EVALUATION OF NETWORK PERFORMANCE OBJECTIVES OVER DISN ATM CONNECTIONS

Ferial T. EL-Mokadem, Ph.D.
Karl J. Pitt

The MITRE Corporation
Telecommunications Systems Engineering Department
Reston, Virginia

ABSTRACT

The Defense Information Systems Agency (DISA) has selected the Asynchronous Transfer Mode (ATM) technology as a means to integrate a broad range of information, including voice, video and data applications onto the Defense Information System Network (DISN). This paper evaluates the network performance objectives over DISN ATM connections for the Constant Bit Rate (CBR) traffic case, as would be typically found when migrating the legacy systems to ATM. A set of representative connections for the transmission topology in the DISN Outside the Contiguous United States (OCONUS) regions is used for the evaluation. ATM network performance is derived from the accumulation of performance impairments through the physical links and ATM switches encountered in the connection. The results of the evaluation indicate that the latency and jitter performance of some DISN-OCONUS ATM deployed and remote connections is likely to exceed the international standards specified for CBR traffic.

INTRODUCTION

The deployment of ATM as the statistical multiplexing and switching fabric for global DISN requires changes in both the DISN transmission backbone and recognition of the impact of global DISN on ATM performance. In the Contiguous United States (CONUS), the DISN is being bundled onto a fiber-based terrestrial backbone. The resulting DISN ATM network in CONUS will be optimally based on OC-3 or larger terrestrial links connecting Department of Defense (DoD) controlled ATM switches.

In the regions of DISN OCONUS, the transmission infrastructure is not primarily fiber optic, relying heavily on satellite communications to satisfy the Warfighter requirements for strategic survivability and diversity. Efforts are underway to bundle the predominately terrestrial- and geosynchronous satellite-based T-1 backbone onto terrestrial T-3s as soon as the bandwidth is affordable and available. Locally, within specific OCONUS regions such as central Germany, Okinawa, Korea, and Hawaii, OC-3/OC-12 backbones are either available or being implemented. The current deployment strategy is to interconnect these regions with CONUS using T-3s.

In the near future, the bundled bandwidth in the Global DISN will be sufficient to support a moderately robust T-3 network to many major DoD locations under normal conditions. On the other hand, the need to satisfy DISN requirements for diversity and survivability will continue to rely on geosynchronous satellites and terrestrial T-1 links in the backbone. In addition, some remote locations and deployed users in the Pacific and Indian Oceans will remain connected to the backbone network using satellite T-1 links for the foreseeable future. Under stressed conditions, connectivity to deployed users or to remote locations in these regions may contain double-hop satellite links operating at T-1 rate. Figure 1 depicts the anticipated DISN backbone extension to regions in the Pacific and Indian Oceans.

ATM NETWORK PERFORMANCE PARAMETRS

The ATM Forum User-Network Interface (UNI) Specification [1] defines ATM network performance parameters and their relationships with fundamental references such as ITU-T Recommendation I.356 [2]. The four primary ATM network performance parameters are the cell loss ratio (CLR), cell error ratio (CER), cell transfer delay (CTD), and the cell delay variation (CDV). The ITU-T Recommendation I.356 provides the definitions of ATM performance parameters and recommends end-to-end performance objectives to be achieved internationally for each parameter. Some of these values depend on the Quality of Service (QoS) class specified for the connection. Transporting CBR signals (or "circuits") using ATM requires stringent cell delay variation and cell loss performance that is sufficient to meet the jitter requirements for the reconstructed CBR channel being emulated. To meet such stringent requirements, the ATM Forum's Circuit Emulation Service (CES) Interoperability Specification [3] specifies quality of service (QoS) Class 1 for effective transport of circuit emulation traffic over ATM. The physical impairments of the underlying physical links and the impairments resulting from the ATM switches and multiplexers affect the performance of an ATM connection. In

