A NEXT GENERATION DISTRIBUTED NETWORK MANAGEMENT SYSTEM

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Abstract: Network management of geographically diverse telecommunication systems, such as undersea cable networks, poses special operational challenges above and beyond customer expectations of high quality data transmission. These include ease of use and low costs of deployment, operation and maintenance. This paper presents the architecture and functional capabilities of Tyco Telecommunications' next generation Network Management System (TEMS-NMS) specifically designed to meet the challenges of these types of cable networks. TEMS-NMS supports geographically diverse undersea networks providing NMS high reliability and with significant new capabilities that effectively mitigate customer issues which often arise with more traditional NMS systems.

1 OVERVIEW

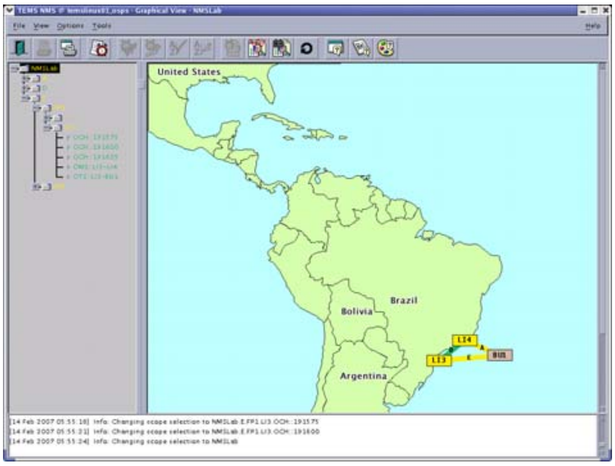

Figure 1 - Main Window

TEMS-NMS is a software based product based on an R&D project initiative to develop an Undersea cable Network Management System (NMS)[1] that fulfills the Network Management Layer (NML) functionality, as defined by the ITU Telecommunications Management Network (TMN) standard[i], while removing issues and challenges which often surfaces with other NMS's. Requirements for TEMS-NMS were generated based on analysis of specific customer needs related to large deployed Undersea cable NMS. The requirements include the following:

- Complete network discovery from the underlying Element Management System (EMS) layer
- No required additional hardware beyond what is normally provided at the EMS layer
- No data persistency for historical and topological information
- Flexibility, requiring minimal knowledge of the managed Network Elements (NE's) and automatic discovery of wavelength upgrades
- Only normalized data
- Root-Cause Analysis (RCA) capabilities without the need for rule identification or expert user intervention
- Automatic self-healing of NMS services
- Distributed architecture, but without the need for data synchronization
- An OSS (Operations Support System) interface
- Minimal Data Communications Network (DCN) traffic (as the reader will notice, the TEMS-NMS architecture and resulting features have been designed with this requirement as a large influencing factor)
- Automatic event and alarm synchronization,
- Automatic report generation
- Trail management as applicable to the network and in accordance with the ITU-T framework
- Minimal user maintenance
- First alert report (see **¡Error! No se encuentra el origen de la referencia.**)

[1] See Section 7 for a complete list of acronyms.

• State-of-the-art expected features such as an intuitive point and click Graphical User Interface (GUI), with color-based alarm indications, that is accessible from any privileged user workstation, including a Network Operations Center (NOC) connected to the NMS DCN.

This paper discusses the architecture and techniques implemented to satisfy these complex requirements.

