NETWARS

C4ISR Communication Modeling Standard

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ABSTRACT: The Navy Modeling and Simulation Management Office (NAVMSMO) N6M is responsible for the centralized management of Navy Modeling and Simulation (M&S) activities, coordination of M&S efforts across functional areas, and development of policies and procedures for Navy M&S standardization. The Navy also participates in M&S efforts throughout the DoD and the Joint Services to ensure that Naval interests are addressed, and most importantly, to provide technical feedback to the standards process and procedures of the Navy. One area of active participation is in a Joint Chiefs of Staff (JCS) J6 initiative called Network Warfare Simulation (NETWARS). The objectives of NETWARS are to provide a common M&S framework for communications burden analysis for a Joint Task Force (JTF), and a robust analysis capability to assist in communication planning that includes assessments of the impacts of leading edge technologies on JTF communications. The NETWARS Standards Group was formed to develop a modeling standard to enhance the re-usability and interoperability of models throughout the Joint Services. The Navy has led the development of an approach that involves a classification of network applications, devices and protocols into Network Element Classes. Focusing on J6's communication analysis requirements, the Navy derived a set of Measures of Effectiveness/Performance (MOE/MOP), which were used in the derivation of essential attributes for each specific network element class. The work presented in this paper is the basis for the NETWARS Reference Federation Object Model (FOM). This reference FOM serves a dual purpose: (a) It provides a necessary and sufficient set of attributes for a communication modeling environment to participate in a NETWARS simulation run. (b) It provides information on the types of data that may be available for other of simulations that participate in a federation.

1. Introduction

The Navy Modeling and Simulation Management Office (NAVMSMO) OPNAV N6M is responsible for the establishment of guidelines, policy and procedures for Modeling, Simulation, and Analysis in order to provide for Navy-wide requirements in this area. As part of a major on-going effort in enhancing reuse, NAVMSMO has established a Navy Modeling and Simulation Information System (NMSIS) to provide a central repository for Modeling and Simulation (M&S) guidelines, policy, instructions, and information on various models that are being used or developed. It is envisioned that potential model designers will access the information from NMSIS to facilitate development of their models. Recognizing that there are many modeling environments in use or under development, NAVMSMO considers it essential that model capabilities be made known and easily available to the general M&S community.

In order to facilitate the re-use of models Navy-wide, NAVMSMO invests in the development of standards for communication system models. Additionally, NAVMSMO engages in the study and documentation of the Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR) modeling environment through capture of capabilities of classification. The intent of this task is to further enhance the Navy's thrust toward reusability and interoperability of communications networks modeling and analysis efforts.

The purpose of this paper is to present the network simulation standards development performed for the NAVMSMO. The objective of the standards documentation is to promote model reusability and interoperability and assist in the development of High Level Architecture (HLA) Simulation and Federation Object Models (FOMs) through standardization of attributes. This report documents the set of list classes and attributes of the Reference FOM. The approach is intended to minimize the impact to model development and to leverage definitions from existing commercial and Department of Defense (DoD) models, Information Exchange Requirements (IERs), and established standards.

The results of this effort can be used to facilitate the development of a core, reusable, communications M&S capability such as the NETwork WARfare Simulation (NETWARS) program. The standards are primarily intended as a starting point for engineers and developers who are embarking on the development of new models. The standards provide a framework for model development as well as a reference for key attributes that are required for proper model functionality. While legacy models can be modified to conform to the standards, the intent is to guide and assist M&S developers in building new models of communications devices (i.e. routers, switches, etc.). The utilization of the standard element classes and attributes is intended to apply to most communication modeling environments.

2. Communication Modeling Approach

This section presents the standard network modeling approach and the hierarchy of communications network models.

2.1 Modeling Environment

The OPtimized Network Engineering Tools (OPNET) Modeler/Radio tool by MIL-3 provides the current modeling environment in NETWARS. While the Reference FOM is applicable to most modeling environments, the OPNET modeling environment provides a good example of the hierarchy, modularity, and parameterization of models upon which the network modeling approach is based. OPNET provides a hierarchical modeling environment as shown in Figure 2-1. At the *process model* level, a finite state transition diagram is used to represent the behavior of an algorithm or protocol. The process model may have embedded code based on Proto-C language constructs. At the middle level, the *node model*, discrete functions such as buffering, transmitting, receiving, and processing data packets are performed by separate objects, some of which may rely on an underlying lower level process model. These objects can be connected together to form a higher-level node model. At the highest level, node objects based on underlying node models are deployed and connected by links to form the *network model*. The network model defines the specific communications system that is simulated.

