiple suppliers and the interoperability with OSS will be addressed in the following sections.

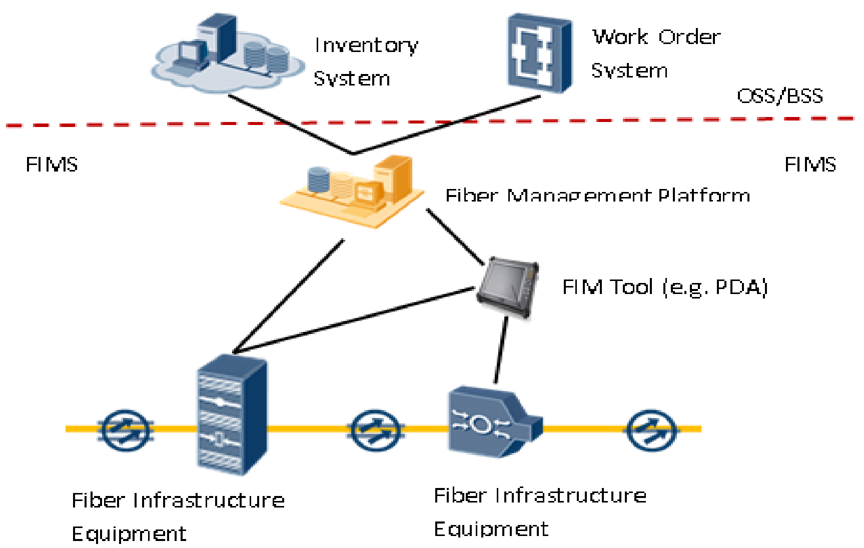

Figure 3 Deployment use cases

6.1.1 Installation: Initial Resource Data Collection and Verification

Business Drivers: In legacy ODN systems, initial resource data collection is always done manually without verification, which leads to low efficiency and high risk of inaccuracy.

Operation Process: After a service provider completes planning and design of a FIMS, Fiber Infrastructure Equipment is installed and configured accordingly. Then, the Fiber Infrastructure Equipment is discovered, and its initial resource data is uploaded in an automated process. For the uploaded resource data, a Fiber Management Platform provides storage and verification capabilities, and it enables synchronization/updating to the Inventory system(s) for further processing in the OSS/BSS. Fiber Infrastructure Management Tool (e.g. PDA) implements communications proxy for Fiber Infrastructure Equipment which has no capability of connecting to the Fiber Management Platform directly.

6.1.2 Service Provisioning: Patch Cord Connection

Business Drivers: For ODN systems, service provisioning is always driven by work orders on paper records with low efficiency and high risk of error. When a field operation is completed, verification and resource data updating are conducted manually, resulting in low operational/maintenance efficiency and high risk of inaccuracy.

Operation Process: When the task of service provisioning starts, it always involves the patch cord connection operation. Therefore, the Work Order System in the OSS/BSS downloads the work order to the Fiber Management Platform which processes the work order and sends the command for field operation guidance (e.g. lighting the LED port indicator) to Fiber Infrastructure Equipment. Then, a field operator carries out the patch cord connection operation according to the guidance provided. When the field operation is completed, the Fiber Infrastructure Equipment reports the added resource data to the Fiber Management Platform for patch cord connection verification and resource data synchronization/updating with the Inventory System in the OSS/BSS.

6.1.3 Resource Inventory and Verification: Periodic Resource Data Consistency Check

Business Drivers: For ODN systems, periodic resource data consistency check is always driven by work orders on paper with low efficiency and high risk of error. Resource data updating and consistency checks are conducted manually with low efficiency and high risk of inaccuracy.

Operation Process: A Service provider always needs to conduct resource data consistency check periodically in order to ensure the consistency of resource data. When the task of resource data consistency check starts, the Work Order System in the OSS/BSS downloads the work order to the Fiber Management Platform which processes the work order and sends the command to the Fiber Infrastructure Equipment. The Fiber Infrastructure Equipment uploads the full resource data to the Fiber Management Platform for resource data consistency check and synchronization/updating to the Inventory System in the OSS/BSS.

6.1.4 Troubleshooting and Fault Locating: Optical Fiber Re-routing

Business Drivers: For legacy ODN systems, query of available resource data for optical fiber re-routing is not possible in the field. Thus, after the optical fiber re-routing is conducted, the resource data updating and consistency checks are done manually, resulting in low efficiency and high risk of inaccuracy.

