Developing Functional and Performance Requirements for Broadband Satellite Networks

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1. INTRODUCTION

Broadband satellite service providers will market affordable broadband multimedia communication services, on a local to global basis, via a network of space and ground facilities. In many cases, these service providers will be partnering, affiliating, or servicing customers using the providers' own satellite network, which must be integrated into a terrestrial system. That network will create and maintain the relationship between the broadband satellite service provider and his affiliates, partners, and customers.

TRW has developed a processing payload – a space-borne, broadband ATM switch together with advanced RF technology – that provides the essential Ka-band access links to BSN subscribers. We have also developed a system engineering discipline, called Network Engineering, to assist our customers in defining an end-to-end network architecture that best exploits our payload product to deliver an optimum mixture of service offerings. This paper describes our approach to defining Network Functional and Performance Requirements for these broadband networks, which consist of a space segment, a ground terrestrial segment, and user terminals.

The description is based on the work TRW has done on its Gen*Star Satellite Network program.

2. BACKGROUND

Satellite networks are emerging as commercial and military satellite systems migrate from transponded communication relays to digital networks consisting multiple satellites, many spot beams, and many millions of traffic terminals having direct access to the satellite.

In the narrowband area, LEO, MEO, and GEO constellations with many satellites require MESH connectivity. In the military area, SBIRS, Advanced EHF, and the Gapfiller/DSCS follow-on require a network design. In the broadband commercial area, Astrolink, Teledesic, Spaceway, and TRW's GESN (Global EHF Satellite Network) are all being planned as satellite networks as opposed to transponded communication relay satellites.

The challenge in each of these applications, including commercial broadband satellite networks, is to use a network engineering approach that integrates service, business, and technical requirements in defining an architecture that meets the specific needs of a network service provider, and its affiliated subproviders.

TRW's Network Engineering is designed to meet that challenge. It defines the functional and performance requirements of a network and its constituent space, ground, and user segments. Its services include synthesis and evaluation of alternative architectures, selection and refinement of a best architecture, specification of the requirements of the network and its components, and definition of integration and testing requirements for the roll-out of the network. Throughout the process, and especially during the formative stages, Network Engineering gives consideration to the three major interacting domains of the project: user demand, network design, and financing.

The objective of Network Engineering is to produce a seamless network access transparent to the user rather than using a strict backbone approach, which puts constraints on user access. Broadband satellite service will use fast packet-switched satellites with on-board switching and routing because this configuration provides the highest throughput for bandwidth on demand. These packet-switched satellite network architectures require system-engineered solutions that take into account communication payloads, network control, and terminals. TRW's Gen*Star Satellite Network, a TRW-funded effort, provides such solutions, offering architectures and products for broad applications to commercial and military systems.

