Analysis Of The Perceptronics' Architecture

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Analysis of the Perceptronics' Architecture
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# TABLE OF CONTENTS

1. Introduction ................................................. 1  
   1.1 List of Acronyms ........................................ 1  

2. Description of the Perceptronics System ................. 1  

3. Test Procedures ........................................... 3  
   3.1 General Observations .................................. 3  
   3.2 Compliance ............................................. 4  
   3.3 Entity State Coherency ................................. 4  
      3.3.1 Spatial Coherency ................................ 5  
      3.3.2 General Correlation ............................... 7  
   3.4 Other PDU Coherency .................................. 7  
   3.5 Temporal Coherency .................................... 8  

4. Analysis Methodology ....................................... 9  
   4.1 Description of Test Data ............................... 9  
   4.2 Description of Test Environment ...................... 9  
   4.3 Description of Comparison Tool ....................... 10  

5. Discussion of Analysis Results ........................... 11  
   5.1 Compliance Results .................................... 11  
   5.2 Spatial Coherency Results ............................. 11  
   5.3 Temporal Coherency Results ............................ 14  
      5.3.1 Effect of Window Size ............................ 14  
      5.3.2 Effect of Timeout Period ......................... 20  

6. Conclusions and Suggestions .............................. 20  
   6.1 Applicability to Analyze Other Traffic Reduction  
       Schemes ............................................. 21  
   6.2 Future Enhancements to the Comparison Tool .......... 21  
   6.3 Suggestions to Improve DISFE ......................... 22  

References .................................................. 24  

Appendix A - Configuration Parameters ..................... 25  

Appendix B - Analysis Results .............................. 32  

Appendix C - Description of Test Data Files ............... 45
1. Introduction

This report presents an analysis of the efficacy of the Perceptronics' (Dr. Danny Cohen's) approach to reducing network traffic over Wide Area Networks.

This report is a deliverable item under subtask 3.1.2.2, "Test Perceptronics' Architecture", of the U.S. Army Simulation, Training and Instrumentation Command (STRICOM) contract N61339-94-C-0024, entitled "TRIDIS: A Testbed for Research in Distributed Interactive Simulation".

1.1 List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDP</td>
<td>Format used to communicate information between DISFEs</td>
</tr>
<tr>
<td>DIS</td>
<td>Distributed Interactive Simulation</td>
</tr>
<tr>
<td>DISFE</td>
<td>Distributed Interactive Simulated Front-End</td>
</tr>
<tr>
<td>ESPDU</td>
<td>Entity State PDU</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>I/ITSEC</td>
<td>Interservice/Industry Training Systems and Education Conference</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>STRICOM</td>
<td>U.S. Army Simulation, Training and Instrumentation Command</td>
</tr>
<tr>
<td>PDU</td>
<td>Protocol Data Unit</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide Area Network</td>
</tr>
</tbody>
</table>

2. Description of the Perceptronics System

The design of the DISCOM is described in [Kirsh94]. The objective of the DISCOM is to reduce the bandwidth needed for Distributed Interactive Simulation (DIS) over Wide Area Networks (WANs). DISCOM utilizes DIS Front-Ends (DISFEs), which are programs that provide the interface between the simulators on a Local Area Network (LAN) and a WAN. The main functions performed by the DISFEs are compressing DIS Protocol Data Units (PDUs) from a LAN, transmitting these over the WAN, and decompressing them on the remote LANs.

The simulation applications are unaware of the presence (or absence) of a DISFE. In addition to this transparency, the main objectives of the DISCOM are to:

- Obtain a factor of reduction on the DIS PDU traffic.
- Maintain DIS compliance of the PDU traffic (i.e. maintain the integrity of the traffic).
- Maintain a consistent state of the simulation (between all the sites)

For the purpose of the analysis which is described in this document, no prior knowledge of the DISFE and the DISCOM is necessary. A summary of the system follows. A previously logged DIS PDU stream (henceforth referred to as the local PDU stream) is compressed by a
DISFE into the DDP format (described in [Kirsh94], but irrelevant to this analysis) and received by another DISFE, which in turn decompresses this DDP stream into another DIS PDU stream (henceforth referred to as the remote PDU stream).

The local and remote PDU streams are not expected to be bit-by-bit identical. The four functions performed by the DISFE which may cause discrepancies and which are essential to our analysis are:

- Reduction of redundancy.
- Reduction of accuracy.
- Introduction of transients.
- Removal of network errors.

Reduction of redundancy. One method employed by the DISCOM to reduce the WAN traffic is to reduce the amount of redundancy. One observation is that a significant portion of DIS PDU traffic consists of the Entity State PDU (ESPDU). The communication architecture for DIS states that each entity must rebroadcast its state at a constant rate (also known as the heartbeat rate), irrespective of change in location or appearance. In actuality, not all entities adhere to this predetermined constant rate, and some may rebroadcast at their own rate (often higher). The number of redundant rebroadcasts is reduced by the DISFE (the details of this operation is outside of the scope of this report). The key observation is that entities which rebroadcast at a much higher rate (contributing to a large number of redundant ESPDUs in the local PDU stream) are rebroadcasting at a lower rate in the remote PDU stream.

Reduction of accuracy. Another means by which the DISCOM reduces the WAN traffic is by transmitting only the information in an ESPDU which has changed instead of the entire packet. The accuracy reduction occurs when these changes are sent in a more compact format (e.g. using 8 bits of accuracy rather than 32 bits). Thus, in these changed fields, the local and remote PDU streams may differ in the accuracy of the information. The loss of accuracy only occurs in ESPDUs, and not in the other kinds of DIS PDUs. Upon encountering a non-ESPDU, the entire PDU is transmitted, bit-by-bit.

Introduction of transients. The remote DISFE has the function of rebroadcasting keep-alive messages from entities of other sites. It continues doing this for a predetermined fixed period, even if it does not receive new state information from those entities (either rebroadcasts or changed broadcasts). If, after having kept these entities alive in an artificial fashion for that duration of time, the remote DISFE still has not received any new ESPDUs from these entities, it stops the process of transmitting ESPDUs (also called transients, because they are identical to the last received ESPDUs).

Removal of network errors. Because the analysis is performed off-line, network errors which have been introduced while logging the local PDU stream are removed by the DISFE. One such type of error is
that of identical DIS PDUs (even identical in the timestamps). These duplicate PDUs are then removed, leaving only unique PDUs in the local PDU stream. These errors are expected to occur very rarely.

DISCOM attempts to achieve its first objective by compressing the local PDU streams into the DDP format. The efficacy of this is not within the scope of this report. Instead, the latter two objectives (compliance and consistency) can be analyzed based on the local and remote PDU streams.

3. Test Procedures

This section describes the test procedures devised to test the Perceptronics' Architecture on the two of the three objectives stated in Section 2 (compliance and consistency). Note that the analysis on the compression ratio obtained by the Perceptronics' Architecture is not part of this report.

To test the compliance of the architecture, the values and ranges tested against can be found in the DIS PDU standard for the version being implemented (in this case, version 2.0.3).

To test the consistency of the simulation states, tolerance values were provided and supplied by Perceptronics. In particular, these values pertain to the spatial and temporal coherency tests and are handled as a configuration file (included in Appendix A). These tests will be discussed in detail in the following sections.

3.1 General Observations

From the description in Section 2, we can view both PDU streams to consist of three different types of PDUs (here a PDU is understood to be the content of the DIS Simulation PDU, excluding the DIS PDU header information which contains, among other things, the timestamp).

- Type #1 - ESPDUs reflecting a change (in at least one field) from the previous occurrence from that same entity.
- Type #2 - ESPDUs reflecting no change (i.e. transient) from the previous occurrence from that same entity.
- Type #3 - Non-ESPDUs (e.g. Fire, Detonation, Transmitter, Emission, etc).

In order to test the Perceptronics' Architecture, it is essential to first define the relationships which must exist between these three types of elements found in the local and remote PDU streams in order to satisfy criteria proving compliance and consistency.

Relationship #1. ESPDUs reflecting a change in the local PDU stream must occur in the remote PDU stream, with the same timestamp. There may be reduction in accuracy in some fields, requiring coherency tests.
Relationship #2. Transient ESPDUs in the local PDU stream may not occur in the remote PDU stream, due to the reduction of redundancy. Their absence should not affect any compliance or coherency tests.

Relationship #3. Transient ESPDUs in the remote PDU stream may not occur in the local PDU stream, due to the artificial creation of these ESPDUs by the remote DISFE. These transients should be identical to some previously transmitted ESPDUs (except for the timestamp). Any differences between these transients and the previously transmitted ESPDUs may be cause for non-compliance (unless the original ones were themselves non-compliant).

Relationship #4. Non-ESPDUs in the local PDU stream must occur in the remote PDU stream and must occur in an identical number, and representation, and order. This is because no operation is performed on these PDUs by the DISFEs.

3.2 Compliance

The objective of this test is to determine whether the DISFEs introduce any non-compliant PDUs into the remote PDU stream. Hence the remote PDU stream should not have any PDUs which do not comply with the DIS PDU standard (in this case version 2.0.3), unless they were already present in the local PDU stream.

Tests for compliance in the remote PDU stream depend on what type of PDU is encountered:

- **Type 1** - the compliance of this type of PDU is contingent upon the compliance of the local PDU corresponding to this PDU (which should be present based on Relationship #1). Any differences between the local and remote Type 1 ESPDU which are not due to loss of accuracy, must be checked for possible introduction of non-compliance.

- **Type 2** - the compliance of this type of PDU is contingent upon the compliance of the ESPDU it is a transient of. Any differences between rebroadcasts of identical ESPDUs must be checked for possible introduction of non-compliance.

- **Type 3** - the compliance of non-ESPDUs in the remote PDU stream is contingent upon the compliance of the local non-ESPDUs (see Relationship #4). Any difference between the local and remote non-ESPDUs must be checked for possible introduction of non-compliance.

3.3 Entity State Coherency

The bulk of the traffic consists of ESPDUs. At the time of analysis, the ESPDUs produced by the DISFEs underwent reduction of accuracy, and redundancy. The accuracy reduction analysis was performed on a fixed number of fields of the ESPDU and are detailed in section 3.3.1. The other fields on which no accuracy reduction was
performed, should remain identical. These fields are described in section 3.3.2.

This section describes the conditions which must be met before a DISFE performs accuracy reduction on ESPDUs. The reduction rules and ranges are also described, and for specific values the reader is referred to Appendix A where the configuration file containing these values is listed. Coherency tests evaluate the degree to which a local PDU stream agrees with its corresponding remote PDU stream after undergoing processing by DISFEs. These test against the same parameter values used to reduce the accuracy. Two categories of coherency tests have been defined:

1. **Spatial coherency.** Spatial coherency refers to the degree to which a local and remote entity correlate in space. Features which characterize an entity in space are represented by fields such as (a) orientation, (b) velocity, (c) location, (d) acceleration, and (e) angular velocity. An entity has representations for each of these in its ESPDUs.

