TESTING CONFORMANCE FOR DISTRIBUTED INTERACTIVE SIMULATION (DIS) STANDARDS

Amy Vanzant-Hodge, Sandra Cheung, and Scott Smith
Institute for Simulation and Training (IST)
Orlando, Florida, 32826-0544

ABSTRACT

The standards for the interoperability of networked defense simulations, also known as the Distributed Interactive Simulation (DIS) standards, have been prototyped, implemented, and put to the test through interoperability demonstrations at I/ITSEC '92 and I/ITSEC '93 conferences as well as in military programs such as Warbreaker, BFTT, and CCTT. To achieve interoperability between the various DIS systems, all systems must implement the same agreed-to criteria. To ensure that this occurred for the demonstrations at the previous I/ITSEC conferences, the Institute for Simulation and Training (IST) was tasked with testing each system for its level of conformance with the criteria, i.e. parts of the DIS Protocol Data Unit (PDU) draft standard and the Communication Architecture for DIS (CADIS) draft standard. To perform this testing, IST created the DIS Testbed.

This paper describes the DIS Testbed, which consists of hardware equipment, test tools, and test documents, and the test methodologies used for testing. For the I/ITSEC DIS demonstrations a system could be tested in-house at IST, via long-haul connection over phone lines, or on-site at the organization's location. The test methodology used by IST uses a Capabilities Statement filled out for the System Under Test (SUT) and tests the SUT based on its stated capabilities. The tests are outlined in detail in the Test Procedures document. Data from tests is logged with data recording tools and then analyzed to determine if the data is correct. Results from the tests are recorded on a Results Sheet, which is updated for retesting or continuation of tests. A Summary Sheet is filled out when testing is completed and sent to the organization for their review.

ABOUT THE AUTHORS

Amy F. Vanzant-Hodge received B.S. and M.S. degrees in Computer Science from the University of Central Florida in 1983 and 1989 respectively. She is currently Co-Principal Investigator for the Testbed for Research In DIS (TRIDIS) project at the Institute for Simulation and Training. She is currently involved in research for DIS compliance testing, networking, and DIS interoperability.

Sandra E. Cheung obtained her B.S. from Florida Institute of Technology, and Ph.D. from the University of Florida in 1988 and 1993 respectively. Her research interests include performance evaluation, traffic characterization, high speed networks, interconnection networks, and parallel architectures. Since joining IST in 1993, she has been involved in DIS compliance testing, and is currently involved in the analysis of DIS data traces and the characterization of DIS traffic patterns.

Scott H. Smith received an M.S. in Computer Science from the University of Central Florida in 1981. He is currently Project Manager for the TRIDIS project and Program Manager for DIS related activities at IST. His research interests lie in the areas of DIS, CGF, and Constructive Simulations.

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1. INTRODUCTION

The standards for Distributed Interactive Simulations have been under development through the "Standards For The Interoperability of Defense Simulations" Workshops for the past four years. The first standard to be adopted by the IEEE was the Protocol Data Unit (PDU) standard version 1.0 [1]. Since that time several drafts of version 2 of the PDU standard have been generated and draft standards for Communication Architecture for DIS (CADIS) [2] and Fidelity, Exercise Control and Feedback Requirements (FECFR) have also been created [3]. The latest versions of these drafts are currently going through the IEEE balloting process.

As these draft standards are created, reviewed, stabilized, and balloted, more organizations are using them to implement DIS systems. Because several versions of the drafts exist and these drafts are not always backward compatible, compliance with the different versions must be tested to ensure interoperability. The Institute for Simulation and Training (IST) has had the responsibility of compliance and interoperability testing of systems for the 1992, 1993, and 1994 Interservice/Industry Training Systems and Education Conferences' (I/ITSEC) DIS Demonstrations. Testing is specific to the current version of the DIS PDU draft standard and to the current CADIS draft standard.

1.1 Interoperability In DIS

Interoperability in DIS requires some initial assumptions. First, the version of the standard being used for the "exercise" must be agreed to by all players and this is the version being tested against. Second, inconsistencies in the standard must be resolved for the exercise so that all systems implement the standards the same way. This is key to achieving interoperability. Third, the communications infrastructure (protocols and physical media) must be agreed to by all participants so that this can also be tested. Fourth, a common simulation environment, i.e. terrain database, must be chosen. Once these four points are agreed to, testing can begin.

