Using Distributed Interactive Simulation (DIS) Filtering in a Testing and Experimentation Environment

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ABSTRACT: The USAF Distributed Mission Operations Center (DMOC) Participates in a myriad of experimental and test oriented events including the Air Force Research Laboratory's Advanced Concept Event (ACE), the Joint Theatre Air and Missile Defense Organization's Defense of the Homeland against asymmetric Missile Attacks event (DoHMA) and the Defense Advanced Research Projects Agency's (DARPA) Joint Air/Ground operations: Unified, Adaptive Replanning event (JAGUAR). In addition, the DMOC sponsored Virtual Flag training event features a month long calendar of testing events in preparation.

These events are dedicated to experimental testing activities as well as testing for training events combined as a host of Virtual (Single Entity and Operator system with High Fidelity Display and Realistic controls) and Constructive (Computer Software typically with many Entities and controlled with keyboard and mouse) systems utilized in a distributed manner in order to include as many participants and systems as possible. Experimental systems as well as simulations that are first time participants in a distributed event bring many challenges to event planners in regards to their individual requirements, limitations and capabilities that they represent using the Distributed Interactive Simulation (DIS) protocol. Experimental systems using non-standard DIS packets to represent a new capability could adversely affect another system. That same system may also not be compatible with another representation presented by another system or have a limitation in terms of network traffic which it can display or process, an occurrence that is common in a distributed event that contains larges amounts of participants. Even if a system is robust enough to handle all traffic in a given event it may not be relevant for that system to receive all that data to achieve its goals.

The question becomes for the event planner, how do you tailor the experiment or testing while accounting for a specific system's technical limitations and requirements? To assist in providing separate systems with precisely the network picture they need the DMOC has developed a network application called the DIS Filter, in use at the facility since its creation there in 2001. The DMOC DIS Filter features many capabilities that can be used to filter and transform DIS data to tailor a network picture for any given system. The purpose of this paper is to overview the DMOC DIS Filter application and how it is used in experimentation and testing events to ensure success.

1. Introduction

The United States Air force Distributed Mission Operations Center (DMOC) is the home of Virtual Flag, a distributed large scale Battlespace exercise which is held three to four times a year. Virtual Flag (VF) is a joint exercise with Army, Navy and Air Force participation during every event and the Marines participating when availability allows.

Although Virtual Flag is the DMOC primary exercise, the facility also participates in many testing and experimental based events throughout the year. These include the Air Force Research Laboratory's Advanced Concept Event (ACE), the Joint Theatre Air and Missile Defense Organization's Defense of the Homeland against asymmetric Missile Attacks event (DoHMA) and the Defense Advanced Research Projects Agency's (DARPA) Joint Air/Ground operations: Unified, Adaptive Replanning event (JAGUAR). Additionally, the Virtual Flag exercise includes a month long calendar featuring extensive testing.

The planner for any type of distributed testing or experimental based simulation event must take into account technical factors and requirements at an equal standing to achieve a successful event by using technology.

The main consideration from a technical perspective in a large distributed event with many participants is to not overwhelm the limitations that a virtual simulation may have from an entity count perspective so that it remains stable, therefore providing system uptime for the longest amount of time possible. Larger events are often built to provide training to many participants meaning that portions of it are tailored to individual systems. A consideration is to provide a high level of fidelity without bombarding the receiving simulation with information they do not need.

The DMOC facility utilizes the IEEE 1278-1 Distributed Interactive Simulation (DIS) network packet standard to pass simulation data among distributed participants. Other standards including the IEEE 1516 High Level Architecture are accommodated using gateways to DIS. As a User Datagram Protocol (UDP) broadcast packet based standard it is possible to manipulate data in a variety of ways.

To meet various event needs, the DMOC has developed the DIS Filter application which can tailor a training experience for a particular simulation; picking and choosing from a forty thousand entity exercise and at the same time protect a simulation by maintaining a manageable load.