Operation Process: When a trouble report is received from a customer, the fault management process is initiated. In this case, one or more changes in optical fiber connection need to be considered in specific Fiber Infrastructure Equipment. In accordance with the fault management process, a work order is dispatched to a field operator who carries a Fiber Infrastructure Management Tool. The field operator uses the Fiber Infrastructure Management Tool to inquire about available resource data for optical fiber re-routing. Then, the field operator carries out the optical fiber re-routing operation under visual guidance. When the field operation is completed, the Fiber Infrastructure Equipment reports the added/changed resource data from the Fiber

Infrastructure Equipment to the Fiber Management Platform for resource data verification and synchronization/updating with the Inventory System in service provider's OSS/BSS.

6.2 Implementation Scenarios for Passive Node Elements with ID Tag

According to the needs of SP's network, there could be three possible passive node element (PNE) implementation scenarios as schematically depicted in Figure 4: New area scenario, Hybrid area scenario and Migration area scenario. For the new area scenario, passive node element with ID tags can be implemented as well as FIMS. For the migration area, the existing legacy PNEs are migrated to PNEs with ID tags, so FIMS can manage these PNEs. For the hybrid area scenario, not all the existing legacy PNEs are migrated to PNEs with ID tags. This could present migration difficulties. Thus, a FIMS installation could and should manage both PNEs with ID tags and legacy PNEs.

Considering the construction challenges, the new area scenario is easy to be implemented since there is no need to migrate existing PNEs. Considering the maintenance and operation tasks, the new area scenario and the migration area scenario are similar while the hybrid area scenario requires FIMS capability to manage and operate both PNEs with ID tags and legacy PNEs.

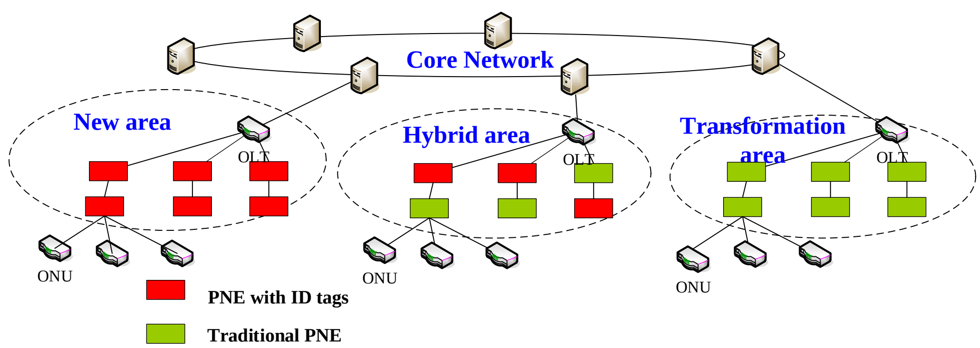

Figure 4 Passive node element with ID tag implementation scenario

6.3 Interoperability with OSS

Operation Support Systems (OSS) used in service provider networks include Inventory Systems and Work Order Systems. FIMSs are designed to interoperate with OSS via a Northbound Interface by uploading/downloading work order information and updates on network resource information. However, these OSS products show variations in both operations and interfaces from one location to another in a given service provider network. Such variations make interoperability of the FIMS difficult with OSS. Figure 5 shows one possible architecture of interoperability with OSS systems that deploy a uniform interface platform.

This uniform interface platform works as an interface between FIMS and OSS. I6 (Work Order Management -Northbound Interface) and I7 (Fiber Network Management-Northbound Interface) are translated by the uniform interface platform so that FIMS can interoperate with OSS (including Inventory Systems and Work Order Systems). By introducing uniform interface platform, uniform adaptation to each OSS can be achieved by implementing different IX interfaces which are possibly unique for each OSS. This capability also enables uniform management for FIMS products from different suppliers.

