

DIS Network Traffic Analysis Estimation Techniques

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Abstract

One of the most critical factors in developing Distributed Interactive Simulation (DIS) is that of defining the performance to be supplied by the network. Although the performance of a given network implementation is a scalable quantity, beyond a certain level (e.g., 1.5 Mbs) it becomes a heavy cost (and sometimes schedule) driver. The situation is further complicated by the interactive nature of DIS since each session or exercise poses a unique set of requirements. To the ability to accurately estimate those requirements in advance is a goal of the DIS community.

This paper will describe a mathematical estimating tool that is being jointly developed by Grumman and UCF/IST. A preliminary version of the tool, implemented in the form of a spreadsheet executable on either PC or Macintosh platforms, was used to estimate the network traffic prior to the DIS demonstration at the 1992 I/ITSC conference. A "post mortem" of that demonstration is included, comparing actual I/ITSC traffic to that predicted by this technique. The paper will also describe future enhancements to the tool.

ABOUT THE AUTHORS

Kenneth Doris is a Technical Advisor in Grumman's Combat Systems organization. He is currently directing several research projects, including one devoted to DIS investigation. He is an active member of both the Communications Architecture and the Emissions subgroups of DIS. Last fall Mr. Doris lead the Grumman team at the 14th I/ITSEC DIS demonstration held in San Antonio. He holds a Bachelor of Electrical Engineering from Rensselaer Polytechnic Institute and has twenty-five years experience in Simulation and C³I, specializing in computer architecture and software engineering.

Margaret Loper received a B.S. degree in Electrical Engineering from Clemson University in 1985 and an M.S. degree in Computer Science from the University of Central Florida in 1991. She is currently Principal Investigator for the Distributed Interactive Simulation (DIS) project at the Institute for Simulation and Training, Orlando. Her current research interests include simulation networking, OSI protocols, and multicast communications.

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INTRODUCTION

One of the top objectives of Distributed Interactive Simulation (DIS) is to accommodate very large exercises. Just *how* large is typically described in terms of the number of entities that will simultaneously be active in the exercise. Numbers as high as 10^4 and 10^6 are being discussed as near term goals. While it is generally acknowledged that such exercises will generate a tremendous amount of network traffic, there is anticipation that technologies such as asynchronous transfer mode (ATM) and multicast addressing (MCA) will mitigate the problem. In any case, cost and availability of network resources will continue to be important issues to be considered in exercise planning. How much traffic will a given exercise generate is a common question. Or, looking at it from the other viewpoint, given that the network has a specified maximum throughput, what size exercise can be accommodated?

The above questions have no straightforward answers since there is no direct conversion from exercise size to network traffic rate. Depending on the mixture of entity types (e.g., tank vs. aircraft) the types, sizes, and frequencies of messages (called Protocol Data Units or PDUs) varies. The situation is further complicated by the *interactive nature of DIS* -- The rate the PDUs are issued by each entity is a function of its relative activity at any point during the exercise.

NETWORK PERFORMANCE ISSUES

The network performance issues related to DIS are similar to classic network paradigms with the added requirement for real-time operation. This requirement places a premium on high throughput and low latency. Although the latter is of equal importance to the DIS community, this paper addresses only the throughput issue, specifically

the development of a tool for estimating the DIS network traffic.

DESCRIPTION OF A DIS TRAFFIC ESTIMATING TOOL

In early 1992, Grumman, as one of the authors of the Communications Architecture for DIS (CADIS) specification, developed a software tool to estimate DIS traffic. The tool uses a spreadsheet to calculate the network traffic in terms of bits per second, PDUs per second and packets per second (assuming PDUs are concatenated into datagram sized packets). It assumes that the vast majority of the traffic will result from (at most) the following subset of PDU types:

- Entity State PDU (ESPDU)
- Fire PDU (FPDU)
- Detonation PDU (DPDU)
- Emission PDU (EMPDU)
- Signal PDUs (Voice and Datalink)

It also assumes that each entity in a given exercise generates network traffic at a varying rate. The rate varies depending on the particular involvement of that entity with others. For example any vehicle that is transiting to or from its assigned duty area will exhibit very predictable dynamics and therefore generate low network traffic. Conversely, an entity entering into conflict or close cooperation with another will typically generate a fairly high level of traffic. In both cases the traffic is a result of the size and frequency of the PDUs generated. Estimating sizes of PDUs for selected entity types is a comparatively straightforward process while estimating the frequency at which they are generated is fairly complex and more subjective. The formulae for determining the size of the first four PDU types listed above are shown in Table 1

