CHARACTERIZATION OF PACSAT-1 TRAFFIC VIA DOWNLINK MONITORING

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ABSTRACT

This paper provides a characterization of certain aspects of PACSAT-1 downlink traffic obtained by monitoring and processing the downlink data stream. Among the aspects presented are: the proportions of the three major traffic types--broadcasting, file server, and telemetry; the interarrival times of successful file server connections; the service times for file server transactions; the AX.25 data-link level response times for file server transactions; and the downlink byte counts for file server transactions. Even though the monitoring operation is subject to various factors affecting the received block and bit error rates, the data presented here should be good approximation of the parameters of the PACSAT-1 communications system.

INTRODUCTION

Between January, 1991 and July, 1991, a total of six downlink data samples were collected--four from PACSAT-1 and two from UoSAT-3. These are summarized in Table 1. This paper is concerned only with sample nos. l(D), 2, and 3 which represent the data collected using a beam antenna (KLM-18C) and computer-controlled tracking. PACSAT-1 sample nos. l(0) and 4 were collected using an omni-directional antenna (Cushcraft AFM-44DA). Details of the analysis of the PACSAT-1 omni-directional antenna samples and the UoSAT-3 samples will be published at a later date.

The "Percent of Capacity" column in Table 1 gives an estimate of the data captured assuming that the downlink was busy for the entire time the satellite was in view of the monitoring station. For PACSAT-1 the downlink is busy almost 100 percent of the time when its footprint is over the continental U.S. Even on an individual pass it is hard to account for more than about 90 percent of the downlink time. This is due to periodic pauses in downlink data transmission and bit errors in received frames caused by propagation anomalies and ground station local noise conditions.

DOWNLINK TRAFFIC MIX

Table 2 gives the frame and byte counts for each of the three primary traffic types--broadcast (QST), file server (BBS or FTL0), and telemetry (TLM). Digipeating constituted such a small part of the downlink traffic that it has been ignored in this analysis. The percentages are of the total byte count for the sample. Because the percentages in each category are relatively

Table1
PACSAT-1 AND UoSAT-3 DOWNLINK DATA SAMPLE SUMMARY

Sample No.	Satellite Name	Time Period	Orbit Count	Downlink Time HH:MM:SS	Byte Count	Percent of Capacity
1(T)			52	09:49:59	3.6 Mb	68.1
1(O)	PACSAT-1	01/01 - 01/20	28	05:06:43	1.5 Mb	52.5
1(D)			24	04:43:16	2.1 Mb	04.9
2	PACSAT-1	02/01 - 02/28	48	09:40:47	4.4 Mb	83.4
3	PACSAT-1	03/17 - 05/29	32	06:41:28	3.2 Mb	87.7
4	PACSAT-1	03/23 - 06/14	32	06:37:14	1.5 Mb	42.7
5	UoSAT-3	03/04 - 04/29	27	05:19:06	12.7 Mb	55.2
6	UoSAT-3	05/05 - 07/14	29	06:05:41	7.6 Mb	28.9

uniform, it would be interesting to further subdivide the traffic into a few more categories. For example, daytime versus evening and weekday versus weekend.

Table 2
PACSAT-1 DOWNLINK TRAFFIC MIX

	Sample No. 1(D)	Sample No. 2	Sample No. 3
QST			
Frames	6,272	12,081	11,860
Bytes	981,891	1,915,835	1,630,643
Percent	45	44	51
BBS			
Frames	9,706	19,226	10,281
Bytes	1,062,230	2,150,138	1,353,752
Percent	49	49	43
TLM			
Frames	1,409	3,261	2,211
Bytes	120,108	293,132	184,259
Percent	6	7	6
TOTAL			
Frames	17,387	34,568	24,352
Bytes	2,164,229	4,359,105	3,168,924

FILE SERVER CONNECTION INTERARRIVAL TIMES AND SERVICE TIMES

File server connection interarrival time and service time statistics are given in this section. For these and the other measurements described later, the sample mean and standard deviation were computed and an empirical cumulative density function (CDF) was plotted. Then, depending on the values of the mean and standard deviation and the shape of the CDF, a Chi-Square test for goodness of fit of the data with a hypothesized distribution was made. Usually the sample data was tested for

either an exponential or normal distribution with parameters estimated from the sample being tested.