1.2 The Need For Testing

As stated in the above paragraph, assumptions and agreements must be made in order for systems to participate in a DIS environment. This is because the standards are not specific in many areas. Those areas are left to the interpretation of the developer of the system. Even when the non-specified areas are agreed to, there is no guarantee that the implementations will work together. Testing is needed to insure that the systems will operate in a consistent manner given the standards and the assumptions/agreements for non-specified areas. Testing insures that a system is producing valid DIS PDUs and can receive and interact with valid DIS PDUs. Testing is also used to determine the effects of adverse and erroneous data or conditions on the System Under Test (SUT).

1.3 DIS Testbed Approach

IST has created sets of test tools and test documentation in support of the I/ITSEC demonstrations that have been distributed to organizations being tested as well as being used in the Testbed. Using these tools, systems could be debugged prior to the actual compliance testing. The test documentation, specifically the Test Procedures, indicates which tests each system must pass to be interoperable based on their stated capabilities. Each organization therefore knows ahead of time what tests its systems will be required to pass.

2. DIS TESTBED

2.1 Hardware

The DIS Testbed at IST consists of several types of computers connected by an internal network. The Testbed is configured in such a way that any test system being used for testing can be isolated on a separate network with the SUT. This type of flexibility allows prototyping of new parts of the standard and new types of systems to be added to the Testbed without affecting the rest of the Testbed. Experiments can be conducted with the prototypes/new systems while testing can be conducted unaffected on another part of the Testbed. Long haul connections into the Testbed exist via the use of phone lines and a connection to the Defense Simulation Internet (DSI).

2.1.1 Computer Resources – The IST DIS Testbed currently has several 386 and 486 PCs . Each PC has an Ethernet 10 base 2 (thin coax) interface to the network. The Testbed also has a variety of UNIX based systems; two Sun Sparcs, four Motorola chasses which each contain two 88110 single board computers, and two Silicon Graphics systems which will be used as Stealth 3–D displays. Testing is done with a combination of the PCs and the Motorola's and using the Silicon Graphics to do visual confirmation.

2.1.2 Network Resources – The network in the Testbed consists of thin coax Ethernet. A patch panel is used to allow subnetworks to be connected and disconnected for testing and experiments. To separate machines from the rest of the network, i.e. to isolate a test system and a SUT, the coax cable for that subnet is disconnected from the patch panel.

Recently, the Testbed has been adding new network capabilities, specifically a very flexible network hub. This hub has connections for the thin coax as well as higher speed media such as fiber. Two ports for FDDI, a high speed alternative to Ethernet, and a translation module between Ethernet and FDDI will allow the Testbed to expand and incorporate FDDI devices. The hub also has network management built in so that these various connections can be isolated via software rather than disconnecting a cable and multiple levels of filtering can be done for each connection. Filtering will allow some network traffic to get through while other network traffic is stopped. Using filtering, test systems and a SUT don't have to be physically disconnected from the network. Instead, incoming and outgoing network traffic is limited.

2.1.3 Long Haul Resources – The Testbed currently has two 1–800 numbers which can be used for testing. A BReeze 1000 bridge is used at each end of the phone connection to allow DIS traffic to flow non–stop across the phone line. IST has two BReezes which stay by the Testbed phone lines and four BReezes which can be sent to organizations testing in this manner.

Through the hub mentioned above, a connection to the DSI is being established. A fiber connection allows IST to access the DSI. This fiber is connected to the hub and the Testbed network. Through this connection, IST will be able to exchange network traffic with any organization that is connected to the DSI. This connection will be used for testing and experimentation.

2.2 Test Tools

Testing from any perspective cannot be done without some type of tool to aid in the process. IST has created a set of test tools that perform, record and analyze tests. The test tools were originally created to run on PC machines and have since been ported to other platforms (see Section 5). These tools allow IST to perform the tests as described in the Test Procedures document and to analyze to results.