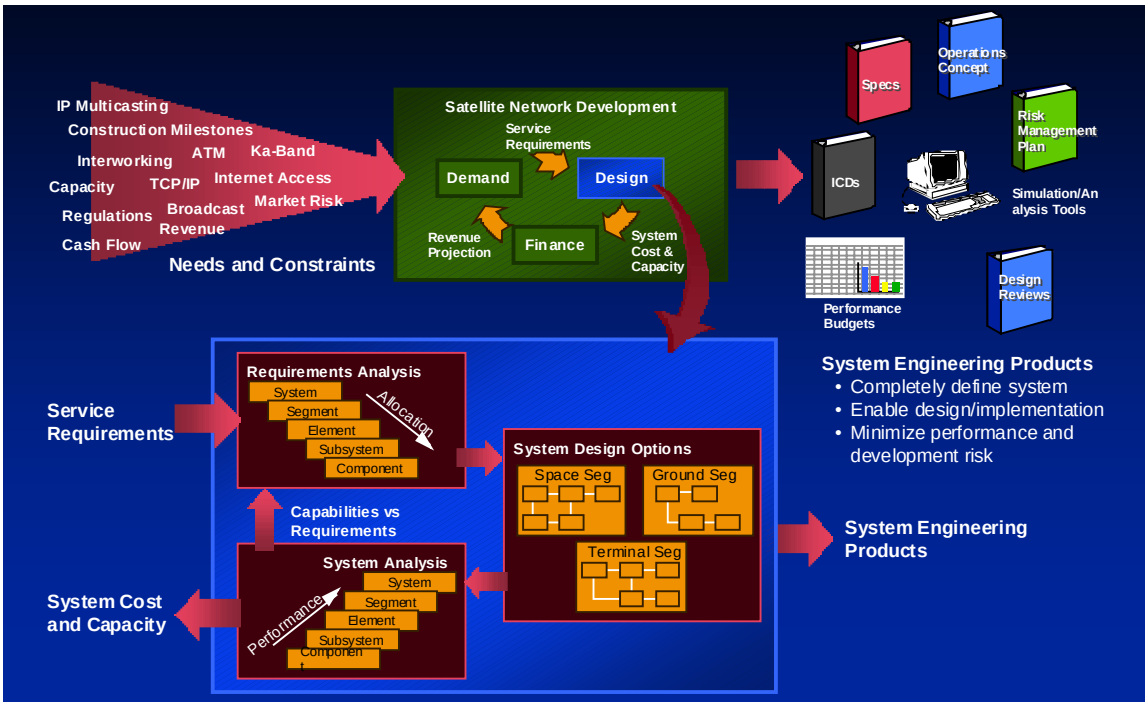
3. TRW'S ARCHITECTURE APPROACH

TRW's approach to designing a network architecture for a potential Network Service Provider is illustrated in Figure 1. The process begins with the Service Provider's needs and constraints. TRW's Network Engineering translates these needs and constraints into a definition of demand in terms of markets, service definitions, and traffic models. We then work with the Network Service Provider to synthesize an architecture that addresses these needs. This front-end cooperative development period is the most critical time in the project life-cycle. Properly conducted, the synthesis will resolve ambiguities and uncertainties, rein in or give life to grand ideas, set the pace of system development and roll-out, and build the strong, comprehensive foundation upon which the network will stand.

To be successful, a network architecture must consider the demand that will be placed on it for services, the design that will address that demand, and the financial environment within which the network will operate. As Figure 1 shows, these considerations affect each other, and they must be addressed simultaneously. The interactions among demand, design, and finance are easy to understand when the system is viewed as a business venture, giving rise to questions such as, "How will demand change as available Quality of Service (QoS) changes?" and "How will internal rate of return be affected by an enhanced capacity?"

One of the most important aspects of this integrated system architecture approach is that it addresses the concerns of ***all*** the stakeholders interested in the system: customers, financiers, service providers, the system operator, and marketing, and not just the technical developers.

Figure 1. TRW's Network Architecture Design Approach



Network Engineering uses the service requirements to define how the various network functions are divided among an architecture's three segments:

- Space Segment
- Ground Segment
- Terminal Segment

Network designers conduct trades of the cost, schedule, and operations and implementation risks associated with these segments to provide the data needed to close the network business plan that links service requirements to system cost and capacity.

These trades also produce the system engineering products needed to design the system, such as specifications, interface control documents, the network operations concepts, performance budgets, and a risk management plan.

Satellite Network Considerations

The objective of TRW's Gen*Star Satellite Network architecture design is to maximize the network's capacity and maintain satisfactory quality of service while minimizing network deployment and operations cost. In Network Engineering TRW uses traditional network design methodology that is adapted to address specific satellite-unique capabilities and constraints. Our approach incorporates all essential elements:

- Services definition and requirements
- Traffic engineering
- Satellite-centric network synthesis
- Performance modeling
- Network optimization
- Business Operations
- Systems Engineering products

Uncertainty about future user applications and traffic development mandates that network architecture be flexible regarding the long-lived broadband satellites, which are one node in the network. These uncertainties have influenced TRW's Gen*Star architecture approach to follow a protocol methodology at network edges.

Satellite operators wanting to tailor their broadband systems to meet their defined markets sometimes have requirements that can be met several ways technically. For the architect, a major challenge is balancing the complexity and cost between the satellite, ground and terminal segments. Our Gen*Star approach enables satellite operators to participate in these all-important trade-offs.

Gen*Star Satellite Network Overview

The Gen*Star Network was planned as an integrated network architecture consisting of space, ground, and terminal segments. Its purpose is to give TRW and potential service providers the opportunity to carry out the process described in Figure 1.