For the data presented here, all of the Chi-Square tests resulted in rejection of H,, that the sample data fit the distribution of interest. However, for some of the cases,, the resulting Chi-Square statistic was very near the critical value. Consequently, the Chi-Square statistic closest to the critical value is reported in each case along with the type of test being performed. If "E" appears in the "χ^2 Stat" column, the value given resulted from a test for an exponential distribution. An "N" means that the test was for a normal distribution. For easy reference, the following critical values are included: $\chi^2_{0.01,8}$ = 20.1 and $\chi^2_{0.05,8}$ = 15.5 for the exponential test and $\chi^2_{0.01,7}$ = 18.5 and $\chi^2_{0.05,7}$ = 14.1 for the normal test. Other values may be found in any text on statistics or simulation.

Successful Connect Request Interarrival Times

The time between successful file server connections was determined by measuring the time between state changes in the BBSTAT message. These measurements are subject to any time delays occurring between the actual AX.25 connection and the time of appearance of the BBSTAT message on the downlink. Moreover, the monitoring station could miss a BBSTAT frame. Table 3 gives a summary of the means and standard deviations fcr successful connection interarrival times. Figure 1 shows the exponential distribution of interarrival times from sample no. 3.

Table 3
SUMMARY OF SUCCESSFUL CONNECTION
INTERARRIVAL TIME ANALYSIS

Sample No.	Number of Observations	Mean (Seconds)	Std Dev (Seconds)	χ^2 Stat and Test
1(D)	299	61	45	53.1 E
2	682	54	45	81.7 E
3	477	55	49	44.2 E

File Server Connection Service Times

When the downlink AX.25 frame sequence indicated the start of a new file server connection, the time was noted. After that, the arrival time of each frame was logged. When the frame sequence indicated that the connection had terminated, the starting time of the connection was subtracted from the last frame time giving the service time for the transaction. In cases where LOS occurred before the connection terminated, the service time was computed based on the time of the last received frame.