2 TEMS-NMS ARCHITECTURE

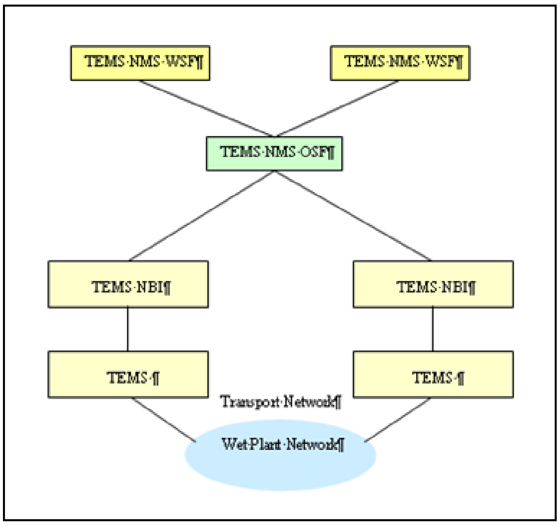

Figure 2 - Logical High Level Architecture

TEMS-NMS is built upon the Tyco Telecommunications EMS offering, called the Tyco Telecommunications Element Management System (TEMS). TEMS is the successor of the Undersea Network Management Equipment which was discussed in the framework of the FLAG network at Suboptic '97[ii]. The TEMS management domain is cable station equipment-centric, encompassing the Line Termination Equipment (LTE) level domains as well as the Power Feed Equipment (PFE) and other supporting elements. TEMS-NMS is trail-centric encompassing the above listed equipment but only at a holistic network level. Both systems are implemented primarily using C++ and Java programming languages and currently execute on the Linux operating system using commercial off the shelf hardware.

2.1 TEMS Client server model

To address the challenges imposed by geographically diverse undersea networks (e.g. NMS DCN availability, maintenance authority policies, etc.), a TEMS hardware server and user workstation are typically deployed at every cable station so that reliability of management of Network Elements (NE's) is maximized. TEMS workstations may also be located at the customer NOC's to facilitate 24 by 7 monitoring of the entire network.

2.2 TEMS-NMS Client-server model

TEMS-NMS capitalizes on this client-server architecture by adding server applications (i.e., Operations Support Function or OSF) to each existing TEMS hardware server and by adding a TEMS-NMS client GUI (i.e., Work Station Function or WSF) to each existing TEMS client workstation, including ones at the NOC(s). The OSF server(s) interact with each underlying TEMS server via a CORBA (Common Object Request Broker Architecture) North Bound Interface (NBI); see Figure 2. Additional details of the OSF are shown in Figure 3, where the NMS NBI module supports the optional OSS interface.

2.3 OSF LiFE cycle management

Under normal operating conditions, only one OSF server is actively hosting the TEMS-NMS functions in the network. However, any other OSF server may assume the active host role, should the designated OSF server become unavailable. As such, OSF servers are state-based and switch states (e.g. running, standby, etc.) automatically in response to client normal operational queries (e.g. WSF or OSS Simple Network Management Protocol (SNMP) or Transaction Language 1 (TL1) interface), as well as notifications exchanged between all OSF servers. Each state comprises a set of required tasks the OSF must perform in order to provide clients with available and accurate network management information. Each state also identifies which services the OSF can support at a given position in its life cycle. The state transitions are governed by milestones reached in the OSF application algorithm execution, stimulated by self-sanity checking operations, and by client-issued requests. One of the more interesting scenarios that this architecture supports is one in which the DCN is cut[2] into multiple domains thus requiring complimentary multiple NMS domains. The life-cycle aspects of automatic OSF state management will create as many OSF running states as is required to support these network "islands". Furthermore, when the network connectivity is restored (islands reconnected), the active OSF servers use the exchanged notifications among themselves to determine whether they should yield to higher priority servers, putting themselves on a standby state, and thus minimizing the number of running OSF's in the network. Switching states occurs within seconds to a few minutes, since it depends only on exchanged notifications across the NMS DCN. In such cases, data

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[2] Either by a planned network topology change or by a network impairment such as a cable cut.

synchronization is not required, as there are no databases requiring consistency checks.

2.4 DCN USAGE

TEMS-NMS is based on intelligent data discovery techniques using optimized queries that minimize system overhead as well as NMS DCN usage. For reference, traditional NMS server architectures may duplicate data from the underlying subsystems (e.g. EMS or NE’s) or implement geo-redundant server architectures that require periodic, if not continuous, database synchronization, potentially taxing the DCN. Unlike those architectures, TEMS-NMS will mostly create DCN traffic when needed to service a client. Generated DCN traffic includes data to support initial topology discovery, alarm events from each TEMS server, and on-demand measurement data discussed in more detail below. The WSF has been designed to also minimize DCN traffic by uploading topology information only when needed to view a certain domain, and by appropriate caching of more frequently utilized information. These methods are expected to reduce DCN usage substantially as compared to prior generation undersea NMS solutions.