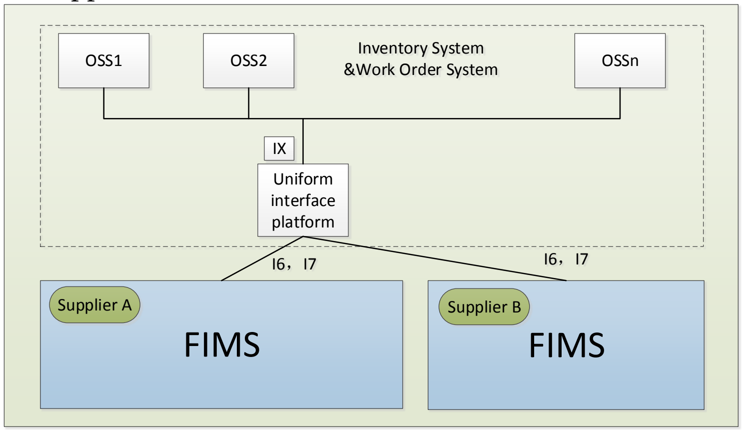

Figure 5 One possible architecture of interoperation/cooperation with OSS systems

6.4 Interoperability of FIMS Equipment from Multiple Suppliers

In a service provider network, one location may have such passive node elements as ODFs from several suppliers. However, it is not practical to build a management system dedicated to each supplier due to its high cost and inefficient OAM. In Section 6.3, a solution with uniform interface platform is described for management of FIMS from different suppliers.

In order to realize further interoperability, two potential interoperability solutions are shown in Figure 6. For solution #2, one field operator should use several field tools (PDAs). However, this feature makes this solution unrealistic. For solution #1, only one fiber management platform is proposed for one location, and one type of field tool can be used to operate on passive node elements/equipment from several suppliers. Thus, solution #1 becomes practical, and feasible. It should be noted that the architecture described in 6.3 can also function as an interoperability solution under certain conditions.

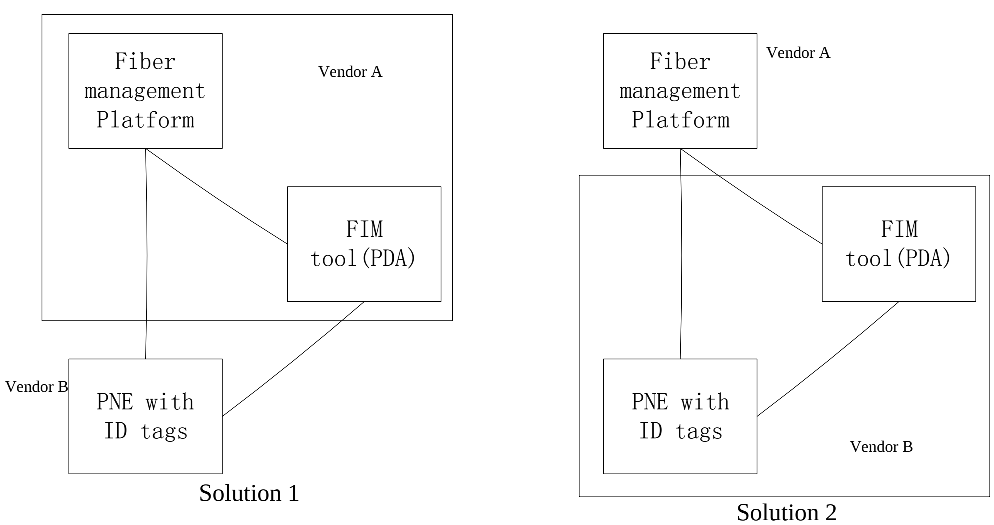

Figure 6 Potential interoperability solutions

6.5 Cost Challenge

After years of large scale product development, legacy fiber infrastructure equipment in operator networks has become technologically mature and cost effective compared to earlier generations of equipment. However, emerging FIMS equipment with electronic ID tags, circuit boards and frame controllers, fiber connectors equipped with ID tags, fiber management platforms and field operation tools will continue to evolve. Consequently, these systems have not reached their state of technological maturity and cost effectiveness yet.

6.6 Migration from Legacy Fiber Infrastructure Network

Many global operators have been deploying fiber infrastructure networks on a large scale. Smooth migration from these networks to FIMS requires new solutions.
One key challenge is that the migration should be planned and carried out with minimal interruption / disruption of service to existing subscribers. An equally important challenge is the existence of fiber infrastructure equipment from many suppliers installed over a long period of service. In most cases, the equipment installed from different suppliers may have proprietary, non-standard features such as physical characteristics.

