Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Network Management System for (FUTON-like) Radio-over-Fiber Infrastructure

Santiago, Carlos; Gangopadhyay, Bodhisattwa; Ramkumar, Venkata; Prasad, Neeli R.; Arsenio, Artur

Published in:
International Journal of Computer and Communication Technology

Publication date:
2010

Document Version
Early version, also known as pre-print

Network Management System for (FUTON-like) Radio-over-Fiber Infrastructure

C. Santiago, B. Gangopadhyay B., A. Arsenio
Nokia Siemens Networks Portugal
Amadora, Portugal
{carlos.santiago,bodhisattwa.gangopadhyay, artur.arsenio}@nsn.com

M. V. Ramkumar, N. R. Prasad
Aalborg University
Aalborg, Denmark
{rk, np}@es.aau.dk

Abstract[1]— **EU-Project FUTON Radio-over-Fiber (RoF) infrastructure proposes high transmission rates at small antenna costs, implying competitive CAPEX for next generation networks. But to be cost-efficient, it needs to employ new network architectures and intelligent technology solutions for decreasing network operational costs. The RoF Network Manager manages the network equipment on the optical front haul between the Central Unit (CU) and all Remote Antenna Units (RAU)s connected by it, as well as the communication links, while enabling end-to-end service problem resolution and service quality management by the FUTON Middleware. Although a significant amount of prior research work can be found in the literature related to RoF, there is still significant lack of technologies concerning RoF networks management. RoF Manager and its sub-systems target to fill such gap, proposing a novel concept in the form of Channel Forwarding Table (CFT). RoF Manager follows an autonomous and generic network management framework, designed to be scalable in terms of adding new network elements (NEs). It targets multi-technology, multi-service and multi-vendor NEs in the network using Simple Network Management Protocol (SNMP). It can also provide alternative paths in case of failure. This work puts forward a new paradigm towards RoF management solution managing network performance, network faults, network security and configurations for convergent networks.**

Keywords- radio-over-fiber, network management, infrastructure, convergent, configuration, fault, performance

I. INTRODUCTION

EU-Project FUTON [1] proposes a flexible architecture for wireless systems which jointly processes the radio signals from different remote antenna units (RAUs) supported by a transparent optical fiber infrastructure to answer the growing demand for wireless services. This is based on the vision of the 4G systems aiming at the provision of true broadband wireless access, successfully overcoming the quest for high bit rates in wireless communication (1Gbits/s for pedestrian and 100MBits/s for high mobility) [1].

This work is concentrated at the management of the hybrid optical-radio infrastructure existing between the fiber-optic interface of the CU and the RAUs in the FUTON architecture. It is to be noted that, FUTON brings a new paradigm by moving the UMTS node B and the RNC functionalities together into the CU and that the RAUs managed by the RoF Manager might support different wireless technologies. RoF Manager and the allied components are technology agnostic and so different from the traditional network management systems. Figure 1 depicts several RAUs connected to one CU with NEs existing on the optical front haul between the CU and all RAUs. It illustrates a topology where RAUs support different technologies such as GSM, UMTS, WiMAX, LTE or WLAN.

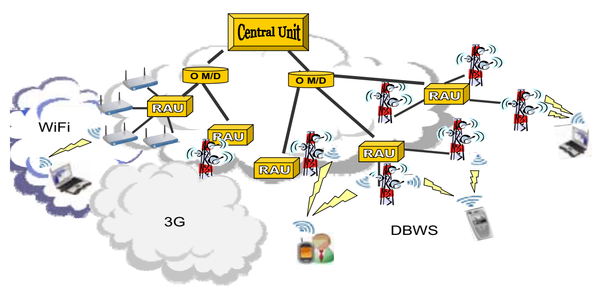


Figure 1 – FUTON Architecture

This paper is structured as follows. Section II highlights the FUTON infrastructure, RoF Manager and allied challenges. This justifies the novelty of RoF Manager related to the FUTON-like infrastructure management scope. Section III describes the solution to the challenges, introduces the RoF Manager and the associated module in details. Section VII concludes the paper.