2. **Temporal coherency.** Temporal coherency refers to the degree to which a local and remote simulation correlate in time. The state of a simulation at any time consists of the number of active entities (and their states) and the events which have occurred up to that time.

The conditions which a local and a remote ESPDU must meet in order to have the coherency tests performed on them are:

- Both local and remote ESPDUs must agree on the entity identifier and exercise fields, i.e. both ESPDUs were issued by the same entity in the exercise.
- One of the two conditions below MUST hold:
  1. Both ESPDUs have the same timestamp, i.e. a local non transient ESPDU, must have a mirror ESPDU in the remote file (it may or may not be a remote non transient).
  OR
  2. Both ESPDUs are transients (timestamps may differ).

### 3.3.1 Spatial Coherency

The objective of spatial coherency is to determine whether the local and remote states spatially correlate within a certain threshold of each other. There are 5 categories of spatial coherency:

- Orientation
- Velocity
- Location
- Acceleration
- Angular Velocity

This type of coherency must be performed on Type #1 PDUs. Assume `local_pdu` and `remote_pdu` refer to the ESPDUs in the local and remote
PDU streams respectively. For specific names and values used for this analysis refer to Appendix A.

**Orientation.** The orientation vector elements (psi, theta, phi) are handled as scalars (i.e. psi, theta and phi are treated as individual elements). These values in the remote_pdu have to be within a certain threshold precision value (set by the DISFE) of the corresponding elements in the local_pdu. The precision is defined per vector element, but is the same for all types of entities.

The test to be performed for each angle (psi, theta, phi) is:

\[
\text{ABS}(\text{local_pdu(angle)} - \text{remote_pdu(angle)}) \leq \text{angle\_precision}
\]

where

1) angle is either psi, theta or phi.
2) angle\_precision is the threshold precision value (angle specific) in degrees defined in Appendix A.
3) ABS is the absolute value.

**Velocity, Acceleration and Angular Velocity.** The velocity, acceleration and angular velocity are represented as vectors, each with three elements (in the x, y, and z directions). Spatial coherency is performed on the entire vector by comparing the norms (magnitudes) of the local and remote vectors.

The degree of compression (the act of reducing the accuracy by the DISFE) of the velocity, acceleration, or angular velocity depends on the magnitude of their norms, and the type of the entity. The DISFE distinguishes the following types of entities:

1. Land
2. Air
3. Surface
4. Subsurface
5. Space
6. Lifeform
7. Munition

For each type of entity, three entries are defined and arranged in columns (see Appendix A). These are to be interpreted as follows:

The first column lists the minimum value for that feature. For vectors which have a norm less than the minimum value, the precision is defined to be that value itself. The second column lists the maximum value. For features whose vectors exceed the maximum value, the precision is zero (meaning that the value will not be compressed but sent as is). The third column gives the precision of the vectors whose norms fall in between the minimum and the maximum range. The third column is unit-less, and is to be interpreted as a percentage.
For example, Appendix A gives the following entry for air entities' velocities:

<table>
<thead>
<tr>
<th>Entity-Type</th>
<th>VelMin</th>
<th>VelMax</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>velAirType</td>
<td>0.046</td>
<td>750.00</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Thus, for air vehicles which have a velocity of 0.046 m/sec or less, the compression will not exceed the value of the velocity itself (so the difference in the local and remote ESPDUs velocities will not exceed the local ESPDU velocity). For air vehicles that have velocities which exceed 750.00 m/sec, the local and remote velocities must be identical (no compression, no reduction of accuracy). For velocities which are greater than 0.046 m/sec but less than 750.00 m/sec, the remote velocity will be within 0.78% of the local velocity.

**Location.** The location is represented as a vector, with x, y, and z components. Like the velocity, acceleration and angular velocity, spatial coherency is performed on the entire vector, by comparing the norms (magnitudes) of the local and remote vectors. However, the degree of compression depends only on the type of the entity. In Appendix A, the compression accuracy is defined per entity type as a single column following the entity type, and is to be interpreted as the percentage.

For example, "locMunitonsType" is listed as 0.0254 meters (1 inch). What this value implies is that the DISFE will compress the local location, and represent the changes with no less accuracy than 0.0254 meters. In other words, the difference between the remote and the local location vectors' norms will not exceed 0.0254 meters.

### 3.3.2 General Correlation

The remainder of the ESPDUs must correlate identically. This includes the fields such as:

- DIS PDU header (version, exercise, kind and length)
- Force ID
- Number of articulation parameters
- Entity type
- Entity guise
- Dead reckoning algorithm
- Entity marking
- Entity capabilities
- Every articulated parameter record

### 3.4 Other PDU Coherency

PDUs which are not ESPDUs must agree in terms of number, contents, location and order. These conditions make it very desirable to have the local and remote streams "synchronize" at these PDUs. However, this is only the ideal situation. In the following we define a
number of inconsistencies that can occur (and which will lead to an
incoherent state of the simulation):

- Non-ESPDUs do not correlate in contents. Both the local and
remote non-ESPDU are of the same kind (e.g. Fire), but part of the
contents got corrupted. This may have happened on the wire, and
not necessarily as part of the DISFE.

- Non-ESPDUs are omitted from either stream. These are the non-
ESPDUs in the local PDU stream which do not get transmitted over
to the remote PDU stream, or similarly, these can also be non-
ESPDUs which appear "mysteriously" in the remote PDU stream, but
have not been issued in the local PDU stream.

- Non-ESPDUs are out of order. These are non-ESPDUs that have one
order of arrival in the local PDU stream, but another in the
remote PDU stream. These are dangerous to the precise state
coherence of the simulation because events are out of order, and
may affect the state of the rest of the simulation.

3.5 Temporal Coherency

The objective of the temporal coherency test is to determine whether
the state of the simulation was maintained over the course of time.
The state of the simulation at time \( t \) is defined by the number and
the states of all the active entities at time \( t \) and all the events
leading up to time \( t \). An event, in this document, is defined to be
information which does not contain state information, but rather
represents an action in the simulation. We will assume non-ESPDUs
represent events.

The state of an entity can be given by describing the entity
(uniquely defined by the exercise and entity identifier) in terms of
its location, velocity, orientation, acceleration, and angular
velocity.

In the ideal case, in order to perform any type of temporal
coherency, the concept of a clock must be defined. We define a clock
to be a counter which increases in a monotonic fashion (with an
occasional rollover). There are several types of clocks that can be
defined which would aid the temporal coherence analysis
considerably:

- Global clock per exercise. This implies that the exercise is
synchronized at the global level. The state represented at time
\( \text{global	extunderscore} t \) in the local PDU stream (consisting of a set of entities
in their respective states) must be consistent with the state (at
that same global time) in the remote PDU stream.

- Local clock per site. In the context of the DISCOM, a local and
remote global clock may be maintained, but not necessarily
synchronized. To test for temporal coherency, the state
represented at time \( \text{local	extunderscore} t \) in the local PDU stream must correlate
with the state at some time \( \text{remote	extunderscore} t \) in the remote PDU stream. The
skew between local_t and remote_t cannot be assumed to remain constant.

- Local clock per entity. Same as above, but the temporal coherency must be performed on a per entity basis.

4. Analysis Methodology

To test the Perceptronics' Architecture based on the two sets of test procedures described in Section 3, IST designed a tool to compare two PDU flows (the local and remote PDU streams), and which produces a correlation report based on the PDUs encountered in these files.

4.1 Description of Test Data

Data traces for the Perceptronics' Architecture test purposes were obtained in pairs. The format these were delivered in is described in [Kirsh94]. The local PDU streams were directly played back to a LAN and recorded in this format.

Remote files were obtained using the following method:

- Logged files (local PDU streams) containing DIS PDUs from varying sources (such as recordings done at the 1993 Interservice/Industry Training Systems and Education Conference (I/ITSEC) were played back onto a LAN and processed by a DISFE.
- The DISFE then converted the data into the DDP format and transmitted this over another LAN (simulating the WAN) to another DISFE.
- The latter DISFE then interpreted the DDP stream and issued an equivalent DIS PDU stream to the LAN it was connected to.
- A recording mechanism (logger) on this last LAN then obtained all the DIS PDUs and collected these as a data trace (remote PDU stream).

4.2 Description of Test Environment

There were 12 sets of data traces to be analyzed which were placed on an anonymous FTP node at Perceptronics. An executable program "DISPlayBack" was also placed on this node. After obtaining all data files and the DISPlayBack executable on a Silicon Graphics platform, the first step was to convert all the data files into an agreed upon format (that of the logger). By isolating the Silicon Graphics with a single IST PC logger, we proceeded to play the data files back onto the network using the DISPlayBack routine on a Silicon Graphics platform and then log each data file with the IST PC datalogger. The isolated environment was chosen for several purposes:

- To avoid logging other miscellaneous traffic, making the analysis of sets of files more difficult.
- To avoid dropping any meaningful PDUs from the playback.
While capturing data on the PC we verified additionally that the number of packets logged by the PC logger was identical to the number played back by the DisPlayBack routine. In all cases they were identical.

The final step was to transfer the converted data files from the PC to a UNIX file system which could be accessed by the tool which we developed on a Silicon Graphics platform. A description of each of the files is provided in Appendix C (the files with the ".dis" extension are the local PDU streams and those with the ".proc" extension are the remote PDU streams corresponding to the local streams).

4.3 Description of Comparison Tool

The comparison tool (for which the source code is provided in Appendix D) takes as its input a local and a remote PDU stream logged in the IST logger format. The core of the tool extracts one PDU at a time per stream, and attempts to achieve a corresponding match (or not). After comparison, one or both of the file pointers will be incremented to the next PDU in the stream. The comparison ends when both files are fully exhausted and all PDUs are accounted for.

To assist in the coherency analysis, local and remote entity databases are maintained. New entities are added as their ESPDUs are encountered in the PDU streams and state information for existing entities is updated when additional ESPDUs from these entities are processed. Entities which have not transmitted ESPDUs after a certain timeout interval must be "removed" from the entity database. In actuality they are not removed, but are just considered inactive. Thus the contents of the local and remote entity databases represent the state of the simulation on which the spatial and temporal coherency analyses can be performed.

Some phenomena observed in the data traces required a slight change in design:

- The absence of a monotonically increasing clock per entity (in the data traces) threatened to make the temporal coherency analysis an impossible task. The absence of a global clock (per exercise, per site) in the data traces (primarily collected at the 1993 I/ITSEC) made the removal of entities based on timeouts difficult. Not having either of the two elements to rely on, the comparison tool used the logger timestamp as a surrogate global clock instead. It was reasonable to assume that the logger had an accurate, and monotonically increasing clock.

- All entities remained in the entity database until the end of the exercise (in this case, until the end of the logged file). The reasons for this approach were twofold:
(1) To keep statistics on the number of transients and non-transients consistent. If we were to remove entities after their time-out period (which can be changed for each run of the analysis) the first ESPDU of a previously timed out entity would be considered a non-transient, although in the logged file, it is actually an identical copy of an ESPDU which was issued before the time-out window.