Given these formulae it is possible to estimate the PDU sizes for classes of entity types. For

PDU	FORMULA	REMARKS
ESPDU	$1152+128A$	where: A = # of articulated part records
FPDU	704	H = # of articulated parts hit
DPDU	$800+128H$	E = # of emitters
EMPDU	$192+E(160+B(416+64T))$	B = # of beams per emitter T = # of targets in beam

Table 1 Formulae for PDU Sizes

example, for a given type of tank the minimum number of articulated part records may be 5 (azimuth and azimuth rate for turret, elevation of the barrel, and up/down position for two hatches) and the number of emitters 1 (laser range finder). Similar assumptions can be made regarding aircraft and surface ships (see Table 2).

The next step in estimating the bandwidth requirement of a given exercise is to approximate the rates at which the different entity classes will issue each of the above PDU types. Since this rate can vary a great deal within a given exercise, one method of estimation is to give values representing some average low and high rates (see Table 3).

Estimating the size and frequency of Signal PDUs does not fit into the above methodology. Each type of link will produce a variable sized PDU but at a constant burst rate. For example, a voice link will produce 65 Kbs (assuming 8-bit u-Law encoding) for as long as the speaker talks. At the low end, this could result in as few as 2 PDUs per second (assuming it is broken into maximum datagram sizes of 4K bytes) but this would cause severe intelligibility problems. A more likely number is 16 PDUs per second. Similarly, data links have fixed burst rates ranging from as low as 2.5 Kbs to a high of 230 Kbs and result in 4 to 16 PDUs/sec.

The final step is to determine the number of each major entity type and the tactical data links that will participate in the exercise. Given all of these factors, the determination of a range of probable network traffic for an exercise with a thousand entities, fifty voice channels and 20 data links can be easily calculated using the spreadsheet. (see Table 4).

APPLICATION OF THE TOOL TO THE 1992 I/ITSEC DIS DEMONSTRATION

There are two types of simulation LANs: homogeneous and heterogeneous. A

homogeneous LAN is one in which all equipment (i.e., computing platforms, image generators, and simulation models) is supplied by a single vendor. For example, SIMNET constitutes a homogeneous LAN. Within this environment, processing delays and throughput capabilities are usually constant and predictable across all simulators.

Conversely, a heterogeneous LAN is composed of dissimilar computing platforms (PCs, workstations, etc.), image generators (fixed vs. dynamic priority) and simulation models. A heterogeneous environment introduces a range of operating speeds and performance to the network. One of the results of heterogeneity is a reduction in the number of entities that can be simultaneously represented on the network. An example of a heterogeneous LAN is the 1992 I/ITSEC demonstration network.

Because the I/ITSEC application of DIS was the first major implementation of a heterogeneous network, an analysis to determine the maximum number of entities that could be simultaneously represented was performed by IST several months before the actual demonstration.

The first step in the analysis was to define the simulator processing constraints. Five constraints were identified, as shown below:

1. the bandwidth of the physical media
2. the rate at which the physical interface hardware can read/write information (in PDUs/sec)
3. the rate at which data can traverse the communication protocol stack (in PDUs/sec)
4. the number of entities each simulator can track
5. the number of dynamic coordinate systems each simulator's image generator can manage.

	K	H	F	B	T	ESPDU	FDDU	DPDU	EMDDU
TANK	5	1	1	1	1	2220	1132	1356	1260
AIRCRAFT	10	2	3	1	2	2860	1132	1484	2732
SURFACE SHIP	50	5	10	1	5	7980	1132	1868	9580
OVERHEAD BITS/PDU =									428

Table 2 Sample PDU Sizing

	LOW RATE				HIGH RATE			
	ESPDU	FDDU	DPDU	EMDDU	ESPDU	FDDU	DPDU	EMDDU
TANK	0.2	0	0	0.2	2	0.1	0.1	1
AIRCRAFT	0.2	0	0	0.2	8	0.1	0.1	4
SURFACE SHIP	0.2	0	0	0.2	1	0.1	0.1	4