II. FUTON-LIKE ROF INFRASTRUCTURE AND NETWORK MANAGEMENT CHALLENGES

As RoF technology enables centralization of network management, processing and network functions [2], FUTON aims at distributed antenna systems (DAS) connected by a

1 This work is supported in part by the European Commission, in the context of the project FUTON "Fibre Optic Networks for Distributed, Extendible Heterogeneous Radio Architectures and Service Provisioning", grant agreement FP7 ICT-2007-215533
Bodhisattwa Gangopadhyay wishes to thank Fundação para a Ciência e a Tecnologia, Portugal, for support under grant SFRH/BDE/33799/2009.
Carlos Santiago wish to thank Fundação para a Ciência e a Tecnologia, Portugal, for support under grant SFRH/BDE/15549/2005.

hybrid fiber-radio network connecting RAUs to CU. The RAUs are eventually "dumb" and all processing functionalities have been moved to the CU.

Figure 2 explains the FUTON generic architecture, covering a geographical area divided into several serving areas, where the multi-frequency RAUs are located. These RAUs are linked to a CU, using a transparent optical fiber system, and can send/receive signals from different wireless systems.

The CU can be seen as an entity connected to the network, collecting all the optical signals that each RF/optical interface placed at the RAU locations is providing to the optical network, and also houses several Joint Processing Units (JPUs), each of which processes several RAUs. Though CU houses several functional units, the focus of this paper is RoF Manager.

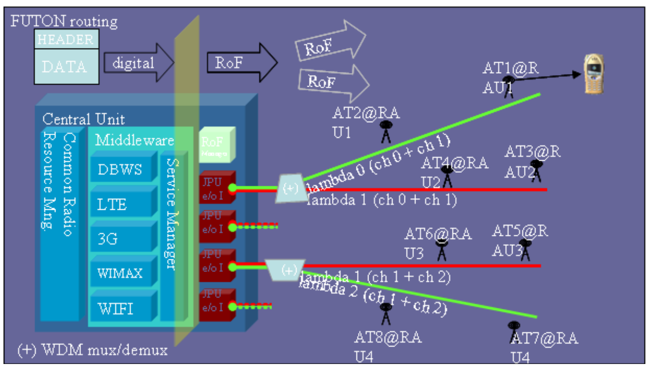


Figure 2 – FUTON generic architecture

The centrally located RoF Network Manager, responsible for the management of the FUTON optical infrastructure,. is tasked with monitoring and configuring all NEs from the CU up to the antenna, providing and updating information concerning network topology, optical links status (available for distributed antenna signal processing modules and other Middleware), and the sole entity communicating through the signaling control channel. The RAU, through RoF Manager, can also provide information concerning the connectivity status to an antenna (electrical physical connection between RAU and antenna) as well information concerning other antenna parameters.

However, RoF Manager requires a different approach from existing network management systems (NMSs) due to the centralized FUTON architecture and the use of RoF technologies to transport radio signals. FUTON requires a central management (directly connected with Radio Resource Management) of the optical links toward the destination RAUs and Antennas, and all the optical devices in the path. Also, being technology agnostic was important for supporting different technologies as mentioned before. The dynamic nature of the network with the recovery scenarios also imposes demand on the NMS. In brief, RoF Manager is expected to handle crucial network management tasks such as Configuration (CM), Fault (FM) and Performance Management (PM) avoiding high operational expenditures (OPEX) during the network lifetime. The current lack of technologies concerning specifically RoF management thus requires a novel approach to cope with the management of such networks.

