NETWORK MANAGEMENT APPROACH FOR THE TSAT NETWORK

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ABSTRACT

The Transformational Satellite Communications System (TSAT) is the DoD's next generation geosynchronous satellite communications constellation. The TSAT system features packet and circuit interfaces that support a wide variety of military missions by providing communication services to fixed ground, mobile ground, marine, and airborne terminals. These terminals access a variety of link rates and communications services and allow the TSAT system to interoperate with many different peer networks. The TSAT system features several types of coverage, steerable beams, and adaptive waveforms that can be configured dynamically in real-time. The TSAT system responds to user requests for services ranging from long-term fixed service, to on-demand short-term communications, to critical services under emergency conditions. The TSAT system must also provide network security services at physical, link, and network layers. Finally, the TSAT system must provide highly available services and be able to operate autonomously.

In order to achieve these goals of providing a wide range of services in an automated and responsive manner, TSAT employs a sophisticated TSAT Mission Operations System (TMOS). TMOS provides highly capable, agile and adaptive network planning and management services. This paper discusses the TMOS approach for planning and network management. The first goal of the paper is to explain the approach for reliable configuration of the satellite and terminal network elements. The second goal is to explain the approach for fault and performance management in the TSAT network.

I. INTRODUCTION

This paper describes the network management approach for the TSAT system, a DoD next generation satellite communications system. This section begins the paper with a brief overview of the TSAT system and the TSAT network architecture.

A. TSAT System Overview

The TSAT system constitutes a core component of the Global Information Grid (GIG). The GIG architecture uses satellite communications (SATCOM) to achieve the goals of: real-time "sensor to shooter"; worldwide persistent connectivity of Intelligence Surveillance and Reconnaissance (ISR) assets; Communications On-The-Move (COTM) to small highly mobile units; survivable communications for Strategic Forces and Homeland Defense; and connectivity of all Global Information Grid (GIG) assets.

Figure 1 illustrates the operational role of the TSAT system. The TSAT system includes the TSAT geosynchronous satellite constellation; the TSAT terminals, which can be land-based, ship-based, airborne, or space-based; the teleports and CONUS Ground Gateway Element (CGGE), which provide connectivity to the DISN; and operational management systems for network and satellite operations, including fixed and endurable (mobile) facilities. Figure 1 also depicts the TSAT interoperability with the other GIG programs via terminals, teleports, and gateways and interoperability with SATCOM programs including the Advanced Extremely High Frequency (AEHF), Mobile User Objective System (MUOS), Wideband Global SATCOM (WGS) and Enhanced Polar System (EPS) satellite systems.

B. TSAT Network Architecture

The TSAT network provides packet (IPv6) and circuit transport services that enable the warfighter to obtain voice, data, video, broadcast, imagery, and multicast services. The TSAT network is composed of TSAT terminals, satellites, gateways, and management systems.

TSAT terminals communicate with the TSAT satellites using a variety of frequencies and waveforms. TSAT supports Extremely High Frequency (EHF) terminals using both the legacy AEHF Extended Data Rate (XDR) waveform for circuit services, as well as the XDR+ waveform for packet services. TSAT also supports High Data Rate (HDR) circuit services using Ka band and lasercom.

The TSAT satellites communicate with each other via lasercom crosslinks. The TSAT space core backbone provides support for both packet and circuit services over Synchronous Optical Network (SONET). The space core backbone is capable of supporting ring, strings, fragments, full mesh, and partial mesh topologies using SONET paths.

