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IEEE Standard for Distributed Interactive Simulation (DIS)— Communication Services and Profiles

IEEE Computer Society

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SISO Standards Activity Committee

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USA

IEEE Std 1278.2™-2015
(Revision of
IEEE Std 1278.2-1995)

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Abstract: Communication services to support information exchange between simulation applications participating in the distributed interactive simulation (DIS) environment are defined. These communication services describe a connectionless information transfer that supports real-time, as well as non-real-time, exchange. Several communication profiles specifying communication services are provided.

Keywords: communication service, DIS, distributed interactive simulation, IEEE 1278.2™, multicast, protocol data units (PDUs), simulation network

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Introduction

This introduction is not part of IEEE Std 1278.2™-2015, IEEE Standard for Distributed Interactive Simulation (DIS)—Communication Services and Profiles.

Distributed interactive simulation (DIS) is a government/industry initiative to define an infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual worlds for the simulation of highly interactive activities. This infrastructure brings together systems built for separate purposes, technologies from different eras, products from various vendors, and platforms from various services and permits them to interoperate. DIS exercises are intended to support a mixture of virtual entities with computer-controlled behavior (computer-generated forces), virtual entities with live operators (human-in-the-loop simulators), live entities (operational platforms and test-and-evaluation systems), and constructive entities (war games and other automated simulations). DIS draws heavily on experience derived from the simulation networking (SIMNET) program developed by the Advanced Research Projects Agency (ARPA), adopting many of SIMNET's basic concepts and heeding lessons learned.

In order for DIS to take advantage of currently installed and future simulations developed by different organizations, a means had to be found for assuring interoperability between dissimilar simulations. These means were developed in the form of industry consensus standards. The open forum (including government, industry, and academia) chosen for developing these standards was a series of semi-annual Workshops on Standards for the Interoperability of Distributed Simulations that began in 1989. The workshops resulted in several IEEE standards and recommended practices.

The relationship between the component documents constituting the set of IEEE DIS documents is shown in Figure 1. Used together, these standards and recommended practices will help produce an interoperable simulated environment.

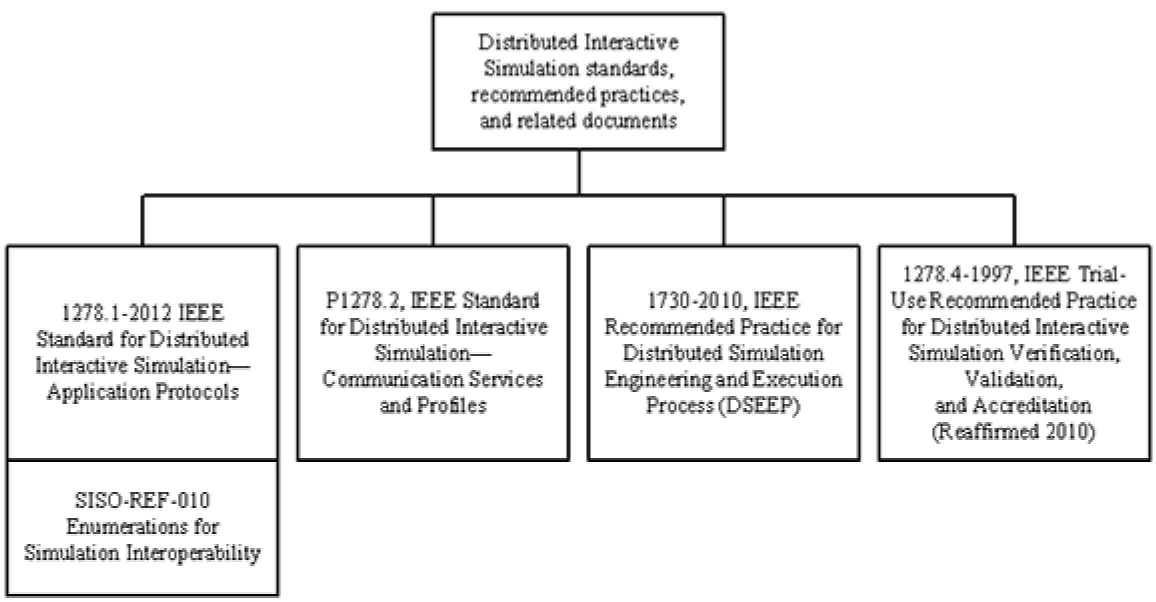

Figure 1—IEEE DIS documents

The interoperability components addressed by these standards and recommended practices are:

— Application protocols

— Communication services and profiles

— Distributed simulation engineering and execution

— Verification, validation, and accreditation

IEEE Std 1278.1™-2012 defines the format and semantics of data messages, also known as protocol data units (PDUs), that are exchanged among simulation applications and simulation management. The PDUs provide information concerning simulated entity states, types of entity interactions that take place in a DIS exercise, data for management and control of a DIS exercise, simulated environment states, aggregation of entities, and the transfer of ownership of entities. IEEE Std 1278.1-2012 also specifies the communication services to be used with each of the PDUs.

An additional non-IEEE document is required for use with IEEE Std 1278.1-2012. This document is entitled "Enumerations for Simulation Interoperability" and is available from the Simulation Interoperability Standards Organization, Orlando Florida.

This standard, IEEE Std 1278.2-2015, defines the communication services required to support the message exchange described in IEEE Std 1278.1-2012. In addition, IEEE Std 1278.2-2015 provides several communication profiles that meet the specified communications requirements.

IEEE Std 1730™-2010 is recommended practice defining the processes and procedures that should be followed by users of distributed simulations to develop and execute their simulations. It is intended as a higher-level framework into which low-level management and systems engineering practices native to user organizations can be integrated and tailored for specific uses. This recommended practice is intended to replace IEEE Std 1278.3™-1996. This recommended practice is used in conjunction with IEEE Std 1278.1-2012 and IEEE Std 1278.2-2015.

IEEE Std 1278.4™-1997, IEEE Trial-Use Recommended Practice for Distributed Interactive Simulation Verification, Validation, and Accreditation, provides guidelines for verifying, validating, and accrediting a DIS exercise. This recommended practice, used in conjunction with IEEE Std 1730-2010, presents data flow and connectivity for all proposed verification and validation activities and provides rationale and justification for each step.

The principal changes between IEEE Std 1278.2-1995 and the present standard are as follows:

a) Incorporation of rules on PDU bundling

b) Addition of section on the use of Multicast for Interest Management

c) Definition of Internet Protocol Version 4 (IPv4) multicast service profile

d) Definition of Internet Protocol Version 6 (IPv6) multicast service profile

e) Addition of rules on maximum transmission unit (MTU)

f) Reorganization of the document to aid readability and create a more logical place for new content such as IPv6 and interest management

g) Addition of annex providing guidance for using IP multicast addressing

Contents

IEEE Standard for Distributed Interactive Simulation (DIS)— Communication Services and Profiles

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1. Overview

1.1 General

This standard specifies the communication service requirements and applicable profiles required for use with distributed interactive simulation (DIS) communication systems. This standard is divided into six clauses and associated informative annexes. Clause 1 provides the scope and purpose of the standard and key assumptions concerning the DIS applications using the standard. Clause 2 lists references to other standards that are required for use with this standard. Clause 3 provides a list of definitions of terms and acronyms that are used in this standard. It is imperative for the user of this standard to thoroughly review these definitions before proceeding on to other clauses. Clause 4 contains requirements concerning the communication services at the network and transport layers that are necessary to support DIS communications. Clause 5 contains requirements to support DIS communication in the application layer. Clause 6 details the profiles recommended for use by DIS systems. These profiles support the required communication services described in Clause 4 and Clause 5. Annex A provides guidance for using IP multicast addressing. A bibliography is provided in Annex B.

The communication services definition for DIS employs a layered model that supports both the four-layer Internet model defined in RFC 1122[1] and the seven-layer Open Systems Interconnection Reference Model (OSIRM) defined in ISO/IEC 7498-1:1994. The communication functions of the network are divided into a hierarchical set of layers. Each layer performs an integral subset of special functions required to communicate with another layer of similar type.

[1]Information on references can be found in Clause 2

Examples of DIS functions provided by each layer are listed in Table 1.

Table 1—DIS functions by layer

Internet Model Layer	OSI Reference Model Layer	Example of content	Service Requirements for DIS
4. Application	7. Application	PDU Bundling PDU sizing for MTU Interest management	Clause 5
	6. Presentation	Data compression	
	5. Session	Connection establishment Session Initiation	
3. Transport	4. Transport	Application to application addressing (port) Best effort and reliable mechanisms	Clause 4
2. Internet	3. Network	Unicast, broadcast, and multicast host computer to host computer addressing	
1. Link	2. Data Link	Ethernet framing Media Access Control (MAC) addressing	
	1. Physical	Category 5 cable, fiber optic cable	

To avoid confusion between the Internet and OSI models, the layer numbers are not used in this standard, rather, the OSI layer names are used. Any services that appear in the presentation or session layers in the OSI reference model are usually considered to be in the application layer in the Internet model. This standard addresses the communication services in the network/transport layers (Clause 4) and the application layer (Clause 5). The lower layers (data link and physical) are generally a matter of detailed network infrastructure and are not addressed in this standard. Services that are not common to DIS simulations are not addressed. This does not prevent DIS exercises from using those services if necessary.