(2) To ease the keeping of global statistics (such as total number of entities which were active in the entire exercise/logged file).

By implementing a non-removal entity database, we have not limited the capability of the analysis. Instead, during the traversal of the entity database, the last ESPDU update of the entities is checked and it can easily be determined which entities are "active" and "current".

- Non-ESPDUs (e.g. Fire and Detonation PDUs) are considered events in the simulation.

5. Discussion of Analysis Results

This section discusses the results obtained from the analysis performed on the 12 sets of data traces provided by Perceptronics. The general statistics obtained for all these files can be found in Appendix B.

5.1 Compliance Results

The compliance of the test data was obtained using another analysis tool developed at IST, namely the "Scanner". The Scanner is capable of doing full DIS PDU Version 2.0.3 validation (checks for correct ranges) and identifies items that have violated the standard.

The data files used for the analysis of the DISFE implemented the 2.0.3 version of the DIS Standard, so the Scanner was used to perform the compliance analysis. The objective in the compliance testing for the DISFE was to determine whether any anomalies (non-compliance) were introduced in any of the remote files, which were not already present in the local ones. The results of the using the Scanner on the 12 sets of files indicated that there were no such discrepancies introduced into the remote files.

5.2 Spatial Coherency Results

There were 3 sets of files that had no correlation problems. These were also some of the smallest files. These files were:

- ENC-9-07.dis and ENC-9-07.proc
- ENC-9-08.dis and ENC-9-08.proc
- ENC-9-09.dis and ENC-9-09.proc
Of the remaining 9 sets of files, 4 of them had 3 or fewer correlation problems. These were either uncorrelated local or remote non-transients. These files were:

- ENC-9-04.dis and ENC-9-04.proc (1 error)
- ENC-9-05.dis and ENC-9-05.proc (1 error)
- ENC-9-06.dis and ENC-9-06.proc (1 error)
- ENC-9-10.dis and ENC-9-10.proc (3 errors)

Each of the other files merits description on an individual basis. The errors are detailed in the reports accompanying each file set comparison.

IDAModsaf1.0.dis and IDAModsaf1.0.proc had 8 correlation errors for land vehicles. The remote velocities were all set to 0, while the local velocities were not below the minimum velocity defined for entities of the category land (which according to the configuration file was set to: 0.003 meters/second).

ENC-7-02.dis and ENC-7-02.proc had a mixture of miscorrelations in ESPDUs as well as non-ESPDUs (see Appendix B). One non-compliant ESPDU (having a large value in the location fields, and in the orientation value for psi) in the local stream miscorrelated with an ESPDU in the remote stream. Also, two Transmitter PDUs "issued in a certain order in the local PDU stream" arrived in the opposite order in the remote PDU stream.

ENC-9-01.dis and ENC-9-01.proc encountered 55 uncorrelated velocities and 3 uncorrelated accelerations. Only one non-transient was not matched. Interestingly, all the problems occurred on land entities which had velocities greater than the specified maximum velocity of 50 meters/second. No compression should have taken place, so the remote values should have been identical to the local values.

ENC-9-11.dis and ENC-9-11.proc had the greatest number of non-ESPDUs which were out of order. There were instances in which the local PDU stream would have a sequence of PDU_a, PDU_b, PDU_c. In the remote PDU stream the sequence was found to be PDU_b, PDU_c, PDU_a.

One detrimental side effect of miscorrelation of non-ESPDUs (aside from affecting the state of the remote simulation) is that local non-transient ESPDUs were unable to be matched at the right time because a remote non-ESPDU was out of order.

The following example illustrates the above mentioned problem. Assume that the local PDU stream has a sequence of ESPDU_a, non-ESPDU_a, ESPDU_b, non-ESPDU_b and the remote PDU stream has a sequence of non-ESPDU_b, non-ESPDU_a, ESPDU_a, ESPDU_b.

Suppose that FPl (local file pointer) and FPr (remote file pointer) are pointing to ESPDU_a and non-ESPDU_a, respectively. At that time, ESPDU_a is said to have no match found in the remote PDU stream.
(though it is there, but later). The remote file pointer does not get incremented, since it is awaiting an identical match. Then FP1 points to non-ESPDUs, and finds that there is no match between non-ESPDUs (locally) and non-ESPDUs (remotely). An error message indicating a failed match is then issued. Both file pointers move forward, and during the next match, there is no remote transient for ESPDUs, an error message is issued, and the local file pointer is incremented. The next match attempted is between non-ESPDUs and non-ESPDUs, which fails for the same reason the earlier set of non-ESPDUs did not match. This phenomenon manifests itself when non-ESPDUs are issued out of order, and is aggravated if there are several ESPDUs interleaved between non-ESPDUs. Using non-ESPDUs to synchronize PDU streams can be done in a very effective and easy manner, provided they maintain their order and coherency. If this is not guaranteed, the analysis for coherency in both space and time obeys no logic and proceeds in an ad hoc fashion.

ENC-9-15.dis and ENC-9-15.proc had the greatest number of spatial mismatches. There were 173 uncorrelated velocities, 115 uncorrelated accelerations, 364 uncorrelated angular velocities, and 1 mismatched entity marking. Only 2 non-transients were not matched in the files. There were some interesting findings from this analysis:

- Only one set of ESPDUs had more than 1 error. In fact, ESPDU number 31550 in the local PDU stream (ENC-9-15.dis) and number 20815 in the remote PDU stream (ENC-9-15.proc) had three mismatches, in the acceleration, angular velocity and entity marking. The error report shows that the local ESPDU was a corrupted PDU, with accelerations and angular velocities that were not acceptable values. Apparently, the DISFE had introduced "reasonable" values in these fields.

- The above yields a percentage of \( \frac{651}{65308} \times 100\% \) (0.997\%) ESPDUs in the local PDU stream which did not correlate with the remote PDU stream.

- The entity types on which the mismatches were manifested were of type "air" and "munitions". The velocity of munitions often exceeded the maximum velocity allowed according to the configuration parameters (at which time no compression is to be performed, but DISFE compressed it anyhow). This was also true for the accelerations and angular velocities of munitions. For air entities which failed to correlate the values were usually slightly more than the minimum according to the configuration parameters, at which time compression should take place by the DISFE. Instead, a value of zero was sent.
5.3 Temporal Coherency Results

The results of temporal coherency are described in terms of the effects of the window size and the timeout period. These are defined as follows:

- **Window Size:** Number of seconds during which the simulation is allowed to continue before displaying the state of the local and remote streams. This affects the number of events (non-ESPDUs) collected.

- **Timeout Period:** Maximum lifetime (in seconds) of an entity after the issuance of an ESPDU. In order to stay active, the entity needs to update at a rate higher than the timeout period. If no ESPDU has been received after the timeout period, the entity has effectively expired and need no longer be modeled.

5.3.1 Effect of Window Size

The size of the window affects the number of times the state of the simulation is checked. For the set of files IDAModsaf1.0.dis and IDAModsaf1.0.proc the size of the window did not affect the number of entities that were active. The first iterations of window sizes 25 and 10 are shown next. The main difference between these two is in the number of events each of them has accumulated. Events are listed in a Last-In-First-Out order (thus the most recent event is shown first, and the oldest event last). Note that the event time in the event list is not monotonically decreasing (this event time is the timestamp found in the header of the protocol data unit rather than the timestamp provided by the logger). In both cases the timeout period was held at 12 seconds.

Next, the state output of the first iteration with window size 25 is listed. At each iteration, the window size and iteration number is printed. First, the local simulation time and entities (including their state) are dumped. Entities are not sorted in any way (not even by exercise number), so are identified uniquely by their exercise identifier, site, application, and entity identifier. Each entity is characterized by its location, velocity and orientation. After the local entity list is fully exhausted, the remote entity list is dumped. Generally, the number and order of entities must agree (if fully synchronized). To examine the state of coherency, similar entities' characteristics must be matched.

For example, local entity 1 (EX 3, ID 16/100/1007) must be correlated with remote entity 1 (EX 3, ID 16/100/1007). The location, velocity and orientation of this entity must be correlated according to the same set of rules with which the DISFE spatial coherency was tested.

After the remote entities are dumped, the local events are listed sequentially, in order of decreasing timestamp. This is then
followed by the remote events. The events are numbered, and characterized by the type of event (given in non-ESPDU kind) and its event time (found in the header of the non-ESPDU). There is no event kind of one (1), because ESPDU have kind 1 according to the DIS PDU Standard 2.0.3. For illustrative purposes, the same set of files has been subjected to a window size of 10 and the results are shown as well.

**IDAModsafl.O.dis and IDAModsafl.O.proc**

**STATE OF SIMULATION - WINDOW SIZE 25 SECONDS - ITERATION 1**

**LOCAL time is 25**

**Entity Number 1**  EX 3  ID: 16/100/1007

- **Location**: X = -2677424.829595 Y = -4423966.377465 Z = 3721788.124693
- **Velocity**: X = 1.857859 Y = -1.195148 Z = -0.239130
- **Orientation**: Psi = -0.571646 Theta = 0.107829 Phi = -2.338750

**Entity Number 2**  EX 3  ID: 16/100/1004

- **Location**: X = -2677307.130368 Y = -4424255.472965 Z = 3721554.111653
- **Velocity**: X = 2.066111 Y = -0.772777 Z = -0.258632
- **Orientation**: Psi = -0.357916 Theta = 0.116713 Phi = -2.305823

**Remote time is 24**

**Entity Number 1**  EX 3  ID: 16/100/1007

- **Location**: X = -2677424.836721 Y = -4423878.698665 Z = 3721847.850869
- **Velocity**: X = 1.949804 Y = -0.963317 Z = -0.376661
- **Orientation**: Psi = -0.458883 Theta = 0.171493 Phi = -2.292081

**Total Number of Entities** 10
Entity Number 3 EX 3 ID: 16/100/1006
Location : X = -2677400.290804 Y = -4424152.973978 Z = 3721627.118559
Velocity : X = -5.920411 Y = -2.441406 Z = 0.537109
Orientation: Psi = -0.392699 Theta = -0.085903 Phi = -2.319379

Entity Number 4 EX 3 ID: 16/100/1005
Location : X = -2677350.460344 Y = -4425169.997175 Z = 3721553.912773
Velocity : X = 1.885987 Y = -0.683594 Z = -0.195313
Orientation: Psi = -0.349748 Theta = 0.095107 Phi = -2.307107

Entity Number 5 EX 3 ID: 16/100/1002
Location : X = -2675661.848760 Y = -4425169.997175 Z = 3721553.912773
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 1.003223 Theta = -0.647340 Phi = -2.985127

Entity Number 6 EX 3 ID: 16/100/1001
Location : X = -2675457.824766 Y = -4425267.390822 Z = 3721532.573162
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.997088 Theta = -0.862097 Phi = -3.086369