From a packet networking perspective, the TSAT space constellation functions as a Tier 1 transit network for the GIG, providing high-speed, high-capacity global transit services. Each TSAT payload includes a Next Generation Processor Router (NGPR), which can be configured to realize any of a number of logical topologies using the underlying SONET paths, including ring and string topologies. TSAT uses Open Shortest Path First (OSPFv3, RFC
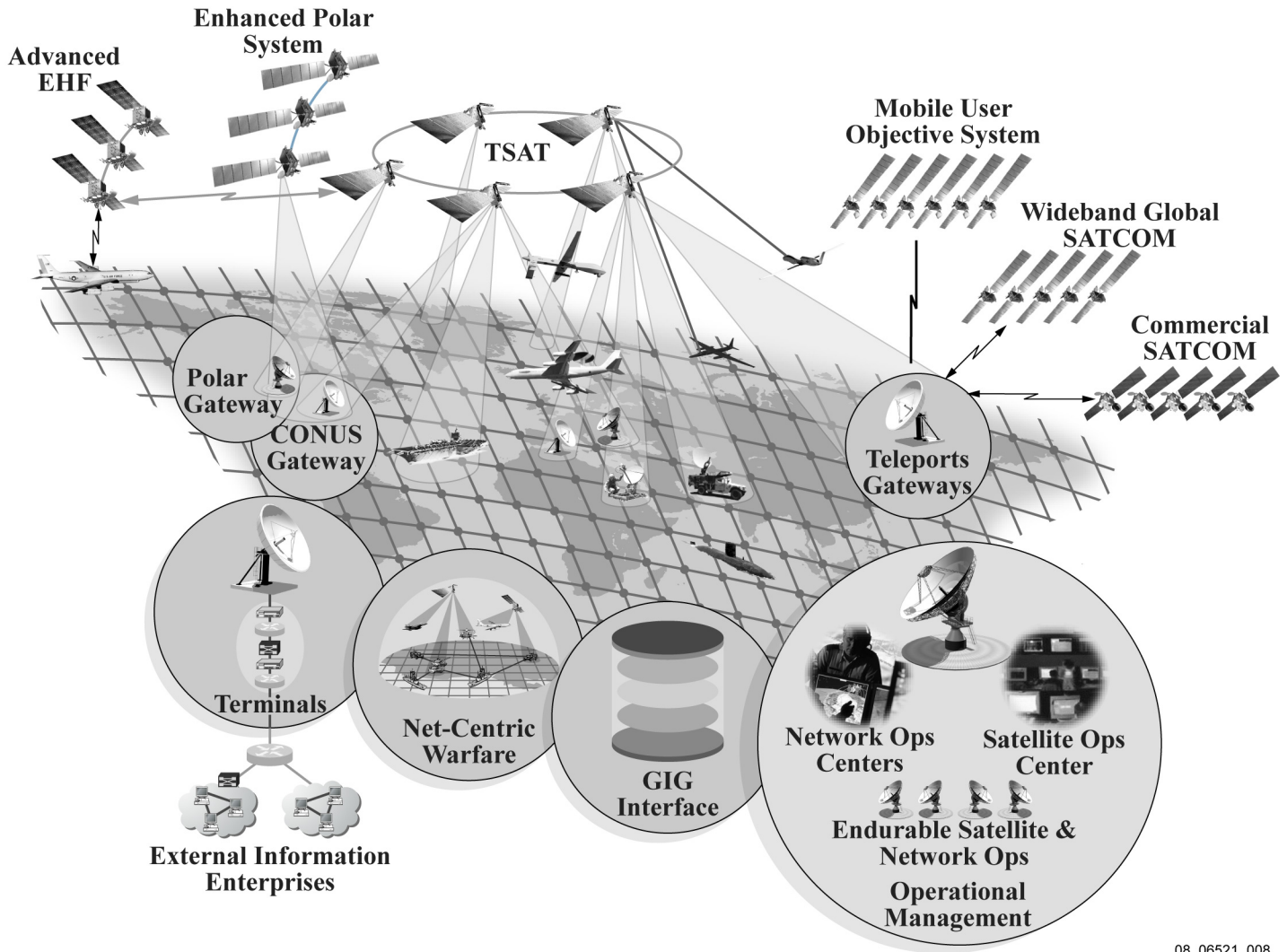
Figure 1. TSAT System Operational View

2740) as the Interior Gateway Protocol (IGP) and Border Gateway Protocol (BGPv4, RFC 4271) as the Exterior Gateway Protocol (EGP).

In addition to the payload routers, the TSAT routing network includes the TSAT GIG Border Element (TGBE) routers (the edge routers with connectivity to the DISN Core), the teleport routers, and the Provider Edge (PE) routers in the terminals, as shown in Figure 2. From a logical perspective, each terminal connection between the TSAT network and a user network requires a Provider Edge (PE) – Customer Edge (CE) router pair. Physically, the CE router may be a separate router internal to the ter-
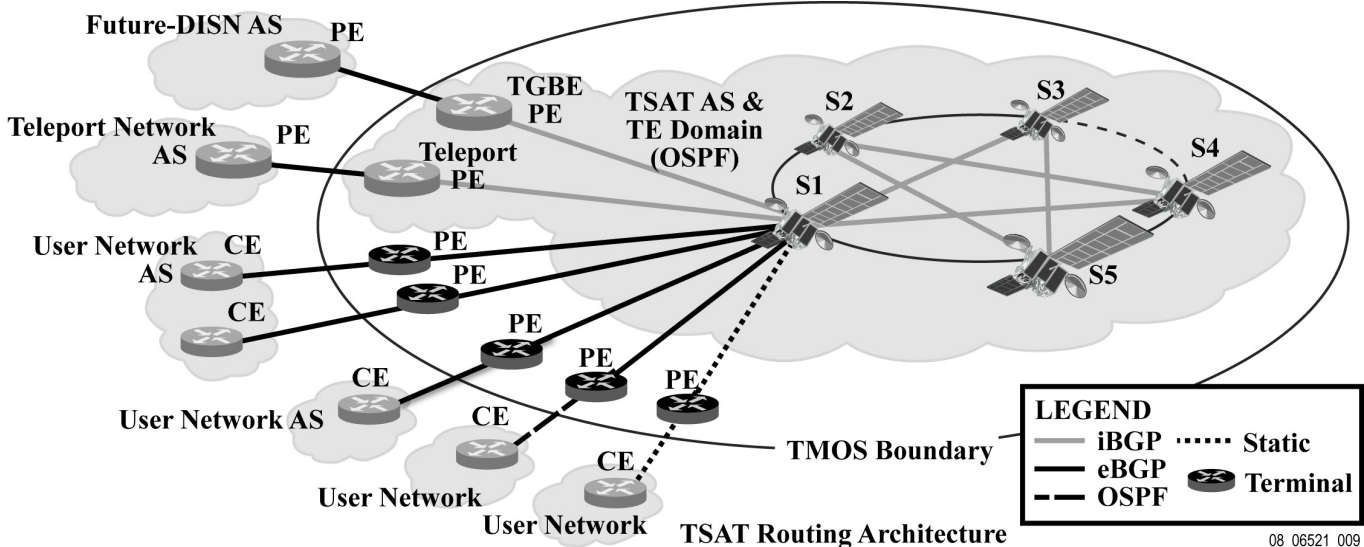
Figure 2. TSAT Backbone and Edge Routers