2.2.1 Data Logger / Playback – The first tool used for testing is the Data Logger/Playback system. The Data Logger records packets from the physical network and logs them into a file in either binary or text mode. The recorded file in text mode will take the binary values of the network protocols, including DIS, and translate them into the ASCII or decimal or hexadecimal values. Recording in text mode is very useful for debugging a SUT because the it displays packets in an understandable English format. A recorded binary file can be played back onto the network using the Playback tool. The Playback tool uses the information in the header of the recorded network packet to know when to put the packet back onto the network. Playback is used for generating network traffic and for automation of testing.

2.2.2 Computer Generated Forces (CGF) – The second tool is the Computer Generated Forces (CGF) simulator. This CGF has been modified for testing so that it can create many different entities, move them in unusual ways, beam them to locations, beam weapons to locations, move at incredible speeds, etc. The CGF can also accept script files which contain sets of commands used to drive the operation of the CGF. This flexibility is necessary so that the IST CGF can be used consistently and repetitively to force or provoke behavior from SUTs. The CGF is used to create DIS PDUs to preset to the SUT as well as to respond to those generated by the SUT. The planview display of the CGF is used for visual confirmation of SUT behavior.

2.2.3 Scanner Analyzing Tool

The last tool used for compliance testing is the Scanner, an off–line packet examination tool. This tool takes a binary file recorded by the Data Logger as input and allows the tester to "scan" back and forth through the packets in the file. The packets are displayed as vertical lines on a horizontal time line based on the time they were recorded and an arrow is used to point at a specific packet on this line. When the arrow lands on a line representing a packet, the contents of the packet are displayed in a text window on the computer screen. The tester can then page up and down through the contents of the packet, through the network headers, and through

the DIS data in the packet within this window. The data is displayed in ASCII, decimal and hexadecimal form so that values can be easily checked for correctness.

The Scanner also contains orientation windows which display an entity's roll, pitch, yaw, turret azimuth and gun elevation if the DIS PDU is an Entity State PDU. Future plans for the Scanner include automating as many tests as possible so that testing will be consistent and large numbers of systems can be tested in less time.

3. TEST METHODOLOGY

3.1 Test Documentation

Compliance testing for DIS requires coordination and instruction. In support of the I/ITSEC DIS demonstrations, IST created a set of test documents that contain instructions on how to be tested, how to test, and to how to specify system capabilities [4]. Any organization putting a system through compliance testing needs this information. Other organizations have used the IST documents as a starting point for testing their specific DIS applications. The documents are described in the following sections.

3.1.1 Testing Handbook – The Distributed Interactive Simulation Testing Handbook contains an overall view of the test tools, test plans, test methods and Test policies used for DIS compliance testing of any system. The Test Procedures document is usually included as an appendix to the Handbook.

3.1.2 Capabilities Statement – The beauty of the DIS PDU Standard is its flexibility. This flexibility, however, poses some difficulty in determining exactly what needs to be tested in a system for it to be certified to be compliant. The Capabilities Statement was created for the 1993 I/ITSEC DIS demonstration to document a system's stated DIS capabilities. Based on these, the system may be compliance tested for only those capabilities. This version of the Capabilities Statement asks questions specific to the IEEE 1278 version of the PDU Standard but contains many "Other" categories so that it can accommodate information specific to later versions of the PDU Standard. A system is required to have a Capabilities Statement on file before it will be tested.

3.1.3 Test Procedures – The January 31, 1994, Test Procedures are a full scope document for testing DIS 2.0.3 Draft Standard plus extra tests for design decisions that were made for the I/ITSEC 1993 demonstration, specifically the use of Bit 23 in the Appearance field of the Entity State PDU. This document contains Network Level Tests, PDU Tests, Terrain Orientation Comparison Tests, Appearance Tests, and Interactivity Tests. (For a full description of these test refer to [5]). For each of these categories, the document describes tests for ideal, adverse, and erroneous conditions.

3.1.4 Test Results – There is a methodology for using the Test Procedures to test a system and record the results. The Test Results Instructions is an instruction booklet which tells the tester which test to run next, how to run the test, how to data log the test, how to name the logged file, and the criteria for successful completion of the test. The Test Results Recording Sheet is used to record the actual results of the test. Ideally, the tester will use the Capabilities Statement to determine in advance which tests need to be completed for the system based on the capabilities of the system. If testing is interrupted or retests need to occur, this is also indicated on the Results Sheet.