Entity Number 7 EX 3 ID: 16/100/1000
Location : X = -2675496.692637 Y = -4425189.465770 Z = 3721593.186138
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.994020 Theta = -0.901981 Phi = -3.095573

Entity Number 8 EX 3 ID: 16/100/1003
Location : X = -2675563.234693 Y = -4425154.576962 Z = 3721598.246886
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.997088 Theta = -0.806874 Phi = -3.000466

Entity Number 9 EX 3 ID: 16/100/1008
Location : X = -2677474.236727 Y = -4423878.692428 Z = 3721847.841797
Velocity : X = 1.947022 Y = -0.961304 Z = -0.372314
Orientation: Psi = -0.460194 Theta = 0.168738 Phi = -2.294835

Entity Number 10 EX 3 ID: 16/100/1009
Location : X = -2677519.151090 Y = -4423856.262358 Z = 3721859.289510
Velocity : X = 2.270508 Y = -0.936890 Z = -0.421143
Orientation: Psi = -0.392699 Theta = 0.168738 Phi = -2.494253

Total Number of Entities 10

LOCAL EVENTS
Event No. 1 --- PDU Kind 25 Event Time 142.75 Seconds
Event No. 2 --- PDU Kind 25 Event Time 141.74 Seconds
Event No. 3 --- PDU Kind 25 Event Time 141.08 Seconds
Event No. 4 --- PDU Kind 25 Event Time 140.36 Seconds
Event No. 5 --- PDU Kind 25 Event Time 140.31 Seconds
Event No. 6 --- PDU Kind 25 Event Time 140.30 Seconds
Event No. 7 --- PDU Kind 25 Event Time 140.27 Seconds
Event No. 8 --- PDU Kind 25 Event Time 140.24 Seconds
Event No. 9 --- PDU Kind 25 Event Time 140.24 Seconds
Event No. 10 --- PDU Kind 25 Event Time 138.64 Seconds
Event No. 11 --- PDU Kind 25 Event Time 137.69 Seconds
Event No. 12 --- PDU Kind 25 Event Time 136.68 Seconds
Event No. 13 --- PDU Kind 25 Event Time 136.02 Seconds
Event No. 14 --- PDU Kind 25 Event Time 135.30 Seconds
Event No. 15 --- PDU Kind 25 Event Time 135.25 Seconds
Event No. 16 --- PDU Kind 25 Event Time 135.24 Seconds
Event No. 17 --- PDU Kind 25 Event Time 135.22 Seconds
Event No. 18 --- PDU Kind 25 Event Time 135.18 Seconds
Event No. 19 --- PDU Kind 25 Event Time 135.18 Seconds
Event No. 20 --- PDU Kind 25 Event Time 133.62 Seconds
Event No. 21 --- PDU Kind 25 Event Time 132.65 Seconds
Event No. 22 --- PDU Kind 25 Event Time 131.66 Seconds
Event No. 23 --- PDU Kind 25 Event Time 131.01 Seconds
Event No. 24 --- PDU Kind 25 Event Time 130.25 Seconds
Event No. 25 --- PDU Kind 25 Event Time 130.24 Seconds
Event No. 26 --- PDU Kind 25 Event Time 130.23 Seconds
Event No. 27 --- PDU Kind 25 Event Time 130.18 Seconds
Event No. 28 --- PDU Kind 25 Event Time 130.17 Seconds
Event No. 29 --- PDU Kind 25 Event Time 130.17 Seconds
Event No. 30 --- PDU Kind 25 Event Time 128.59 Seconds
Event No. 31 --- PDU Kind 25 Event Time 127.61 Seconds
Event No. 32 --- PDU Kind 25 Event Time 126.57 Seconds
Event No. 33 --- PDU Kind 25 Event Time 126.00 Seconds
Event No. 34 --- PDU Kind 25 Event Time 125.21 Seconds
Event No. 35 --- PDU Kind 25 Event Time 125.18 Seconds
Event No. 36 --- PDU Kind 25 Event Time 125.17 Seconds
Event No. 37 --- PDU Kind 25 Event Time 125.17 Seconds
Event No. 38 --- PDU Kind 25 Event Time 125.16 Seconds
Event No. 39 --- PDU Kind 25 Event Time 125.15 Seconds
Event No. 40 --- PDU Kind 25 Event Time 123.54 Seconds
Event No. 41 --- PDU Kind 25 Event Time 122.58 Seconds
Event No. 42 --- PDU Kind 25 Event Time 121.57 Seconds
Event No. 43 --- PDU Kind 25 Event Time 120.99 Seconds

REMOTE EVENTS
Event No. 1 --- PDU Kind 25 Event Time 142.75 Seconds
Event No. 2 --- PDU Kind 25 Event Time 141.74 Seconds
Event No. 3 --- PDU Kind 25 Event Time 141.08 Seconds
Event No. 4 --- PDU Kind 25 Event Time 140.36 Seconds
Event No. 5 --- PDU Kind 25 Event Time 140.31 Seconds
Event No. 6 --- PDU Kind 25 Event Time 140.30 Seconds
Event No. 7 --- PDU Kind 25 Event Time 140.27 Seconds
Event No. 8 --- PDU Kind 25 Event Time 140.24 Seconds
Event No. 9 --- PDU Kind 25 Event Time 140.24 Seconds
Event No. 10 --- PDU Kind 25 Event Time 138.64 Seconds
Event No. 11 --- PDU Kind 25 Event Time 137.69 Seconds
Event No. 12 --- PDU Kind 25 Event Time 136.68 Seconds
Event No. 13 --- PDU Kind 25 Event Time 136.02 Seconds
Event No. 14 --- PDU Kind 25 Event Time 135.30 Seconds
Event No. 15 --- PDU Kind 25 Event Time 135.25 Seconds
Event No. 16 --- PDU Kind 25 Event Time 135.24 Seconds
Event No. 17 --- PDU Kind 25 Event Time 135.22 Seconds
Event No. 18 --- PDU Kind 25 Event Time 135.18 Seconds
Event No. 19 --- PDU Kind 25 Event Time 135.18 Seconds
Event No. 20 --- PDU Kind 25 Event Time 133.62 Seconds
Event No. 21 --- PDU Kind 25 Event Time 132.65 Seconds
Event No. 22 --- PDU Kind 25 Event Time 131.66 Seconds
Event No. 23 --- PDU Kind 25 Event Time 131.01 Seconds
Event No. 24 --- PDU Kind 25 Event Time 130.25 Seconds
Event No. 25 --- PDU Kind 25 Event Time 130.24 Seconds
Event No. 26 --- PDU Kind 25 Event Time 130.23 Seconds
Event No. 27 --- PDU Kind 25 Event Time 130.18 Seconds
Event No. 28 --- PDU Kind 25 Event Time 130.17 Seconds
Event No. 29 --- PDU Kind 25 Event Time 130.17 Seconds
Event No. 30 --- PDU Kind 25 Event Time 128.59 Seconds
Event No. 31 --- PDU Kind 25 Event Time 127.61 Seconds
Event No. 32 --- PDU Kind 25 Event Time 126.57 Seconds
Event No. 33 --- PDU Kind 25 Event Time 126.00 Seconds
Event No. 34 --- PDU Kind 25 Event Time 125.21 Seconds
Event No. 35 --- PDU Kind 25 Event Time 125.18 Seconds
Event No. 36 --- PDU Kind 25 Event Time 125.17 Seconds
Event No. 37 --- PDU Kind 25 Event Time 125.17 Seconds
Event No. 38 --- PDU Kind 25 Event Time 125.16 Seconds
Event No. 39 --- PDU Kind 25 Event Time 125.15 Seconds
Event No. 40 --- PDU Kind 25 Event Time 123.54 Seconds
Event No. 41 --- PDU Kind 25 Event Time 122.58 Seconds
Event No. 42 --- PDU Kind 25 Event Time 121.57 Seconds
Event No. 43 --- PDU Kind 25 Event Time 120.99 Seconds
Number of transients : 0
Number of non-transients: 297
Number of non-espdu: 43

LOCAL

Number of transients : 0
Number of non-transients: 297
Number of non-espdu: 43

REMOTE

Number of transients : 0
Number of non-transients: 297
Number of non-espdu: 43

IDMadsaf1.0.dis and IDMadsaf1.0.proc

STATE OF SIMULATION - WINDOW SIZE 10 SECONDS - ITERATION 1

LOCAL time is 10

Entity Number 1 EX 3 ID: 16/100/1007
Location : X = -2677449.375303 Y = -4423949.613523 Z = 3721790.744674
Velocity : X = 1.812585 Y = -1.275404 Z = -0.172511
Orientation: Psi = -0.613163 Theta = 0.077660 Phi = -2.283310

Entity Number 2 EX 3 ID: 16/100/1004
Location : X = -2677327.335902 Y = -4424248.800884 Z = 3721555.685393
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.999217 Theta = -0.824534 Phi = -2.907753

Entity Number 3 EX 3 ID: 16/100/1006
Location : X = -2677434.77604 Y = -4424138.673778 Z = 3721623.638759
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.993523 Theta = -0.972940 Phi = -3.061761

Entity Number 4 EX 3 ID: 16/100/1005
Location : X = -2677369.12934 Y = -4424175.708213 Z = 3721620.393365
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.999217 Theta = -0.824534 Phi = -3.066300

Entity Number 5 EX 3 ID: 16/100/1002
Location : X = -2675661.848760 Y = -4425169.997175 Z = 3721553.912773
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 1.004051 Theta = -0.645401 Phi = -2.982303

Entity Number 6 EX 3 ID: 16/100/1001
Location : X = -2675457.824766 Y = -4425169.997175 Z = 3721553.912773
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.999816 Theta = -0.805404 Phi = -2.999904

Entity Number 7 EX 3 ID: 16/100/1000
Location : X = -2675496.692637 Y = -4425189.465770 Z = 3721593.186138
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.996583 Theta = -0.900146 Phi = -3.094068

Entity Number 8 EX 3 ID: 16/100/1003
Location : X = -2675563.234693 Y = -4425154.576962 Z = 3721598.246886
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.999816 Theta = -0.805404 Phi = -2.999904

Entity Number 9 EX 3 ID: 16/100/1008
Location : X = -2677496.607853 Y = -4423868.609049 Z = 3721852.718456
Velocity : X = 0.366714 Y = -0.165648 Z = -0.079724
Orientation: Psi = -0.424273 Theta = 0.195594 Phi = -2.499143

Entity Number 10 EX 3 ID: 16/100/1009
Location : X = -2677540.839908 Y = -4423847.319794 Z = 3721863.376251
Velocity : X = 2.183423 Y = -0.916174 Z = -0.420769
Orientation: Psi = 0.397292 Theta = 0.175865 Phi = -2.493860