2. DMOC DIS Filter History

The current iteration of the DMOC's DIS Filter application has been in use at the facility since 2001. However, there have been implementations of DIS PDU filtering and manipulation that have taken place at the Air Force facility since it was known as the Theatre Aerospace Command and Control Simulation Facility (TACCSF, 1990 - 1993). Specifically there have been development projects undertaken at the facility that have acted as predecessors to the current DIS Filter application.

In addition, the DIS filter application has evolved over the years since it's inception in order to satisfy ever expanding requirements and take advantage of improvement in computer hardware and operating systems. In the sections that follow are paragraphs detailing some of the systems, events and ideas which eventually led to the creation of the DMOC's DIS filter as well as milestones and important upgrades.

2.1 UDP Network Devices

During the 1994 – 1995 timeframe the TACCSF facility participated in a distributed event known as the Synthetic Theatre of War – Europe (STOW-E) featuring participants from all four defense branches in the United States as well as US and UK forces in England and US Army forces in Germany.

Connections to the distributed participants of this event were made using commercial T-1 lines and available Asynchronous Transfer Mode (ATM) networks. The STOW-E network was primarily a High Level Architecture (HLA) exercise but also featured DIS interface connections at sites including TACCSF. UDP network devices including various routers and switches were used to regulate both bandwidth and traffic to the interface at the TACCSF facility, programmed to key off of the DIS data header at the PDU level.

2.2 MSIM Gateway

The Master Simulation (MSIM) Environment Generator (EG) was the primary EG in use at the TACCSF facility throughout the 1990s. The system worked with LAN-connected virtual simulation systems using a proprietary message format before the establishment of the DIS protocol. Once DIS was created, the TACCSF facility created the MSIM gateway to allow MSIM nodes to translate proprietary messages into their DIS equivalent. The MSIM gateway also featured system utilities to manipulate and filter data between the two formats.

2.3 TACCSF Simulation Architecture

As the TACCSF facility invested in new system capabilities and began to host as well as participate regularly in larger distributed events with the backbone of the DIS protocol, the need arose for a way to interconnect devices with proprietary architectures.

In the same manner as the MSIM gateway, the TACCSF Simulation Architecture was designed as a DIS gateway with the ability to be adapted to different proprietary interfaces, enabling a given system to be DIS compliant. Systems which were adapted to use this gateway included the Scenario Toolkit and Generation Environment (STAGE) and Air Warfare Simulation (AWSIM) Environment Generators.

Like the MSIM gateway, the TACCSF Simulation Architecture gateway featured capabilities to transform and filter data between DIS and whatever proprietary system it was adapted for.

2.3 DMOC DIS Filter Iterations

Released in 2001, the first iteration of the DMOC DIS Filter ran on the Silicon Graphics IRIX operating system. About a year after the initial release of the DMOC's DIS Filter there were internal discussions debating the advantages and disadvantages of migrating to a different operating system in place of IRIX. The two candidates were Windows and Linux, with Linux coming out ahead based on overall flexibility and the easier migration method. The DMOC DIS Filter is still a Linux based application and there are no plans for another operating system migration.

Over the years, different capabilities have been added and other modifications have been made as needed based on specific customer requirements.

3. DMOC DIS Filter Capabilities

The DMOC DIS filter is a Linux application that is designed to run on a PC with at least two UDP broadcast network interfaces. The application passes data in either direction between those interfaces and is designed to only pass DIS protocol UDP packets.

The DMOC's DIS Filter features a multitude of filtering and transformation capabilities which have been developed based on the requirements of a large, distributed exercise. Following is an overview of those capabilities as they exist today.

3.1 Route Creation and Configuration

At the heart of the DMOC DIS filter is the route. In terms of the DIS filter a route is defined as the path between two UDP broadcast DIS protocol networks which the DIS filter passes data. Up to sixteen routes can be defined for a given DIS filter, each configured to send data, filtered based on a number of criteria, in a specified direction between networks.