Moreover, state-of-the-art network management systems were based on ITU-T or IETF standards [3]. But these network management systems were built to cater individual technologies, which is an impediment to FUTON scenario serving simultaneously all kinds of technologies such as PSTN, PSDN, PLMN, WLAN, WiMax, ultrawide-band (UWB) signals, and DBWS signals. Though there was a solution to manage IMS components independent of heterogeneous management protocols, but management of core network elements is not in the scope of RoF Manager [4]. Similar to FUTON RoF scenario, management of hybrid RoF wireless sensor network architecture is proposed in [5] where heterogeneous cluster head sensor node represents the FUTON RAU, complemented by simple topology control algorithm and data collection protocol, and further analyzes network delay and energy consumption.

State-of-the-art research related to configuration management of RoF infrastructure exhibits scalable network management systems [6] [7] specific to scenarios with large population, heterogeneous networking technologies and so on. But none of them answers the problem persisting in the scope of FUTON, that requires a central management (directly connected with Radio Resource Manager) of the optical links toward the destination RAUs and Antennas, and all the optical devices in the path. In current FUTON architecture, each RAU has one wavelength in upstream and one wavelength in downstream; and the radio signals for the antennas within the same RAU are separated using sub-carrier multiplexing.

III. Solution

In line with the challenges put forward in the previous section, the RoF Manager is presented here, built following the basic characterization of network management functions "FCAPS"—Fault, Configuration, Accounting, Performance and Security. RoF Manager will introduce some key requirements and capabilities for the support of a FUTON-like RoF infrastructure, but only concentrated towards managing network performance, network faults and configurations for convergent networks.

The functionalities of the RoF Manager are described below. RoF Manager monitors all NEs from the CU up to the antenna while provides and updates information concerning network topology and optical link status. The latter information will be available for Middleware and Centralized Radio Resource Management (CRRM). The operating logic of the NEs are not interfered but only the configuration parameters are monitored and if necessary changed. It is to be noted that the RoF Manager operates exclusively in the signal control plane and thus have no access to the user specific data or flows, but can access information such as NE traffic on a specific port to infer on performance.

RoF Manager also has the exclusive access to NE data within the scope of FUTON. All other components of the CU that need to have access to NE data have to request them directly to the RoF Manager. Information related to the CRRM is also available from the Middleware database that is updated by the RoF Manager.

Figure 3 shows the RoF Manager architecture explaining the inter-working within the different blocks. The main components of RoF Manager that controls the network and network equipments are listed here: Configuration Management (CM); Fault Management (FM); Performance Management (PM); Security Management. These sub-systems constitute the base platform and are integrated with other FUTON modules, namely Middleware, CRRM and the NEs via a Mediator.

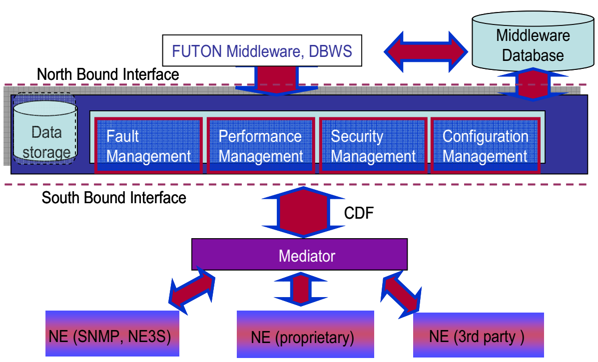
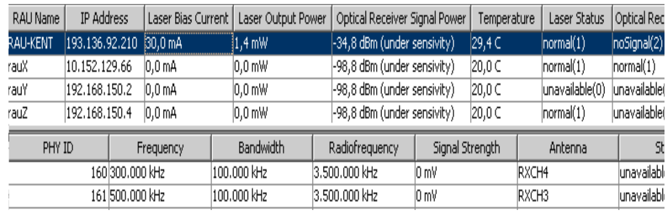


Figure 3 – RoF Manager Architecture

This solution is based on a novel concept of CFT which puts forward the distribution of channels among the different RAUs. This CFT maps the wavelengths and sub-carriers with the antennas and allows identification of all the active elements that can be used along the paths from the CU to any of the antennas and consists of a table with the physical address of the antennas matched with the channel identification attached to the antenna. Thus, information about all the optical devices transporting the radio signal is available in one single table which facilitates the CM, PM and FM of any of those (active) elements easily, as depicted hereafter:



RAU Name	IP Address	Laser Bias Current	Laser Output Power	Optical Receiver Signal Power	Temperature	Laser Status	Optical Rec
RAU-KENT	193.136.92.210	30,0 mA	1,4 mW	-34,8 dBm (under sensivity)	29,4 C	normal(1)	noSignal(2)
rauX	10.152.129.66	0,0 mA	0,0 mW	-98,8 dBm (under sensivity)	20,0 C	normal(1)	normal(1)
rauY	192.168.150.2	0,0 mA	0,0 mW	-98,8 dBm (under sensivity)	20,0 C	unavailable(0)	unavailable(
rauZ	192.168.150.4	0,0 mA	0,0 mW	-98,8 dBm (under sensivity)	20,0 C	normal(1)	unavailable(

PHY ID	Frequency	Bandwidth	Radiofrequency	Signal Strength	Antenna	St
160	300.000 kHz	100.000 kHz	3.500.000 kHz	0 mV	RXCH4	unavailabl
161	500.000 kHz	100.000 kHz	3.500.000 kHz	0 mV	RXCH3	unavailabl

Figure 4 – Channel Forwarding Table

The image above represents an instance of the RoF Manager CFT which contains a detailed version of the CFT where each row corresponds to an optical link between the CU and an antenna. There is one row for the upstream and other for the downstream link. Each row is identified by an index, termed PHY_ID. From this index is possible to distinguish the index of the JPU that identifies the optical port toward the RAU, the index of the wavelength and the index of the channel that identifies the sub-carrier containing the radio signal to be forward to the antenna. Beside this index, each row contains the value of the central frequency, the bandwidth that corresponds to the given channel index, and the value of the radio frequency. Finally, each row contains the antenna ID, the link status. This centralized CFT facilitates the dynamic adaptability and easy configuration of the RoF resources. Detailed observation on the CFT is available in [3]. For each channel, the CFT gives information of: JPU towards each antenna; wavelengths used to communicate with the RAU (that has the antenna), either in upstream or in downstream; the sub-carrier central frequency; the sub-carrier bandwidth; and the radio transmission frequency. As explained in [3], Middleware only requires the physical address of the antenna for necessary decision making. The CFT table also caters to MIMO model, where the Middleware queries the CFT for the status of the entire channel IDs serving the terminal. The CM module updates the CFT when configuration changes occur in the channel, which can be either static or dynamic.

Keeping in view the dynamic channel allocation scenario that can be achieved by using CFT, a recovery scenario where a complete new set of wavelengths and sub-carriers is used in a new alternative path was proposed in [8].

RoF Manager has its own database to store configuration, performance and fault data which are updated regularly either by network triggering or due to regular polling at specified granularity periods, accessible by the Middleware. The Middleware uses this data for various upper level network management activities. This database resembles the Channel Forwarding Table (CFT), which maps the wavelengths and sub-carriers with the antennas (RAUs). The FUTON Middleware can read the link status from this database using a Web Service interface. This database houses the hardware information base, case-based reasoning (CBR) cases, policies related to PM, network data and logs.

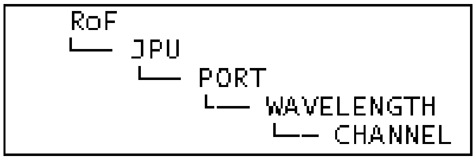


Figure 5 – Hardware information base structure

The information structure inside the hardware information base is shown in Figure 5, where a JPU is a card directly connected to the CU and each of the JPU port is represented by the Port group. Each of the wavelengths available on each port is presented in the wavelength group and each sub-carrier available within each wavelength is presented in the Channel group.