minal; a separate router external to the terminal; or the terminal may contain a single router which performs both the PE and CE router functions. The interface between the PE and CE router constitutes the boundary of the TSAT network.

As shown in Figure 3, the TSAT network is a "black core" network, i.e., TSAT assumes that all user traffic is encrypted prior to entering the TSAT network and tunneled through to the far end. User red network routes are not exchanged with TSAT routers. The red/black boundary element for classified packet services is instantiated in the High Assurance IP Encryptor (HAIPE).

The TSAT QoS architecture is an integrated approach that provides resource allocation for both packet and circuit services, with support for military priorities and Multi-Level Precedence and Preemption (MLPP). For packet services, TSAT uses a Differentiated Services (DiffServ) (RFC 2475) forwarding plane with standards-based Per-Hop Behaviors (PHBs) and Per-Domain Behaviors (PDBs) (RFC 3086) to implement the TSAT service classes. The TSAT QoS architecture also integrates with Layer 2 Dynamic Bandwidth Resource Allocation (DBRA) to provide priority among aggregated flows.

The TSAT network architecture is described in more detail in [1] and [2].

II. KEY OBJECTIVES FOR TSAT NETWORK MANAGEMENT

Network operations and management for the TSAT network are performed by the TSAT Mission Operations System (TMOS). TMOS functions in the context of the overall GIG Operations Management as shown in Figure 4.

At the highest level, external entities such as USSTRATCOM, JTF-GNO, NSA, and Combatant Commands provide operational policy inputs that guide or constrain TSAT operations and network management decisions. Such operational guidance generally addresses high level, global issues and concerns such as:

- How conflicting Mission Service Requests (MSRs) are resolved or handled
- Availability and operating margins for the system
- Security and risk posture for the network

At the **Operations Management (OM)** level, TMOS supports the definition of system policies for the TSAT network consistent with operational policies. TMOS receives Mission Service Requests (MSRs) that represent user requests for network services. TMOS provides capacity planning, mission planning, and decision support tools to determine the optimal allocation of TSAT network resources to meet rapidly changing mission requirements. Planners receive back from TMOS a Service Level Agreement (SLA) to document the service commitment. During operation, TMOS provides Situational Awareness and Common Operational Picture (SA/COP) for the TSAT network.