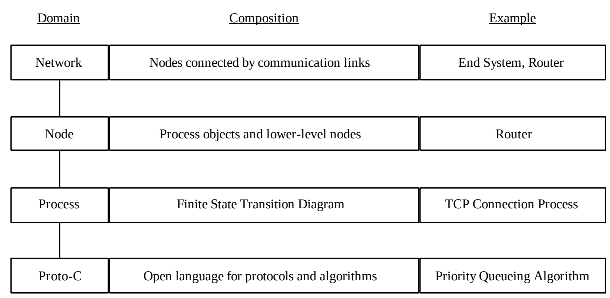

Figure 2-1 OPNET Modeling Hierarchy

2.2 Model Development

Network model development utilizes the OPNET modular network modeling environment as illustrated in Figure 2-2. The hierarchical and modular approach is used to model systems at the highest network/subnetwork levels down to the lowest process levels by assembling the components with the appropriate parameters. Thus, model development is characterized by parameterized and modular models in order to maximize model reuse and potential study options.

As shown in Figure 2-2, typical network models can be composed of subnetwork modules that are interconnected by channel media models. The subnetwork models are composed of clients/servers, links, and routers/gateways. The communications between clients and servers are characterized by the use of reliable protocols such as the Transmission Control Protocol (TCP) and unreliable protocols such as the User Datagram Protocol (UDP). The clients and servers can also utilize protocols such as Ethernet for basic network connectivity. Links are defined by type (e.g., point-to-point or bus) and configuration parameters (e.g., transmission rate and propagation delay). Gateways are characterized by switching/routing algorithms and port connectivity configurations (e.g., serial links and Ethernet).

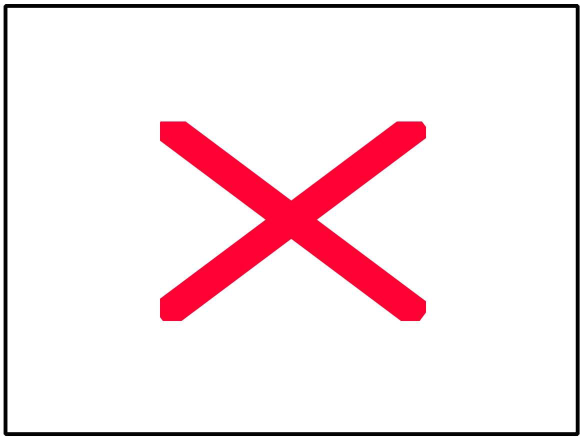

Figure 2-2 Network Modeling Environment

The development approach involves an incremental build of capabilities that are verified at intermediate levels to ensure confidence in the results obtained from subsequently more complex models and simulations. The hierarchical and modular model development plan involves the construction of individually validated models from the process level to the network level which then become the foundation of the final system model and simulation.

2.3 Model Validation

Model validation criteria ensure the proper operation of process, node, and network models. Model validation criteria consist of both functional and performance characteristics. Functional validation is achieved by tracing traffic flows through predetermined scenarios to verify proper network model operation. Network model performance validation is achieved by monitoring statistical probes of associated network elements. In general, deterministic traffic scenarios are run in order to facilitate comparisons of predicted versus simulated results. A validated model is used as an operational and performance baseline in subsequent analyses. The validated models developed in a task can be added to a reusable model library.

2.4 Model Standards Development

The model standards development complements the modular framework of the network modeling environment which provides the ability to create network models from parameterized combinations of lower level models. The development of model standards is expected to evolve and grow with increased participation and support from the M&S community. At a minimum, model standards should provide increasingly valuable guidelines to diverse modelers to assist them in the development of reusable communications models.

3. Standard Model Components

This section describes the components of the model standards and their definitions. As illustrated in Figure 2-2, the modular framework of the network modeling environment provides the ability to create network models from parameterized combinations of lower level models.

3.1 Model Classes

Communications elements are grouped into model classes. The model classes are presented in Section 4.