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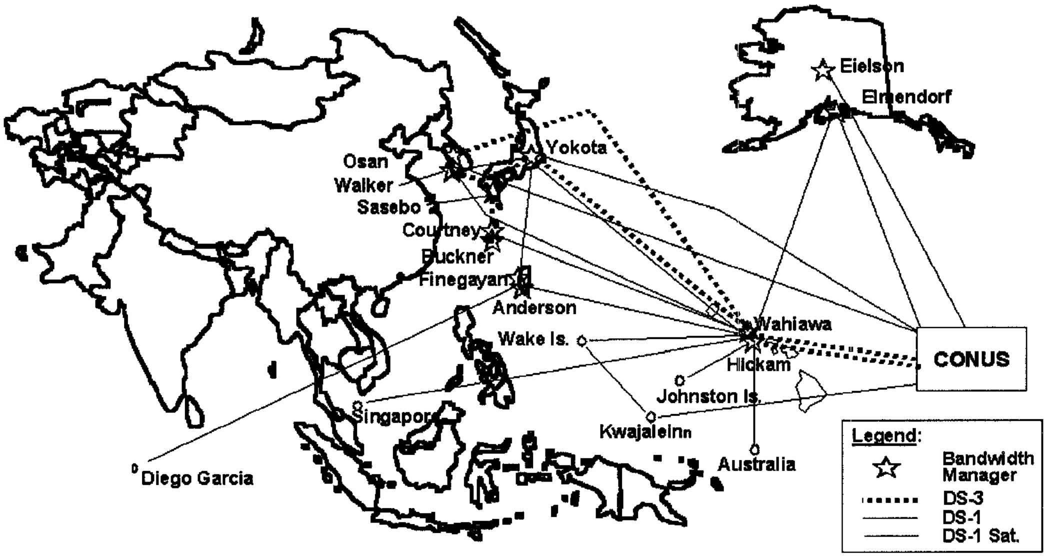

Figure 1. DISN Backbone Topology in the Pacific and Indian

general, the performance impairments grow with increasing distance and the number of additional switching and queuing stages.

DISN PACIFIC-CONUS CONNECTIONS

In order to evaluate the DISN ATM network performance, three representative DISN connections supporting DS1 circuit emulation services were considered. The connections were selected to represent normal, deployed, and remote Pacific-CONUS connectivity configurations. The situations analyzed include both nominal and stressed conditions (e.g., failure and/or threat conditions) for each configuration resulting in six reference connections to evaluate.

1. The Nominal reference connection is a DS1 emulated circuit from an East Coast CONUS location to Korea via Hawaii. It would be typically found when migrating DISN legacy systems in the Pacific to an ATM environment.
2. The Stressed Nominal reference connection assumes that the path from Hawaii to Korea has been rerouted over a T-1 satellite link. This connection could be used for diversity, reconstitution or cost reasons.
3. The Deployed reference connection uses a representative Nominal connection to a Standardized Tactical Entry Point (STEP) site in Okinawa, Japan, followed by a T-1 link over a Defense Satellite Communications System (DSCS) satellite to a deployed switch.
4. The Stressed Deployed reference connection uses a representative Stressed Nominal connection from CONUS to the STEP site in Okinawa (i.e., rerouted over a T-1 satellite link), and then followed by a T-1 link over a DSCS satellite to the deployed switch. This situation is roughly analogous to a double-hop DSCS connectivity.
5. The Remote reference connection provides a connection from CONUS to Diego Garcia via Hawaii and Guam. The primary assumption is that the satellite link to Diego Garcia is operating at T-1.
6. The Stressed Remote reference connection includes two T-1 based satellite hops in the backbone. While this is not viewed as an optimal scenario it is believed to be a realistic situation for remote users under various failure and threat conditions.

The performance objectives for each of the six reference connections are determined as follows. The number and type of performance affecting network elements, such as transmission links, switching elements and CES interworking units, are identified. Assumed amounts of impairment characterized by the ATM performance parameters are allocated to the individual network elements. The end-to-end performance is then obtained by taking into account the manner in which the performance impairment characterized by each parameter builds up through the representative chain of network elements in a connection. In principle [4], the build-up of the cell transfer delay, cell loss ratio and cell error ratio are additive through the chain of transmission paths and ATM switches. The build-up of the distribution of cell delay variation is estimated as a convolution of the CDV distributions that each of the ATM switches would contribute. The following discussion describes the standards and methodology used for the allocation of ATM performance parameter objectives to network elements.