At the **Network Management (NM)** level, TMOS supports the implementation and enforcement of system policies. TMOS determines network configurations and provisions network resources to meet mission requirements. TMOS monitors network performance for resource utiliza-
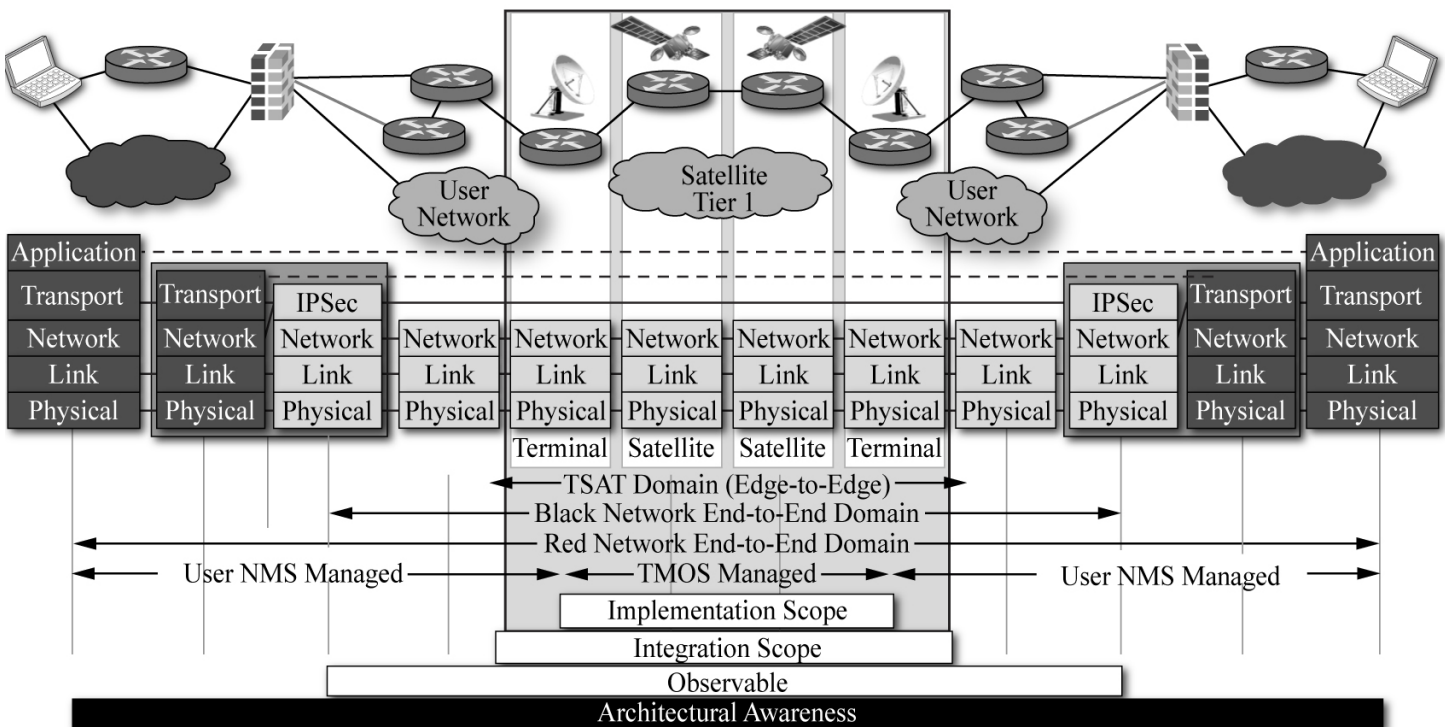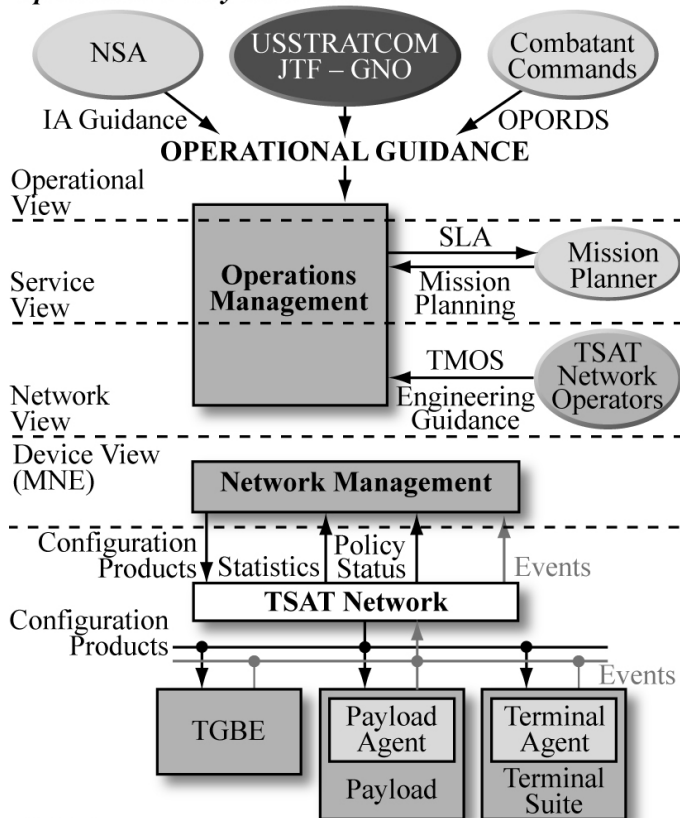

