1-1-1992

Communication Service Requirements For Distributed Interactive Simulation: Part 2, Multicast Service Characterization

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Recommended Citation
Communication Service Requirements for Distributed Interactive Simulation

Part 2: Multicast Service Characterization

Investigation of OSI Protocols for Distributed Interactive Simulation

Prepared for:
U.S. Army Simulation, Training and Instrumentation Command

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12424 Research Parkway, Suite 300
Orlando FL 32826

University of Central Florida
Division of Sponsored Research

IST-TR-92-23
Contract Number N61339-91-C-0103
CDRL A003

Communication Service
Requirements for Distributed
Interactive Simulation

Part 2: Multicast Service Characterization
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Investigation of OSI Protocols for Distributed Interactive Simulation

Prepared for:
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Prepared by
Margaret Loper

Reviewed by
Scott A. Small
COMMUNICATION SERVICE REQUIREMENTS FOR DISTRIBUTED INTERACTIVE SIMULATION

PART 2: MULTICAST SERVICE CHARACTERIZATION

PREPARED FOR:

U.S. ARMY SIMULATION TRAINING AND INSTRUMENTATION COMMAND
12350 Research Parkway
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INVESTIGATION OF OSI PROTOCOLS FOR DISTRIBUTED INTERACTIVE SIMULATION

CONTRACT N61339-91-C-0103
CDRL A003

July 28, 1992

Institute for Simulation and Training
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1. INTRODUCTION

Distributed Interactive Simulation (DIS) will require state of the art communication services and protocols. To facilitate the interoperability of dissimilar simulations and reduce cost, industry communication standards will be adopted to maximize the use of commercial-off-the-shelf (COTS) products and maximize the base of practical technical knowledge. While the majority of the communication services required by DIS can be satisfied with COTS protocols, there are requirements which cannot. Consequently, the DIS service requirements fall into two categories: interim services, which are required to support immediate DIS experiments, demonstrations, and tests, and long-range services, which require development. One service requirement which cannot be met with COTS protocols is multicast.

Multicast is a transmission mode in which a single message is sent to multiple network destinations, i.e. one-to-many. Large scale DIS exercises will require multicast to selectively filter information. This filtering will reduce the amount of PDU traffic a simulator must process by sorting out information which is of no interest to it. Generally, simulation entities are only interested in other simulation entities which are within some sphere of interest (e.g., visual range). Another application for multicast is to differentiate multiple simultaneous exercises on the same network.

DIS requires a full range of multicast capabilities [4] which are not currently available in any protocol. Development of multicast protocols has begun in OSI and a comprehensive multiplex/multicast architecture is being designed. However, DIS will have to wait three to four years to get these multicast services. Consequently, multicast will need to be phased into the architecture over a period of years. To realize a graceful evolution, the Transition Plan developed for DIS should synchronize multicast capabilities with the phases of the architecture (i.e., Phase 0 - Phase 2). The time frames established for each phase will depend on many factors including the availability of multicast standards (and corresponding products) and exercise requirements for multicast (based on the number of entities playing on the DIS network). This paper discusses two elements related to exercise requirements which help characterize the multicast time frame: the projects and the simulators.

2. DIS PROJECTS

2.1 DIS Applications

There are three categories of DIS applications: Simulations, which include both manned Simulators and Computer Generated Forces (CGF); Instrumentation, which brings real hardware into the loop; and Wargames, which incorporates aggregate level entities. For all categories, there are both existing DIS applications, which will require retro-fitting for the new standard and

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1 The availability of multicast standards and products will be documented in the Multicast Final Report for contract N61339-91-C-0103.
new procurements, which have called out the DIS standard. Each application has different bandwidth, PDU, and entity requirements. The following sections give a brief introduction to each application area, the programs which will use DIS for interoperability, and the approximate time frames (when available) for deployment.

2.1.1 Simulation Programs

A simulation is a computer replication of actual battlefield entities or collections of entities (units) which are fully automated or partially automated [2]. Simulations/simulators will use the DIS Protocol Data Units (PDUs) to communicate data from one simulation entity to another. Simulations/simulators are interconnected via Local Area Networks (LANs) and Wide Area Networks (WANs) which can provide high data rates on the order of Gigabits/s. It is anticipated that DIS LANs will support 1,000 simulation entities and WANs must support 100,000 simulation entities by the mid 1990's.

There is only one new procurement currently requiring DIS; however, there are numerous existing simulations and simulators which will use DIS for interoperability. The Interservice/Industry Training System Conference (I/ITSC) DIS Interoperability Demonstration is an example of connecting existing simulators. Approximately 25 simulators from 16 participants will be interconnected for the first DIS exercise.