PERFORMANCE CONSIDERATIONS FOR TRANSMISSION PATHS

Cell Transfer Delay (CTD) - The propagation delay of a terrestrial transmission path is proportional to the length of the path. The CTD allocation for the route length (R_{km}) between two points is specified in ITU-T Recommendation I.356 as:

CTD (in microseconds) $\leq R_{km} \times 6.25$

The relationship between the route length, in kilometers, and the air-route distance (D_{km}) between two points is defined by ITU-T G.826:

- if $D_{km} < 1000$ km, $R_{km} = 1.5 \times D_{km}$
- if $1000 \leq D_{km} \leq 1200$ km, $R_{km} = 1500$ km
- if $D_{km} > 1200$, $R_{km} = 1.25 \times D_{km}$

When a connection portion contains a geosychronous satellite hop, this portion is allocated a fixed propagation delay, equal to 260 milliseconds.

Error Performance - The error performance objectives for dedicated digital services in various transmission media are mapped into cell loss ratio (CLR) and cell error rate (CER) impairment contributions for an ATM connection using the procedure described in Annex A of the ATM Forum CES Interoperability Specification. For example, a 45 Mbps transmission path (which utilizes 119,681 payload cells/s) characterized with an Errored Second (ES) objective of less than 3.5% (or 1 in 28.57 of the seconds) would be characterized by a CER+CLR objective less than 1/(119681 x 28.57), that is CER+CLR $< 2.9\times10^{-7}$.

Geosynchronous satellite links are generally characterized with bursty error performance that can prevent reliable delivery of ATM cells unless forward-error-correction (FEC) is implemented. FEC methods can be used to protect an entire link (both the header and payload) from errors, or to provide protection for the header data while allowing the protection of the payload data to be service-specific selective based on traffic needs. For the purpose of this analysis, it is assumed that with the use of FEC methods, the CER+CLR objective of a conditioned satellite link is in the order of 1×10^{-6}.

PERFORMANCE CONSIDERATIONS FOR ATM SWITCHES

The delays introduced by an ATM switching/ multiplexing system is dependent on a number of factors including traffic loading and buffer management. The switching functions that contribute to delay include the buffering of the line signal to ensure that both jitter and wander do not cause line errors, the cell buffering during the switching function, and the buffering required to write the cell to the line output. The delay going through a switch is usually affected more by the line/trunk input and output rates than it is by the internal clock rate used within the switch. The maximum one-way delay objective is approximated by the following equation [5]:

Objective for one-way delay = 3 x [53x8 (bits) /Lowest Line Data Rate (bits/s)] x 1000 + 0.250 (milliseconds)

The DISN ATM System Specification [6] provides the performance objectives for ATM switch connections on standard interfaces at OC-3c/STM-1 or OC-12/STM-4, DS3/E3, and DS1/E1 rates. In general, CTD and CDV increase as transport rates decrease.

PERFORMANCE CONSIDERATIONS FOR CES INTERWORKING FUNCTION

The CES Interworking Function (IWF) implemented in devices at the edge of the network allows ATM systems to interwork with classic T1/E1 facilities and equipment. The maximum one-way delay introduced by the CES IWF is approximated by the following equation [5]:

Objective for one-way delay = 5 x [53x8 (bits) /Lowest Line Data Rate (bits/s)] x 1000 + 0.250 (milliseconds)

For a T1 line, the one-way delay across the CES-IWF approximately equals 1.6 milliseconds.

To cope with the uncertain CDV in an ATM network, the CES-IWF at the receiving end of the emulation path holds CBR cells in the reassembly buffer to bridge gaps caused by CDV. The size of the CES-IWF reassembly buffer must be large enough to accommodate the largest CDV present on a virtual channel to prevent buffer overflow or underflow conditions, with resulting slip events or reframe. At the same time, buffers larger than required to accommodate CDV will result in additional overall delay.

In some CES-IWF implementations, the maximum size of the reassembly buffer is set to a default value constrained by the network objectives for CDV, e.g., the 3 milliseconds objective specified by ITU-T I.356. Some CES-IWF implementations would enable the size of the reassembly buffer to be software configurable, by setting the delay to a small value if the connection will produce minimal CDV and a large value if the connection will produce large CDV.