Figure 3. TSAT Network Boundaries

Operational Policy Guidance

Figure 4. TMOS Role

tion and compliance with SLAs. TMOS monitors network faults and supports fault localization and correction. TMOS supports TSAT network assurance including enforcement of network security policies, distribution of cryptographic keys, and Attack Sensing, Warning, and Response (ASWR).
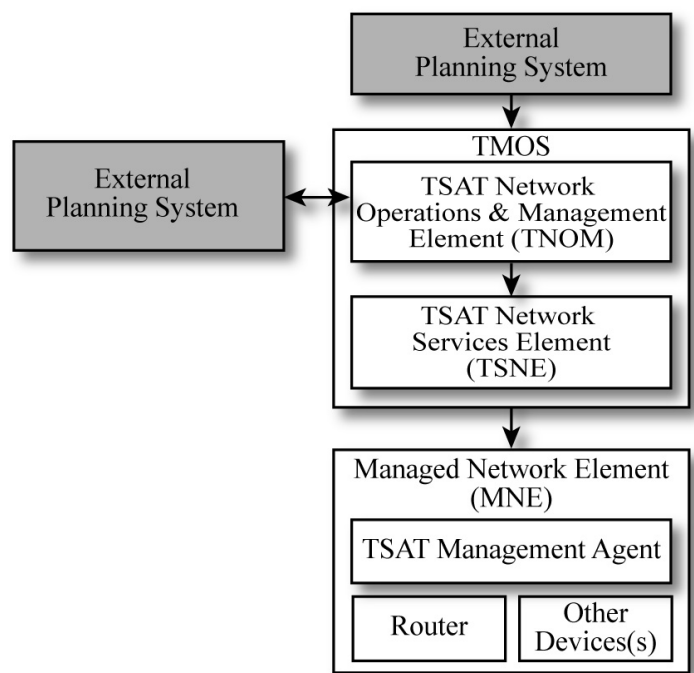
Figure 5. Logical Network Management Hierarchy

Finally within the TSAT network, the TSAT Managed Network Elements (MNEs), including the payloads, terminals, and TGBE, are capable of implementing element configuration directives, monitoring element performance, detecting and reporting faults, implementing security policies (e.g., packet filters), and providing ASWR inputs.

III. NETWORK MANAGEMENT HIERARCHY

TSAT employs a hierarchical, distributed network management architecture. A logical view of the network management hierarchy is shown in Figure 5.

- The **TSAT Network Operations and Management (TNOM)** element provides overall Operations Management (OM) and Network Management (NM) for the TSAT network. TNOM accepts Mission Service Requests (MSRs) from an external planning system, and generates Service Level Agreements (SLAs) in response. TNOM also interoperates with external Network Management Systems (NMSs) for peer networks (e.g., the DISN Core).
- The **TSAT Network Services Element (TNSE)** is a distributed element that manages a subset of the TSAT network and enables key management functions to be located closer to the warfighter.
- A **Managed Network Element (MNE)** is a TSAT payload, TSAT terminal, or TGBE. The MNE contains a TSAT Management Agent that communicates with the TNSE and provides the management interface to the router and other devices within the MNE.

IV. KEY NETWORK MANAGEMENT SERVICES

TMOS provides user interfaces for network operators located at the TNOM and also interoperates with external systems, compliant with GIG standards, to support end-to-end GIG network management. TMOS is based on a Service Oriented Architecture (SOA). Interfaces to external planning and network management systems are defined as Web services. This section describes some of the key TMOS network management services.

A. Mission Service Request (MSR)/Service Level Agreement (SLA)

Mission planners enter communications service requirements into TMOS in the form of a **Mission Service Request (MSR)**. The MSR includes start and end time, priority, terminal id(s), service class, bandwidth, and other details depending on the type of packet or circuit service being requested. Depending on availability of resources and operational policies for adjudicating between requests, some negotiation may take place to determine the actual resource allocations.

Once planning products have been generated, TMOS issues a **Service Level Agreement (SLA)** back to the requestor. The SLA includes the MSR contents as well as the committed bandwidth and QoS parameters (for packet

services, these may include delay, jitter, and loss depending on the service class).

B. Situational Awareness/Common Operational Picture (SA/COP)

Situational Awareness (SA) is an understanding of critical health and status data on network nodes, services, infrastructure and environment. It also includes status of SLAs established for TSAT users and the overall consumption of resources to fulfill mission needs. Situational Awareness will be generated by TNOM and distributed to External Planning, External Network Management Systems, and TSAT Operations.

Common Operating Picture (COP) is a single identical display or sets of displays of relevant and multi-source information shared by more than one command. A COP facilitates collaborative planning and assists all echelons to achieve situational awareness. In the network sense, it will be a display of the functional or theater-level view of the current connectivity, configuration, and performance of telecommunication networks and systems to include information assurance data and reports. COPs will be repeatable and tailorable so that an identical view can be created and distributed to a defined set of users. SA/COP will provide data that can be used for quick "network status at a glance" needed by warfighters while providing all the data necessary for replanning, fault analysis and tracking, and current system configuration data to provide a GIG-NetOps style Network Management capability.