Profiles are a defined set of technologies that meet the service requirements defined in Clause 4 and Clause 5. Clause 6 includes several profiles that are typical for DIS exercises. It is up to the users to determine which profile will satisfy the requirements for a particular exercise. Other profiles are possible and are allowed for use by DIS simulations where necessary.

The PDUs detailed in IEEE Std. 1278.1™ define the common language by which simulation applications communicate. This includes simulators of different and unrelated design and architecture, including instrumented live platforms and virtual and constructive simulations. The only restriction placed on the participating simulator or site is the way it communicates within a DIS exercise.

Where the DIS PDUs define the information passed between simulation applications, this standard defines how the host computers for those simulation applications can be connected in a modular fashion to facilitate the communication at the local and global levels. This will be done through the required use of communications standards that promote interoperability.

1.2 Scope

This standard establishes the requirements for the communication services to be used in a DIS simulation. This standard supports IEEE Std 1278.1.

1.3 Purpose

The purpose of this standard is to establish requirements for communication subsystems that support DIS applications. This standard provides service requirements and associated profiles that can be individually selected to meet specific DIS system operational requirements.

1.4 Key assumptions

This standard makes a number of assumptions about underlying requirements of the DIS application and how they will be applied. The assumptions are as follows:

a) *Real-time considerations*: Many DIS applications operate in a real-time environment that includes live, virtual and constructive simulations. This type of environment requires timeliness in the exchange of information.

b) *DIS network topology*: DIS applications within a site are connected via a local-area network (LAN). Sites are connected to other sites via a wide-area network (WAN). This standard defines the functional and performance characteristics that will be satisfied by both LAN and WAN communications service.

c) *Multi-architecture environments:* DIS applications participate in multi-architecture environments where other simulation applications are using different protocols and architectures. Nothing in this standard precludes a DIS application from participating in a multi-architecture environment. Multi-architecture requirements to allow DIS to interoperate with other architectures and protocols are beyond the scope of this standard.

d) *Multiple exercises*: DIS has the ability to accommodate multiple exercises over the network by assigning each exercise a different exercise identifier. Exercise identifiers are assigned by a procedure outside the scope of this standard.

e) *Non-protocol data unit (PDU) traffic*: The communication service is specified to support several types of data transmission, not just DIS PDUs. Non-PDU data can coexist on the same network along with DIS PDUs. Examples of non-PDU traffic include voice and video communications used for exercise coordination.

f) *Network management requirements*: This standard neither recommends nor precludes the use of network management protocols.

g) *Security*: Security requirements and methods are outside the scope of this standard.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 1278.1™, IEEE Standard for Distributed Interactive Simulation—Application Protocols.[2,3]

ISO/IEC 7498-1:1994, Information technology—Open Systems Interconnection—Basic Reference Model: The Basic Model.[4]

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RFC 768, User Datagram Protocol.[5]

RFC 791, Internet Protocol.

RFC 793, Transmission Control Protocol.

RFC 1122, Braden, R., Requirements for Internet Hosts—Communication Layers.

RFC 2460, Internet Protocol, Version 6 (IPv6) Specification.

RFC 3493, Basic Socket Interface Extensions for IPv6.

RFC 3973, Protocol Independent Multicast—Dense Mode (PIM-DM): Protocol Specification (Revised).

RFC 4601, Protocol Independent Multicast—Sparse Mode (PIM-SM): Protocol Specification (Revised)

RFC 4604, Using Internet Group Management Protocol Version3 (IGMPv3) and Multicast Listener Discovery Protocol Version 2 (MLDv2) for Source-Specific Multicast

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. [6]

application layer: The layer of the OSI Reference Model (ISO/IEC 7498-1: 1994) that provides the means for simulation applications to access and use the network's communications resources.

best effort service: A communication service in which transmitted data is not acknowledged. Such data typically arrives in order, complete, and without errors. However, if an error occurs, or a packet is not delivered, nothing is done to correct it (e.g., there is no retransmission).

broadcast: A transmission mode in which a single message is sent to all network destinations, (i.e., one-to-all). Broadcast is a special case of **multicast**.

cell: A volume of a routing space defined by the intersection of a given segment on each dimension. Each cell is assigned one unique multicast address.

communication service: network software and infrastructure that provide the means to convey data between computers and processes.

data link layer: The layer of the OSI Reference Model that provides the functional and procedural means to transfer data between stations, and to detect and correct errors that can occur in the physical layer.

datagram: A unit of data that is transferred as a single, non-sequenced, unacknowledged unit.

dimension: An axis of a routing space. Dimensions are divided into two or more segments.

[5]Internet Requests for Comments (RFC) are available at http://www.rfc-editor.org/
[6]*IEEE Standards Dictionary Online* subscription is available at:http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

dimension criteria: The logical rules using protocol data unit (PDU) information to determine the segment on each dimension to which the PDU maps, ultimately determining the multicast address used to issue the PDU.

distributed interactive simulation (DIS): A time-and-space coherent synthetic representation of world environments designed for linking the interactive, free-play activities of people in operational exercises. The synthetic environment is created through exchange of data units between distributed simulation applications in the form of simulations, simulators, and instrumented equipment interconnected through standard computer communicative services. The simulation applications can be present in one location or can be distributed geographically.

exercise: See: **simulation exercise**.

host computer: A computer that supports one or more simulation applications. All host computers participating in a simulation exercise are connected by network(s) including local-area networks (LANs), wide area networks (WANs), radio frequency links, etc.

interest management: A means to reduce bandwidth and processing resources by causing a protocol data unit (PDU) to be received by only the simulation applications that are interested in it.

local-area network (LAN): A communications network designed for a moderate size geographic area and characterized by moderate to high data transmission rates, low delay, and low bit error rates.

long-haul network: See: **wide-area network**.

multicast: A transmission mode in which a single message is sent to multiple network destinations, (i.e., one to many).

network layer: The layer of the OSI Reference Model that performs those routing and relaying services necessary to support data transmission over interconnected networks.

network management: The collection of administrative structures, policies, and procedures that collectively provide for the management of the organization and operation of the network as a whole.

node: A general term denoting either a switching element in a network or a host computer attached to a network.

non-real-time service: Any service function that does not require real-time service.

Open Systems Interconnection Reference Model (OSIRM): A model that organizes the data communication concept into seven layers and defines the services that each layer provides.

peer: Elements of a distributed system that communicate with each other using a common protocol.

physical layer: The layer of the OSI Reference Model that provides the mechanical, electrical, functional, and procedural characteristics access to the transmission medium.

presentation layer: The layer of the OSI Reference Model that frees the application processes from concern with differences in data representation.

profile: A set of one or more base standards, and, where applicable, the identification of chosen classes, subsets, options, and parameters of those base standards, necessary for accomplishing a particular function. In this standard that function is to provide communication services appropriate for DIS simulation applications.

protocol: A set of rules and formats (semantic and syntactic) that determines the communication behavior of simulation applications.

protocol data unit (PDU): A DIS data message that is passed on a network between simulation applications according to a defined protocol.

NOTE— The term PDU is used in this standard to refer to application layer PDUs (as defined in IEEE Std 1278.1) that are passed on a network between application processes.[7]

protocol suite: A defined set of complementary protocols within the communication service profile.

real-time: A mode of simulation operation where 1s of real world time, as measured by a chronometer, equals 1s of simulation time.

real-time service: A service that satisfies timing constraints imposed by the service user. The timing constraints are user specific and are such that the user will not be adversely affected by delays within the constraints.

reliable service: A communication service in which the received data is guaranteed to be exactly as transmitted.

routing space: A set of zero or more orthogonal dimensions used to describe the partition of transmissions for interest management. There can be multiple routing spaces in an exercise but they cannot intersect in any way.

routing space criteria: The logical rules using protocol data unit (PDU) information to determine the routing space to which a PDU maps.

segment: A subdivision of a dimension in a routing space. At least two segments are defined per dimension. Each segment has explicit lower and upper bounds along the dimension or a defined discrete value to place it on the dimension.

session layer: The layer of the OSI Reference Model that provides the mechanisms for organizing and structuring the interaction between two entities.

simulation application: The executing software on a host computer that models all or part of the representation of entities, other objects and elements within the synthetic environment. The simulation application represents or simulates real world phenomena for the purpose of training or experimentation. Examples of simulation applications include manned vehicle simulators, computer generated forces, environment simulators, and computer interfaces between a distributed interactive simulation (DIS) network and real equipment. The simulation application receives and processes information concerning entities created by peer simulation applications through the exchange of DIS protocol data units (PDUs). More than one simulation application can simultaneously execute on a host computer. The simulation application is the application layer protocol entity that implements the protocol defined in this standard.

NOTE— The term simulation can also be used in place of simulation application.

simulation entity: An element of the synthetic environment that is created and controlled by a simulation application and affected by the exchange of distributed interactive simulation (DIS) protocol data units (PDUs). Examples of types of simulated entities are: tank, submarine, carrier, fighter aircraft, missiles, bridges, or other elements of the synthetic environment. It is possible that a simulation application can control more than one simulation entity.

NOTE— Simulation entities are also referred to as entities in this standard.