3.2 Broadcast UDP to Broadcast UDP

The first step in configuring a route in the DIS Filter is to determine the UDP networks which comprise it. The IP address, UDP port and DIS exercise ID of each network are specified in this configuration.

3.3 DIS PDU Type Filter

Once a route is configured at the network level the filtering specifications may be set. The first of these filters is the DIS PDU Type Filter. The DMOC DIS Filter does not accept all types of PDUs, but rather a subset of DIS PDUs used in Virtual Flag exercises. This subset of PDUs has expanded over the years as requirements emerge.

Figure 3.1- DIS PDU Type Filter

3.4 Site Application Entity Id Filter

The next Filter is logically ANDed in the DIS Filter's logic with the DIS PDU Type Filter and is called the Site Application Entity Id Filter. If a given DIS PDU is allowed to pass as specified by the PDU Type Filter it is then tested by its Site, Application and Entity Id in a list as either allowed or denied as specified by the user. This filter does allow a wildcard character so that all PDUs from a given Site or Site and Application match may be specified without having to go into the full detail of including each Site or Entity Id. The default for this filter is to allow all Site, Application and Entity Ids.

3.5 Entity State Enumeration Filter

The next two filters are logically ANDed with the previous filter but are logically ORed so that only one or the other may be used in a given route. Like the previous filter, the default is to allow all PDUs which have passed the previous filters to be passed through.

The Entity State (ES) Enumeration Filter is used to Allow or Deny Entity State, Fire and Detonation PDUs based on their Entity Type enumeration. The user creates a list that is line delimited and contains enumerations in the 000-000-0000-000-000-000-000 format, with wildcards allowed in any of the seven portion of an Entity Type enumeration. This list is specified in the filter and then either allowed or denied as specified by the user.

3.6 Entity State Range Filter

Building off of the Entity Type enumeration filter, the user may allow or deny a list of Entity State PDUs based on their Entity Type enumeration within a spherical or cylindrical range about an entity or geographic region. Entities that exist within the given range specified are the only ones that will be passed using this filter.

3.7 DIS Header Version Transformation

There are some simulations that are only compatible with a specific version of DIS and do not process older or newer versions. The DMOC DIS filter has the capability of converting the version number in the header of PDUs in a given route so that they appear to be of a different version to meet the requirements of a simulation that expects a distinct version of DIS.

3.8 Entity State Enumeration Transformation

Some simulations, virtual and constructive do not have an internal model for the variety of Entity Type enumerations that may exist in an exercise. There are times that they support a model that is close and for that reason the Entity State (ES) Enumeration Transformation was created in the DIS Filter.
The ES Enumeration Transformation reads a user-generated file that is line delimited. The first item on each line is the Enumeration (in 000-000-0000-000-000-000-000 form) to be converted, followed by a text description and then the Enumeration to be converted too, followed by a text description. The filter then converts each Entity State PDU to contain the second enumeration for every PDU containing the first.

3.9 Data Link Signal Format Deny Filter

This filter denies any Raw Binary Data Signal PDU that is in either the TACCSF-J or SISO-J format.

3.10 Data Link Signal Format Conversion

One of the early specifications used to represent Link-16 in the DIS environment was the TACCSF-J Signal PDU format developed in the 1990s. As Link 16 fidelity requirements evolved, the DMOC supported development of the SISO-STD-002-2006 “SISO-J” format.

This DMOC DIS Filter transformation converts between the two formats including the addition (SISO-J) or subtraction (TACCSF-J) of an accompanying Transmitter PDU. The VF Link-16 environment is primarily SISO-J, but features several simulations which utilize TACCSF-J.

3.11 Transmitter/Signal SAE Transformation

This transformation changes the Site, Application and Entity IDs in Transmitter and Signal PDUs on a given route as specified by the user.

3.12 Entity State Heartbeat Specification

The VF exercise plan calls for an entity state heartbeat of 5 seconds for air based and 55 seconds for ground and sea based entities.