Gen*Star's space segment consists of geostationary satellites to provide worldwide coverage. It includes:

- Satellites with up to 64 beams, each supporting 125 MHz of spectrum
- Ka-band uplinks and downlinks for user data, payload control and TT&C
- On-board packet switch providing uplink-to-downlink and uplink-to-crosslink beam connectivity under ground control
- Intersatellite links providing intercontinental connectivity within network

The ground segment consists of U. S. and overseas system operations centers (SOCs) interconnected via a terrestrial WAN (wide-area network):

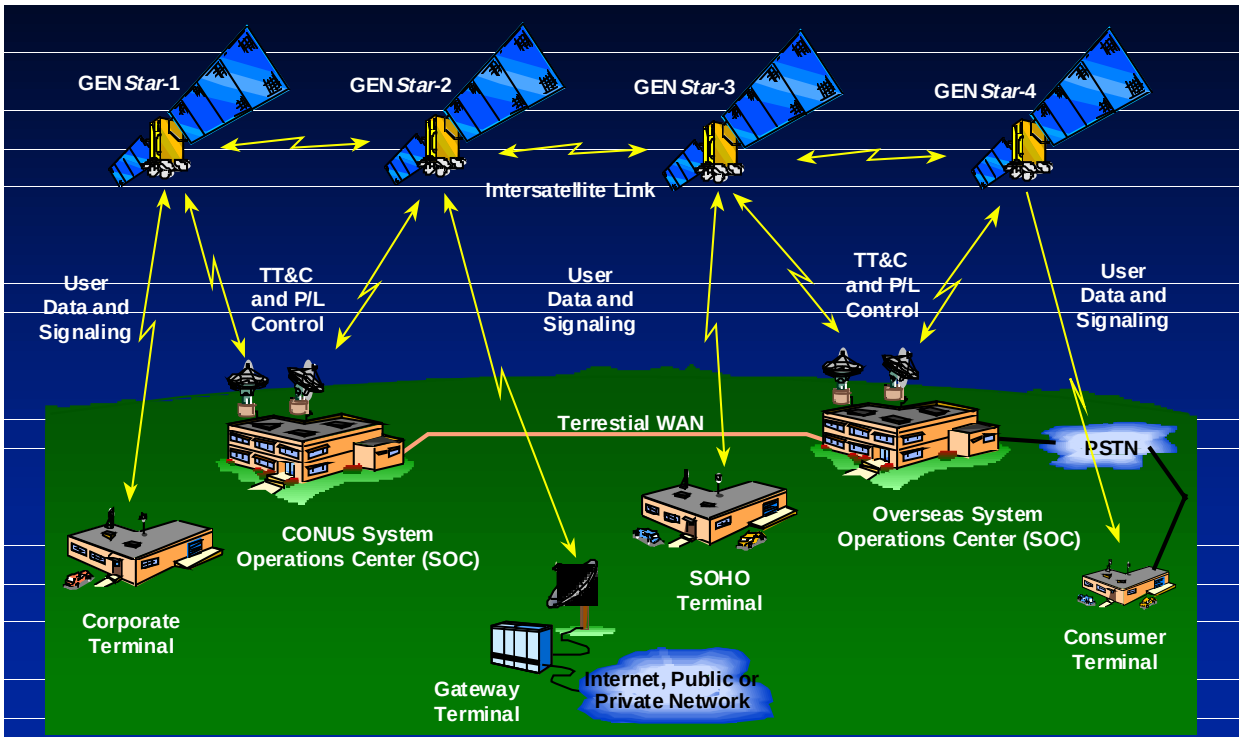
- Each SOC includes a network operations center (NOC) and a satellite management center (SMC) with independent fail-over capability
- The NOC communicates with the payload and terminals to support user access and establish network connections
- The NOC provides overall network management

- The SMC provides satellite command, control and health status monitoring via Ka-band links

The terminal segment consists of user-owned equipment providing data interface, modulation, and transmit/receive for connection to the satellite. TRW's approach includes use of three types of terminals whose performance can be adjusted to the satellite providers needs: low data rate, medium data rate, and high data rate terminals.

TRW's Gen*Star Network is shown in Figure 2.