[7]Notes to text, tables, and figures are for information only and do not contain requirements needed to implement the standard.

simulation exercise: An exercise that consists of one or more interacting simulation applications. Simulations participating in the same simulation exercise share a common identifying number called the exercise identifier. These simulations also utilize correlated representations of the synthetic environment in which they operate.

simulation host: See: **host computer**.

simulation site: The location of one or more simulation hosts connected by a local-area network (LAN).

synthetic environment: The integrated set of data elements that define the environment within which a given simulation application operates. The data elements include information about the initial and subsequent states of the terrain including cultural features, and atmospheric and oceanographic environments throughout a distributed interactive simulation (DIS) exercise. The data elements include databases of externally observable information about instantiable DIS entities, and are adequately correlated for the type of exercise to be performed.

transport layer: The layer of the OSI Reference Model that accomplishes the transparent transfer of data over the established link, providing an end-to-end service with high data integrity.

unicast: A transmission mode in which a single message is sent to a single network destination, (i.e., one to one).

wide-area network (WAN): A communications network designed for large geographic areas. Sometimes called long-haul network.

3.2 Acronyms and abbreviations

The following acronyms are used in this standard:

DIS	distributed interactive simulation
GRE	generic routing encapsulation
IGMP	Internet Group Management Protocol
IP	Internet protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 5
LAN	local-area network
MLD	multicast listener discovery
MMS_R	maximum message size that can be received
MTU	maximum transmission unit
OSIRM	Open Systems Interconnection Reference Model
PDU	protocol data unit
PIM	protocol Independent multicast
QoS	Quality of Service
RTP	real-time transport protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
WAN	wide-area network

4. Network/transport layer service requirements

4.1 Requirements overview

The purpose of the communication services for DIS is to provide an appropriate interconnected environment for effective integration of locally and globally distributed simulation entities. There are many diverse aspects of this integration, ranging from the nature of the entities represented within the common simulated environment, to the common communication interface used for receiving information from other simulators. This standard is concerned only with the necessary communication system standards that are used to support the integrated framework.

This clause contains the requirements for DIS communication services provided by the network and transport layers. These requirements include support of large-scale DIS applications. The network and transport layers services are general in purpose and not specific to DIS applications. These services are commonly provided by the network software that is included in most computer operating systems. The services required to be provided by the communication subsystem of DIS applications are divided into three categories:

- Communication service classes
- Performance
- Error detection

These service requirements are based on experience with state-of-the-art distributed simulation activities as well as projections based on anticipated use and evolution of the technology base.

4.2 Communication service classes

4.2.1 General

The capability of a single simulation to send PDUs to a group of other simulation hosts is a fundamental requirement of a network supporting DIS exercises. Certain PDUs can be sent point to point.

IEEE Std. 1278.1 specifies the use of three classes of communication service as follows:

- *Class 1:* best-effort multicast communication service
- *Class 2:* best-effort unicast communication service
- *Class 3:* reliable unicast communication service

The use of the term “multicast” in this context is in the sense of “one-to-many” communication, which by definition includes both multicast and broadcast addressing. This is in contrast to Internet Protocol (IP) multicast addressing, which does not include broadcast. To keep the distinction clear, this standard is consistent in use of “best-effort multicast communication service” for the former and “multicast addressing” for the latter.

4.2.2 Class 1: best-effort multicast communication service

Class 1 service is a mode of operation where PDUs are issued with a one-to-many address mechanism that allows the PDU to be sent once and received by multiple host computers simultaneously. This shall be achieved either by broadcast or multicast addressing. This service class shall add no mechanisms for reliability except those inherent in the underlying service.

Broadcast addressing, the minimal form of best-effort multicast communication service, shall consist of simultaneous transmittals to a group consisting of all host computers on a LAN.

NOTE— PDUs addressed with broadcast do not typically pass through routers so it is limited to simple LAN topologies. Gateways are required to convert broadcast addressing into either multicast or unicast to allow more complex network topologies.

Multicast addressing, a more general form of addressing, shall allow one-to-many communication to a group that is a subset of all host computers and shall allow individual simulation applications to join a group of interest. Multicast addressing should be supported by all simulation applications.

For networks employing multicast service beyond the minimal broadcast form, the following services shall be required to support DIS:

a) A multicast addressing group shall be able to include members anywhere on the network.
b) The maximum number of members in a single multicast group shall be large enough to encompass all host computers within the DIS system supported by the multicast network.
c) The multicast service shall have the capability to support multiple, independent exercises sharing the same networks.

4.2.3 Class 2: best-effort unicast communication service

Class 2 service is a mode of operation where the service provider shall use no added mechanisms for reliability except those inherent in the underlying service. PDUs using Class 2 service shall use individual addressing, implying a one-to-one form of communication. A PDU shall be issued multiple times if there is more than one simulation application that is required to receive it.

4.2.4 Class 3: reliable unicast communication service

Class 3 service is a mode of operation where the unicast service provider shall use whatever mechanisms are available to help ensure that the PDUs are delivered in their original sequence with no duplications, no missing PDUs, and no detected errors. Like Class 2, the PDU shall be issued using individual addressing.

4.3 Performance

4.3.1 General

This subclause describes the performance requirements for a particular DIS exercise. The performance requirements specified in this subclause refer to network bandwidth and quality of service (QoS). These performance requirements are the basis for selection of network hardware and software in a DIS exercise.

4.3.2 Network bandwidth requirements

Network bandwidth requirements are exercise specific and shall be determined on a per-exercise basis.

4.3.3 Quality of service (QoS) requirements

4.3.3.1 Introduction

The QoS parameters defined here, and their associated requirements, provide guidance for communication networks that will promote the reliable and timely exchange of DIS data. Although a DIS exercise or activity can choose to use over-provisioning of bandwidth (i.e., obtaining enough bandwidth to account for estimated peak loading plus a reserve capacity) as the primary means of meeting QoS requirements, this may not be sufficient to meet all QoS requirements.

Where routers are present, the ability to configure routers to allow, for example, the prioritization of PDU packets and processing-specific priority inside a packet header received from a simulation application is available. In addition, a simulation application can reduce or eliminate certain QoS issues by software application functionality related to the transmission or reception of DIS data. This has been successfully used, for example, to reduce or eliminate network jitter related to streaming voice data.

A minimum set of recommended QoS parameters and basic transport-to-transport latency classes are provided in this standard for guidance only. The actual QoS parameters, their associated criteria and values, are defined by appropriate program agencies or as agreed upon by participants in a DIS exercise or activity. In the latter case, requirements related to QoS are expected to be contained in an exercise agreement or other appropriate documentation.

4.3.3.2 QoS classes

Two QoS classes, as a minimum, are required. They are as follows:

a) *High:* The QoS required to meet requirements related to such things as maintaining a required level of realism, critical real-time interactions, and data used by real-time visual or other sensor models are satisfied.

b) *Normal:* The QoS required to meet all other participant requirements.

4.3.3.3 QoS parameters

The following are the minimum QoS parameters required to be implemented for DIS applications:

a) *Transport-to-transport latency*: Total acceptable latency between any two simulators, from the input of the transport layer at the sending simulator to the output of the transport layer at the receiving simulator.

b) *Transport-to-transport acceptable reliability*: Percentage of PDUs to be delivered within the transport-to-transport acceptable latency, with remaining PDUs randomly distributed over the entire stream of PDUs.

c) *Transport-to-transport jitter*: Maximum dispersion of latency among any sequence of PDUs for those PDUs falling within the transport-to-transport acceptable reliability fraction.

d) *Transport-to-physical acceptable latency*: Maximum latency between the input of the Transport layer and the output of the Physical layer of any DIS simulation.

Table 2 provides a minimum set of recommended QoS parameters and associated values.

Table 2—QoS parameter and recommended values

QoS Parameter	Recommended values
Transport-to-transport latency	High – 100 ms Normal – 300 ms
Transport-to-transport acceptable reliability	High – 98% Normal – 95%
Transport-to-transport jitter	50 ms
Transport-to-physical acceptable latency	10 ms

NOTE 1— Voice streaming applications using the Signal PDU are unique and separate from these requirements.

NOTE 2— The use of scaled real time, i.e. when simulation time advances at a constant rate relative to real-world time other than 1:1, will affect the required latency QoS values. When the rate is greater than 1:1 (faster than real time) the required QoS latency values will be less than shown above; when the rate is less than 1:1 (slower than real time) the required QoS latency values can be greater than shown above. When the rate is much greater than 1:1 the required latency values may be such that the High QoS class of service cannot be supported.

Figure 2 shows the relationship between the QoS parameters and the Internet and OSI models.