3.1.5 Logged Testing Document – For those organizations electing to do compliance testing by submitting data logged files recorded at their site, the Logged Testing Instruction Booklet was created. The Logged Testing Instructions tell organizations how to perform the compliance tests, how to record the data, how to name the files, and which tests to perform, based on system capabilities. The organization will then submit the logged files to IST for analysis of results. The Logged Testing Instructions also inform the organization what test tools are needed to perform and record the tests (IST Data Logger, Computer Generated Forces software, and script and binary files).

3.1.6 Test Status Summary Sheet – After compliance testing is completed for a system, it is necessary to return the results of the tests to the organization as well as to have a summarized version on file for further reference. The Test Status Summary Sheet is a short version of the Test Results Sheet that contains only the indication "Passed or "Not Applicable" and some comments for each test. When this sheet is filled out, a copy of it is given to the organization so that they have a written record of what compliance tests their system has passed.

3.2 Performing Tests

IST currently has four methods of testing available. These methods were developed and have been used for I/ITSEC DIS demonstrations. The first method is for the SUT to be brought in-house to IST and connected to a test network. The second method is for the SUT to be connected to the test network at IST via a long haul connection over the

dial-up phone lines. The third method is to use the DIS test tools to run the tests at the SUT facility and log the results. The data logged files are then sent to IST for evaluation. The fourth method is testing on-site at a SUT's facility.

3.2.1 In-House Testing - This method of testing allows the quickest turn around time in testing and data analysis. IST's Testbed lab allows physical access to permit large equipment to be placed next to test systems. Immediate oral and visual feedback as well as operating with a variety of DIS devices are the advantage to in-house testing.

3.2.2 Long Haul Testing - As stated in Section 2.1.3, IST can accommodate testing via phone lines and the DSI. Testing using the BReeze 1000's and the phone lines has proved to be the most popular. Though the BReezes are connected to 1-800 numbers, a separate voice line is needed between IST and the organization in order to conduct the test. As the SUT is put through tests, the network traffic from the tests is logged at IST and then analyzed. Feedback from the analysis is immediate in most cases and usually within a couple hours in other cases.

The most important aspect of this method of testing is the scheduling. Not only is a test time scheduled, but use of the loaner BReezes is also scheduled. BReezes are usually shipped next day delivery, but if there are problems with an address or the organization which had the BReeze previously does not send it on time, it may not arrive at the current organization's facility in time to test. Another problem that limits this method is phone line/switch problems that do not allow network traffic out or into the organizations facility. Proper planning is the key to success.

3.2.3 Logged Testing - The Logged Testing method can be done by any organization which secures a copy of the IST DIS Test Tools. The Logged Testing Instruction Booklet (Section 3.1.5) guides the organization step-by-step in how to conduct the tests and data log the results. The resulting logged files are sent to IST for analysis to be done. Turn around time varies on the level of testing activity within the Testbed, but the organization can schedule to have results by a certain date.

3.2.4 On-Site Testing - This last method of testing involves the movement of test equipment from IST to the site of the SUT. If Long Haul testing cannot be accommodated for systems that cannot be moved, this is the next alternative. IST is working on a more portable test system that will include all the test tools.

3.3 Testing Process

The order of testing, as defined by the Test Procedures, relates to the way a packet is taken off the network and the information in the packet is analyzed in a hierarchical fashion. Network Level tests are performed first to guarantee that the SUT can establish a network connection and send and receive traffic. PDU Level tests come next to verify that the DIS packets are being sent and received with the correct data in the correct fields. Terrain orientation tests and Appearance tests follow for those systems that generate entities. These are used to make sure an entity has the correct orientation and appearance when put through set movements and activities. Last are Interactivity tests which are used to verify interoperability of simulated entities. Finally, once the SUT can handle ideal traffic, errors are introduced into the test data.