Figure 2. TRW's Gen*Star Satellite Network

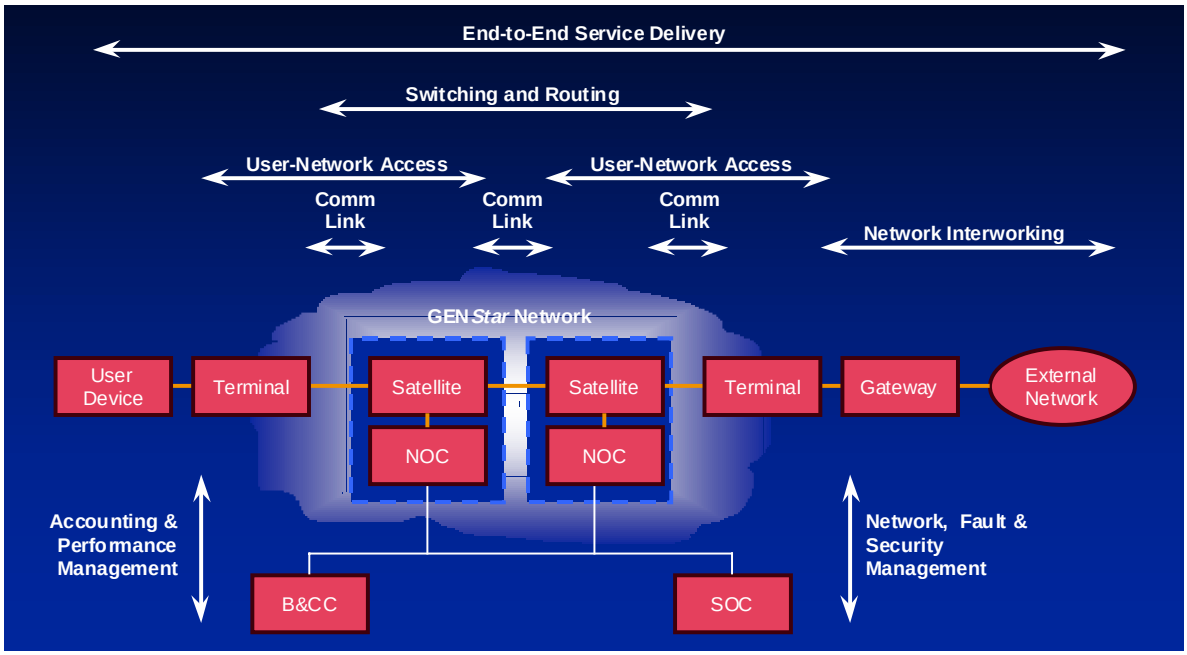


Network Architecture Approaches with Gen*Star

Using Network Engineering the Gen*Star program was devised to demonstrate an efficient service delivery, to select a distributed switch architecture that minimizes onboard complexity, and to provide analyses that demonstrate performance and capacity. The following text and figures describe TRW's approach to achieving these objectives.

Broadband Satellites networks, having potentially millions of direct access terminals, must be able to provide an end-to-end service delivery. Figure 3 describes TRW's concept. Within the network, the functions of switch and routing, user-network access, and network interworking must be provided. The network must also provide operational capabilities to the satellite service provider such as accounting and performance management and network fault and security management.

Figure 3. Network Architecture Integration



To achieve the efficient distribution of the switch architecture, TRW advocates a collaborative effort with the service provider. The traditional ATM switch functions are distributed between the Gen*Star network elements:

- User earth terminal
- Satellite
- Network Operations center

The relationships between the elements and the functions of each are described in Figure 4

Network architectures must be validated with capacity and performance calculations and simulations. TRW's Gen*Star assembles User Applications into traffic model scenarios and then simulates the capacity and quality of service with simulation models. An earlier paper written by TRW used this capability to evaluate the capacity of the fast-packet, circuit-switched and bent pipe satellite architectures carrying multimedia traffic. TRW's network capacity and performance measurement approach is described in Figure 5.