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Connection Component	Transmission Path Performance Allocations						ATM Switching System Allocations					End-to-End Connection		
	Rate (Mbps)	Distance (km)	Route Length (km)	Cell Transfer Delay (msec)	% ES	CLR + CER	Input Interface Rate (Mbps)	Output Interface Rate (Mbps)	Cell Transfer Delay (msec)	Cell Delay Variation (msec)	CLR	Cell Transfer Delay (msec)	Cell Delay Variation (msec)	CLR + CER
CES Interworking Unit							1.5	155	1.6	~0	1.00E-10	1.6	~0	1.00E-10
SDN switch in CONUS							155	155	0.15	0.25	1.00E-10	0.15	0.25	1.00E-10
CONUS transmission path	155	3700	4625	28.91	3.5	8.50E-08						28.91		8.50E-08
CONUS - PAC gateway switch							155	45	0.325	0.38	1.00E-10	0.325	0.38	1.00E-10
CONUS - Hawaii transmission path	45	4130	5163	32.27	3.5	2.90E-07						32.27		2.90E-07
Hawaii switch							45	45	0.5	0.5	1.00E-10	0.5	0.5	1.00E-10
Hawaii - Korea transmission path	45	7300	9125	57.03	3.5	2.90E-07						57.03		2.90E-07
Korea switch							45	45	0.5	0.5	1.00E-10	0.5	0.5	1.00E-10
Korea transmission path	45	270	405	2.53	3.5	2.90E-07						2.53		2.90E-07
SDN switch in Korea							45	155	0.325	0.38	1.00E-10	0.325	0.38	1.00E-10
CES Interworking Unit							155	1.5	Av buffer fill	~0	1.00E-10	Av buffer fill	~0	1.00E-10
Built-up Connection				120.74		9.55E-07			3.4	0.92	7.00E-10	**124.14**	**0.92**	**9.56E-07**
ITU-T Recommendation I.356 for QoS Class 1 International End-to-End Connection												**400.00**	**3.00**	**4.30E-06**

Table 1. Nominal Reference Connection Performance

Connection Component	Transmission Path Performance Allocations						ATM Switching System Allocations					End-to-End Connection		
	Rate (Mbps)	Distance (km)	Route Length (km)	Cell Transfer Delay (msec)	% ES	CLR + CER	Input Interface Rate (Mbps)	Output Interface Rate (Mbps)	Cell Transfer Delay (msec)	Cell Delay Variation (msec)	CLR	Cell Transfer Delay (msec)	Cell Delay Variation (msec)	CLR + CER
CES Interworking Unit							1.5	155	1.60	~0	1.00E-10	1.60	~0	1.00E-10
SDN switch in CONUS							155	155	0.15	0.25	1.00E-10	0.15	0.25	1.00E-10
CONUS transmission path	155	3700	4625	28.91	3.5	8.50E-08						28.91		8.50E-08
CONUS - PAC gateway switch							155	1.5	1.07	2.00	1.00E-10	1.07	2.00	1.00E-10
CONUS - Camp Courtney transmission path	1.5	GEO Satellite	GEO Satellite	260.00	3.5	1.00E-06						260.00		1.00E-06
Camp Courtney switch							1.5	155	1.07	2.00	1.00E-10	1.07	2.00	1.00E-10
Okinawa transmission path (Camp Courtney - Camp Buckner)	155	54	81	0.51	0.6	1.50E-06						0.51		1.50E-06
Camp Buckner switch							155	1.5	1.07	2.00	1.00E-10	1.07	2.00	1.00E-10
Okinawa - GMF (DSCS)	1.5	GEO Satellite	GEO Satellite	260.00	3.5	1.00E-06						260.00		1.00E-06
Deployed SDN switch							1.5	155	1.07	2.00	1.00E-10	1.07	2.00	1.00E-10
CES Interworking Unit							155	1.5	Av buffer fill	~0	1.00E-10	Av buffer fill	~0	1.00E-10
Built-up Connection				549.41		3.59E-06			6.03	4.01	7.00E-10	**555.44**	**4.01**	**3.59E-06**
ITU-T Recommendation I.356 for QoS Class 1 International End-to-End Connection												**400.00**	**3.00**	**4.30E-06**

Table 2. Deployed Stressed Reference Connection Performance