Close Combat Tactical Trainer (CCTT) is a simulation system wherein various simulated elements replicating actual combat vehicles, weapon systems, and command and control elements will be networked for real-time, fully interactive collective task training on computer generated terrain [3]. According to [3], long-haul networking is a preplanned product improvement, indicating only Local Area Network (LAN) exercises during initial deployment. The LAN will be required to support a minimum of 851 (performance goal of 1000) entities operating concurrently in real-time, with a minimum of 200 manned simulators and the remaining entities being emulated. CCTT must be capable of supporting five concurrent exercises. The CCTT contract could be awarded in late 1992 or early 1993. Consequently, deployment would not occur until the 1995 time frame.

2.1.2 Instrumentation Programs

Field instrumentation programs bring real platforms into the simulation environment. Exercise participants, e.g. aircraft, ships, and land vehicles, have complete autonomy within the constraints imposed by the Rules of Engagement. Each participant periodically collects its own kinematic information from real systems (i.e., GPS and/or INS) and detection/tracking information from tactical sensors. This information in encapsulated in messages that are transmitted over datalinks to a core system, and then to other participants. Instrumentation systems require only a subset of the information contained in the current DIS PDUs. Consequently, research efforts are recommending reduced-sized PDUs for these applications which will then be transformed to "normal" DIS PDUs at the "core systems" before entering the

An entity includes manned and unmanned simulators, simulations, computer generated forces, environment entities, instrumented operational equipment, and aggregated entities.
simulation environment. Instrumentation PDUs are communicated via low bandwidth RF data links, on the order of 1200bps - 121kbps. Field instrumentation programs will also rely on satellite communication.

The majority of new procurements requiring DIS are instrumentation programs. The following sections provide a brief introduction to some of these programs.

**Battle Force Tactical Trainer (BFTT)** will provide realistic combat system team training onboard, in all warfare areas (e.g., Anti-Air (AAW), Anti-Submarine (ASW), and Anti-Surface (ASUW)), utilize On Board Trainers (OBTs), link ports for BF/BG training, and improve ship's force accessibility to maximize training opportunities. It is slated for FY 93-97 and is divided into three phases. Phase 1 (1992) will include connectivity of six sites with 10-23 radios and AAW, ASUW, and ASW capabilities. Phases 2 (end of 1994) and 3 (1997) will increase the number of sites and capabilities of the system.

**Tactical Combat Training System (TCTS)** is the tactical training concept for the year 2000. It will support realistic battle group training and assessment and train all warfare areas. A total of 130 entities are planned including: 100 aircraft, 24 ships, and 6 submarines. No visuals are required. From [1], the critical design review will be in November 1995 and production in late 1997. Fielding will occur in the late 1990s. TCTS will use both simulated/stimulated contacts and "real" threat platforms. Significant security is expected.

**Mobile Automated Instrumentation Suite (MAIS)** is being developed to support Army operational and force development tests employing realistic real-time casualty assessment. The total system will include four Command, Control and Communications (C3) Centers with 1830 player units (PUs). However, the initial system will be comprised of one C3 center with 250 PUs: 28 dismounted troops, 148 ground vehicles, 50 crew served weapons, 4 fixed wing, and 20 rotary wing. PUs do not have adequate computing resources to support a "global" view of the simulation, so the transformation of PU PDUs to DIS PDUs will occur at the C3 centers.

**Tactical Aircrew Combat Training System (TACTS)** will provide realistic combat training for Navy aircrews in all areas of tactical air warfare, including electronic warfare training. Currently, 36 aircraft with surface to air threats and air to surface weapons are anticipated.

**Joint Aircrew Combat Training System (JACTS)** is a joint effort between the US Navy and the US Air Force to train in the area of tactical air warfare. Entities will include 72 aircraft and the latest weapons simulations.

### 2.1.3 Wargaming Programs

Wargames will incorporate aggregate level entities (e.g., platoons, flight, and surface action groups) into the DIS environment. Wargames are event oriented as opposed to time based. The current research on Aggregate and Deaggregate PDUs [5] are examples of integrating wargames into the simulation environment.
2.2 DIS Exercises

To date, the largest simulator exercise, WAREX '90, was conducted in March and April 1990 between five sites. The communications medium was a mix of Ethernet LANs connected by DARPA's Terrestrial Wideband Network (TWBNet). The exercise supported as many as 1500 simulated vehicles with a peak of approximately 800 entities running concurrently. Ten simultaneous voice channels were used to support command and control links among the sites.