Total Number of Entities 10

REMOTE time is 10

Entity Number 1 EX 3 ID: 16/100/1007
Location : X = -2677449.375303 Y = -4423949.604845 Z = 3721790.738748
Velocity : X = 1.809693 Y = -1.272583 Z = -0.170898
Orientation: Psi = -0.613592 Theta = 0.076699 Phi = -2.285631

Entity Number 2 EX 3 ID: 16/100/1004
Location : X = -2677327.335902 Y = -4424248.800884 Z = 3721555.685393
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.997088 Theta = -0.825282 Phi = -2.908427

Entity Number 3 EX 3 ID: 16/100/1006
Location : X = -2677434.377604 Y = -4424138.673778 Z = 3721623.638759
Velocity : X = 0.000000 Y = 0.000000 Z = 0.000000
Orientation: Psi = 0.990952 Theta = -0.975612 Phi = -3.061826
<table>
<thead>
<tr>
<th>Entity Number</th>
<th>Location</th>
<th>Velocity</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
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<td>4 EX 3</td>
<td>X = -2677369.129344 Y = -4424175.708213 Z = 3721620.393365</td>
<td>X = 0.000000 Y = 0.000000 Z = 0.000000</td>
<td>Psi = 0.997088 Theta = -0.825282 Phi = -3.067962</td>
</tr>
<tr>
<td>5 EX 3</td>
<td>X = -2675661.848760 Y = -4425169.997175 Z = 3721553.912773</td>
<td>X = 0.000000 Y = 0.000000 Z = 0.000000</td>
<td>Psi = 1.003223 Theta = -0.647340 Phi = -2.985127</td>
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<tr>
<td>6 EX 3</td>
<td>X = -2675457.824766 Y = -4425267.390822 Z = 3721532.573162</td>
<td>X = 0.000000 Y = 0.000000 Z = 0.000000</td>
<td>Psi = 0.997088 Theta = -0.862097 Phi = -3.086369</td>
</tr>
<tr>
<td>7 EX 3</td>
<td>X = -2675496.692637 Y = -4425189.465770 Z = 3721593.186138</td>
<td>X = 0.000000 Y = 0.000000 Z = 0.000000</td>
<td>Psi = 0.994020 Theta = -0.901981 Phi = -3.095573</td>
</tr>
<tr>
<td>8 EX 3</td>
<td>X = -2675563.234693 Y = -4425189.465770 Z = 3721593.186138</td>
<td>X = 0.366211 Y = -0.165558 Z = -0.079346</td>
<td>Psi = -0.426447 Theta = 0.193282 Phi = -2.500389</td>
</tr>
<tr>
<td>9 EX 3</td>
<td>X = -2677496.614127 Y = -4423868.608628 Z = 3721852.718597</td>
<td>X = 0.366211 Y = -0.165558 Z = -0.079346</td>
<td>Psi = -0.426447 Theta = 0.193282 Phi = -2.500389</td>
</tr>
</tbody>
</table>

**LOCAL EVENTS**

<table>
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<th>Event No.</th>
<th>PDU Kind</th>
<th>Event Time</th>
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</thead>
<tbody>
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<td>128.59</td>
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<td>25</td>
<td>121.57</td>
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<td>14</td>
<td>25</td>
<td>120.99</td>
</tr>
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</table>

**REMOTE EVENTS**

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<th>PDU Kind</th>
<th>Event Time</th>
</tr>
</thead>
<tbody>
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<td>128.59</td>
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<td>121.57</td>
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<tr>
<td>13</td>
<td>25</td>
<td>120.99</td>
</tr>
</tbody>
</table>

Number of transients: 92
Number of non-transients: 92
Number of non-espdu: 14

TOTAL NUMBER OF ENTITIES: 10

LOCAL EVENTS

- Event No. 1: PDU Kind 25 Event Time 128.59 Seconds
- Event No. 2: PDU Kind 25 Event Time 127.61 Seconds
- Event No. 3: PDU Kind 25 Event Time 126.57 Seconds
- Event No. 4: PDU Kind 25 Event Time 126.00 Seconds
- Event No. 5: PDU Kind 25 Event Time 125.18 Seconds
- Event No. 6: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 7: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 8: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 9: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 10: PDU Kind 25 Event Time 125.15 Seconds
- Event No. 11: PDU Kind 25 Event Time 123.54 Seconds
- Event No. 12: PDU Kind 25 Event Time 122.58 Seconds
- Event No. 13: PDU Kind 25 Event Time 121.57 Seconds
- Event No. 14: PDU Kind 25 Event Time 120.99 Seconds

REMOTE EVENTS

- Event No. 1: PDU Kind 25 Event Time 128.59 Seconds
- Event No. 2: PDU Kind 25 Event Time 127.61 Seconds
- Event No. 3: PDU Kind 25 Event Time 126.57 Seconds
- Event No. 4: PDU Kind 25 Event Time 126.00 Seconds
- Event No. 5: PDU Kind 25 Event Time 125.18 Seconds
- Event No. 6: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 7: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 8: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 9: PDU Kind 25 Event Time 125.17 Seconds
- Event No. 10: PDU Kind 25 Event Time 125.15 Seconds
- Event No. 11: PDU Kind 25 Event Time 123.54 Seconds
- Event No. 12: PDU Kind 25 Event Time 122.58 Seconds
- Event No. 13: PDU Kind 25 Event Time 121.57 Seconds
- Event No. 14: PDU Kind 25 Event Time 120.99 Seconds

Number of transients: 92
Number of non-transients: 92
Number of non-espdu: 14

TOTAL NUMBER OF ENTITIES: 10
5.3.2 Effect of Timeout Period

The length of the timeout period determines the number of entities that are considered alive. A timeout period of infinity results in all entities being active when at least one ESPDU has been received per entity.

The timeout period is varied from 1 to 12 seconds, in increments of 1 for the files ENC-9-07.dis and ENC-9-07.proc. The window size was kept constant at 20. The results are shown below:

<table>
<thead>
<tr>
<th>Timeout Interval</th>
<th>Average number of active entities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4594</td>
</tr>
<tr>
<td>2</td>
<td>1.3378</td>
</tr>
<tr>
<td>3</td>
<td>1.9054</td>
</tr>
<tr>
<td>4</td>
<td>2.2027</td>
</tr>
<tr>
<td>5</td>
<td>2.4324</td>
</tr>
<tr>
<td>6</td>
<td>2.9324</td>
</tr>
<tr>
<td>7</td>
<td>3.0000</td>
</tr>
<tr>
<td>8</td>
<td>3.0000</td>
</tr>
<tr>
<td>9</td>
<td>3.0000</td>
</tr>
<tr>
<td>10</td>
<td>3.0000</td>
</tr>
<tr>
<td>11</td>
<td>3.0000</td>
</tr>
<tr>
<td>12</td>
<td>3.0000</td>
</tr>
</tbody>
</table>

In fact, any timeout interval greater than 7 seconds would yield the maximum number of entities which are present during the simulation, namely 3. Even varying the window size did not change this entity distribution which is solely dependent on the timeout interval.

6. Conclusions and Suggestions

The performance and efficacy of DISFE was analyzed and described in this report. Below is a summary of the key elements found during the analysis:

- Compression was not performed in a uniform manner, i.e. there were miscorrelations. These happened primarily in the vector correlations that had a minimum, maximum and precision threshold.

- Non-transients did not always have a mirror non-transient in the other file. Local non-transients may not always appear as a non-transient in the remote stream, depending on the compression (or the lack of it) performed on the local non-transient. It is a more serious problem to have remote non-transients which do not have a clear match in the local stream.

- Non-ESPDUs did not always synchronize, and sometimes arrived out of order (with respect to other non-ESPDUs). This ordering of event causes a misrepresentation of the state of the simulation between the local and remote sites. In the cases
when it happened before the analysis, the types of PDUs which were mis-ordered were all radio PDUs (interleaving of Signal and Transmitter PDUs).

- Though non-ESPDUs did not always appear in the same order, the mis-ordering always happened at the same logger time. This seems to indicate that the remote DISFE bundles all the PDUs during a certain time window and dumps them onto the network, not necessarily in a certain order. ESPDUs however, seemed to maintain their order.

- Some non-compliant ESPDUs in the local PDU stream were made compliant, and by doing so caused a slew of miscorrelations. This is a side-effect that DISFE is not supposed to manifest.

- DISFE did not make any local compliant PDU non-compliant due to the compression and decompression.

To analyze the efficacy of the DISFE over a WAN in a real-time fashion would necessitate a topology which would allow the comparison tool to receive both the local and the remote PDU streams. One method to achieve this would be to connect the comparison tool to the LAN where the "local" DISFE resides, and have a long-haul connection from the "remote" LAN to the comparison tool. To prevent the "echo" effect of PDUs, care must be taken to send the traffic from the remote LAN to the local LAN in a point to point fashion (with the station having the comparison tool as the destination address).

6.1 Applicability to Analyze Other Traffic Reduction Schemes

Another traffic reduction scheme is the Protocol Independent Compression Algorithm (PICA), developed at the MIT Lincoln Labs. The main differences between PICA and DISFE are:

- DISFE is protocol dependent, PICA is not.
- DISFE reduces the accuracy of the ESPDUs, PICA does not, i.e. PICA allows the application to obtain the exact representation of the PDUs (lossy vs lossless)

Both PICA and DISFE send delta updates from point of references for Entity State PDUs. The format they send these in is dependent on the scheme. The comparison tool however takes the one PDU stream (before reduction) and compares it with a PDU stream which is re-generated from the reduced form, into an "equivalent" stream. In essence, the comparison tool is "reduction scheme independent".

6.2 Future Enhancements to the Comparison Tool

There are several enhancements which could be added to the existing comparison tool. These enhancements would further the understanding of the scheme being analyzed. Some rudimentary forms of the
enhancements listed below have been implemented, albeit not integrated into the comparison tool.

- A dump facility that will dump the contents of non-correlating ESPDUs. This will yield insight as to where the thresholds were exceeded.

- Description of events should be more detailed than just giving the event type (the kind of non-ESPDU) and the event time. In order to describe events, the comparison tool would have to be able to parse non-ESPDUs individually. This is not difficult to add. For example, a weapons fire/detonation event can be tracked as a pair and the state of the simulation surrounding such an event can be checked for coherency.

- Integrate the comparison tool with the compliance checking mechanism. For the purpose of this analysis, the compliance test has been performed independently from the comparison itself (one had no effect on the other).

- It would have been useful to integrate other functions into this analysis tool. These functions are very common functions of any traffic analysis tool, such as giving statistics on the number of entities broken down in terms of their kind and domain.

- The operation of the tool could be greatly enhanced by providing a Graphical User Interface (GUI) to it.

- Instead of looking at one PDU of each stream at a time, one could implement a look ahead buffer (or maintain a buffer for a fixed number or all of the "unmatched" non-transients).