3.1.1 Minimum Attributes

Each model class has an associated minimum set of attributes that describes the functionality and performance of the communications device. The minimum attributes for each model class are presented in Section 4. Depending upon the desired level of model fidelity, the value of each attribute may or may not be defined. For some high fidelity models, it may be necessary to include more attributes. This document attempts to present a minimum set of attributes that are common to all high fidelity models in that functional class.

3.1.2 Attribute Types

The six different types of attributes are as follows:

- **String** – Text string value
- **Real** – Double precision floating point number
- **Integer** – Long integer number
- **Boolean** – True/False, 1/0, Enabled/Disabled, On/Off
- **Enumerated** – Datatype that can be assigned only a finite set of values
- **Complex** – Datatype that consists of a group of multiple attribute types in a single structure

3.1.3 Attribute Classifications

For model development purposes, attributes are also classified as mandatory/optional and static/dynamic.

3.1.3.1 Mandatory and Optional Attributes

An attribute is designated as *mandatory* if it is required to adequately model a device at all levels of fidelity. If it is possible to model the device functionality at some level of fidelity without the attribute, then the attribute is designated as *optional* or *not mandatory*. The illustration in Figure 3-1 provides a visual representation of the concept of mandatory attributes with respect to the levels of modeling fidelity. As shown in Figure 3-1, models of the lowest level of fidelity are composed entirely of *mandatory* attributes, and models of higher fidelity are composed of *mandatory* and *optional* attributes. Examples of *mandatory* attributes are *interface_name* and *interface_speed* for device interfaces. The *interface_name* attribute is required to identify an interface and the *interface_speed* attribute is an essential parameter of the device functionality. Examples of *optional* attributes are *interface_state* and *interface_failure* for device interfaces. These attributes are used to define the current availability state and the state change characteristics of an interface. While high fidelity models might likely include these attributes, they are not necessary to model the basic device functionality in all simulation cases.

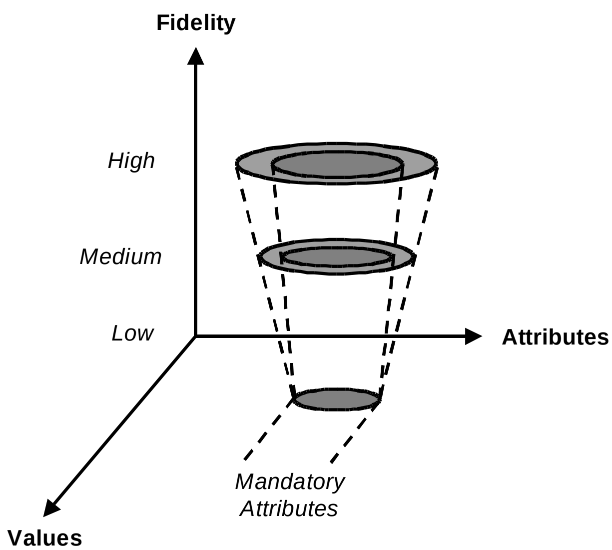

Figure 3-1 Mandatory Modeling Attributes

3.1.3.2 Static and Dynamic Attributes

An attribute is designated as *static* if its value must remain constant during the course of a simulation. An attribute is designated as *dynamic* if its value must be capable of changing during the course of a simulation. The static/dynamic aspect of an attribute is also designated as *dynamic* if the dynamic or static capability of the attribute is not essential for all cases and can be left to the discretion of the developer. An example of a *static* attribute is *object_name*, which defines the name of the communications device. An example of a *dynamic* attribute is *orbit_latitude* for a satellite model that has time-varying orbit position parameters. The device *object_state* attribute is designated as *dynamic* under the static/dynamic classification, because the capability for an object state change is determined by the designer/developer based on system analysis requirements.

4. Model Classes & Minimum Attribute List

This section presents an overview of the network element class models and their respective minimum set of attributes. Attributes are also classified as *mandatory/optional* and *static/dynamic*. Further descriptions and details of attributes can be found in [3] where each attribute has an associated definition, type, units, and default value. Actual device examples for some model classes are also provided. The device examples include data for their respective attribute values.

The network element classes are shown in Table 4-1.