The testing process depends on the order of testing defined in the Test Procedures. First a capabilities statement is completed for the SUT. Next, a method of testing is chosen and testing is scheduled. Tests are then performed based on the capabilities for that system. If a SUT fails the tests, then testing must be rescheduled after the problem is fixed. When one level of testing is passed, the SUT proceeds to the next level. When the SUT passes all tests based on its stated capabilities, a Summary Sheet is given to the organization to verify this.

3.3.1 Capabilities Statement - The Capabilities Statement is a crucial addition to the testing process that was not used for the 14th I/ITSEC demonstration. When a Capabilities Statement is filled out for a SUT, it is used to help specify which tests the SUT should be subjected to. If a system claims to have certain capabilities then the system will be tested for those capabilities and no others. This way a system cannot claim to be DIS compliant in areas other than those it is tested for.

For systems that simulate entities, the capabilities of each entity must be listed in detail. For example, a CGF system must have a Capabilities Statement that describes in detail each different entity that the system can simulate.

3.3.2 Hooking up to Test - Once the Capabilities Statement has been completed and the tests selected, a SUT can be tested. The typical setup for compliance testing consists of 2 PCs isolated on a network with the SUT. One PC is used to run a version of the IST CGF software. The other PC is used to record the data from the network using the Data Logger and to analyze the

data for correct values using the Scanner. If the SUT is at IST or on-site it is connected via some physical medium directly to the two PCs. If the SUT is connected long haul, a "BReeze 1000" bridge is used on both sides of the phone connection to create a seamless testing network.

3.3.3 Testing and Retest – When the SUT is connected to the test network, testing begins. The order of testing ensures that initial tests must be passed before proceeding. For example, PDU tests cannot begin if the SUT cannot send and receive network traffic. As the SUT is subjected to each level of testing, the results of testing at that level are fed back as soon as possible so that problems may be resolved. If problems can be fixed in a small amount of time, then testing will continue during this test period. If problems are more severe, the organization may have to stop testing and schedule a time for retest when they feel the problem has been resolved.

3.3.4 "Certification" – After compliance testing is completed for a system, it is necessary to return the results of the tests to the organization as well as to have a summarized version on file for further reference. The Test Status Summary Sheet is a short version of the Test Results Sheet that contains only the indication "Passed" or "Not Applicable" and some comments for each test. When this sheet is filled out, a copy of it is given to the organization so that they have a written record of what compliance tests their system has passed.

4. SHORTCOMINGS IN THE TESTBED

The IST DIS Testbed and testing process originated when the first DIS demonstration at I/ITSEC was conceived in 1992. At that time, those organizations who were participating in the DIS Standards Workshops knew that shortcomings in the PDU standard would not allow full interoperability. To insure that systems would interoperate, the concept and process of testing and test procedures for the standard was developed. As the PDU standard has matured and been implemented by more organizations and as DIS demonstrations have continued, the testing process has expanded. Other organizations implemented their versions of test or development tools so that initial on-site verification could take place. Even with this growth of experience with DIS implementations and testing, shortcomings still exist in the standards and in testing.

4.1 Performance in Equipment

One of the first limitations for the IST DIS Testbed was the early decision to use PCs for the test tool platform. The IST DIS Test Tools, specifically the CGF and Data Logger/Playback, were developed as part of a project for low cost CGF prior to conception to use them for testing. The PC platform was a perfect match at the time. For testing, however, the need to have more than 12 entities and the limitations of buffering on the Ethernet card make the PCs inadequate for some of the tests. The same limitations on the network card affect the ability of the Data Logger to capture all DIS packets on the network. For example, high speed aircraft would put out too much traffic for the PC Data Logger to capture. The same test would sometimes have to be repeated three or four times before the data was finally captured.

Another limitation has been on the long-haul equipment. The public phone lines impose a bandwidth limit of approximately of 56 kilobits per second. If this limit is exceeded, the BReeze 1000s have to buffer packets. When the buffers overflow, packets are lost.

4.2 Lack of Tools

At the time of testing for the 1992 and 1993 I/ITSEC demonstrations, the only tools to be used for testing were those developed by IST. Since these tools were PC based, it was easy to find a system to run them on, but the performance of the tools (CGF and Data Logger) was still a factor limiting he type of testing that could be done. This year, the tools are being moved to a faster, more robust platform running (Motorola). This is discussed in detail in the next section.