- Verification of temporal coherency (i.e. checking the state of the local and remote simulation) is manual, and done by examining the dump of each site (a tedious task if the window size is small and time-out period large). This can be automated to provide statistics and perform entity to entity comparison. A better representation of the temporal coherency is to visually display the entities with respect to each other on the same terrain. Ideally, the local and remote images should collapse into one, and a minimal skew can be tolerated (but these thresholds must be defined).

6.3 Suggestions to Improve DISFE

The strength of DISFE lies in its ability to represent state changes with less accuracy, while still maintaining a sense of coherency (within a certain threshold). Perceptronics has identified 5 areas where this reduction in accuracy can be tolerated: velocity, location, orientation, acceleration and angular velocity. Another improvement would be to reduce the accuracy of articulation parameter values.
The only kind of PDUs being considered by DISFE is ESPDUs. Though these represent over 90% of DIS traffic (currently), there are other kinds of PDUs which already promise to contribute significantly to the traffic (namely Emissions and Radio traffic).

In the DIS Standards Emissions working group, a pioneering effort is already taking place to differentiate between "state updates" and "delta updates". As their names imply, the Emission state updates describe all the emitter systems and beams of a particular entity, while a delta update is to convey a change in one of these systems. However, like the ESPDU, Emission state updates are issued at a predetermined heartbeat rate (for the same reasons as the ESPDU). Often times, Emission state updates are identical and can be categorized as being "transient". DISFE may want to consider performing compression on Emission PDUs, as these will play a considerable role in future DIS exercises. One additional point to consider is that Emission state updates could potentially be large PDUs if the entity has a large number of emitter systems.

Radio traffic on the other hand, may be more of a nuisance because of its size (in particular the Signal PDU). Voice traffic is not new to network implementers, and the compression of this type of traffic (as well as video) is well documented in the literature. Because the amount of DIS radio traffic will grow, it may be advantageous for the DISFE to consider compressing radio traffic as well.
References


[Fidel] "Fidelity and Compliance Check for the Perceptronics System" - Perceptronics.

Appendix A - Configuration Parameters

#- FILE NAME: dis.config
#- DESCRIPTION: main user configuration file for the DISCOM related issues
#- AUTHORS: Boris B., Moshe K., Ron Nagamati
#- PROJECT: DISCOM
#- CONTRACT: N61339-93-C0094
#- RCS INFO: $Id: dis.config,v 1.26 94/08/04 10:18:45 nagamati Exp$
#

#- FRONT END MACHINE
#

# IP addresses and UDP Ports
#

# Sending IP Address
disSendIP 0

# Sending UDP Port No.
disSendPort 2999

# Receiving UDP Port No.
disRecvPort 3000

# DDP Port No.
ddpPort 4000

#- UEID list (will be replaced in SIP)
#

# UEID Interval
uEIDseq1 1 1000

# UEID Interval
uEIDseq2 1002 2000
# Queue Parameters

# Queue send threshold in bytes (0 to turn off Qing)
qSize 1400

# Timeout for flushing Q Manager
# [mSec]
timeoutFlush 50

# Reliability

# Retransmission Sending Delay
# [mSec]
reXmtSendDelay 10

# Retransmission Request Sending Delay
# [mSec]
reXmtReqSendDelay 10

# Maximum number of event pending
maxEvent 1000

# Timeout for no-input-exit
# [mSec]
timeoutNoInput 900000

# Timeout for dead-entity removal
# [mSec]
timeoutDeadEntity 3000

# Timeout for printing statistics
# [sec]
timeoutPrint 0

# Timeout for rebroadcast
# [mSec]
timeoutRebroadcast 5000
durationRebroadcast 25000
# Timeout for empty transients
# [mSec]
timeoutTransient 7500

# Duration for empty transients
# [mSec]
durationTransient 15000

#--------------------------------------------------------------
# TOLERANCE FOR ORIENTATION:
#--------------------------------------------------------------

# Orientation Psi
#--------------------
# # of Intervals :
oriPsiIntNum 1
# Precision value :
# [deg]
oriPsiPrecision 0.88

# Orientation Theta
#--------------------
# No. of Intervals :
oriThetaIntNum 1
# Precision values :
# [deg]
oriThetaPrecision 0.44

# Orientation Phi
#--------------------
# No. of Intervals :
oriPhiIntNum 1
# Precision values :
# [deg]
oriPhiPrecision 0.88

#--------------------------------------------------------------
# VELOCITY PRECISION
#--------------------------------------------------------------

# VelMin
# |
# |
# VelMax
#
#  \------------------------\       |Velocity|
#  \                      /        /     \\  \\
#  \_______________________/       |      |
#  \                         /       /       \\
#  \_______________________/       |      |
#  \                      /        /       \\
#  \------------------------\       |      |
#  \\
#
# PRECISION:               VelMin  Precision[\%]  0
#
# Precision for value which falls in the range
# VelMin <= |v| <= VelMax is specified in the table.
# Precision for value below VelMin is implicitly defined as the
# value itself.
# Precision for value above VelMax is implicitly defined as 0.

#----------------------------------
# Entity type VelMin VelMax Precision
# [m/sec] [m/sec] [\%]
#----------------------------------
# velAirType  0.046  750.00  0.78
# velLandType 0.003  50.00  0.78
# velSubsurfaceType 0.001  20.83  0.78
# velSurfaceType 0.002  27.78  0.78
# velSpaceType 0.183  3000.00  0.78
# velLifeformsType 0.001  5.56  0.78
# velMunitionsType 0.092  1500.00  0.78
# None of above velDefaultType 0.002  100Km/h  0.78
#----------------------------------
# LOCATION PRECISION
#----------------------------------
#----------------------------------
# Entity type Precision
# type [m.]
#----------------------------------
# locAirType  1.0
# locLandType  1 inch
# locSubsurfaceType  1 foot
# locSurfaceType  1 foot
# locSpaceType  1.0
# locLifeformsType  1 inch
# locMunitionsType  1 inch
# None of Above  2 cm (Location's default)
locDefaultType  0.0200

#-----------------------
# ACCELERATION PRECISION
#-----------------------
#
#
<table>
<thead>
<tr>
<th>Entity type</th>
<th>AccMin [m/sec^2]</th>
<th>AccMax [m/sec^2]</th>
<th>Precision [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>accAirType</td>
<td>0.006</td>
<td>98</td>
<td>0.78</td>
</tr>
<tr>
<td>accLandType</td>
<td>0.003</td>
<td>49</td>
<td>0.78</td>
</tr>
</tbody>
</table>
### ANGULAR VELOCITY PRECISION

<table>
<thead>
<tr>
<th>Entity Type</th>
<th>AVelMin</th>
<th>AVelMax</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1rpm</td>
<td>0.0004</td>
<td>6.28</td>
<td>0.78</td>
</tr>
<tr>
<td>avelAirType</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2rpm</td>
<td>0.0008</td>
<td>12.57</td>
<td>0.78</td>
</tr>
<tr>
<td>avelLandType</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None of above</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Angular Velocity

Precision for value which falls in the range $AVelMin <= |v| <= AVelMax$ is specified in the table.

Precision for value below $AVelMin$ is implicitly defined as the value itself.

Precision for value above $AVelMax$ is implicitly defined as 0.
### AvelSubsurfaceType

<table>
<thead>
<tr>
<th>Value</th>
<th>RPM</th>
<th>0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0008</td>
<td>12.57</td>
<td></td>
</tr>
</tbody>
</table>

# 1rpm

### AvelSurfaceType

<table>
<thead>
<tr>
<th>Value</th>
<th>RPM</th>
<th>0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0004</td>
<td>6.28</td>
<td></td>
</tr>
</tbody>
</table>

# 10rpm

### AvelSpaceType

<table>
<thead>
<tr>
<th>Value</th>
<th>RPM</th>
<th>0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0019</td>
<td>31.42</td>
<td></td>
</tr>
</tbody>
</table>

# 1rpm

### AvelLifeformsType

<table>
<thead>
<tr>
<th>Value</th>
<th>RPM</th>
<th>0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0004</td>
<td>6.28</td>
<td></td>
</tr>
</tbody>
</table>

# 10rpm

### AvelMunitionsType

<table>
<thead>
<tr>
<th>Value</th>
<th>RPM</th>
<th>0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0019</td>
<td>31.42</td>
<td></td>
</tr>
</tbody>
</table>

# None of above

### AvelDefaultType

<table>
<thead>
<tr>
<th>Value</th>
<th>RPM</th>
<th>0.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0008</td>
<td>12.57</td>
<td></td>
</tr>
</tbody>
</table>

# Scheme for handling bad PDU’s (such as those with bad lengths)
# EHthrowAway=1, EHsendRaw=2, EHmodify=3, EHignore=4
# Note: EHsendRaw not supported yet

```
exceptionScheme 1
```
Appendix B - Analysis Results

FILES: ENC-7-02.DIS and ENC-7-02.PROC

--------------------- General Statistics ---------------------

Total Number of PDUs in local file : 66767
Total Number of PDUs in remote file : 52747

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors : 0
IP header errors : 0
UDP header errors : 0
DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDU COHERENCY
Non-correlating (generic) : 2
Length mismatch : 0
Out of order : 0

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity : 31
Uncorrelated location : 1
Uncorrelated orientation : 2
Uncorrelated acceleration : 11
Uncorrelated angular velocity : 28
Other non-coherency : 2

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients : 35
Number of uncorrelated remote non-transients : 12
Number of uncorrelated local non-EsPDUs : 0
Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts : 0
Uncorrelated duration of transients : 0
FILES: ENC-9-01.DIS and ENC-9-01.PROC

---------- General Statistics ----------

| Total Number of PDUs in local file | 20989 |
| Total Number of PDUs in remote file | 19608 |

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
- Ethernet header errors : 0
- IP header errors : 0
- UDP header errors : 0
- DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDUS COHERENCY
- Non-correlating (generic) : 0
- Length mismatch : 0
- Out of order : 0

GLOBAL STATISTICS - SPATIAL COHERENCY
- Uncorrelated velocity : 55
- Uncorrelated location : 0
- Uncorrelated orientation : 0
- Uncorrelated acceleration : 3
- Uncorrelated angular velocity : 0
- Other non-coherency : 0

GLOBAL STATISTICS - MISSING PDUs
- Number of uncorrelated local non-transients : 0
- Number of uncorrelated remote non-transients : 1
- Number of uncorrelated local non-EsPDUs : 0
- Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
- Uncorrelated rebroadcasts : 0
- Uncorrelated duration of transients : 0
FILES: ENC-9-04.DIS and ENC-9-04.PROC

------------- General Statistics -------------

| Total Number of PDUs in local file | 29840 |
| Total Number of PDUs in remote file | 27185 |

GLOBAL STATISTICS - NETWORK HEADER COHERENCY

| Ethernet header errors | 0 |
| IP header errors       | 0 |
| UDP header errors      | 0 |
| DIS header errors      | 0 |

GLOBAL STATISTICS - NON-ESPDUS COHERENCY

| Non-correlating (generic) | 0 |
| Length mismatch           | 0 |
| Out of order              | 0 |