3 FUNCTIONAL CAPABILITIES

The TEMS-NMS solution provides TMN functions (ITU, 1985). The WSF provides aggregated views of the overall cable system, including active alarms that can be simply scoped and filtered appropriately to reflect the domain that the end user is interested in monitoring. The WSF also supports trail-based configuration and performance reporting for the management categories described in the following sections.

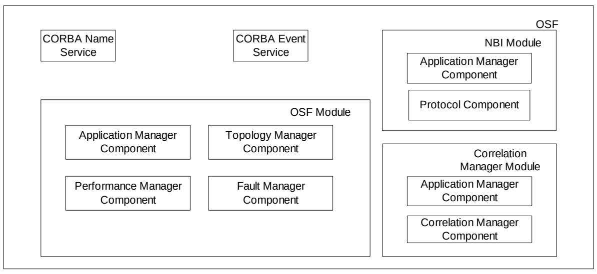

Figure 3 - OSF Architecture

3.1 Configuration Management (CM)

The managed trails[iii], including the supported optical transport layers (see

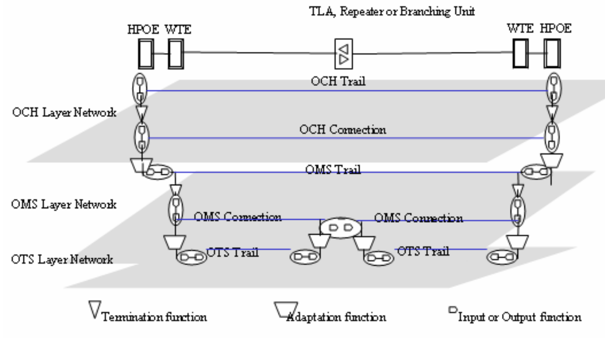

Figure 4 - Optical Transport Layer Networks

Optical Channel (OCH), Optical Multiplex Section (OMS), and Optical Transmission Section (OTS), are realized by dynamic trail generation[iv]. This is achieved when the OSF servers “sew” the discovered termination points and their connectivity pointers into the appropriate network trails. This “sewing” occurs anytime an OSF server becomes active or anytime a user wishes to force a rediscovery of the network via the GUI Control Panel (for instance after additional wavelengths are added during a dry plant upgrade). Discovery and sewing has been observed to take only a few minutes for large systems (e.g. ten or more geographically diverse cable stations around Central and South America) as compared to prior generations of undersea NMS solutions that could take weeks of manual, trial and error provisioning. Trail generation and the ensuing trail inventory information are used by both the fault management and performance management feature sets described below. The WSF Configuration Management (CM) features also support user designation (provisioning) of customer name(s), notes, etc. to be associated with OCH trails. Since the underlying TEMS servers maintain a database of equipment inventory, the OSF stores and retrieves the information from the appropriate TEMS servers via the TEMS NBI. By assigning customer names in accordance with the transport system, operators may quickly and visually relate TEMS-NMS alarm reports to those generated by the transport system NMS to help in manually correlating potential transport faults with undersea faults.

3.2 Fault Management (FM)

Fault or Alarm management for the managed network is achieved by automatic event notification, including alarm synchronization, from each of the TEMS servers via the TEMS NBI. It should also be noted that in this architecture, reported alarms include NMS system alarms (for example faulty hard drives, CPU alarms, DCN alarms, etc.). Thus FM includes fault management of the management system[3] as well as the undersea system. As such, the OSF maintains a real-time copy of the undersea network's active alarm list, providing each registered client with automatic updates. Furthermore, traffic affecting alarms are associated with the trails and affected customer lists generated by CM, such that a WSF client may easily and quickly scope and filter alarms locally without issuing OSF queries, which would increase DCN traffic. The active alarms are listed either in a tabular form or indicated on the main network topological schematic (see **¡Error! No se encuentra el origen de la referencia.**) at the originating location (monitored cable stations or segments), including alarms identified by the Line Monitoring System (LMS) for undersea segments. Colors are used to designate the highest severity alarm being reported at the designated location. Additional graphical trail views, based on user selected topological scopes, also indicate alarm origination by location, thus allowing a user to quickly determine impact of equipment failures and potentially the common cause without the need for extended investigation. The active alarm list is also used by the RCA engine[v], which, upon user request, will analyze the current alarms within a specific scope to determine parents or root causes, as well as provide potential corrective actions, based on accurate topology-based fault analysis. The RCA engine is designed for undersea cable network architectures, thus it requires no user configuration such as rules. However, the means to define rules are provided should a user, based on atypical network management policies or behavior, wish to identify new potential root causes or over-ride the automatic RCA algorithms delivered. The RCA engine utilizes managed NE behavioral models combined with a topological model of the undersea network to accurately arrive at root causes. By taking into account both temporal and spatial relationships of alarmed NEs, the RCA engine efficiently filters unrelated alarms to minimize the plethora of alarmed events presented to the user due to a complex network fault. These features effectively eliminate the need to define rules on an equipment basis which can be quite complicated and cumbersome for complex NE's. The RCA feature compliments the various trail view mechanism for quickly locating the root cause of undersea alarms. Depending on where in the trail hierarchy RCA is initiated, appropriate scoping of the alarm information delivered to the RCA engine is automatically performed to determine root causes at the desired network scope.