Table 4-1 Network Element Class Descriptions

Class	Description
Antenna	Antenna models.
ATM Communication Layers	ATM communications device models with attributes drawn from ATM protocol layer functionality.
Communications Link	Serial, bus, and radio communications link models.
Encryption Device	Communications device models with Key Generator (KG) encryption device functionality.
End System	Communications device models with workstation (client/server) functionality.
OSI Communication Layers	Unique and hybrid/composite models, which support communications devices that do not fit in any one class. Model attributes are drawn from the applicable Reference Model of OSI layer functionality.
Networking Equipment	Communications devices with network (gateway, router, bridge, switch, hub) functionality.
Radio	Communications devices with radio functionality.
Satellite	Communications device models with satellite functionality.

4.1 Common Attributes

The following attributes correspond to those attributes that are common to communications device models.

Attribute	Type	M/O[1]	S/D[2]
object_name	String	M	S
object_version	String	M	S
mode_name	String	M	S
icon_name	String	M	D
Inheritance	Complex	O	S
position_x	Real	M	D
position_y		M	D
position_z		M	D
velocity_x	Real	M	D
velocity_y		M	D
velocity_z		M	D
object_state	Boolean	O	D
object_failure	Complex	O	D

1. Mandatory (M) or optional (O) attribute.
2. Static (S) or dynamic (D) attribute value.

4.1.1 Interface Attributes

The following attributes correspond to those attributes that are common to communications device interfaces.

Attribute	Type	M/O	S/D
interface_name	String	M	S
interface_type	Enumerated	M	S
interface_speed	Real	M	D
interface_medium	Enumerated	M	S
interface_data	Complex	M	S
interface_protocols	Enumerated	M	S
interface_address	String	M	D
interface_state	Boolean	O	D
interface_failure	Complex	O	D
device_id	String	M	S
link_id	String	M	D

4.1.2 Message Attributes

The following table lists the minimum set of attributes contained in message structures.

Attribute	Definition	Type	M/O
msg_source	Source	String	M
msg _destination	Destination	String	M
msg _priority	Priority	Real	O
msg _date	Message creation time	Real	O
msg _death	Perishability	Real	O
msg _protocol	Protocol	Enumerated	O
msg _id	Identification number	Integer	M
msg _seq_no	Sequence number	Integer	O
msg _overhead	Overhead	Real	O
msg _error_code	FEC / Code	Complex	O
msg _size	Size	Real	M
msg _data_field	User-defined data	Complex	O

4.2 Networking Equipment

The following table lists the minimum set of attributes for communications device models with network equipment (e.g., gateway, router, bridge, switch, hub) functionality.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
data_fwd_rate	Real	M	D
routing_info	Complex	M	D
data_buffers	Complex	M	D

4.3 Radio

The following table lists the minimum set of attributes for communications device models with radio functionality.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
tx_rate	Real	M	D
tx_power	Real	O	D
tx_modulation	Complex	O	D
tx_frequency	Real	O	D
radio_bandwidth	*Real*		

In the next section, an example instantiation of the radio network element class is provided.

4.3.1 AN/WSC-3(V) Radio

Source: AN/WSC-3(V) Operation and Maintenance Instructions [1]; Jane's Military Communications 1996-97 [2]

Attribute	Type	Units / Range
Common attributes		
Interfaces	Complex	
tx_rate	Real	FSK - 75 bps; PSK - 75, 300, 1200, 2400, 4800, 9600 bps
tx_power	Real	30 W AM, 100 W FM and data mode
tx_modulation	Complex	AM; FM; FSK - 75 bps; PSK - 75, 300, 1200, 2400, 4800, 9600 bps; External Modem
tx_frequency	Real	225-399.975 MHz
radio_bandwidth	*Real*	*7000 channels in 25 kHz steps*

4.4 Antenna

The following table lists the minimum set of attributes for antenna models. For maximum flexibility and to address custom antenna designs, antenna patterns are defined through the use of the *antenna_gain* attribute.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
antenna_gain	Complex	M	D
antenna_orientation	Complex	O	D