The I/ITSC demo will be the first DIS exercise and will be conducted in San Antonio, Texas in November 1992. The exercise will be composed of simulations and simulators. Currently there are 17 participants with an estimated 25 simulators expected to be connected on the showroom network. Current bandwidth calculations indicate no more than 100 entities will be able to participate concurrently, due to the mix of low and high performance simulators. The limitations, which can be improved by multicast communications, will be discussed in the following section.

There are plans for long haul simulations starting in 1994 with the Louisiana (LA) Maneuvers and also another WAREX in 1996. These exercises will include a mixture of simulations, instrumentation, and wargames.

3.0 SIMULATORS

3.1 Processing Delays

An analysis to determine the maximum number of entities that can be simultaneously represented on a network has identified five main processing constraints:

(i) the bandwidth of the physical medium,
(ii) the number of PDUs/sec the physical interface hardware can handle,
(iii) the number of PDUs/sec the communication protocols can process,
(iv) the number of entities each simulator's math models can track, and
(v) the number of dynamic coordinate systems each simulator's image generator (IG) can visualize.

From a survey of I/ITSC DIS interoperability demonstration participants, values for constraints (ii) through (v) have a broad range corresponding to low-performance and high-performance platforms (see Figure 1).
Using a bandwidth analysis similar to that presented in [1]³, let’s examine a sample network traffic analysis and identify which simulator delays will present problems. The exercise will consist of 100 tanks, 11 aircraft, and 1 ship which broadcast Entity State (ESPDU), Fire (FPDU), and Detonation (DPDU) Protocol Data Units (PDUs) (no Emitter PDUs or tactical voice links). In a low conflict environment, i.e. only ESPDUs are generated at a rate of .2 Hz, traffic on the DIS network will be on the order of 55,018 bits/sec or 22 PDUs/sec; a low rate

³ This analysis was conducted by Ken Doris of Grumman Space and Electronics.
that can be handled by any simulator participating in an exercise. But what if the environment is high conflict, where PDUs are broadcast at the following rates: 2 Hz for a tank ESPDU, 8 Hz for an aircraft ESPDU, 1 Hz for a ship ESPDU, .1 Hz for all FPDUs, and .1 Hz for all DPDUs. The PDU traffic increases to 843,930 bits/sec or 311 PDUs/sec. The results of this analysis are shown in Table I. The following formula were used to determine the size of each PDU (in bits):

<table>
<thead>
<tr>
<th>PDU</th>
<th>FORMULA</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESPDU</td>
<td>1152 + 128A</td>
<td>A = # of articulated part records</td>
</tr>
<tr>
<td>FPDU</td>
<td>704</td>
<td></td>
</tr>
<tr>
<td>DPDU</td>
<td>800 + 128H</td>
<td>H = # of articulated parts hit</td>
</tr>
<tr>
<td>EPDU</td>
<td>192 + E(160+B(304+96T))</td>
<td>E = # of emitter beams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B = # beams per emitter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T = # of targets per beam</td>
</tr>
</tbody>
</table>

While 843k bits/sec will not exceed the bandwidth of Ethernet or IEEE 802.3, the rate of 311 PDUs/sec begins to push the upper bound of the processing capability of some 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 the UDP/IP communication protocols and running only one process, i.e. sending DIS PDUs but not dead reckoning position, 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 communication protocols of these simulators.

It is important to note that it is unlikely (for the near term) that a scenario involving 100 tanks, 11 aircraft, and 1 ship would be orchestrated where all 112 entities are in a high conflict environment. It is more likely that some subset of the entities would be in high conflict areas with the remaining involved in low or no conflict areas. This will reduce the number of PDUs generated per second; however, the high conflict data presents an upper bound to the problem.

In a scenario such as the one described above, it would be very useful to have multicast communication services so that information could be filtered and delivered only to those simulators that are tracking an entity's dead reckoning or visual state information. This, among other things, would reduce the amount of traffic each individual simulator must process. Consequently, processing power could be used for other applications or for supporting additional entities on the DIS network.

In exercises consisting of limited entities in scenarios which disseminate the simulated entities in both low and high conflict areas, broadcast transmissions will be sufficient. But as the scenarios grow to include multiple sites, large numbers of entities, and more than three types of PDUs, it will be necessary to have multicast.