There are some simulations which do not feature to capability to change their heartbeat value by the user, leading to this DIS Filter feature. It will change the Entity State PDU heartbeat of a specified simulation to a user selectable value. This transformation utilizes the Dead Reckoning algorithm specified in the ES PDU to accurately model the entity which it is transforming.

3.13 Auto Subscribe for DIS Audio

The Auto Subscribe function of the DMOC DIS Filter enables a site to dynamically allow only those Encoded Audio Signal PDUs containing DIS Voice to which their radios are currently tuned.

By monitoring the Transmitter PDUs of an end site, this function only sends the DIS voice on the frequencies to which the end site is listening, providing a very useful feature in the Virtual Flag environment where many different frequencies in use that may overwhelm a DIS voice application.

3.14 Transmitter/Signal Frequency Filter

The Transmitter/Signal Frequency Filter denies or allows Transmitter and Signal PDUs over a given route based on the frequency value in the PDU.

3.15 IFF Mode IV Conversion

The DMOC DIS Filter provides the capability of converting between primary and alternate Mode IV IFF. This function is used primarily for simulations that can not alter their modes as a user-definable function.

3.16 Display GUI

The main display GUI of the DMOC DIS Filter also features useful tools to monitor DIS traffic traveling throughout a given route. The first is the monitor window that allows a user to display the packets passed through a given route and at the individual PDU level those sent, received and rejected over a route. The next allows the user to search for PDUs from a specific Site Application and Entity Id (with wildcards allowed) being passed through the filter, providing the user with the specific route, if it was passed, the PDU type and the Entity Type enumeration for Entity State PDUs.

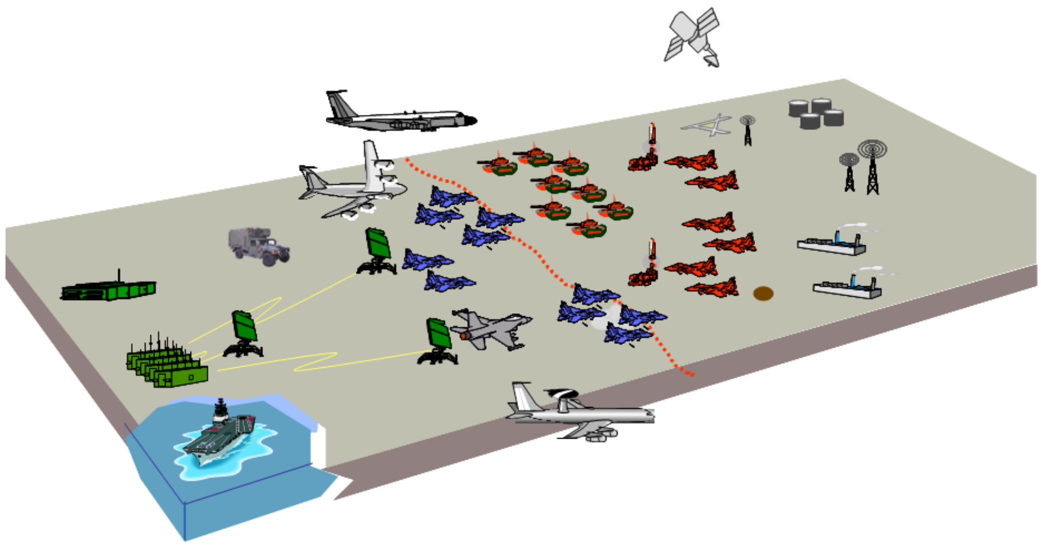

Figure 4.1- A Crowded Distributed Battlespace

4. DMOC DIS Filter Methodologies

The method in which the DMOC DIS Filter is to be employed is to have various systems connected using the DIS Filter as a go-between from a common LAN that contains all network traffic. An example of several systems connected through the DIS Filter is illustrated below in Figure 4.2.