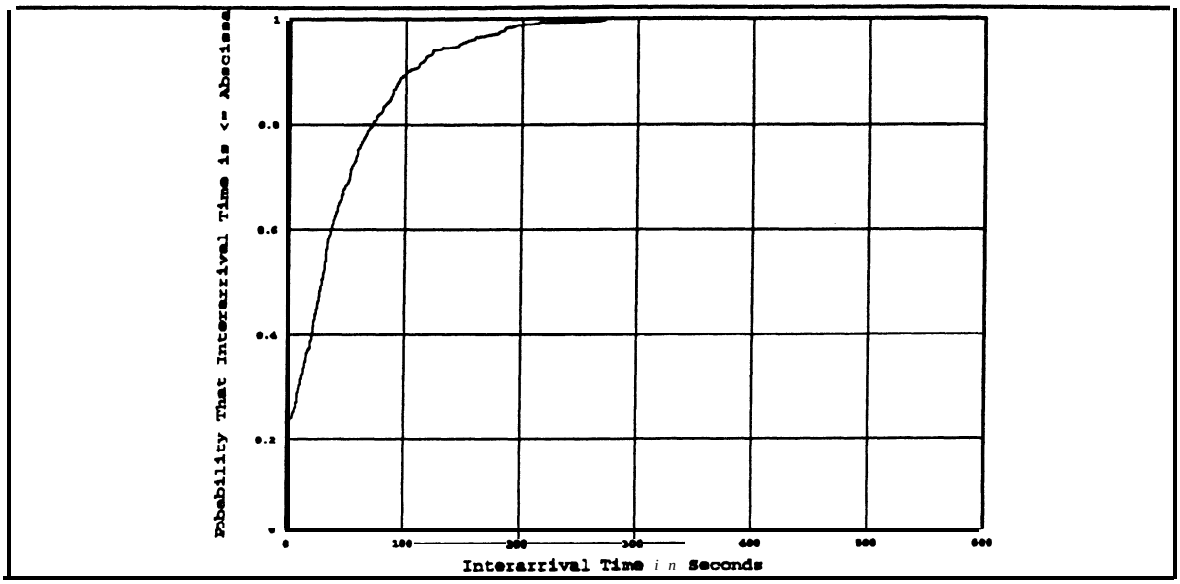

Figure 1. Empirical CDF for FTLO successful connect interarrival times constructed from PACSAT-1 data sample no. 3. $\bar{y} = 55$, $s = 49$.

However, only connections that started while the satellite was in view of the monitoring station were counted.

A summary of the transaction service time statistics can be found in Table 4. A representative empirical CDF for sample no. 3 is shown in Figure 2.

Table 4
SUMMARY OF FTLO TRANSACTION SERVICE TIME ANALYSIS

Sample No.	Number of Observations	Mean	Standard Deviation	χ^2 Stat and Test
1(D)	228	128	104	22.8 E
2	472	115	90	42.6 E
3	330	108	95	35.2 E

AX.25 DATA-LINK LEVEL STATISTICS FOR FILE SERVER CONNECTIONS

Two data-link level statistics were computed for file server connections--the response time and the byte count. For an individual connection, the response time is the average time between AX.25 frames associated with the client/server connection. Note that this does not necessarily correspond to what the user may perceive as response time since there may be more than one data-link level exchange before there is any noticeable "response" observed by the ground station operator. This is particularly true when error-recovery procedures have been executed at the data-link level.

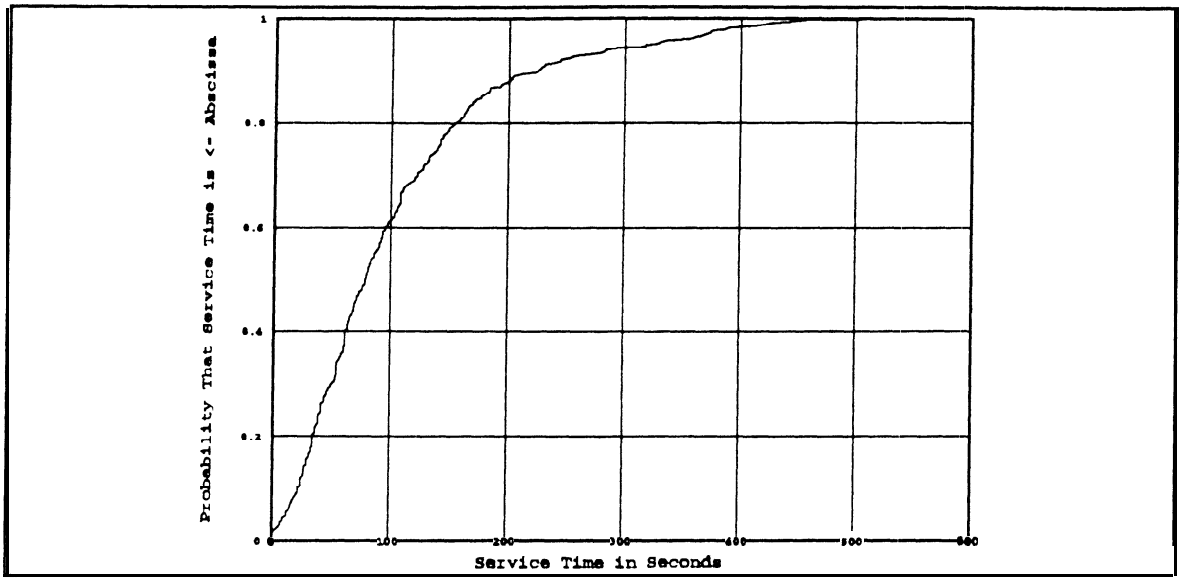

Figure 2. Empirical CDF for FTL0 transaction service times constructed from PACSAT-1 data sample no. 3. $\bar{y}$ = 108, s = 95.