GLOBAL STATISTICS - SPATIAL COHERENCY

| Uncorrelated velocity    | 0 |
| Uncorrelated location    | 0 |
| Uncorrelated orientation | 0 |
| Uncorrelated acceleration| 0 |
| Uncorrelated angular velocity | 0 |
| Other non-coherency      | 0 |

GLOBAL STATISTICS - MISSING PDUs

| Number of uncorrelated local non-transients | 1 |
| Number of uncorrelated remote non-transients | 0 |
| Number of uncorrelated local non-EsPDUs    | 0 |
| Number of uncorrelated remote non-EsPDUs   | 0 |

GLOBAL STATISTICS - TEMPORAL COHERENCY

| Uncorrelated rebroadcasts | 0 |
| Uncorrelated duration of transients | 0 |
FILES: ENC-9-04.DIS and ENC-9-04.PROC

----------------- General Statistics -----------------

Total Number of PDUs in local file : 29840
Total Number of PDUs in remote file : 27185

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors : 0
IP header errors : 0
UDP header errors : 0
DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDUS COHERENCY
Non-correlating (generic) : 0
Length mismatch : 0
Out of order : 0

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity : 0
Uncorrelated location : 0
Uncorrelated orientation : 0
Uncorrelated acceleration : 0
Uncorrelated angular velocity : 0
Other non-coherency : 0

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients : 1
Number of uncorrelated remote non-transients : 0
Number of uncorrelated local non-EsPDUs : 0
Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts : 0
Uncorrelated duration of transients : 0
FILES: ENC-9-05.DIS and ENC-9-05.PROC

------------ General Statistics ------------

Total Number of PDUs in local file : 4944
Total Number of PDUs in remote file  : 2211

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors : 0
IP header errors : 0
UDP header errors : 0
DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDU COHERENCY
Non-correlating (generic) : 0
Length mismatch : 0
Out of order : 0

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity : 0
Uncorrelated location : 0
Uncorrelated orientation : 0
Uncorrelated acceleration : 0
Uncorrelated angular velocity : 0
Other non-coherency : 0

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients : 1
Number of uncorrelated remote non-transients : 0
Number of uncorrelated local non-EsPDUs : 0
Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts : 0
Uncorrelated duration of transients : 0

36
FILES: ENC-9-06.DIS and ENC-9-06.PROC

----------------- General Statistics -----------------

Total Number of PDUs in local file  :  5396
Total Number of PDUs in remote file  :  2685

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors  :  0
IP header errors       :  0
UDP header errors       :  0
DIS header errors       :  0

GLOBAL STATISTICS - NON-ESPDU COHERENCY
Non-correlating (generic)  :  0
Length mismatch           :  0
Out of order              :  0

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity     :  0
Uncorrelated location     :  0
Uncorrelated orientation  :  0
Uncorrelated acceleration :  0
Uncorrelated angular velocity:  0
Other non-coherency       :  0

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients :  0
Number of uncorrelated remote non-transients :  1
Number of uncorrelated local non-EsPDUs      :  0
Number of uncorrelated remote non-EsPDUs     :  0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts :  0
Uncorrelated duration of transients :  0
FILES: ENC-9-07.DIS and ENC-9-07.PROC

----------------- General Statistics ----------------

Total Number of PDUs in local file : 4983
Total Number of PDUs in remote file : 2210

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors : 0
IP header errors : 0
UDP header errors : 0
DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDUS COHERENCY
Non-correlating (generic) : 0
Length mismatch : 0
Out of order : 0

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity : 0
Uncorrelated location : 0
Uncorrelated orientation : 0
Uncorrelated acceleration : 0
Uncorrelated angular velocity : 0
Other non-coherency : 0

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients : 0
Number of uncorrelated remote non-transients : 0
Number of uncorrelated local non-EsPDUs : 0
Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts : 0
Uncorrelated duration of transients : 0
**FILES: ENC-9-08.DIS and ENC-9-08.PROC**

--- General Statistics ---

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of PDUs in local file</td>
<td>4980</td>
</tr>
<tr>
<td>Total Number of PDUs in remote file</td>
<td>2212</td>
</tr>
</tbody>
</table>

**GLOBAL STATISTICS - NETWORK HEADER COHERENCY**

- Ethernet header errors: 0
- IP header errors: 0
- UDP header errors: 0
- DIS header errors: 0

**GLOBAL STATISTICS - NON-ESPDU COHERENCY**

- Non-correlating (generic): 0
- Length mismatch: 0
- Out of order: 0

**GLOBAL STATISTICS - SPATIAL COHERENCY**

- Uncorrelated velocity: 0
- Uncorrelated location: 0
- Uncorrelated orientation: 0
- Uncorrelated acceleration: 0
- Uncorrelated angular velocity: 0
- Other non-coherency: 0

**GLOBAL STATISTICS - MISSING PDUs**

- Number of uncorrelated local non-transients: 0
- Number of uncorrelated remote non-transients: 0
- Number of uncorrelated local non-ESPDU: 0
- Number of uncorrelated remote non-ESPDU: 0

**GLOBAL STATISTICS - TEMPORAL COHERENCY**

- Uncorrelated rebroadcasts: 0
- Uncorrelated duration of transients: 0
FILES: ENC-9-09.DIS and ENC-9-09.PROC

--------------------- General Statistics ---------------------

| Total Number of PDUs in local file | 4983 |
| Total Number of PDUs in remote file | 2211 |

GLOBAL STATISTICS - NETWORK HEADER COHERENCY

| Ethernet header errors | 0 |
| IP header errors | 0 |
| UDP header errors | 0 |
| DIS header errors | 0 |

GLOBAL STATISTICS - NON-ESPDUS COHERENCY

| Non-correlating (generic) | 0 |
| Length mismatch | 0 |
| Out of order | 0 |

GLOBAL STATISTICS - SPATIAL COHERENCY

| Uncorrelated velocity | 0 |
| Uncorrelated location | 0 |
| Uncorrelated orientation | 0 |
| Uncorrelated acceleration | 0 |
| Uncorrelated angular velocity | 0 |
| Other non-coherency | 0 |

GLOBAL STATISTICS - MISSING PDUs

| Number of uncorrelated local non-transients | 0 |
| Number of uncorrelated remote non-transients | 0 |
| Number of uncorrelated local non-EsPDUs | 0 |
| Number of uncorrelated remote non-EsPDUs | 0 |

GLOBAL STATISTICS - TEMPORAL COHERENCY

| Uncorrelated rebroadcasts | 0 |
| Uncorrelated duration of transients | 0 |
**FILES: ENC-9-10.DIS and ENC-9-10.PROC**

--- General Statistics ---

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of PDUs in local file</td>
<td>5184</td>
</tr>
<tr>
<td>Total Number of PDUs in remote file</td>
<td>2599</td>
</tr>
</tbody>
</table>

**GLOBAL STATISTICS - NETWORK HEADER COHERENCY**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet header errors</td>
<td>0</td>
</tr>
<tr>
<td>IP header errors</td>
<td>0</td>
</tr>
<tr>
<td>UDP header errors</td>
<td>0</td>
</tr>
<tr>
<td>DIS header errors</td>
<td>0</td>
</tr>
</tbody>
</table>

**GLOBAL STATISTICS - NON-ESPDUS COHERENCY**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-correlating (generic)</td>
<td>0</td>
</tr>
<tr>
<td>Length mismatch</td>
<td>0</td>
</tr>
<tr>
<td>Out of order</td>
<td>0</td>
</tr>
</tbody>
</table>

**GLOBAL STATISTICS - SPATIAL COHERENCY**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrelated velocity</td>
<td>0</td>
</tr>
<tr>
<td>Uncorrelated location</td>
<td>0</td>
</tr>
<tr>
<td>Uncorrelated orientation</td>
<td>0</td>
</tr>
<tr>
<td>Uncorrelated acceleration</td>
<td>0</td>
</tr>
<tr>
<td>Uncorrelated angular velocity</td>
<td>0</td>
</tr>
<tr>
<td>Other non-coherency</td>
<td>0</td>
</tr>
</tbody>
</table>

**GLOBAL STATISTICS - MISSING PDUs**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of uncorrelated local non-transients</td>
<td>0</td>
</tr>
<tr>
<td>Number of uncorrelated remote non-transients</td>
<td>1</td>
</tr>
<tr>
<td>Number of uncorrelated local non-EsPDUs</td>
<td>0</td>
</tr>
<tr>
<td>Number of uncorrelated remote non-EsPDUs</td>
<td>2</td>
</tr>
</tbody>
</table>

**GLOBAL STATISTICS - TEMPORAL COHERENCY**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrelated rebroadcasts</td>
<td>0</td>
</tr>
<tr>
<td>Uncorrelated duration of transients</td>
<td>0</td>
</tr>
</tbody>
</table>

41
FILES: ENC-9-11.DIS and ENC-9-11.PROC

------------- General Statistics -------------

Total Number of PDUs in local file : 37397
Total Number of PDUs in remote file : 37724

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors : 0
IP header errors : 0
UDP header errors : 0
DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDUS COHERENCY
Non-correlating (generic) : 15
Length mismatch : 1
Out of order : 8

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity : 15
Uncorrelated location : 1
Uncorrelated orientation : 2
Uncorrelated acceleration : 32
Uncorrelated angular velocity : 10
Other non-coherency : 3

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients : 42
Number of uncorrelated remote non-transients : 43
Number of uncorrelated local non-EsPDUs : 0
Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts : 0
Uncorrelated duration of transients : 0

-------------- General Statistics ---------------

Total Number of PDUs in local file : 65308
Total Number of PDUs in remote file : 50643

GLOBAL STATISTICS - NETWORK HEADER COHERENCY
Ethernet header errors : 0
IP header errors : 0
UDP header errors : 0
DIS header errors : 0

GLOBAL STATISTICS - NON-ESPDUS COHERENCY
Non-correlating (generic) : 0
Length mismatch : 0
Out of order : 0

GLOBAL STATISTICS - SPATIAL COHERENCY
Uncorrelated velocity : 173
Uncorrelated location : 0
Uncorrelated orientation : 0
Uncorrelated acceleration : 115
Uncorrelated angular velocity : 364
Other non-coherency : 1

GLOBAL STATISTICS - MISSING PDUs
Number of uncorrelated local non-transients : 1
Number of uncorrelated remote non-transients : 1
Number of uncorrelated local non-EsPDUs : 0
Number of uncorrelated remote non-EsPDUs : 0

GLOBAL STATISTICS - TEMPORAL COHERENCY
Uncorrelated rebroadcasts : 0
Uncorrelated duration of transients : 0
**FILES: IDA-Modsafl.0.DIS and IDA-Modsafl.0.PROC**

------------ General Statistics  ------------

| Total Number of PDUs in local file | 6365 |
| Total Number of PDUs in remote file | 6500 |