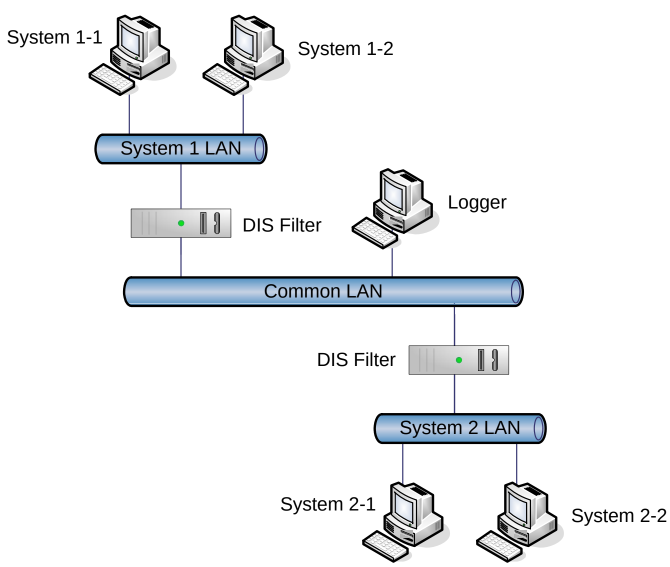

Figure 4.2- Example Networked Usage of the DMOC DIS Filter

The illustration above consists of a Common LAN containing all event traffic and two separated, system specific LANs that are connected through the DIS Filters to a Common Local Area Network (LAN).

After reviewing the capabilities of the DMOC DIS Filter, the user can then determine appropriate filtering and transformation settings for their own usage. In the testing and experimental environment these capabilities can be used in many different and useful ways. The following sections feature examples of how theses capabilities have been used in testing based events.

4.1 DIS Data Separation

The first screen that a user is introduced to upon starting the DMOC DIS Filter is the route window. This starting point for the application features the important capability of port and DIS exercise ID transformation between connections. In a testing environment this function allows the user to separate data on a network by either method as well as combine data that originated from different sources and routed using differing network paths.