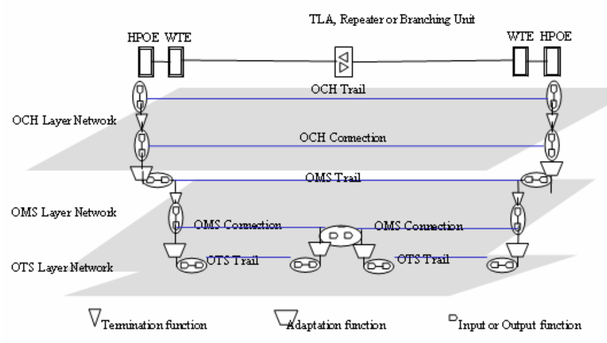

Figure 4 - Optical Transport Layer Networks

3.3 Performance Management (PM)

Performance Management is achieved by capitalizing on the trails created by CM and only activates upon request from the client. Since the underlying TEMS servers maintain a database rich in historical data pertaining to the managed NE's[4] there is no need to duplicate the data in TEMS-NMS. When a client (which may also include the TEMS-NMS automatic PM report generator feature) requests a trail based report with optional filters and scoping, the hosting OSF initiates optimized database queries, via the TEMS NBI to the appropriate underlying TEMS servers only. These servers maintain the historical data for the equipment associated with the trail. PM and the ensuing query responses have been optimized to minimize NMS DCN traffic. This paradigm provides WSF responses within seconds.

3.4 Security Management (SM)

Security Management is achieved by capitalizing on the TEMS SM paradigm. By its very nature, most of TEMS-NMS native client services are read-only. However, a user does require a workstation system-administered login and password to access the WSF. TEMS-NMS WSF write operations are solely for provisioning TEMS-NMS operations. The architecture also supports TEMS GUI cut through from any scope in the topological view as well as the alarm summary view. This cut-through enables users to access information on an equipment basis, thus complementing the trail-based presentations offered by TEMS-NMS. TEMS GUI write operations require

[3] Since the WSF supports TEMS GUI cut through, in actuality a system administrator using the WSF (e.g. in the NOC), may easily drill down and log into any TEMS server for remote troubleshooting, remedial activities, and administration.

[4] For each managed NE such as the LTE's and PFE's in a cable station, TEMS automatically collects 15 minute PM data and depending on the size of the network may maintain the historical records for one or more years.

separate TEMS login privileges. **¡Error! No se encuentra el origen de la referencia.** depicts a TEMS-NMS OCH scoped trail with TEMS cut-through to a unit view of the transmitting LTE hardware.