4.3 Inconsistency In Testing

The last problem that the Testbed faced was inconsistency in testing. Testing conformance to the PDU standard would seem to be straightforward, but there were many areas where bad data was not detected or tests were not run consistently because the expected result was not well defined. The Scanner has the capability to view data inside each network packet. The testing was not automated, however, so that when the Scanner was used to look at data, it was up to the tester to verify values in the fields and to choose the packets to look at. Since only a sample of the data logged file was viewed, not all bad data was caught. Testing in this manner was very time consuming (man power intensive) and boredom on the testers part also contributed to missed results.

5. FUTURE ENHANCEMENTS

In light of the problems discussed in the previous paragraphs, the IST DIS Testbed has been revising the test tools and the testing process to better serve the DIS community.

5.1 More Platforms

The move to improve the Testbed was to take the existing tools and move them to a more powerful platform. The Motorola VME system was chosen because of its flexibility and its ability to provide a high-speed real-time environment for the test tools to run in. The VME system consists of at least two single board computers with RISC processors, one being a motherboard/host and the other being a target. The tools are developed and linked with a real-time operating system on the host and then downloaded to the target board where the executable runs with no interruptions. It has the capability of running extremely fast on the target board. The boards also have a very fast network interface which can accept packets off the network at almost network speeds (10 million bits per second for Ethernet). With this capability, the test tools, specifically the CGF and Data Logger, can be used to test the limits of DIS systems rather that just range of what is specified for an exercise.

In the process of moving the CGF and Data Logger to the Motorola platform, modifications were made so that these tools are almost System V UNIX compatible. With very little effort these tools can be made to be portable to any System V system and can be used for preliminary testing and self testing.

5.2 Automated Testing

The next area of future improvement was to modify the Scanner to be more of an automated test system. Since the Scanner is an analysis tool, it doesn't need to run in real time. The Scanner is being ported to the Motorola system but will run on the host board rather than the target board. The Scanner will be improved in several ways. It will have an X/Motif interface so that it can run on any X platform. Portions of the tests will be automated so that testing is not so manpower intensive. The testing process is being automated so that testing will be consistent for every system tested. All results will be generated by the computer (with hand written comments only where necessary) and the testing process will be menu driven. Default configurations will be set up prior to testing so that all tests for an exercise have the same specifications (ranges, enumerations, etc.). The Scanner will still allow the tester to manually "scan" through a logged file and visually look at the contents of a DIS PDU.

The future of the Scanner analysis tool is for it to be fully automated. An organization that wishes to be tested will acquire a copy of the Scanner, be directed through the tests, step-by-step, be given feedback when a problem arises, and be given the final results when the tests are over. Much of this depends on the stability of the DIS standards and if the draft documents are actually made into standards.

Another tool created to assist with testing is the PDU Editor. This tool will allow a user to create PDUs with any values or edit existing logged files. This tool will specifically be used to create adverse and erroneous data for the tests as well as logged files to play back for tests.

6. CONCLUSIONS

The IST DIS Testbed is a flexible environment that can test the conformance and interoperability of a DIS system. The Testbed has test documents and test tools which accommodate testing and has several methods that a system can be tested. IST's support of the I/ITSEC DIS demonstrations is being used as a means to validate and refine the test tools and test process. Most updates and enhancements to the tools described above are being implemented to support the 1994 I/ITSEC DIS demonstration.

The current testing has been for the DIS PDU Draft Standard 2.0 version 3 and the Communication Architecture for DIS Draft Standard. Until these or future versions of the set of DIS standards are stabilized, the testing for these standards is not stabilized. Testing conformance is straightforward if what is being tested is well defined. There are still many areas of the DIS standards that are not well defined. In these areas assumptions must be made and testing for these areas must be flexible enough to account for these exercise-by-exercise specifications. The IST DIS Testbed has created a test process that works today but must be expanded to meet the future needs of DIS when stability occurs for the various standards. In the meantime, the Testbed (its tools, equipment, procedures) must remain flexible to accommodate the dynamic nature of DIS.

7. REFERENCES

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