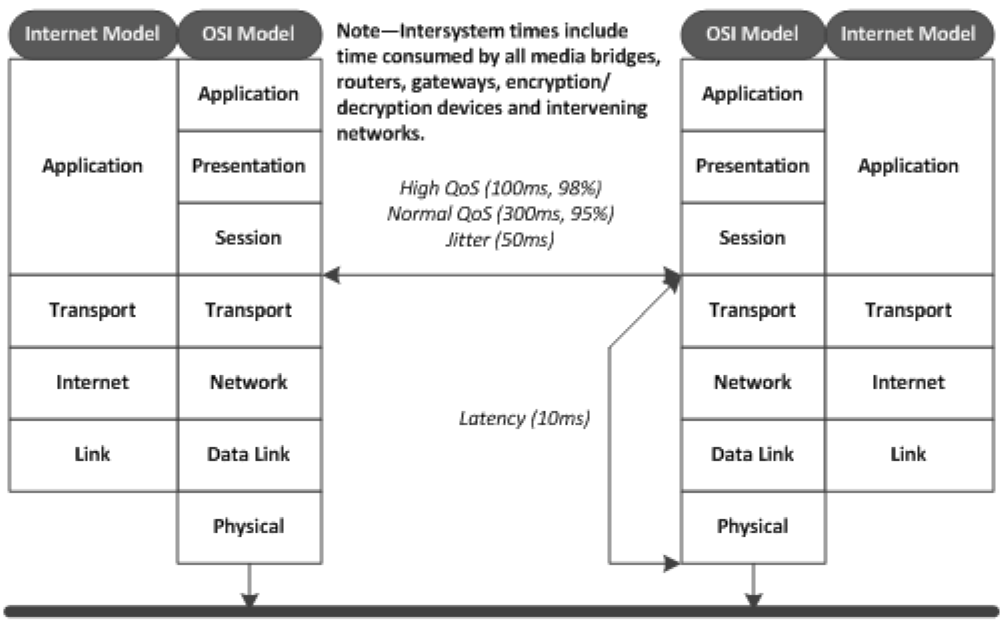

Figure 2—QoS parameters and the Internet and OSI models

4.4 Error detection

The DIS communications service shall include mechanisms to detect with high probability data corrupted in transmission. Such data shall not be delivered.

5. Application layer service requirements

5.1 Introduction

The application layer includes communication services that are unique to the application being served. In the case of DIS, the application layer provides services that are specific to communicating the DIS PDU protocol.

While the PDU protocol itself is in the application layer, it is described in IEEE Std. 1278.1. Only the remaining application services that support the PDU protocol are addressed here. This includes optimizing PDU size based on the maximum transmission unit (MTU) in the network, PDU bundling, and services that support interest management.

5.2 PDU sizing

5.2.1 General

The most efficient network operation is achieved when the minimum number of datagrams is used to convey the necessary data. However, large datagrams that exceed the network MTU causes lower layers of the network to fragment the datagram into smaller units for transfer through the network. The fragmentation and reassembly process reduces efficiency and reliability of the network. This clause describes the means to increase efficiency by optimally sizing PDUs and PDU bundles to avoid fragmentation.

The MTU is a network parameter that indicates the largest amount of data a particular network layer can transmit as a single unit. For example, the MTU for Ethernet frames is 1500 octets. Of those 1500 octets, IP uses 20 octets for Internet Protocol Version 4(IPv4) or 40 octets for Internet Protocol Version 6 (IPv6) if no optional IP headers are present. User Datagram Protocol (UDP) uses eight more octets. Thus, the MTU for the DIS application layer in this example is 1472 octets for IPv4 (1500-20-8) or 1452 octets for IPv6 (1500-40-8). Transmission Control Protocol (TCP) uses 20 octets if no optional TCP headers are present so the MTU is 1460 for IPv4 (1500-20-20) or 1440 for IPv6 (1500-40-20).

If other protocols are included below the DIS application layer, each additional layer reduces the MTU available to the DIS application layer. Examples include real-time transport protocol (RTP) and protocols added by encryptors.

5.2.2 Determining MTU

To aid DIS implementations, a DIS exercise shall determine the smallest MTU in all networks that carry PDUs in the exercise. The MTU shall take into account the number of octets in all protocols below the DIS application layer (e.g., UDP/IP, RTP, encryptors, etc.). The value shall be set in the SMALLEST_MTU_OCTETS variable (see 6.3.4 in IEEE Std. 1278.1-2012) for use by all simulations and gateways in the exercise, such that PDUs kept at or below this size are not fragmented. The SMALLEST_MTU_OCTETS variable is also used in PDU bundling (see 5.3).

NOTE— A process called Path MTU Discovery can be used to determine the MTU on various paths through a network to aid in determining the smallest MTU. Path MTU Discovery is described in RFC 1191 for IPv4 [B2] and in RFC 1981 for IPv6 [B4].[8]

5.2.3 Optimal PDU size

To improve performance in DIS networks, PDUs should have a size less than or equal to SMALLEST_MTU_OCTETS, where practical.

NOTE— PDU size at or below the MTU is desirable because fragmentation and reassembly cause extra network software processing. Also, large PDUs are more likely to suffer a network bit error. An error in any fragment causes the entire datagram, and thus the PDU it carries, to be discarded.

5.2.4 Larger PDUs

Simulations may send DIS PDUs and PDU bundles that are larger than the MTU, up to MAX_PDU_SIZE_OCTETS, which is fixed at 8192 octets (see 6.3.3 in IEEE Std. 1278.1-2012).

[8]The numbers in brackets correspond to those of the bibliography in Annex B.

NOTE— If the size of a UDP datagram exceeds the MTU, the network layer fragments the datagram into multiple packets, each with a size less than or equal to the MTU for transmission over the network. The datagram is reassembled in each receiving host by software in the network layer so that DIS applications receive complete PDUs or PDU bundles.

5.3 PDU bundling

5.3.1 General

Bundling is defined as the process of concatenating two or more PDUs into a single network datagram so that they can be transmitted and relayed through the network in one operation. The increase in network efficiency by the use of bundling works best when there are many PDUs ready to be transmitted at the same time. The number of PDUs in a bundle is typically increased by delaying the transmission for a short amount of time while more PDUs become available to add to the bundle.

Bundling is also useful when two or more PDUs have to be delivered in order as a single coherent unit. Network layers do not split datagrams so bundled PDUs will arrive at the receiver in their original concatenated format.

5.3.2 Issuance rules for PDU bundling

Issuance rules for PDU bundling include the following:

a) Simulations should have the capability to issue bundled PDUs. Simulations shall have the means to enable or disable bundling based on requirements of the current exercise agreement.

b) Simulations may choose to delay transmission of a PDU for a short amount of time to allow more PDUs to become ready to add to the bundle. The amount of delay shall be limited to avoid an excess increase in latency. The latency increase should be weighed against network performance gains when determining the bundling delay. The delay introduced by bundling at the sender shall not cause the total transport-to-transport latency to violate the QoS requirements (see 4.3.3) for any of the bundled PDUs.

c) When bundling PDUs using Class 3 reliable unicast, padding octets shall not be added between PDUs in the bundle.

d) When bundling using Class 1 best-effort multicast or Class 2 best-effort unicast, each PDU shall start on a 64-b boundary relative to the beginning of the first PDU in the bundle. If necessary, the sending simulation shall add bundle alignment padding octets after the previous PDU before concatenating the next PDU. The value of the padding octets shall be zero. Bundle alignment padding octets shall not be added after the last PDU in a bundle. The number of padding octets, P, shall have the value as given by:

$$P = 8\left\lceil \frac{L}{8} \right\rceil - L \qquad (1)$$

where:

L is the length in octets of the previous PDU in the bundle
$\lceil x \rceil$ is the largest integer $< x + 1$

e) The resultant bundle shall contain only DIS PDUs and necessary padding octets.

f) The contents of a PDU shall not be altered when bundling. This includes the length field in the PDU header, which shall not be altered to include the addition of bundle alignment padding octets.

g) The total length of the PDU bundle, including padding between PDUs, shall not exceed MAX_PDU_SIZE_OCTETS.

h) The total length of the PDU bundle should not exceed the SMALLEST_MTU_OCTETS parameter value that was configured for the simulation exercise. If an individual PDU exceeds SMALLEST_MTU_OCTETS, then it should not be bundled with any other PDUs. Exceptions to these rules shall be allowed in cases where the requirement to deliver two or more PDUs in order as a coherent unit outweighs network performance. Examples of this include the following:
    1) Coupled PDU extension, where one PDU is extended by bundling it with another PDU to add extra or custom information (see 5.3.6 in IEEE 1278.1-2012).
    2) A series of PDUs that have to be kept together for purposes of analysis or after action review and not later interleaved with PDUs from other simulations.
i) A new PDU that is too large to fit in a pending bundle shall cause that bundle to be sent immediately. The new PDU starts the next bundle.
j) Simulations should avoid delaying PDUs with critical latency timing (e.g., signal PDUs for voice communication) by immediately sending the bundle after adding the critical PDU.
k) When bundling at an intermediate network device, such as a gateway, the following rules shall apply:
    1) The intermediate network device shall preserve the order of PDUs received from any one network.
    2) If some PDUs are discarded by filtering, the order of the remaining PDUs shall be preserved.
    3) PDUs and bundles of PDUs from different simulation applications may be combined into larger bundles. The combination of bundles shall not cause the total length of any one bundle to exceed MAX_PDU_SIZE_OCTETS.
l) Only PDUs with the same destination address shall be bundled together. PDUs that are to be issued with differing unicast, multicast, or broadcast addresses shall not be bundled. The datagram containing the bundle shall be issued once with the network address.