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4 Remember, this scenario does not include Emitter PDUs which will be generated at approximately the same rate as ESPDUs.
**SAMPLE PDU SIZING**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>H</th>
<th>E</th>
<th>B</th>
<th>T</th>
<th>ESPDU</th>
<th>FPDU</th>
<th>DPDU</th>
<th>EPDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>TANK</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2220</td>
<td>1132</td>
<td>1356</td>
<td>1180</td>
</tr>
<tr>
<td>AIRCRAFT</td>
<td>20</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4140</td>
<td>1132</td>
<td>1484</td>
<td>2588</td>
</tr>
<tr>
<td>SURFACE SHIP</td>
<td>50</td>
<td>5</td>
<td>10</td>
<td>1</td>
<td>5</td>
<td>7552</td>
<td>1132</td>
<td>1868</td>
<td>10060</td>
</tr>
</tbody>
</table>

OVERHEAD BITS/PDU = 428

**SAMPLE RATES PER ENTITY TYPE PER PDU TYPE**

<table>
<thead>
<tr>
<th></th>
<th>LOW RATE</th>
<th></th>
<th></th>
<th>HIGH RATE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESPDU</td>
<td>FPDU</td>
<td>DPDU</td>
<td>EPDU</td>
<td>ESPDU</td>
<td>FPDU</td>
</tr>
<tr>
<td>TANK</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>AIRCRAFT</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0.1</td>
</tr>
<tr>
<td>SURFACE SHIP</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**SAMPLE EXERCISE TRAFFIC ESTIMATES**

<table>
<thead>
<tr>
<th></th>
<th>0%</th>
<th>20%</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
<td>80%</td>
<td>60%</td>
<td>40%</td>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>100 TANKS</td>
<td>44,400</td>
<td>129,296</td>
<td>214,192</td>
<td>299,088</td>
<td>383,984</td>
<td>468,880</td>
</tr>
<tr>
<td>11 AIRCRAFT</td>
<td>9,108</td>
<td>80,726</td>
<td>152,344</td>
<td>223,962</td>
<td>295,580</td>
<td>367,198</td>
</tr>
<tr>
<td>1 SHIPS</td>
<td>1,510</td>
<td>2,779</td>
<td>4,047</td>
<td>5,315</td>
<td>6,584</td>
<td>7,852</td>
</tr>
<tr>
<td>0 TACTICAL VOICE LINKS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 TACTICAL DATA LINKS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL TRAFFIC</td>
<td>55,018</td>
<td>212,801</td>
<td>370,583</td>
<td>528,365</td>
<td>686,147</td>
<td>843,930</td>
</tr>
</tbody>
</table>

Table 1
Sample Traffic Analysis for DIS Exercise
4. CONCLUSIONS

From the projects requiring DIS, it appears that most new programs will not be operational until 1995 (see Figure 2). Therefore, initial DIS exercises will be proof-of-concept demonstrations, e.g. I/ITSC. During this time, potential traffic problems can be alleviated by one or more of the following options: careful scenario development, simulator filtering at the physical interface based on exercise id, or by using an existing multicast protocol (e.g., ST-II) until such time as "DIS Multicast" is available. The first option will be used for the I/ITSC demonstration; further analysis to determine feasibility of the second option is required. The use of existing multicast protocols is beyond the scope of this report; the DIS Communication Architecture and Security Subgroup is leaving this option "open" for participants to decide on a case by case basis.

When new DIS projects become operational, there is potential for a surge of 3000 "new" entities in the network. Of course, the probability of all new DIS projects participating in an exercise initially is very low. For example, MAIS, which becomes operational in mid 1994 will not use DIS Field Instrumentation (FI) PDUs to communicate initially because the project is too far along in development to make a substantial change. The plan is to use DIS PDUs only when interoperating with the simulation world and then to adopt DIS FI PDUs as they mature. The potential swell of 3000 new entities represents a valid data point (not an upper bound) for the problem; remember, 3000 entities is in addition to the existing simulators. In any event, this 3-4 year time frame, as estimated in Figure 2, is when multicast must be developed. After this point, multicast is crucial for DIS.

The initial analysis of simulator delays for the I/ITSC demonstration indicates that mixing low-performance and high-performance simulators will limit the number of entities that can be simultaneously represented on the showroom network. This problem will exist for the DIS network also. If large scale exercises are orchestrated which include PCs and high performance simulations, multicast will be very important. Again, this can be solved for the near term by one of the three options discussed above. However, in the 1995-1996 time frame when new DIS projects are fielded, multicast will be required so that a mixture of low and high performance simulators can successfully participate in exercises.
Figure 2
Projected Timeline for DIS Projects
REFERENCES