AX.25 Response Time Per Connection

The AX.25 response time per connection is summarized in Table 5. An empirical CDF constructed by combining all three PACSAT-1 data samples appears in Figure 3. The CDF has the general shape of a CDF for a normal distribution. The Ax.25 response time data was the only data exhibiting a normal distribution. The mean value for response time given in Table 5 is the average of the individual connection averages. Recall that while any given connection is being measured, the file server could be servicing as many as three other clients and telemetry and broadcast frames are also being generated on the downlink. A better response time measurement could be obtained if both uplink and downlink traffic could be monitored at the same time. However, due to the transaction-oriented operation oft the client/server system, there is no operator keyboard response time to be considered.

Table 5
Ax.25 RESPONSE TIMES FOR FTLO CONNECTIONS
MEASURED ON A PER-CONNECTION BASIS

Sample No.	Number of Observations	Mean	Standard Deviation	χ^2 Stat and Test
1(D)	225	5.0	2.3	31.0 N
2	464	5.1	2.6	42.3 N
3	326	5.2	3.0	54.3 N

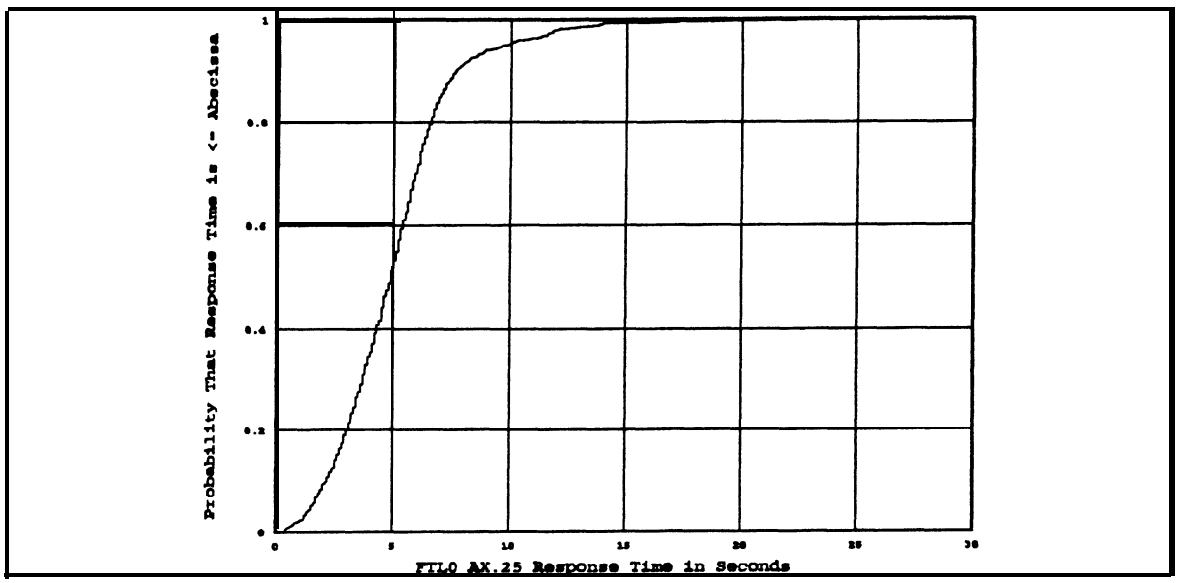

Figure 3. Empirical CDF for FTLO AX.25 response times constructed by combining all PACSAT-1 data samples.