5.3.3 Receipt rules for PDU bundling

Receipt rules for PDU bundling include the following:

a) Simulations should be able to receive bundled PDUs.
b) The length of the datagram provided by the network interface shall be used to determine when all PDUs in a bundle have been processed. After processing each PDU, if more data remains in the datagram, the receiver shall continue to process the remaining data as an additional PDU.
c) For Class 1 best-effort multicast or Class 2 best-effort unicast, if the previous PDU did not end on a 64-b boundary, the receiver shall skip the bundle alignment padding octets to begin the next PDU. The calculation of the number of padding octets to the next 64-b boundary shall be as specified in 5.3.2 d).

5.4 The use of multicast for interest management

5.4.1 Introduction

Interest management is a means to reduce bandwidth and processing resources by causing a PDU to be received by only the simulation applications that are interested in it. Interest management can be achieved on the sending side and the receiving side. Receive-side interest management is more commonly called filtering, which is achieved by discarding uninteresting PDUs at lower levels of application software in receiving hosts.

Send-side interest management is more efficient because the network infrastructure prevents PDUs from being sent to hosts that are not interested in them, thus saving both low-level processing for the receiving hosts and bandwidth on the segments of the networks to which uninterested hosts attach. The practical means for send-side interest management is the use of multiple multicast addresses, which are also referred to as multicast groups.

When each PDU is issued, it is addressed to the one multicast address that has been assigned for its particular exercise, type of PDU, and PDU content. A DIS exercise requires common criteria that define the rules for using PDU information to assign a multicast address to each PDU. Simulations join the multicast addresses for PDUs that match the criteria they are interested in receiving. The network routes a multicast PDU to only those hosts that have joined its multicast address. Therefore, the PDU consumes network bandwidth and computing resources on only the network segments and hosts that are interested in that PDU. Multicast addresses are be used to route PDUs according to filtering criteria such as Exercise ID, PDU Type, site specific information, and geographic area of interest.

Figure 3 shows an example of the use of multicast in a complex wide-area network (WAN) exercise to limit the use of network bandwidth and host processing to the minimum possible. Only those hosts that have subscribed to the particular multicast address for a given PDU will receive it. The switches and routers in the network are cognizant of which hosts have subscribed and route the PDU accordingly.

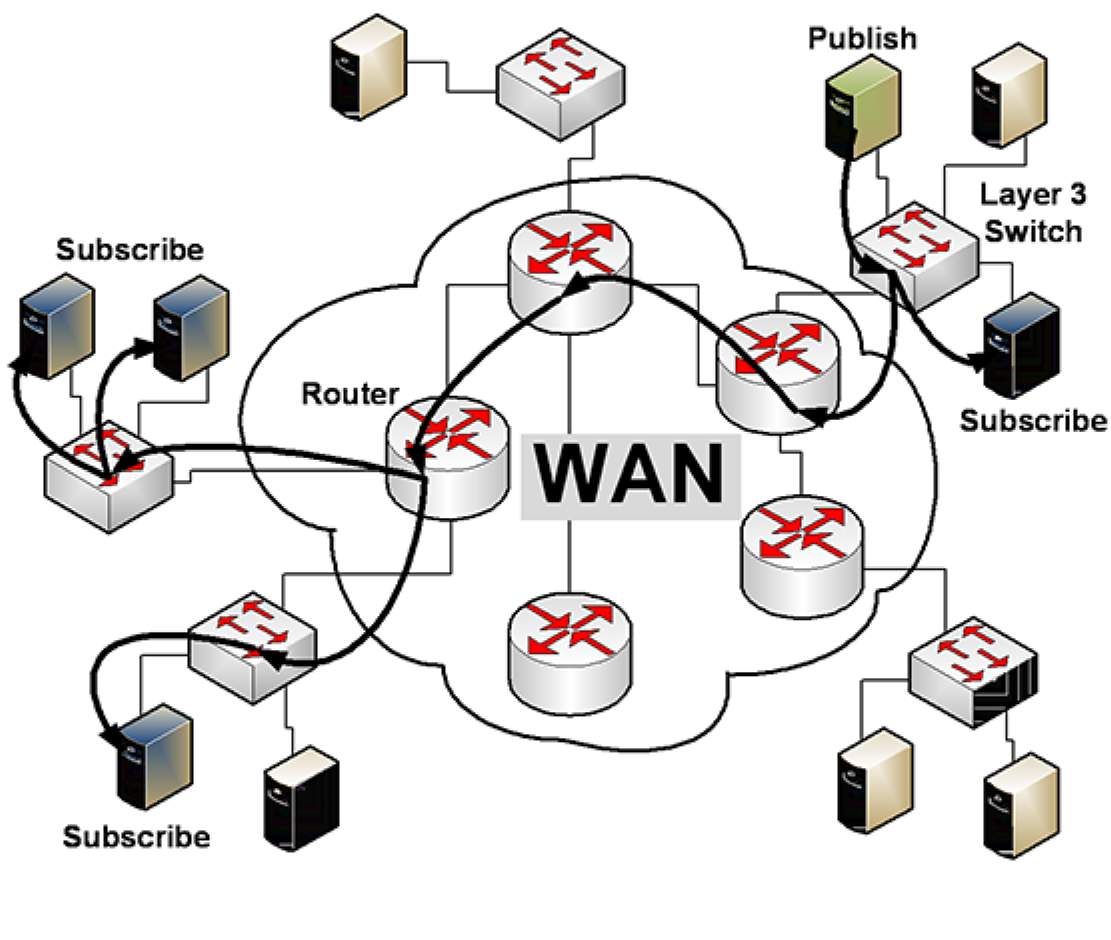

Figure 3—Multicast routing in a WAN

To interoperate properly, it is critical that all simulations in an exercise agree on the mapping of PDUs to multicast addresses. A general set of terminology and rules using the concept of routing spaces makes it possible to unambiguously map the publishing and subscribing of PDUs to the correct multicast addresses.

5.4.2 Multicast address assignment

The following rules apply to exercises that use routing space terminology:

a) The first level of assignment of multicast addresses is the routing space. An exercise shall define one or more routing spaces, which are the divisions of PDUs, into categories that are of interest to the exercise.

b) Routing spaces shall have zero or more dimensions. Dimensions define the axes of the space.

c) A routing space with no dimensions (a point space) shall be assigned one unique multicast address.

d) If a dimension is defined for a routing space, the dimension shall be subdivided into two or more segments.

e) The intersection of a set of segments, one per dimension, defines a cell. Each cell shall be assigned a unique multicast address (see 5.4.4).

5.4.3 Routing space and dimension criteria

5.4.3.1 General

Multicast address assignment criteria are the rules that apply to a set of PDU fields and information that determine how a PDU maps to a routing space and segment on each dimension. There are two types: routing space criteria and dimension criteria. The routing space criteria determine the routing space to which the PDU maps. The dimension criteria determine the segment on each dimension to which the PDU maps.

5.4.3.2 Rules

The following rules apply to multicast address assignment criteria:

a) Multiple field values in a PDU may be combined in an algorithmic way to form routing space and dimension criteria.

b) There shall be one dimension criterion per dimension in the space.

c) Criteria values may be defined for a PDU that are not fields in the PDU. For example, a signal PDU in a radio routing space can have a frequency criterion even though the signal PDU has no frequency field. The frequency is obtained from the transmitter PDU associated with the signal.

d) A simulation may publish to multiple multicast addresses but each PDU shall be issued to only one multicast address. Routing spaces, dimensions, segments, and criteria shall be defined so that any given PDU maps unambiguously to a single multicast address.

5.4.3.3 Example

Table 3 shows an example routing space. The routing space criterion is PDUs whose protocol family is set to Simulation Management. The first dimension criterion is a PDU type combined into logical groupings. The first dimension criterion also specifies that acknowledge PDUs use the segment for the PDU they are acknowledging. The second dimension criterion is the Site Number field of the receiving entity ID record in the PDU. The multicast assignment to cells in the routing space is explained in 5.4.4.

Table 3—Example simulation management routing space

Receiving ID site	Start/Resume, Stop/Freeze, Create Entity, Remove Entity	Data, Set Data, Data Query	Action Request, Action Response, Event Report, Comment
Site 45	224.252.53.n	224.252.54.n	224.252.55.n
Site 28	224.252.50.n	224.252.51.n	224.252.52.n
Site 12	224.252.47.n	224.252.48.n	224.252.49.n
ALL_SITES	224.252.44.n	224.252.45.n	224.252.46.n

5.4.4 Assignment of multicast addresses in routing spaces

5.4.4.1 Rules

The following rules apply to the assignment of the multicast address used to issue or subscribe to a PDU.

a) The lowest octet of the multicast address used when issuing a PDU shall be set to the value in the Exercise ID field of that PDU.

b) Each routing space shall be assigned a starting multicast address by exercise agreement. The lowest octet of the starting address shall be reserved for the Exercise ID. Each successive multicast address assigned within a routing space shall be formed by incrementing by 1 the next to lowest octet of the address.

c) For a zero-dimension space, the starting address shall be the only address assigned.

d) For a one-dimension space, the starting address shall be assigned to the first segment on the dimension axis. Successive multicast addresses shall be assigned in order along the axis.

e) For spaces with two or more dimensions, the starting address shall be assigned to the cell defined by the first segment for all dimensions. Addresses shall be assigned successively along the cells determined by increasing segments of the first dimension axis until its last segment is reached. Then, assignment shall proceed to the second segment of the second dimension and continue along the first dimension segments. This shall be continued until all second-dimension values have been assigned. The process shall repeat for each of the remaining dimensions in order until all cells have been assigned.

f) The set of addresses used in one space shall not overlap with those of any other space.