A. Configuration Management

The configuration management plays a very important role to guarantee fast fault recovery and dynamic system configuration. The RoF Manager CM module is based on the structure of CFT and functions by acting on network and system configuration information. CM module saves the configuration parameters in the NE in a virtual information store, termed the Management Information Base (MIB), located in the software agents (SA) based in the RAUs. The configuration management tasks are achieved by the RoF CM module stationed in the RoF Manager and software (SNMP) agents in the RAUs to be managed.

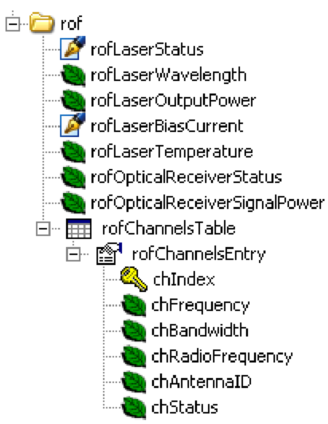


Figure 6 – FUTON-RAU-MIB

Also, associated with them are the MIBs, describing the structure of the management data of a managed device; and uses a hierarchical namespace containing object identifiers (OID). The objects in the MIB are defined using the Abstract Syntax Notation One (ASN.1) as recommended in [9]. Figure 6represents FUTON-RAU-MIB and the hardware information base allows an easy management of the RoF infrastructure in both static and dynamic scenarios.

Figure 7 shows the Configuration Management module in RoF Manager GUI, which can be used for setting, getting parameters at/from the RAUs, and listening to traps. RoF Configuration Management uses the CFT database located in the RoF Manager where data from the RAU agents are written into and also read from.

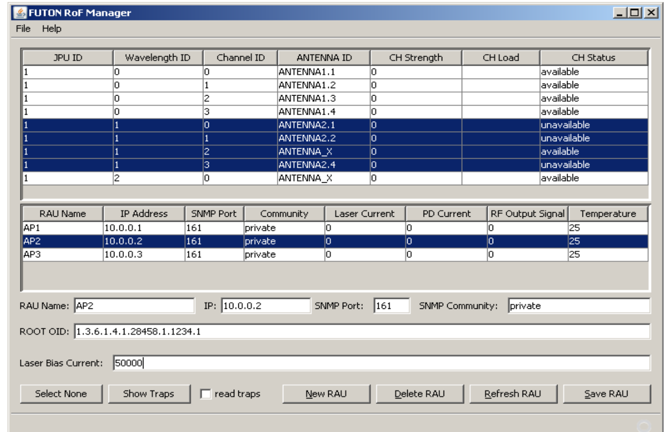


Figure 7 – Configuration Management GUI

Using CM module, change management is implemented which is concerned with keeping track of hardware configuration and changes while maintaining their status update. These changes might occur in equipments that only allow administrative changes (static scenario) or in equipments that allow dynamic configuration of the wavelengths, sub-carrier frequencies or bandwidths (dynamic scenario).

B. Fault Management

FM system is of utmost importance as it is concerned with the detection, reporting and recovery from faults. The Fault Management sub-system is implemented using a FM Server build on the management information available in the SNMP agents placed in the RAUs, and trap messages generated from these agents, the RoF Manager database and the Fault management decision making modules.

The notification management generates messages when a read value is compared and found to be out-of-range of the defined thresholds defined in the FUTON-Threshold MIB. The notification management checks with the SNMP-Notification-MIB for the parameters to be sent within the trap messages. Following this, a check is made with the SNMP-Target-MIB, to check the address to which the notification is to be send.

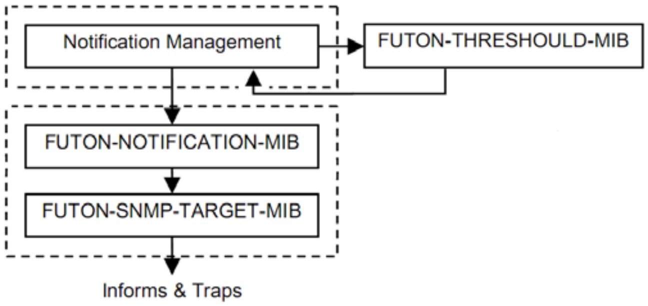


Figure 8 – FUTON RoF Fault Management

Besides traditional case-based-reasoning approach, FM is also achieved using the CFT as the PHY_ID infers the malfunction device by correlating the PHY_IDs of the failing channels.