6.7 Environmental Adaptability

Fiber infrastructure equipment designed for outside plant deployments must satisfy all applicable environmental requirements. These requirements often include operation under exposure to salt fog, high temperature, low temperature, high humidity. For FIMS products, EMC/EMI (Electromagnetic compatibility / Electromagnetic interference) must be considered. The FIMS equipment must meet the same requirements as those that are met by legacy ODN equipment.

6.8 Maintenance Challenge

FIMS equipment is expected to have impact on current OAM practices. Network maintenance personnel would require training that is specific to FIMS equipment to realize the value and benefits of emerging FIMS products.

7 Future Outlook

At present, the FIMS achieves the basic connectivity management based on electronic ID technology and realizes the definition of architecture. In the future, under this framework, FIMS can be expanded and further developed to meet the service provider needs for fiber resource management and to help service providers (SPs) improve the manageability of optical fiber resources.

7.1 Expand the Scope of Resource Management

Based on the current electronic ID-based connection management, FIMS will identify and manage more resources, including cable, pipeline, room, pole, manhole cover and etc. On the other hand, FIMS can achieve more management functions, including the visual management, the dynamic management and analysis of resources. In the network operations management center, SPs can easily monitor the network topology, network resource usage, line operation quality, etc.

7.2 Strengthen the Reliability and Safety of Optical Network

First, FIMS can make the resource data collection more efficient and resource data accurate. By comparing the information of the deployed equipment and the stored information, it can assess the change in equipment information and its accuracy, and generate error message warnings. At the same time, the new change information is reported to the network management center in a timely manner. Secondly, FIMS can integrate a variety of fault identification capabilities, such as OTDR remote optical fiber diagnosis, upstream signal detection-based monitoring of ONU status. Therefore, FIMS can achieve rapid fault warning and positioning. Thirdly, FIMS can integrate node security authentication mechanisms to avoid illegitimate operation, such as passive electronic lock with authorization management.

7.3 Achieve Flexible Resource Scheduling

According to the service requirements, FIMS can perform fast optical fiber routing and scheduling. For important fiber optic links, AODF (Automated Optical Distribution Frame) can expedite allocation of user resources remotely. In the future, FIMS also needs to implement AODF management.

Based on the today's FIMS' capabilities, further development steps are needed to pave the way to an intelligent fiber network in the future. The FIMS automatically reads out the resource data from ID tags to make all fiber ports visible today. This information supports the network engineering process in the field as described in the last section.

The knowledge of all fiber ports enables the operator to combine fibers in bundles or group them to virtual cables. The visible network becomes a flexible network. One of the next steps will be the fault detection and localization along the fiber link by adding active supervision capabilities. The already installed FIMS resources can be re-used for these measurement functions. In this evolution phase, new monitoring functions will improve the robustness of the network.

The last step to an intelligent network will bring new control and configuration elements like switches and attenuators into the foreground. Automated route-switching will protect the data transmission in a very rapid way and field engineers can be directed to the right location/site to recover the network resources in parallel. The development of new measurement and configuration elements is ongoing to build up a future-proofed, versatile fiber infrastructure network.

8 Conclusions

FIMS (Fiber Infrastructure Management Systems) are designed to enable service providers to manage their passive optical networks with improved efficiency and automation. They represent an integrated system based on the use of electronic ID tag technologies. They support service provider goals for rapid service provisioning with minimal field operation errors, and, therefore, improving customer satisfaction and lowering customer churn.

FIMS standards have been developed at ITU-T and BBF in harmonization to ensure that the FIMS emerges as a complete ecosystem with its full potential. The emergence of FIMS enables service providers to enhance the efficiency and accuracy of passive fiber network management.

Architecture of FIMS shows how FIMS enables automated resource data collection and field operations verification as well as streamlines work order downloading / uploading process. Through the northbound interface, FIMS can interoperate with service provider OSS and other operation systems to support many valuable applications.

Several service providers have announced FIMS deployments. Depending on such service provider-specific issues as the existing passive network infrastructure, interoperability with the OSS, and cost of migration, FIMS deployments are expected to continue at accelerating pace in various regions of the world. In the future, suppliers of FIMS will continue to add features and functions to improve performance and service provisioning efficiency with greater savings in CapEx, OpEx, and total cost of ownership (TOC).

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