**GLOBAL STATISTICS - NETWORK HEADER COHERENCY**

| Ethernet header errors | 0 |
| IP header errors | 0 |
| UDP header errors | 0 |
| DIS header errors | 0 |

**GLOBAL STATISTICS - NON-ESPDU COHERENCY**

| Non-correlating (generic) | 0 |
| Length mismatch | 0 |
| Out of order | 0 |

**GLOBAL STATISTICS - SPATIAL COHERENCY**

| Uncorrelated velocity | 8 |
| Uncorrelated location | 0 |
| Uncorrelated orientation | 0 |
| Uncorrelated acceleration | 0 |
| Uncorrelated angular velocity | 0 |
| Other non-coherency | 0 |

**GLOBAL STATISTICS - MISSING PDUs**

| Number of uncorrelated local non-transients | 0 |
| Number of uncorrelated remote non-transients | 0 |
| Number of uncorrelated local non-ESPDUs | 0 |
| Number of uncorrelated remote non-ESPDUs | 0 |

**GLOBAL STATISTICS - TEMPORAL COHERENCY**

| Uncorrelated rebroadcasts | 0 |
| Uncorrelated duration of transients | 0 |
## Appendix C - Description of Test Data Files

### Summary ENC-7-02.dis

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>91.80%</td>
<td>61289</td>
<td>9638640</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.02%</td>
<td>12</td>
<td>1152</td>
</tr>
<tr>
<td>Collision</td>
<td>0.00%</td>
<td>2</td>
<td>120</td>
</tr>
<tr>
<td>Emission</td>
<td>0.04%</td>
<td>28</td>
<td>2800</td>
</tr>
<tr>
<td>Transmitter</td>
<td>8.10%</td>
<td>5405</td>
<td>562120</td>
</tr>
<tr>
<td>Signal</td>
<td>0.02%</td>
<td>12</td>
<td>11633</td>
</tr>
<tr>
<td>Type 128</td>
<td>0.01%</td>
<td>6</td>
<td>872</td>
</tr>
</tbody>
</table>

### Summary ENC-7-02.proc

<table>
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<th>Distribution</th>
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<th>Size of PDUs</th>
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</thead>
<tbody>
<tr>
<td>Entity State</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>89.61%</td>
<td>47269</td>
<td>7236304</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.02%</td>
<td>12</td>
<td>1152</td>
</tr>
<tr>
<td>Collision</td>
<td>0.00%</td>
<td>2</td>
<td>120</td>
</tr>
<tr>
<td>Emission</td>
<td>0.05%</td>
<td>28</td>
<td>2800</td>
</tr>
<tr>
<td>Transmitter</td>
<td>10.25%</td>
<td>5405</td>
<td>562120</td>
</tr>
<tr>
<td>Signal</td>
<td>0.02%</td>
<td>12</td>
<td>11633</td>
</tr>
<tr>
<td>Type 128</td>
<td>0.01%</td>
<td>6</td>
<td>872</td>
</tr>
</tbody>
</table>

### Summary ENC-9-01.dis

<table>
<thead>
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<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>86.45%</td>
<td>18145</td>
<td>3074192</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.10%</td>
<td>22</td>
<td>2112</td>
</tr>
<tr>
<td>Transmitter</td>
<td>13.34%</td>
<td>2800</td>
<td>291200</td>
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</tbody>
</table>

### Summary ENC-9-01.proc

<table>
<thead>
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<th>DIS-PDU Type</th>
<th>Distribution</th>
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<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>85.50%</td>
<td>16764</td>
<td>2878432</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.11%</td>
<td>22</td>
<td>2112</td>
</tr>
<tr>
<td>Transmitter</td>
<td>14.28%</td>
<td>2800</td>
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### Summary ENC-9-04.dis

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<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>99.76%</td>
<td>29767</td>
<td>4332656</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.12%</td>
<td>37</td>
<td>3552</td>
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### Summary ENC-9-04.proc

45
<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>99.73%</td>
<td>27112</td>
<td>3950432</td>
</tr>
<tr>
<td>Fire</td>
<td>0.14%</td>
<td>37</td>
<td>3552</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.13%</td>
<td>36</td>
<td>3744</td>
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**Summary ENC-9-05.dis**

<table>
<thead>
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<th>DIS-PDU Type</th>
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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>99.72%</td>
<td>4930</td>
<td>739008</td>
</tr>
<tr>
<td>Fire</td>
<td>0.14%</td>
<td>7</td>
<td>672</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.14%</td>
<td>7</td>
<td>728</td>
</tr>
</tbody>
</table>

**Summary ENC-9-05.proc**

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>99.37%</td>
<td>2197</td>
<td>347216</td>
</tr>
<tr>
<td>Fire</td>
<td>0.32%</td>
<td>7</td>
<td>672</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.32%</td>
<td>7</td>
<td>728</td>
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</table>

**Summary ENC-9-06.dis**

<table>
<thead>
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<th>DIS-PDU Type</th>
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<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>99.70%</td>
<td>5380</td>
<td>823392</td>
</tr>
<tr>
<td>Fire</td>
<td>0.15%</td>
<td>8</td>
<td>768</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.15%</td>
<td>8</td>
<td>832</td>
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**Summary ENC-9-06.proc**

<table>
<thead>
<tr>
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<th>Size of PDUs</th>
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<tbody>
<tr>
<td>Entity State</td>
<td>99.40%</td>
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<td>435216</td>
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<tr>
<td>Fire</td>
<td>0.30%</td>
<td>8</td>
<td>768</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.30%</td>
<td>8</td>
<td>832</td>
</tr>
</tbody>
</table>

**Summary ENC-9-07.dis**

<table>
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<tr>
<th>DIS-PDU Type</th>
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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>100.00%</td>
<td>4983</td>
<td>763152</td>
</tr>
</tbody>
</table>

**Summary ENC-9-07.proc**

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>100.00%</td>
<td>2210</td>
<td>365792</td>
</tr>
</tbody>
</table>

**Summary ENC-9-08.dis**

<table>
<thead>
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<th>DIS-PDU Type</th>
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<th>Number of PDUs</th>
<th>Size of PDUs</th>
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</table>
Summary ENC-9-08.proc

Number of PDUs: 2212

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>100.00%</td>
<td>2212</td>
<td>366016</td>
</tr>
</tbody>
</table>

Summary ENC-9-09.dis

Number of PDUs: 4983

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<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
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</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>100.00%</td>
<td>4983</td>
<td>763120</td>
</tr>
</tbody>
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Summary ENC-9-09.proc

Number of PDUs: 2211

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>100.00%</td>
<td>2211</td>
<td>365904</td>
</tr>
</tbody>
</table>

Summary ENC-9-10.dis

Number of PDUs: 5182

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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>99.44%</td>
<td>5153</td>
<td>790032</td>
</tr>
<tr>
<td>Fire</td>
<td>0.08%</td>
<td>4</td>
<td>384</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.08%</td>
<td>4</td>
<td>416</td>
</tr>
<tr>
<td>Transmitter</td>
<td>0.41%</td>
<td>21</td>
<td>2184</td>
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Summary ENC-9-10.proc

Number of PDUs: 2599

<table>
<thead>
<tr>
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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>98.88%</td>
<td>2570</td>
<td>425600</td>
</tr>
<tr>
<td>Fire</td>
<td>0.15%</td>
<td>4</td>
<td>384</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.15%</td>
<td>4</td>
<td>416</td>
</tr>
<tr>
<td>Transmitter</td>
<td>0.81%</td>
<td>21</td>
<td>2184</td>
</tr>
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</table>

Summary ENC-9-11.dis

Number of PDUs: 37397

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>92.05%</td>
<td>34425</td>
<td>5682352</td>
</tr>
<tr>
<td>Fire</td>
<td>0.08%</td>
<td>29</td>
<td>2784</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.07%</td>
<td>27</td>
<td>2840</td>
</tr>
<tr>
<td>Collision</td>
<td>0.20%</td>
<td>73</td>
<td>4380</td>
</tr>
<tr>
<td>Transmitter</td>
<td>6.78%</td>
<td>2536</td>
<td>263744</td>
</tr>
<tr>
<td>Signal</td>
<td>0.82%</td>
<td>307</td>
<td>161580</td>
</tr>
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</table>

Summary ENC-9-11.proc

Number of PDUs: 37724

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>92.12%</td>
<td>34752</td>
<td>5811968</td>
</tr>
<tr>
<td>Fire</td>
<td>0.08%</td>
<td>29</td>
<td>2784</td>
</tr>
</tbody>
</table>

47
Detonation  0.07%  27  2840
Collision  0.19%  73  4380
Transmitter  6.72%  2536  263744
Signal  0.81%  307  161580

**Summary ENC-9-15.dis**

Number of PDUs:  65308

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<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>96.78%</td>
<td>63205</td>
<td>9298192</td>
</tr>
<tr>
<td>Fire</td>
<td>0.19%</td>
<td>125</td>
<td>12000</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.19%</td>
<td>125</td>
<td>13000</td>
</tr>
<tr>
<td>Emission</td>
<td>0.62%</td>
<td>405</td>
<td>40500</td>
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<tr>
<td>Transmitter</td>
<td>1.70%</td>
<td>1113</td>
<td>115752</td>
</tr>
<tr>
<td>Signal</td>
<td>0.51%</td>
<td>335</td>
<td>314523</td>
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**Summary ENC-9-15.proc**

Number of PDUs:  50643

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<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
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<td>95.85%</td>
<td>48540</td>
<td>7197248</td>
</tr>
<tr>
<td>Fire</td>
<td>0.25%</td>
<td>125</td>
<td>12000</td>
</tr>
<tr>
<td>Detonation</td>
<td>0.25%</td>
<td>125</td>
<td>13000</td>
</tr>
<tr>
<td>Emission</td>
<td>0.80%</td>
<td>405</td>
<td>40500</td>
</tr>
<tr>
<td>Transmitter</td>
<td>2.20%</td>
<td>1113</td>
<td>115752</td>
</tr>
<tr>
<td>Signal</td>
<td>0.66%</td>
<td>335</td>
<td>314523</td>
</tr>
</tbody>
</table>

**Summary IDA-Modsaf1.0.dis**

Number of PDUs:  6365

<table>
<thead>
<tr>
<th>DIS-PDU Type</th>
<th>Distribution</th>
<th>Number of PDUs</th>
<th>Size of PDUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity State</td>
<td>85.88%</td>
<td>5466</td>
<td>962016</td>
</tr>
<tr>
<td>Fire</td>
<td>0.20%</td>
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<tr>
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<td>0.20%</td>
<td>13</td>
<td>1400</td>
</tr>
<tr>
<td>Transmitter</td>
<td>13.61%</td>
<td>866</td>
<td>90064</td>
</tr>
<tr>
<td>Signal</td>
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<td>7</td>
<td>544</td>
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**Summary IDA-Modsaf1.0.proc**

Number of PDUs:  6500

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