Figure 4. Distributed Switch Architecture

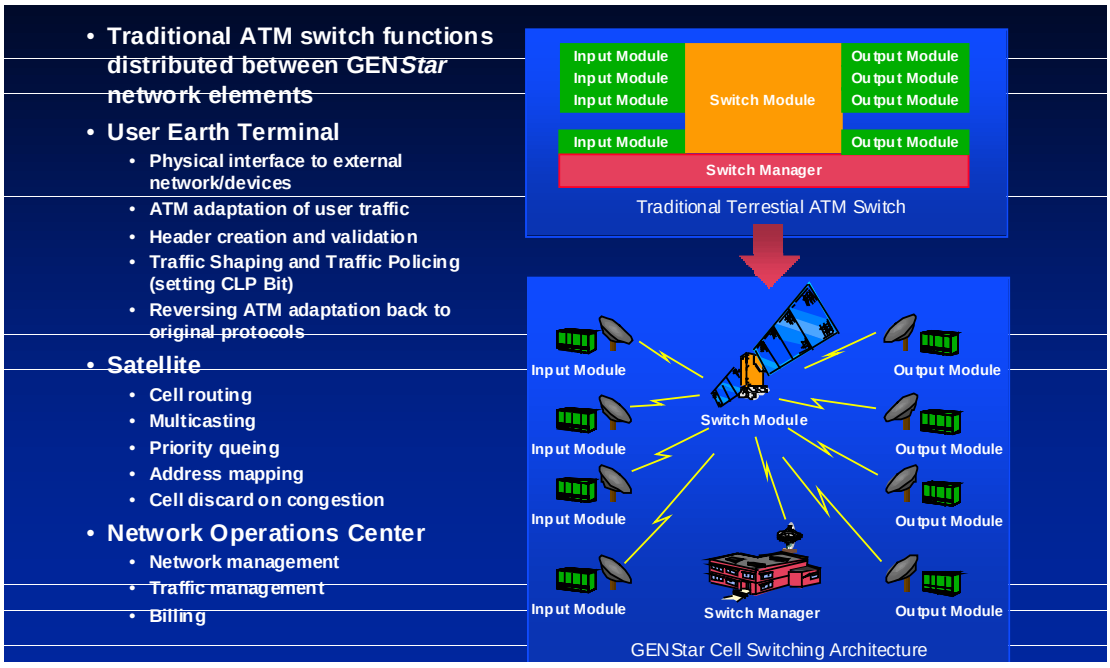
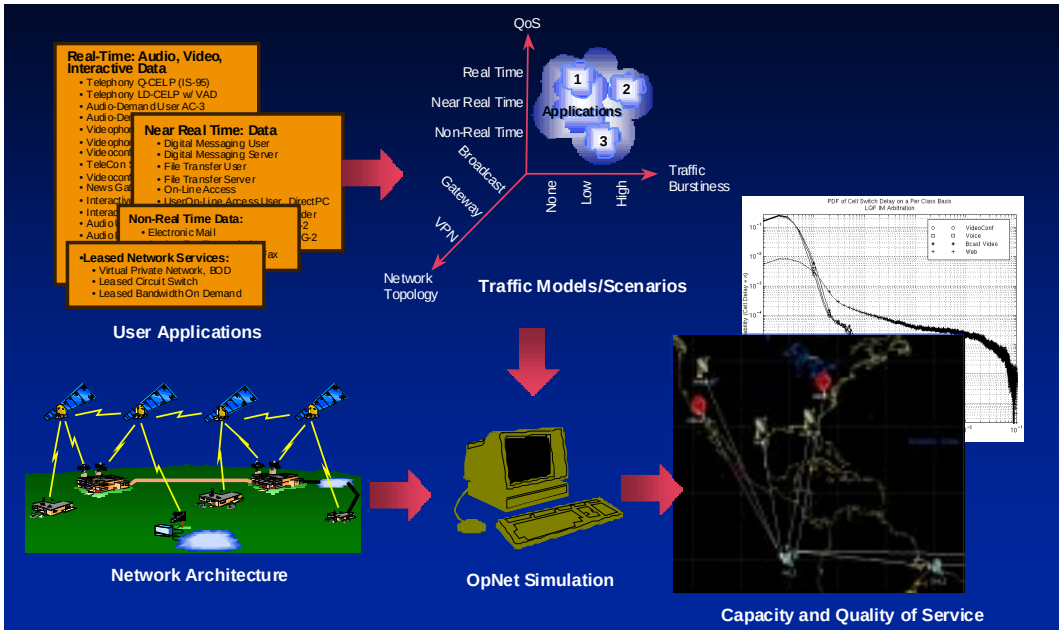


Figure 5. Network Capacity and Performance



SUMMARY

Broadband satellite systems require a new way of planning fixed satellite services to replace the traditional methods used to implement current c- and Ku-band systems. Multiple spot beams carrying multimedia traffic between millions of direct access terminals require planning that will assure that a system has the capacity and connectivity essential for the evolving telecommunications traffic to be carried by these systems over the life of the space and ground assets.

The Gen*Star program was established to provide an end-to-end network design approach that ensures optimum system architecture. All elements of the network, space, ground system, and terminals, are linked through the complex trade space using our Network Engineering methodology.

The Gen*Star approach is able to make these trades so that the individual requirements of a satellite operator can be met in terms of capacity and network integration and operation.

TRW‘s approach to broadband architecture includes giving satellite network operators the opportunity to collaborate early on the design and implementation of their satellite systems and to satisfy all the system stakeholders.