5.4.4.2 Example

Table 4 shows how multicast addresses are assigned in an example routing space with two dimensions. The starting address is 224.252.12.n, where n is replaced by the Exercise ID. The segments of the first dimension have values A–D. The segments of the second dimension have values X–Z.

Table 4—Example routings space multicast address assignment

		First Dimension			
		Segment A	**Segment B**	**Segment C**	**Segment D**
Second Dimension	**Segment Z**	224.252.20.n	224.252.21.n	224.252.22.n	224.252.23.n
	Segment Y	224.252.16.n	224.252.17.n	224.252.18.n	224.252.19.n
	Segment X	224.252.12.n	224.252.13.n	224.252.14.n	224.252.15.n

If a third dimension was added to this example with segment values J and K, the cell defined by (A, X, J) would be assigned the starting address of 224.252.12.n. The cell defined by (A, X, K) would be assigned

224.252.24.n, which is the next successive address after the one assigned to (D, Z, J). 224.252.25.n would be assigned to (B, X, K), and so on.

When the routing space defined by Table 4 is used in an exercise, the Exercise ID replaces the lowest octet of every multicast address. For example, if the assigned Exercise ID is 17, all multicast addresses for PDUs in that exercise would end with 17. A PDU that maps to this routing space and has dimension criteria C and Z would use 224.252.22.17. Receiving simulations with interest in C and Z in this routing space would subscribe to 224.252.22.17.

5.4.5 Rules for interest management

Additional rules for interest management are as follows:

a) An attribute PDU that extends another PDU shall be sent with the same multicast address as the PDU it extends.

b) Voice communications, digital communications, and video may be transmitted using non-DIS PDUs.

c) Matching transmitter and signal PDUs shall not be split across multicast groups.

6. Protocol profiles for DIS

6.1 Introduction

This clause lists the specific requirements for each of the DIS communication subsystem protocol profiles. Each profile fulfills the recommended communication services requirements as specified in this standard. Profiles 1, 2, and 3 are applicable to typical LAN/WAN infrastructures. It is up to the system designer to determine which profile is applicable to their particular system.

6.2 General profile rules

Users may create and use custom profiles. A profile shall address every service in Clause 4 and Clause 5.

All simulation applications in an exercise shall use the same profile for interoperability. Gateway applications may convert between profiles if necessary. An example is conversion from broadcast to unicast at the LAN to WAN boundary.

6.3 Profile 1: Internet protocol profile—IPv4 broadcast service

6.3.1 General

Profile 1 meets the service class requirements using IPv4 with broadcast and unicast addressing. At each site using Profile 1, there shall be a LAN with a local broadcast capability. For testing, demonstrations, and exercises involving multiple sites, the LANs shall be interconnected using a WAN that can provide the required communications services at those locations.

6.3.2 Communication services

Profile 1 (Table 5) is based on the IP suite. Under Profile 1, Class 1, best effort multicast communication service, shall be implemented using UDP over IP (UDP/IP) with broadcast addresses. Class 2, best-effort unicast, shall be implemented using UDP/IP with unicast addressing. Class 3, reliable unicast, shall be implemented using TCP over IP (TCP/IP).

Table 5—Profile 1 IPv4 Broadcast Profile

Class	Communication service requirements	Profile 1
1	Best-effort multicast	UDP (RFC 768)
		IP (RFC 791)
2	Best-effort unicast	UDP (RFC 768)
		IP (RFC 791)
3	Reliable unicast	TCP (RFC 793)
		IP (RFC 791)

Each host computer shall support, at a minimum, the following requirements in RFC 1122:

a) IP reassembly of datagrams, with the maximum message size that can be received (MMS_R) equal to at least 8192 octets and preferably indefinite. See Section 3.3.2 of RFC-1122.

b) IP limited and directed broadcast address. See Section 3.3.6 of RFC-1122.

c) IP and UDP checksums. See Sections 3.2.1.2 and 4.1.3.4 of RFC-1122.

6.3.3 Performance

Performance parameters defined in 4.3 shall apply. The values of the QoS parameters defined in Table 5 should be established on a per exercise basis.

6.3.4 Error detection

IP and UDP checksums as specified in 6.3.2 provide the required error detection. Algorithms to detect bit errors in lower network layers may also be employed, but shall not violate the performance requirements specified in 6.3.3.

6.3.5 PDU sizing

The optimal size of PDUs and PDU bundles shall be determined using the network MTU as specified in 5.2.

6.3.6 PDU bundling

PDU bundling shall be performed as specified in 5.3.

6.3.7 Interest management

Multicast addressing is not available for send-side interest management. Other forms of interest management are available.

6.4 Profile 2: Internet protocol profile—IPv4 multicast service

6.4.1 General

Profile 2 meets the service class requirements using IPv4 with multicast and unicast addressing. At each site using Profile 2, there shall be a LAN with a local multicast capability. For testing, demonstrations, and exercises involving multiple sites, the LANs shall be interconnected using a WAN that can provide the required communications services for this profile at those locations.

6.4.2 Communication services

Profile 2 (Table 6) is based on the IP suite. Under Profile 2, Class 1, best-effort multicast communication service, shall be implemented using UDP/IP with multicast addresses. Class 2, best-effort unicast, shall be implemented using UDP/IP with unicast addressing. Class 3, reliable unicast, shall be implemented using TCP/IP.

Table 6—Profile 2 IPv4 Multicast Profile

Class	Communication service requirements	Profile 2
1	Best-effort multicast	UDP (RFC 768)
		IP (RFC 791)
		Addresses (RFC 2365)
		IGMP (RFC 4604)
		PIM (RFC 4601, 3973)
2	Best-effort unicast	UDP (RFC 768)
		IP (RFC 791)
3	Reliable unicast	TCP (RFC 793)
		IP (RFC 791)
NOTE— RFC 2365 [B5] specifies administratively scoped IP multicast addresses for IPv4. The address range of 224.252.0.0 to 224.255.255.255 is reserved for DIS transient groups (see RFC 2365 Section 6.3).		

Host computers should implement Internet Group Management Protocol (IGMP) as defined in RFC 4604. IGMP allows a host to inform its neighboring routers of its desire to receive IPv4 multicast transmission.

Routers should implement protocol independent multicast (PIM) to distribute multicast group subscriptions to other routers on the network. PIM Sparse Mode is defined in RFC 4601 and Dense Mode in RFC 3973. Sparse Mode is known to scale well for wide area usage.

Each host computer shall support the following requirements in RFC 1122:

a) IP reassembly of datagrams, with the MMS_R equal to at least MAX_PDU_SIZE_OCTETS (see 5.2.4) octets (see 3.3.2 of RFC 1122).

b) IP multicasting (see 3.3.7 of RFC 1122).

c) IP and UDP checksums (see 3.2.1.2 and 4.1.3.4 of RFC 1122).

6.4.3 Performance

Performance parameters defined in 4.3 shall apply to this profile. The values of the QoS parameters defined in Table 2 should be established on a per exercise basis.

6.4.4 Error detection

IP and UDP checksums as specified in 6.4.2 provide the required error detection. Algorithms to detect bit errors in lower network layers may also be employed, but shall not violate the performance requirements specified in 6.4.3.

6.4.5 PDU sizing

The optimal size of PDUs and PDU bundles shall be determined using the network MTU as specified in 5.2.

6.4.6 PDU bundling

PDU bundling shall be performed as specified in 5.3.

6.4.7 Interest management

Send-side interest management should use multicast addressing. Other forms of interest management are also available. If multicast addressing is used for interest management, the following rules shall apply:

a) The lowest octet of the multicast address used when issuing a PDU shall be set to the value in the Exercise ID field of that PDU.

b) A simulation application shall be able to join (receive) more than one multicast address at the same time.

c) A simulation application should be able to join and drop its membership to an address at any time.

d) The exercise agreement shall specify the multicast address assignment as described in 5.4.

6.5 Profile 3: Internet protocol profile—IPv6 multicast service

6.5.1 General

Profile 3 meets the service class requirements using IPv6 with multicast and unicast addressing. At each site using Profile 3, there shall be a LAN with an IPv6 local multicast capability. For testing, demonstrations, and exercises involving multiple sites, the LANs shall be interconnected using a WAN that can provide the required communications services for this profile at those locations.

NOTE— IPv6 does not provide a strict "broadcast" capability. Instead, to emulate a broadcast capability, IPv6 provides an "all hosts" multicast group.

6.5.2 Communication services

Profile 3 (Table 7) is based on the IP suite. Under Profile 3, Class 1, best-effort multicast communication service, shall be implemented using UDP/IPv6 with multicast addresses. Class 2, best-effort unicast, shall be implemented using UDP/IPv6 with unicast addressing. Class 3, reliable unicast, shall be implemented using TCP/IPv6.