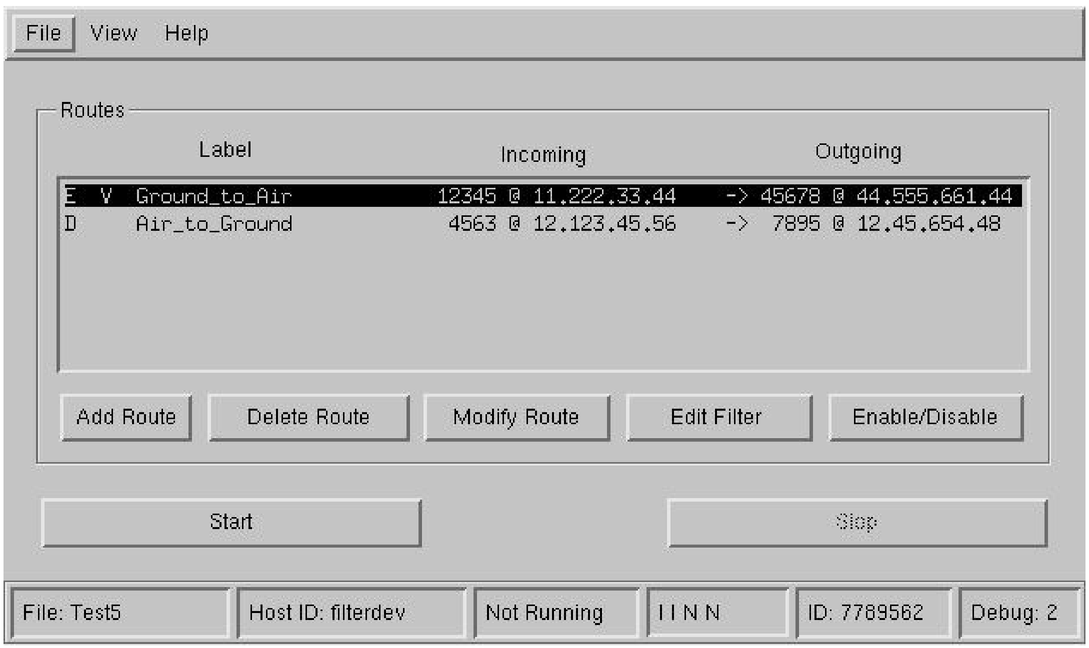

Figure 4.3- DMOC DIS Filter Main GUI

For example, if there are two systems on a network that the user determines should not communicate but should be accessible to other systems; this can be accomplished following two steps. First, both systems are setup using either different ports and or DIS exercise IDs on network one. At the DIS Filter two routes are then created to obtain data from the two different systems and then combine them onto network two. Going the other way, two routes can then be established starting with data originating on network two and sent to both systems.

This type of capability can be useful in instances where two systems exist in the same facility, residing on the same network but have different purposes. This data separation would be necessary if one system either could not handle the traffic of the other or if interoperability problems existed or if there was some security reason.

4.2 Simulation Protection and Content Selection

In just about any distributed simulation event there exists a high volume of network traffic. In larger scale testing events, that volume of traffic is typically created to satisfy the requirements of multiple participants. Most simulations and especially those meant to be used in the testing environment simply cannot handle this high volume of traffic and maintain full functionality. Additionally, because a distributed event contains traffic meant for different purposes, all of it just is not relevant to any one simulation. Superfluous network traffic can easily crash degrade a simulation. In this case the DMOC DIS Filter can then be used to block unnecessary traffic to both protect the simulation and manage network content.

In DIS, each simulation is identified by a unique Site and Application Identifier and each individual entity is represented by an Entity Identifier. The DMOC DIS Filter's Site App Entity Id filter can be used to allow or deny various systems by their DIS identifiers. This particular filter also allows the use of a wildcard character giving the user the option to allow or deny based on any combination of the three identifiers.

For the most part a particular Site and Application Identifier combination represents a system with a particular function. In DMOC distributed events, the Virtual Simulation participants know which of those functions they need and therefore the right systems. Because of this, the user can set up the DIS Filter's Site App Entity Id filter so that the receiving SIM only gets the network traffic they want for relevance and to aid in protecting it from an extraneous network load.

4.3 PDU Level Filtering (Digital Voice Too) and Transformation

After determining the systems from which a given simulation is to receive data from the DMOC DIS Filter gives the user the capability of filtering further from those systems or even transforming certain parts of the data based on changing requirements.

Some Constructive Simulations can produce entity counts in the thousands covering a large range of capabilities and domains. In DMOC Distributed testing events there have been instances where a particular system produces Air, Land and Sea domain entities and a particular Virtual Simulation only requires entities from one of those domains. In other instances a Virtual System's requirements only encompass several entities from a Constructive Simulations catalog of thousands. To provide the requirements at the domain and entity level, the user would use the Entity State Enumeration filter to allow specific entities.

Most Virtual Simulations have a certain range of situational awareness wherein their visual and sensor systems can properly process data. In DMOC distributed test events there is always a defined theatre in a specific geographic area. For reasons of content and requirements management as well as another form of simulation protection, the DMOC DIS Filter features an entity state range filter. Using this filter, the user can pass entity information to a simulation about a given geographic point or even as a radius about a given entity using its Site Application Entity Identifier.

Some simulations that are used expressly in the testing and experimental environment are highly proprietary and are not exactly all that compatible with other systems. A common occurrence is a simulation that does not model certain entities that it requires. Using the DIS Filter's enumeration transformation function the user can change the DIS enumeration for any entity to another, providing that simulation with an entity that it requires modeled as something that it understands.