V. NETWORK MANAGEMENT ARCHITECTURE

Figure 6 shows a simplified view of the TSAT network management architecture, including the major subsystems within the TNOM, TNSE, and the MNEs.

- TNOM OM includes subsystems for capacity and mission planning as well as SA/COP.
- TNOM NM includes subsystems for configuration management and provisioning, Bandwidth Broker Executive (BB-E), fault and performance management, and network security management.
- TNSE includes subsystems for terminal logon and authentication, distributed configuration control, Bandwidth Broker Presence (BB-P), distributed monitoring, and distributed instrumentation (e.g., routing and traffic analytics).
- MNEs include subsystems for configuration control, Bandwidth Broker Agent (BB-A), Scheduled Information Exchange (defined below), event monitoring, and diagnostics.

Figure 6 also shows the TSAT network management architecture's concept of *mechanisms*. Each of the NM mechanisms (shown in Figure 6 as a "swimlane" between TMOS and the MNE) constitutes a logical grouping of TMOS functions, MNE functions, and message exchanges:

- The **Configuration Control** mechanism is responsible for managing the configurations of TSAT network nodes, including configuration validation, activation and deactivation, checkpointing, rollback, storage, and version control.
- The **Bandwidth Broker** service provides hierarchical, policy-based QoS management, and is distributed among the BB-E, BB-P, and BB-A. The BB-A in the MNE manages the Layer 2 QoS interactions with DBRA. The BB-P in the TNSE provides regional distribution and decision-making within policy-defined limits. The BB-E in the TNOM provides centralized control and policy definition.
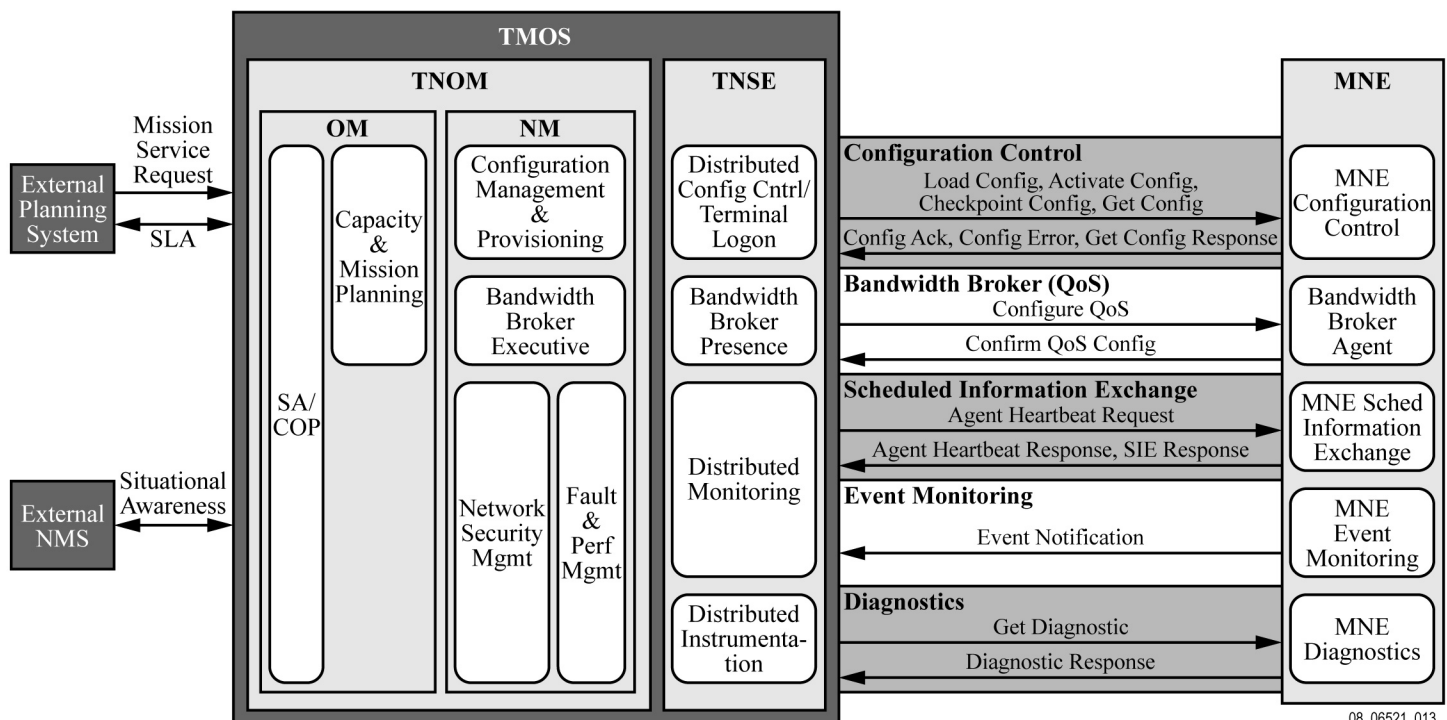