4 REQUIREMENT COMPLIANCE AND GROWTH

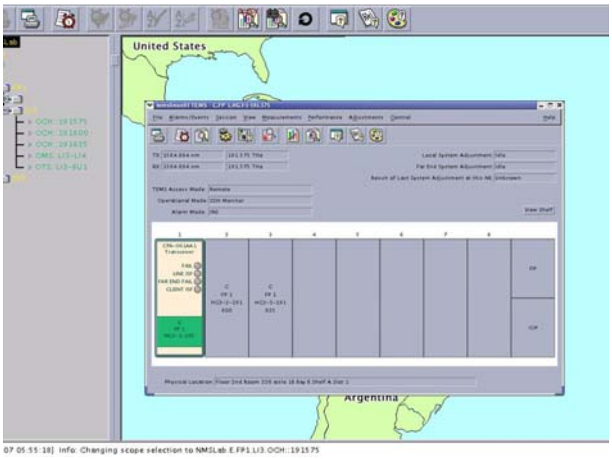

Figure 5 - TEMS-NMS Cut Through to TEMS Equipment View

The flexible, modular distributed architecture of TEMS-NMS ensures that all the stated requirements in the first section are met by this next-generation design. Additionally, since the OSF life cycle management has been architected, designed, and implemented to be generic, it can easily be applied to future OSF software services that may be created to support new TEMS-NMS functionality. As the underlying TEMS grows to support additional NE types, the CORBA-based NBI into TEMS-NMS and WSF internal object model are expected to either eliminate or minimize any specialized development required for TEMS-NMS to provide support for these new NE's. It should also be noted that the Java-based client application is instrumental in optimizing WSF functionality across undersea networks (i.e. minimizing DCN traffic and user response times). However, should a customer need arise to provide Web based access without a local Java client, it has been demonstrated satisfactorily that without additional computing resources on the WSF or OSF, a customer may access TEMS-NMS using Virtual Network Computing (VNC) technology which is supported in common environments such as Microsoft Windows[5] with the Microsoft Internet Explorer[6] browser.

5 OPERATIONS AND MAINTAINABILITY

This next-generation NMS design is essentially maintenance free. It is expected that operators will recognize the greatest savings as per:

- Elimination of dedicated computer hardware assets to support the NMS obviates labor costs associated with maintenance, administration, and repair as well as eliminating costs associated with equipment replacement.

- Elimination of the database prevents labor costs associated with redundant data management including synchronization and backup.

- Auto discovery and automatic trail generation eliminates the labor costs associated with NMS provisioning while significantly reducing the time to manage a reconfigured or upgraded network.

6 CONCLUSION

In this paper we have described challenges faced by undersea cable NMSs, as well as approaches to effectively mitigate them, while meeting customer needs and requirements. The next-generation Tyco Telecommunications NMS (TEMS-NMS) has been designed and developed in accordance with these approaches. TEMS-NMS implements a distributed, modular and expandable architecture that is particularly well suited for the complex applications domain of undersea network management. The system architecture provides a flexible basis for network management, allowing adaptability to network changes (whether forced or planned) while still minimizing expenses such as labor costs, response times, and DCN congestion – problems all too often aggravated by existing traditional NMS designs.

7 ACRONYMS

- Common Object Request Broker Architecture (CORBA)

- Configuration Management (CM)

- Data Communications Network (DCN)

- Element Management System (EMS)

[5] Windows is a registered trademark of Microsoft Corporation in the United States and *other countries.*

[6] Internet Explorer is a registered trademark of Microsoft Corporation in the United States and *other countries.*

- Graphical User Interface (GUI)
- Line Monitoring System (LMS)
- Line Termination Equipment (LTE)
- Network Elements (NE's)
- Network Management Layer (NML)
- Network Management System (NMS)
- Network Operations Center (NOC)
- North Bound Interface (NBI)
- Operations Support Function (OSF)
- Operations Support System (OSS)
- Optical Channel (OCH)
- Optical Multiplex Section (OMS)
- Optical Transmission Section (OTS)
- Power Feed Equipment (PFE)
- Root-Cause Analysis (RCA)
- Simple Network Management Protocol (SNMP)
- Telecommunications Management Network (TMN)
- Transaction Language 1 (TL1)
- Tyco Element Management System TEMS-NMS
- Tyco Element Management System (TEMS)
- Virtual Network Computing (VNC)
- Work Station Function (WSF)

REFERENCES

[i] ITU-T Recommendation M.3010, "Principles for a Telecommunications Management Network", October 1992

[ii] Liss, J. and Kolor, R. "A Next Generation Network Management System for Fiber Link Around the Globe (FLAG)", Suboptic '97.

[iii] ITU-T Recommendation G.805, "Generic Functional Architecture of Transport Networks", November 1995.

[iv] ITU-T Recommendation G.872, "Architecture of Optical Transport Networks", February 1999.

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