Table 1 CFT displaying a failure

ANTENNA_ID	PHY_ID		STATUS
	decimal	binary	
RAU 1 / ANT 1	0	000000	1 (enable)
RAU 1 / ANT 2	1	000001	0 (disable)
RAU 2 / ANT 1	8	001000	2 (failure)
RAU 2 / ANT 2	9	001001	2 (failure)
RAU 3 / ANT 1	32	100000	1 (enable)

For example, Table 1 demonstrates a scenario where by correlating the PHY_IDs of the channels 8 and 9, it is evident that the failure occured in the channels in which PHY_ID starts with 00100. As there is no fully working channel starting with 00100, one can presume that the failure occurs in the device with the longer ID fully contained in 00100 (starting from the left). The answer is a presumable failure in the wavelength identified by ID = 001, as has occurred.

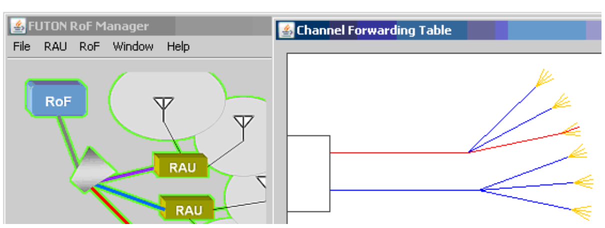


Figure 9 – Fault Management with CFT

Figure 9 represents the RoF Manager GUI where the channel color changes to "RED" on a failure.

Failure recovery is achieved in scenarios where a complete new set of wavelengths and sub-carriers is used in a new alternative path by introducing a new entry in the CFT [8]. This enables self-healing capability in the RoF network.

C. Performance Management

PM Module works in the background of the RoF Management System where a policy based approach is used for the PM actions which depend on the CFT for data collection. RoF Manager is flexible to introduce new thresholds or modify existing ones in run-time.

Figure 10 presents the internal architecture of the PM module in RoF Manager.

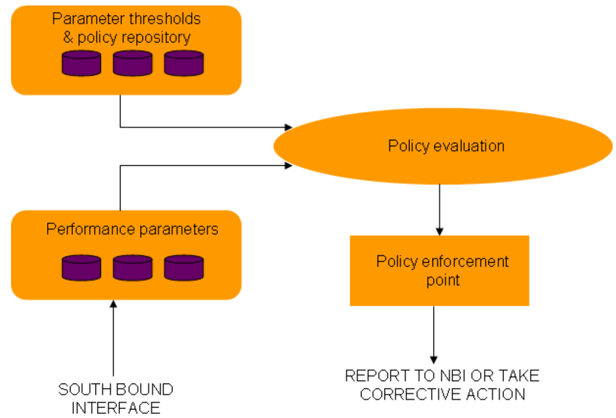


Figure 10 – Architecture PM sub-system

Figure 11 represents the database structure to realize the above mentioned PM activities in RoF Manager used for storing PM Thresholds, decision policies of the evaluation process, definitions of corrective action and PM data collected from the Network.

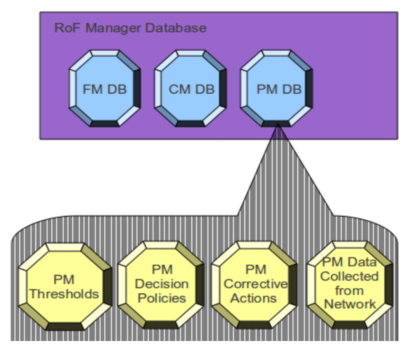


Figure 11 – PM module internal architecture

This approach helps to make the PM module scalable and flexible as well as react actively (and proactively) to network bottlenecks (or degrading conditions) and potential faults. Additionally, prioritizing traffic and maximizing the network resources usage thus improving the overall network performance. Scalability is achieved as hierarchical policy management is supported using such a model; and policy management across multiple policy domains is also a possibility.