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Figure 6. Simplified View of TSAT Network Management Architecture

- The **Scheduled Information Exchange (SIE)** mechanism provides periodic, configurable reporting of data from MNEs to TMOS. SIE is typically used for routine monitoring of measurements such as resource utilization and network performance data.
- The **Event Monitoring (EM)** mechanism is responsible for timely notification from MNEs to TMOS of events that TMOS is interested in, including equipment or network faults, performance threshold crossings, and security relevant events.
- The **Diagnostics** mechanism includes a variety of functions used to assist in fault localization and correction, such as device built-in tests, debugging facilities, loopback tests, etc.

While the figure does not show interactions between the mechanisms (for sake of simplicity), the mechanisms do interact in some cases. A configuration received by Configuration Control may include a change to an SIE reporting interval. Or, a measurand being monitored by SIE may trigger a threshold crossing alert which is reported by EM. Not shown on the figure are the specialized mechanisms used for cryptographic key management, and ASWR, which are outside the scope of this document. For more details on the TSAT network assurance architecture, see reference [3].

VI. DISTRIBUTED NETWORK MANAGEMENT

Figure 7 illustrates a notional management network physical topology. (Figure 7 is notional in that it depicts a specific string topology for the space backbone. Also, the precise number and location of TNSEs is still under investigation.)

Central TNOM instances are located at primary and backup facilities. In the event that both the primary and backup TNOM sites become non-operational, one or more Endurable TNOMs will be deployed at alternate locations to ensure continuity of essential management functions.
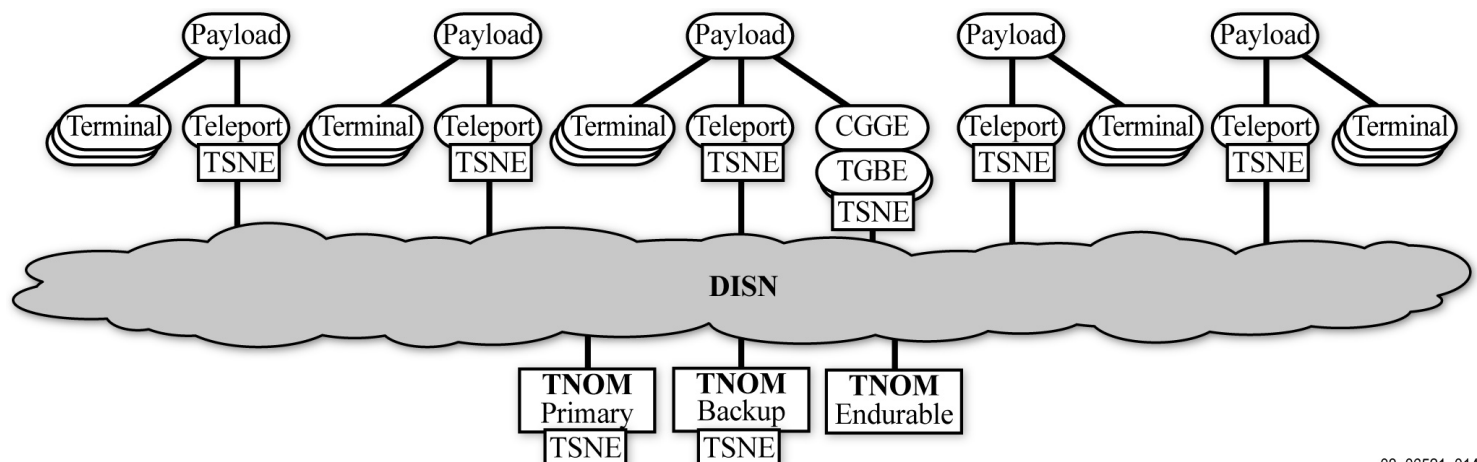
TNSEs will be collocated with the Central TNOMs, TGBEs, and selected additional locations such as the DoD teleport sites. TNSE physical connectivity with the MNEs is indirect via the teleports/TGBEs and the payloads.

Management plane (as well as control plane) traffic is carried over the packet network via the same satellite links as the user data plane traffic. Thus, one goal of the TSAT network management architecture is to ensure that management plane traffic does not create excessive overhead on TSAT system capacity.

The TSAT network management architecture must also take into account the latencies inherent in the management network, including propagation delays to and from geosynchronous orbit, undersea cables, Forward Error Correction (FEC), interleaving, DBRA effects, etc. These will result in significantly greater latencies than typical terrestrial network management systems.