Table 7—Profile 3 IPv6 Multicast Profile

Class	Communication service requirements	Profile 2
1	Best-effort multicast	UDP (RFC 768)
		IPv6 (RFC 2460)
		Addresses (RFC 2365)
		MLD (RFC 4604)
		PIM (RFC 4601, 3973)
2	Best-effort unicast	UDP (RFC 768)
		IPv6 (RFC 2460)

Table continues

Table 7—Profile 3 IPv6 Multicast Profile *(continued)*

Class	Communication service requirements	Profile 2
3	Reliable unicast	TCP (RFC 793)
		IPv6 (RFC 2460)
NOTE— RFC 2365 specifies administratively scoped IP multicast addresses for IPv4. The address range of 224.252.0.0 to 224.255.255.255 is reserved for DIS transient groups (see RFC 2365 section 6.3). Section 8 of RFC 2365 gives the mapping from IPv4 multicast prefixes to IPv6 scope values, which, for the range allotted to DIS is global (0xE). However, this standard does not specify rules regarding the scope or address allocations.		

Host computers should implement multicast listener discovery (MLD) as defined in RFC 4604. MLD allows a host to inform its neighboring routers of its desire to receive IPv6 multicast transmissions.

Routers should implement PIM to distribute multicast group subscriptions to other routers on the network. PIM Sparse Mode is defined in RFC 4601 and Dense Mode in RFC 3973. Sparse Mode is known to scale well for wide area usage.

Each host computer shall support the following requirements in RFC 1122:

a) IP reassembly of datagrams with the MMS_R equal to at least MAX_PDU_SIZE_OCTETS (see 5.2.4) octets (see 3.3.2 of RFC 1122)

b) IP multicasting (see 3.3.7 of RFC 1122)

c) IP and UDP checksums (see 3.2.1.2 and 4.1.3.4 of RFC 1122)

6.5.3 Performance

Performance parameters defined in 4.3 shall apply to this profile. The values of the QoS parameters defined in Table 2 should be established on a per exercise basis.

6.5.4 Error detection

IP and UDP checksums as specified in 6.5.2 provide the required error detection. Algorithms to detect bit errors in lower network layers may also be employed, but shall not violate the performance requirements specified in 6.5.3.

6.5.5 PDU sizing

The optimal size of PDUs and PDU bundles shall be determined using the network MTU as specified in 5.2. Simulation applications shall not use IPv6 jumbograms (see RFC 2675 [B6]) for individual or bundled PDUs.

6.5.6 PDU bundling

PDU bundling shall be performed as specified in 5.3.

6.5.7 Interest management

Send-side interest management should use multicast addressing. Other forms of interest management are also available. If multicast addressing is used for interest management, the following rules shall apply:

a) The lowest octet of the multicast address used when issuing a PDU shall be set to the value in the Exercise ID field of that PDU. For example, an IPv4 multicast address for Exercise ID 3 might be 224.252.7.3 and the corresponding IPv6 address for a link-local scope might be ff12:: e0fc:703 (the key point of this example is that 224.252.7.3 converts as e0fc:703). For an unauthoritative global scope, the first four nibbles (high 16 b) would be ff1e.

b) A simulation application shall be able to join (receive) more than one multicast address at the same time.

c) A simulation application should be able to join and drop its membership to an address at any time.

d) The exercise agreement shall specify the multicast address assignment as described in 5.4.

Annex A

(informative)

Guidance for using IP multicast addressing

A.1 Introduction

This annex provides guidance in setting up networks and applications for the use of multicast addressing in DIS exercises.

A.2 Socket options for IP multicast

Enabling multicast for sending and receiving and managing multiple multicast addresses and UDP ports is typically done in DIS middleware. At the sockets programming level in middleware, multicast is enabled and configured with a set of socket options using the setsockopt() function. The details of each option are readily available on the web or in a textbook on network programming.

For IPv4, the socket options of interest for multicast are as follows. These use option level IPPROTO_IP.

IP_ADD_MEMBERSHIP: subscribes to a multicast address for receiving. Can be called any number of times to subscribe to multiple multicast addresses.

IP_DROP_MEMBERSHIP: unsubscribes from a multicast address.

IP_MULTICAST_IF: indicates which network interface to use when sending multicast through this socket. Otherwise, it will use the host's default multicast route.

IP_MULTICAST_TTL: Sets the multicast Time-to-Live, which is the maximum number of routers (hops) the datagram will be routed through before it is discarded.

IP_MULTICAST_LOOP: Enabled by default, allows other sockets within the same host to receive multicast PDUs sent by that host. Disabling it has the advantage of a simulation not receiving its own PDUs, but has the disadvantage of preventing other simulations or simulation sub-systems running on the same host from seeing the PDUs.

A similar set of socket options is used for IPv6. These are described in RFC 3493. The option level is IPPROTO_IPV6.

IPV6_JOIN_GROUP or IPV6_ADD_MEMBERSHIP

IPV6_LEAVE_GROUP or IPV6_DROP_MEMBERSHIP

IPV6_MULTICAST_IF

IPV6_MULTICAST_HOPS

IPV6_MULTICAST_LOOP

A.3 Generic routing encapsulation

Not all WANs are capable of routing multicast. It is also common that encryptors are not able to forward multicast properly. These problems are solved with generic routing encapsulation (GRE) tunnels, described in RFC 2784 [B7]. The GRE protocol allows routers on the edge of the WAN or on the simulation side of the encryptor (the red or unencrypted side) to tunnel multicast through the encryptors and WAN by encapsulating it in unicast datagrams.

There are two disadvantages to GRE compared to general WAN multicasting. The routers that perform the GRE tunneling require manual configuration to know about each other. This configuration is static for the exercise but would have to be changed as sites are added or removed from the network.

The other disadvantage is that the replication of multicast datagrams is no longer done in the WAN. Instead of PDUs being replicated as close as possible to their destinations, they can only be replicated in the routers that are part of the GRE configuration. This potentially requires multiple copies of the same PDU to be unicast by that router to the other GRE routers it connects to. However, the network can be designed to have multiple GRE "hubs" depending on the geographic location of the sites so that any one PDU is replicated by GRE at the hub closest to a destination. PDUs between hubs need only be transmitted once.

Figure A.1 repeats the example of Figure 3 (see 5.4.1) with the addition of encryptors. GRE is enabled and configured in the routers on the red side of the encryptors. All LAN traffic is multicast, shown by solid lines, so the simulation hosts are unchanged, sending and receiving multicast PDUs as before. The GRE routers convert the multicast to unicast for transmission through the encryptors and WAN, shown by dashed lines. Even though some datagrams are unicast twice over the same network segment, the GRE router at the hub site in the middle will reduce the number of duplicated transmissions.

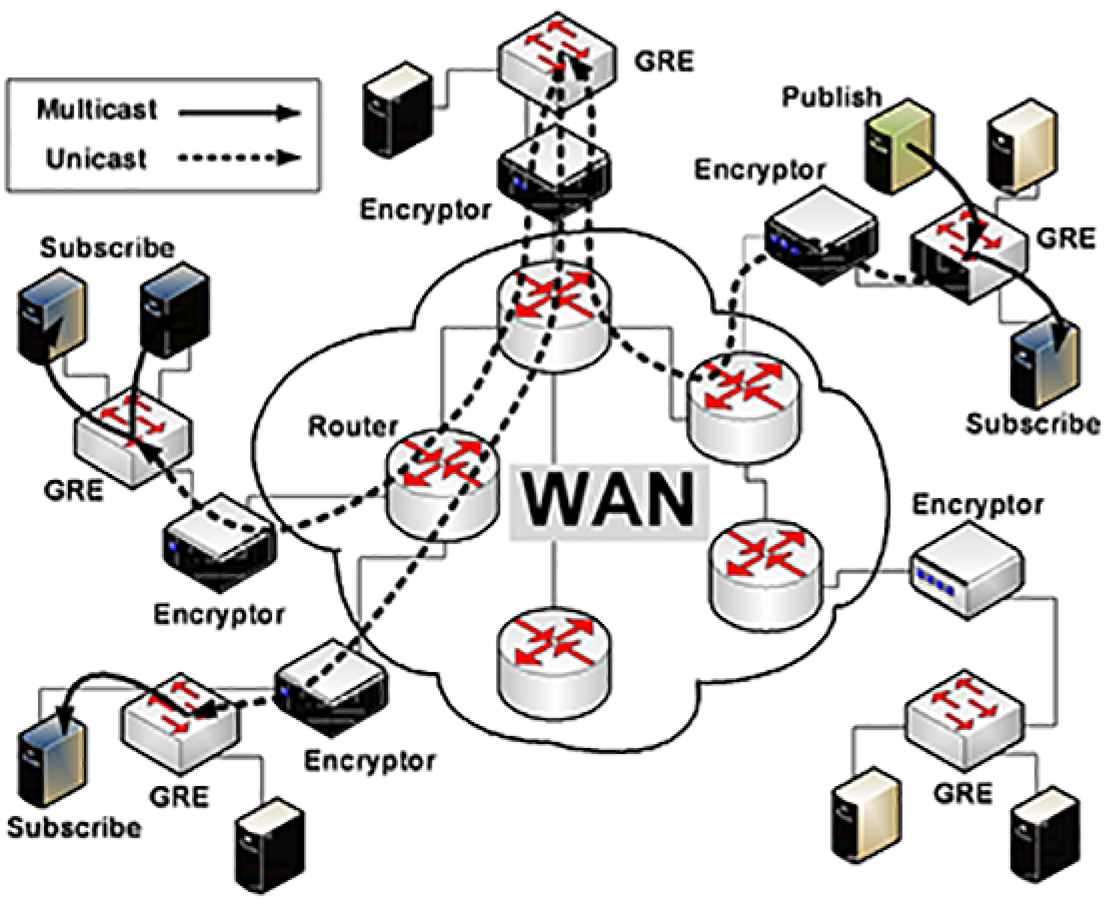

Figure A.1—GRE Tunnels

Regardless of the topology, GRE still has the advantage that the routers automatically manage the multicast routing based on interest subscription without the need for application-specific gateways. Even if gateways are still desirable for their additional filtering, their design and operation is greatly simplified if they are relieved of the broadcast-to-unicast translation and associated unicast routing configuration. Plus, at run time they are alleviated from receiving and processing PDUs that have no local subscription.