AX.25 Frame Byte Counts Per Connection

Table 6 contains a summary of the AX.25 frame byte counts for file server connections. The empirical CDF for the distribution of byte counts for all PACSAT-1 samples combined is shown in Figure 4. Notice that the goodness-of-fit tests of the byte count data resulted in Chi-Square statistics closer to the critical values when compared to the results of the other tests. Data frames for file server connections seen on the downlink are primarily responses to directory and download commands issued by the client stations. Only connections where at least 128 bytes were sent to the client station were counted in these measurements.

Table 6
BYTE COUNTS FOR FTL0 OPERATIONS
MEASURED ON A PER-CONNECTION BASIS

Sample No.	Number of Observations	Mean	Standard Deviation	χ^2 Stat and Test
1(D)	212	3,120	3,371	16.1 E
2	446	2,637	2,845	34.8 E
3	306	2,700	3,692	20.6 E

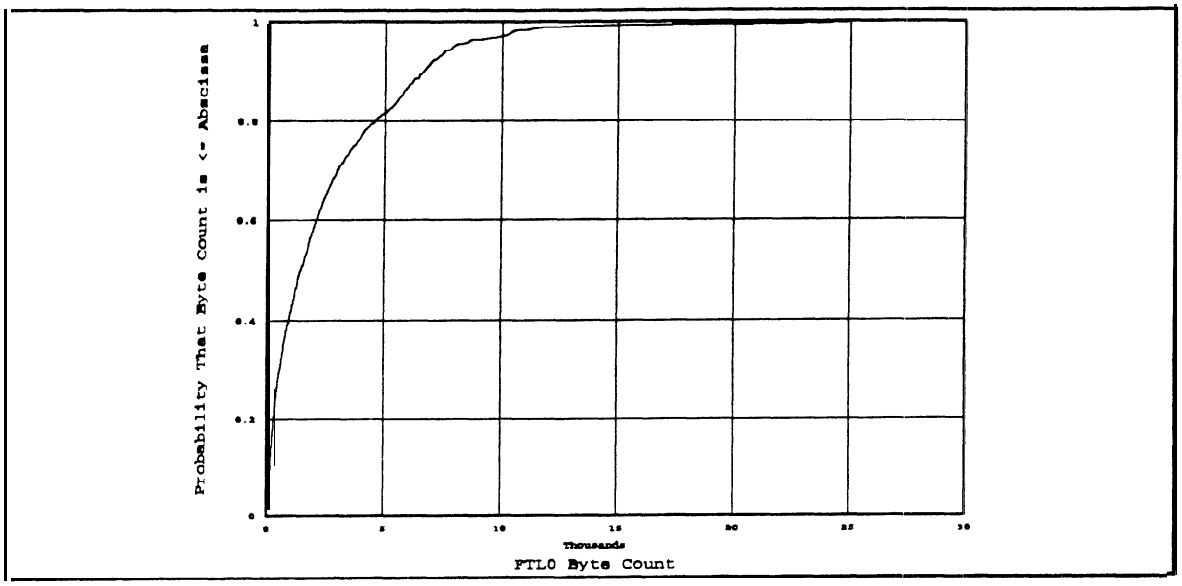

Figure 4. Empirical CDF for FTL0 transaction byte counts constructed by combining all PACSAT-1 data samples.

SUMMARY

The statistics reported in this paper have been compiled in preparation for construction of a simulation model of communication systems similar to those on PACSAT-1 and UoSAT-3. The information provides an operational characterization from the viewpoint of a ground station user. Even though the monitoring process is subject to missing data due to bit errors in received frames, the data samples are large enough and span a long enough time period that they should fairly represent actual operating conditions. In order to minimize the number of errors encountered, only data captured using computer-pointed directional antenna systems have been used during the compilation of the preceding statistics.