IV. Evaluation of RoF Manager

Such a concept of centralized network infrastructure management adds benefits in terms of reduced operational expenditure (OPEX) and capital expenditure (CAPEX). As the management functions are moved into the CU; the RAUs are kept as simple as possible and thus a reduction in CAPEX is possible. Using a policy based management system, it is possible to guide and control the efficient use of the network, through applications that convert policy to network directives and reduce costs associated with individual element management. As demonstrated in [8], it is possible to achieve self-healing using the CFT model and thus a reduction in OPEX. The main innovative concept behind RoF Manager and its sub-systems, CFT, allows identifying all the active elements that can be used along the paths from the CU to any of the antennas. This way the configuration, performance and fault management of any of those (active) elements is easily traceable. In FUTON, RoF Manager makes it possible to obtain entire information about all the optical devices transporting the radio signal in one single table using the CFT.

V. Conclusions

The work presented targets the realization of a network management system tailored for the RoF infrastructure. Currently, RoF Manager was developed in the scope of FUTON but can also be extended to other networks. Issues such as scalability and technology agnostic nature have been taken care of. The solution provides self-healing and pro-active management which is one of the key requirements of networks catering to wireless broadband communication in the future.

Reference

[1] Pato S., Pedro J., Santos J., Arsénio A., Inácio P., Monteiro P., "On Building a Distributed Antenna System with Joint Signal Processing for Next Generation Wireless Access Networks: The FUTON Approach". 7th Conference on Telecommunications, Portugal.

[2] Arismar Cerqueira Sodre´ Jr., D. C. Valente e Silva, M. A. Q. R. Fortes, L. F. da Silva, O. C. Branquinho, and M. L. F. Abbade, "Performance Analysis Of a Radio Over Fiber System Based On IEEE 802.15.4 Standard in a Real Optical Network", © 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 1876–1879, 2009.

[3] "Next generation Radio over Fiber network management for a distributed antenna system", Santiago, C. Gangopadhyay, B. Arsenio, A.M. Ramkumar, M.V. Prasad, N.R.; WirelessVitae, 2009. Page(s): 182-186, May 17-20, 2009 Aalborg.

[4] Karthik B.S.; Jaiswal M.; Menon V.; Kannan V.; Venkobarao S.; Pande M.; Talukder A.; Das D., "Seamless Network Management in Presence of Heterogeneous Management Protocols for Next Generation Networks". 9th International Conference on Information Technology, 2006. ICIT '06. 18-21 Dec. 2006 Page(s):68 – 71

[5] Tang J.; Jin X.; Zhang Y.; Zhang X.; Cai W., "A Hybrid Radio Over Fiber Wireless Sensor Network Architecture". International Conference on Wireless Communications, Networking and Mobile Computing, 2007. WiCom 2007. 21-25 Sept. 2007 Page(s):2675 – 2678

[6] Vegas Olmos J., Kuri T., Kitayama K., "Dynamic Reconfigurable WDM 60-GHz Millimeter- Waveband Radio-Over-Fibre Access Network: Architectural Considerations and Experiment". Journal of Lightwave Technology, Vol. 25, no. 11, November 2007

[7] Kant L., Srisathapornphat C., Jaikaeo C., Zhu C., "A Scalable Manager-Agency-based Network Management Design to provide Adaptive Configuration Management for Tactical Battlefield Networks", MILCOM 2001. IEEE Volume 2, 28-31 Oct. 2001 Page(s):928-932 vol.2

[8] Gangopadhyay B., Santiago C., Arsenio A., "Comparative Evaluation of Failure Recovery Mechanisms for Convergent Networks", WPMC 2009, Sendai, Japan

[9] Information processing systems - Open Systems Interconnection - Specification of Abstract Syntax Notation One (ASN.1), International Organization for Standardization, International Standard 8824, December 1987