A.4 Issues and limitations

A.4.1 Maximum number of multicast addresses

There is a limit to the number of simultaneous multicast addresses that can be handled by a given network infrastructure, typically on the order of 255 to 2000. This limit affects the design of multicast routing spaces for an exercise, including the potential for multiple exercises on the same network.

A.4.2 Issues with multiple applications per host

In some computer operating systems (e.g., Linux), the multicast address of a PDU received by a host is not used to direct that PDU among multiple applications running on the same host. Only the UDP port is used for internal routing. If all PDUs use the same port, applications will receive unwanted PDUs from different multicast addresses that were subscribed to by other applications running on the same host. This is tolerable as long as the applications have receive-side filtering to remove unwanted PDUs. Each multicast address could be assigned a unique UDP port but this complicates the socket implementation. A socket can receive (“bind to”) only one port so many sockets would be required to join multicast addresses with different ports. This would be difficult to manage since the application would be required to receive PDUs on a large number of sockets. It is suggested that each exercise have a single, unique UDP port.

A.4.3 Issues with dynamic routing space criteria

It is possible to change multicast group subscriptions dynamically, that is, during exercise execution. A commonly referenced example is geographic cells with latitude and longitude dimensions, as detailed in Van Hook, et al. [B8]. However, it can take a significant amount of time to propagate the subscription changes throughout a complex network, possibly on the order of many seconds. An example is an aircraft entity with long-range forward-looking radar. As the aircraft turns, the cells in the radar’s view change quickly. This causes rapid changes in the multicast addresses it subscribes to, possibly faster than the network infrastructure can handle.

Another issue with dynamic routing space criteria is the problem of excessive address reassignment when the value for a criterion is near the boundary between two cells. In the geographic dimension example, an entity maneuvering near a cell boundary would often change the multicast address it uses to publish as it moves back and forth between the cells. This would cause the entity to repeatedly disappear and reappear to receivers subscribed to one cell but not the other.

There are techniques to mitigate these issues in dynamic routing spaces. For example, the use of hysteresis avoids excessive changes in the publishing multicast address. Oversubscribing to cells that could be in view soon avoids rapid changes in subscription. Dynamic routing space criteria should be used judiciously and only if necessary, such as in very large-scale exercises. Careful design of the rules for publishing and subscribing is required to avoid the issues described here.

A.5 Routing space example

A.5.1 Overview

A set of routing spaces is given here as an example that could be used by an exercise with a high number of radar and radio PDUs. Multicast routing spaces are defined for send-side interest management of electromagnetic emission, transmitter, and signal PDUs. All other PDUs are assigned to a default space in this example.

Electromagnetic emission PDUs are assigned to a radar routing space. Transmitter and signal PDUs are assigned to a radio routing space. Separate spaces are defined because they require a different set of dimensions. For example, radio has a voice/data link dimension while radar does not.

This set of three routing spaces is complete in that every PDU is unambiguously assigned to a single multicast address. The default space is the simple means to make it complete.

A.5.2 Radar routing space

An example of a radar routing space is as follows (see also Table A.1):

Routing space criteria: electromagnetic emission PDUs

Number of dimensions: 1

Dimension criteria: the Frequency field of the Fundamental Parameter Data record for each beam

Starting multicast address: 224.252.10.n

Usage: electromagnetic emission PDUs are assigned a multicast address based on their frequency values. Simulations with systems that receive electromagnetic emissions PDUs (e.g., radar warning receivers) would subscribe to the multicast address associated with the radar band of that system. If the system spans frequency bands or operates near the edge of a band, it would subscribe to the multicast addresses of the adjacent bands.

It is possible that a single PDU contains information with multiple systems and/or beams that operate in different frequency bands. If that is the case, the multiple bands multicast address is used for sending that PDU. All receiving simulators that process electromagnetic emission PDUs subscribe to multiple bands.

Table A.1—Radar routing space

Frequency Range (GHz) and Band	60 to < 100 (M)	224.252.23.n
	40 to < 60 (L)	224.252.22.n
	20 to < 40 (K)	224.252.21.n
	10 to < 20 (J)	224.252.20.n
	8 to < 10 (I)	224.252.19.n
	6 to < 8 (H)	224.252.18.n
	4 to < 6 (G)	224.252.17.n
	3 to < 4 (F)	224.252.16.n
	2 to < 3 (E)	224.252.15.n
	1 to < 2 (D)	224.252.14.n
	0.5 to < 1.0 (C)	224.252.13.n
	0.25 to < 0.5 (B)	224.252.12.n
	0 to < 0.25 (A)	224.252.11.n
	Multiple bands	224.252.10.n

A.5.3 Radio routing space

An example of a radio routing space is as follows (see also Table A.2):

Routing space criteria: transmitter and signal PDUs

Number of dimensions: 2

First Dimension criteria: voice or data link as indicated by the Category field of the Radio Type record of the transmitter PDU. This example assumes there are no NAVAID radios. This exercise uses only the following enumerated values for Category.

- Voice radio types
  - 1: Voice transmission/reception
- Data link radio types
  - 2: Data link transmission/reception
  - 21-26: Link 16, Link 11, EPLRS/SADL, IFDL, and MADL
  - 39: IBS-I/S terminal
- Mixed voice/data link radio types
  - 3: Voice and data link transmission/reception
  - 27: SINCGARS terminal
  - 28: L-Band SATCOM terminal

Exercises with different types of radios would have to expand this list or alter the radio routing space accordingly.

Second Dimension criteria: frequency field of a transmitter PDU

Starting multicast address: 224.252.50.n

Usage: transmitter PDUs are assigned a multicast address based on their radio type and frequency values. The Radio Identifier record associates signal PDUs to a transmitter. The most recent transmitter PDU for that radio determines the radio type and frequency values used to assign a multicast address to signal PDUs. Receiving simulations would subscribe to the multicast address associated with the type and tuning frequency of their simulated radio. If a radio is capable of changing its tuned frequency to adjacent ranges, the simulation can subscribe to the adjacent multicast address at all times to avoid delay in receiving PDUs as the radio tuning is changed.

Table A.2—Radio routing space

		Radio type		
		Voice	**Data link**	**Mixed voice and data link**
Frequency range (MHz)	**960 MHZ and above (UHF)**	224.252.65.n	224.252.66.n	224.252.67.n
	225 to 400 MHz (UHF)	224.252.62.n	224.252.63.n	224.252.64.n
	108 to 144 MHz (VHF)	224.252.59.n	224.252.60.n	224.252.61.n
	30 to 88 MHz (VHF)	224.252.56.n	224.252.57.n	224.252.58.n
	100 KHz to <30 MHz (HF)	224.252.53.n	224.252.54.n	224.252.55.n
	All other frequencies	224.252.50.n	224.252.51.n	224.252.52.n

A.5.4 Default routing space

An example of a default routing space is as follows:

Routing space criteria: PDUs not in other routing spaces

Number of dimensions: 0

Multicast address: 224.252.1.n

Annex B

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] ISO/IEC TR 10000-1:1992, Information technology—Framework and taxonomy of International Standardized Profiles—Part 1: Framework.[9,10]

[B2] RFC 1191, Path MTU Discovery.[11]

[B3] RFC-1720, Internet Official Protocol Standards.

[B4] RFC 1981, Path MTU Discovery for IP version 6.

[B5] RFC 2365, Administratively Scoped IP Multicast.

[B6] RFC 2675, IPv6 Jumbograms.

[B7] RFC 2784, Generic Routing Encapsulation (GRE).

[B8] Van Hook, D., D. Wilbert, R. Schaffer, W. Milliken, and D. McBride, “Scalability Tools, Techniques, and the DIS Architecture,” Proceedings of the 15th Interservice/Industry Training Systems and Education Conference, pp. 839–846, Nov. 29–Dec. 2, 1993.

[9]ISO publications are available from the ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland (http://www.iso.org/). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).
[10]IEC publications are available from the Sales Department of the International Electrotechnical Commission, 3 rue de Varembé, PO Box 131, CH-1211, Geneva 20, Switzerland (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org).
[11]Internet Requests for Comments (RFC) are available at http://www.rfc-editor.org/

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