Table 3 Sample PDU Rates By Entity Type

	% ENTITIES AT HIGH RATE	% ENTITIES AT LOW RATE						
		0%	20%	40%	60%	80%	100%	
# of TANKS	850 →	591,600	1,484,576	2,377,552	3,270,528	4,163,504	5,056,480	
# of AIRCRAFT	140 →	156,576	1,079,210	2,001,843	2,924,477	3,847,110	4,769,744	
# of SHIPS	10 →	35,120	121,296	207,472	293,648	379,824	466,000	
# of TACTICAL VOICE LINKS	50 →	422,400	1,023,760	1,625,120	2,226,480	2,827,840	3,429,200	
# of TACTICAL DATA LINKS	20 →	230,253	522,373	814,493	1,106,613	1,398,733	1,690,853	
TOTAL TRAFFIC	BITS/SEC →	1,435,949	4,231,215	7,026,481	9,821,746	12,617,012	15,412,277	
	PDU/SEC →	580	1,616	2,652	3,688	4,724	5,760	

Table 4 Sample Exercise Traffic Estimates

From a survey of I/ITSEC demonstration participants, values for constraints 2 through 5 above had a broad range (see Figure 1).

The next step in the analysis was to gather information on the maximum capabilities of each simulator participating in the demonstration. At the time of the survey, eighteen companies responded. These companies reported that they would bring a total of 26 manned/unmanned simulators and listen-only devices. This translated into a maximum total of 245 possible entities; many of the simulators such as CGF could represent multiple entities simultaneously.

From this list of entities, the Grumman DIS traffic estimating tool was used to characterize the network bandwidth. Inasmuch as participants did not anticipate exercising their simulator's maximum capabilities (i.e., producing the maximum number of entities) we chose to use a figure of 112 entities as the peak simultaneous load. (see Table 4). When comparing these predictions with the capabilities of the participants in Figure 1 the following observations

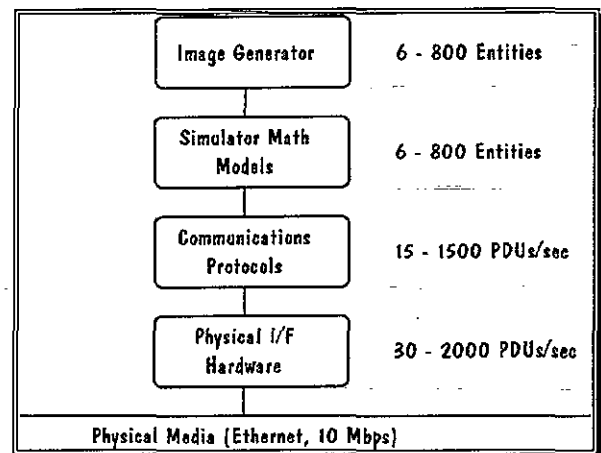


Figure 1 I/ITSEC Participant Performance Ranges

were made. While 731K bits/sec would not exceed the bandwidth of Ethernet, the rate of 311 PDUs/sec begins to push the upper bound of the processing capability of many of the simulators. For example, IST's PC-based simulators can process only 75 PDUs/sec at the Ethernet interface. Also, a 16 MIP single-processor

machine using commercial UDP/IP communication protocols and running only one process (i.e., receiving DIS PDUs but not running dead reckoning) can process only 200-250 PDUs/sec. When a second process is added that rate drops to 80-100 PDUs/sec. A rate of 311 PDUs/sec would quickly overwhelm both the Ethernet interface and the communications protocol processing of these simulators.

On the basis of this information, the I/ITSEC demonstration participants agreed to allow only the minimum number of entities on the network during the formal demonstrations. This prevented any adverse behavior during these periods. The actual number of entities running concurrently during the formal demonstrations ended up closer to 30; however, during non-demonstration times there were upwards of 100 entities simultaneously.

CONCLUSIONS

Obviously the DIS Traffic Estimating Tool has to be updated to account for the new PDUs in DIS 2.0. This could significantly increase the traffic loads seen by individual simulators. For example the newly proposed Emissions PDU may be generated as frequently as Entity State PDUs in some scenarios and the impact of Simulation Management on the network is still unknown.

The DIS Traffic Estimating Tool provided important information to the I/ITSEC demonstration participants for scenario generation. In the future, the estimating tool will be able to provide valuable insight on network bandwidth, allowing the DIS community to scale demonstrations and exercises as the capabilities of the simulators warrant.

During the conference week, a peak of 8 Mbps was observed when a number of jet aircraft began to dogfight and fire air-to-air missiles. This peak was not predicted by the estimating tool and was likely due to differences in dead reckoning implementations. We also observed that 80 entities on the network generated upwards of 350 packets/sec. This exceeded the predicted level of 311 PDUs/sec for 112 entities, as described earlier. This was most likely a result of non-DIS traffic on the network, such as Internet Control Message Protocol (ICMP) packets. Future versions of the tool should account for non-DIS

traffic as well as inconsistencies in dead reckoning implementations.