Tactical data link modeling in the military modeling and simulation arena has evolved over the years to meet new real life requirements and to offer higher fidelity for trainees. In the mid 1990s, the TACCSF (DMOC predecessor) developed a method to model Link-16 tactical data links using the DIS Signal PDU, this method was known as TACCSF-J. Following the formal introduction of the IEEE 1278-1 1995 DIS Standard, the Simulation Interoperability Standards Organization (SISO) was established to maintain it. Several years ago, SISO created an updated signal PDU data link modeling method to provide higher fidelity and adhere to the latest Link-16 standard, known as SISO-J. Most systems that participate in DMOC events use either the TACCSF-J or SISO-J standard and they are not compatible. The DMOC DIS Filter features a transformation function to translate between the two based on particular simulation requirements.

Digital voice modeled in DIS can overwhelm a Simulation based on Network traffic volume in a larger distributed test event. DIS Digital Voice is modeled by frequency and so a receiving simulation really only needs to get the data from those that it is monitoring. The DMOC DIS Filter offers the user two methods by which they can limit the amount of communications data. The user can limit data by frequency or can allow the DIS Filter to dynamically adjust the voice data they receive using the auto-subscribe function.

4.4 New DIS PDU Types Testing

The Air Force Research Laboratory sponsored Advanced Concept Event (ACE) is held once a year to experiment with emerging technology in a distributed battlespace environment. It is centrally controlled from the DMOC with networked participants across the United States. Scenarios for ACE are developed to satisfy the requirements of participants that may or may not interact and to incorporate not only experimental platforms but also new DIS capabilities.

The latest version of the IEEE 1278-1 DIS standard, currently in SISO balloting and likely to be formally released some time in 2008, features new PDUs that are used to represent Directed Energy, to include laser and microwave technology. The 2006 and 2007 ACE events were testing venues for these new PDU types. This venue allowed for the testing of a new capability in systems that actually utilize them, for which no method to accurately model them previously existed.

Because the ACE event is controlled from the Air Force DMOC facility and the DIS Filter is an internally developed product this new capability was added to the application in weeks. This shortened development timeline allowed for these new PDUs to be used in the event with little notice by adding them to the DIS Filters PDU type filter. Using data separation, content selection and PDU level filtering ACE planners were able to ensure that this experimental data was used appropriately and tested appropriately.

5. Conclusion

In any DIS based event, the planner has many considerations in regard to providing the best experience to each participant in form of content. Because of modern network appliances, it is possible to support large amounts of data from an infrastructure standpoint. However, from a simulation technical capability and experimental requirements viewpoint, it usually does not make sense to send the large amounts of DIS data that comprise a large distributed event to each of the participating virtual simulations.

From the strictly technical side, a simulator may not be able to process all the interactions from a large DIS event. Additionally, they likely cannot display the large number of platforms due to individual fidelity and hardware limitations. From the testing and experimental side, there are interactions in a large-scale distributed event that are simply not applicable to all participants. Furthermore, specially designed pieces of theses events may be tailored to only one or few participants.

With these reasons in mind, the USAF DMOC deemed it necessary to build upon previous experience in distributed exercises and network appliances to create a standalone DIS Filter application. The capabilities of the DMOC DIS filter were initially designed and have been refined over the years to address the issues presented by technical limitations and event participant requirements.

Using the capabilities of the DIS Filter, it is possible to support almost any number of simulations while remaining within the confines of numerous technical limitations and requirements. The methodologies discussed in this document outline typical usage of the DIS Filter in testing and experimental events, providing the basis for event planning that considers each system. These methodologies have some similarities among various simulations and requirements, leading to the conclusion that the DMOC DIS filter can be applied to any number of other DIS-based systems and events.

5. Biography

STEVE PADILLA is a Systems Engineer, working for Scientific Research Corporation at the United States Air Force Distributed Mission Operations Center at Kirtland Air Force Base in New Mexico. He has written specifications for several DMOC systems including the DMOC DIS Filter and worked as the technical lead for many small to large distributed simulation events. He holds a Bachelor of Science degree in Electrical Engineering from the New Mexico Institute of Mining and Technology.