The management network links also vary considerably in terms of their availability and reliability. The TSAT network management architecture must ensure that management capability is not lost due to adverse weather conditions, constellation fragmentation, terrestrial network segmentation, etc.

Distributing selected network management functions to the TNSEs enables a limited degree of autonomous operation even if communication to the TNOM is lost. For example, when a mission is planned, terminal configurations will be generated at the TNOM and sent to the TNSEs. As terminals are deployed and establish communication with the satellites, they can retrieve their configurations from the TNSE even if communication with the TNOM is lost.

VII. APPROACH FOR PLANNING AND RELIABLE CONFIGURATION

Figure 8 shows a notional sequence for information exchange in the TSAT Planning and Provisioning process.
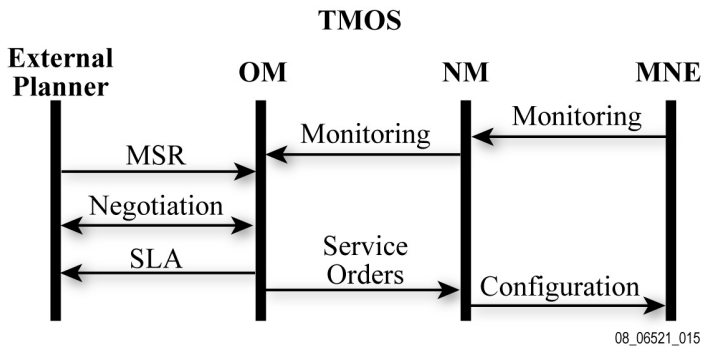

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Figure 7. Management Network Physical Topology (notional)

TMOS

Figure 8. MSR/SLA Message Flow Sequence

An external planner, using an external planning system composes a Mission Service Request (MSR) that describes the circuit and packet services requested for a set of warfighters (specifically for a set of TSAT terminals). The external planner and TMOS planner optionally negotiate the details of the services, based on availability of resources and the relative mission priority of the requested services. TMOS OM supports the negotiation and generation of planning products. The OM view of what new services can be supported is based on NM data reflecting the actual network state and configuration.

Once the planners have negotiated the service requirements, the final MSR is accepted, planned, resources allocated and planning products are generated. TMOS OM returns the SLA to the external planner, and also passes the planning products, known as Service Orders, to TMOS NM. Service Orders contain configuration inputs for the MNEs assigned to the services, as well as data for NM fault, performance and security monitoring functions that provide guidance to allow the network to be managed to ensure that SLA requirements are met.

TMOS NM generates configuration products for the individual MNEs, which may include payloads, terminals, and/or TGBE depending on the mission. TMOS NM uses the Configuration Control mechanism to validate and distribute configuration products to the MNEs, and activate the new or updated configurations at the appropriate times. The Bandwidth Broker service manages the generation and distribution of QoS profiles to ensure that the SLA is implemented correctly per QoS policies.

VIII. APPROACH FOR FAULT AND PERFORMANCE MANAGEMENT

TMOS monitors resource utilization and network performance using the SIE mechanism to ensure compliance with SLAs. If SLA violations occur, TMOS alerts the TMOS operators and sends notifications to external NMSs that have subscribed for those notifications.

TMOS receives fault reports from MNEs via the Event Monitoring mechanism and is also capable of detecting when MNEs have lost communication with TMOS (e.g., through link monitoring and keep-alive messages). TMOS

also supports trouble tickets which may be entered by TMOS operators or received electronically from an external NMS.

TMOS incorporates instrumentation such as Routing Analytics and Traffic Analytics that provide a holistic view of the network control plane and forwarding plane, and alert the operator to abnormal conditions, such as routing misconfigurations, that may not be otherwise detected by individual MNEs.

Event data from all sources is correlated and analyzed by TMOS to localize faults, reduce cognitive load, and provide actionable information to the operator. The Diagnostics mechanism provides a variety of tools which facilitate troubleshooting and service restoration.

Resource utilization, network performance, SLA violations, network health and status, and other indicators are all summarized in SA/COP views which can be tailored for each user to present the relevant information.

IX. CONCLUSIONS AND WAY AHEAD

The TSAT network management approach provides a wide variety of services in a highly automated and responsive manner. This is accomplished by the TMOS system, which interoperates with external NMSs and leverages NM capabilities within the MNEs. TMOS provides comprehensive network management capabilities including capacity and mission planning, resource allocation, QoS and SLA management, configuration, fault and performance management, and SA/COP. TMOS employs a hierarchical, distributed architecture, which places key NM functions closer to the warfighter, enhances the availability of network management, and makes efficient use of TSAT network bandwidth.

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