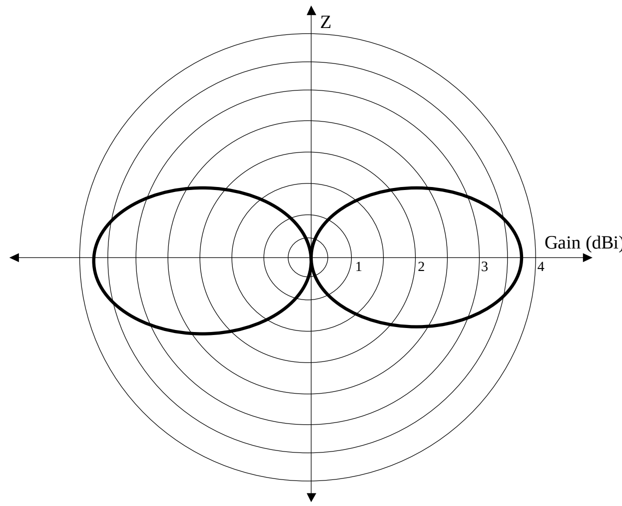

Figure 4-1 Shakespeare Model 4243 Gain Pattern at 85 MHz

4.4.1 Shakespeare Model 4243 VHF Broadband Antenna

Source:

http://www.shakespeare-ce.com/military/4243.htm

Attribute	Type	Units / Range
Common attributes		
Interfaces	Complex	1 50 OHM Coax
Antenna_gain	Complex	See Figure 4-1
Antenna_orientation	Complex	Phi:90 Theta:0

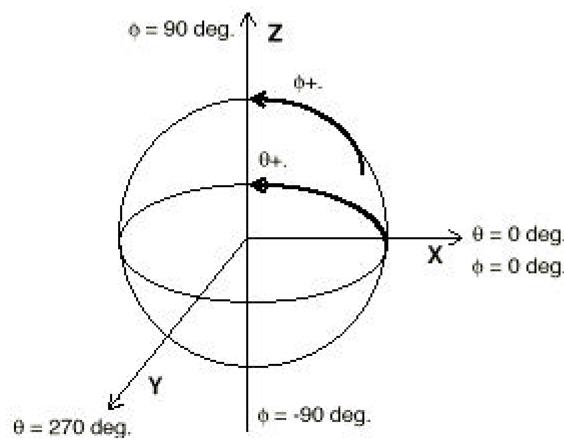

Figure 4-2 Antenna Orientation Parameters

The antenna gain pattern for the Shakespeare Model 4243 at 85 Megahertz (MHz) is shown in Figure 4-1. Antenna orientation parameters ϕ and θ are utilized to indicate the antenna orientation. They are illustrated in figure 4-2.

4.5 Encryption Device

The following table lists the minimum set of attributes for communications device models with Key Generator (KG) encryption device functionality.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
data_encryption	Complex	M	S
encryption_delay	Real	M	D

4.6 Satellite

The following table lists the minimum set of attributes for communications device models with satellite functionality. A satellite device model is defined as a hybrid of radio, network, and end system devices along with orbital position parameters.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
Orbit Position Parameters: orbit_latitude orbit_longitude orbit_altitude orbit_time	Real	M	D
Communications range/coverage			
Communications networking			
End system			

4.7 End System

This section lists the minimum set of attributes for end system communications device models. End systems are defined as devices or users that produce and/or receive data.

4.7.1 Workstation (Client / Server)

The following table lists the minimum set of attributes for communications device models with workstation functionality.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
Client / Source			
req_data_format	Complex	M	
req_rate	Complex	M	D
Server / Sink			
resp_data_format	Complex	M	
processing_rate	Real	M	D

4.8 Communications Link

The following table lists the minimum set of attributes for serial, bus, and radio communications link models. Communications link models provide the means for environmental effects on data/message transmissions. The environmental effects are parameterized through the use of the *error_allocation* attribute.

Attribute	Type	M/O	S/D
object_name	String	M	S
icon_name	String	M	D
position_x position_y position_z	Real	M	D
link_type	Enumerated	M	S
link_medium	Enumerated	O	S
transmission_rate	Real	M	D
propagation_delay	Real	M	D
error_allocation	Complex	O	D
interface_ids	String	M	D
link_state	Boolean	O	D
link_failure	Complex	O	D

4.9 OSI Communication Layers Device

The following table lists the minimum set of attributes for unique and composite models, which support communications devices that do not fit in any one class. Model attributes will be drawn from the applicable Reference Model of Open Systems Interconnection (OSI) layer functionality.

Attribute	Type	M/O	S/D
Common attributes			
OSI Layers			
Physical			
error_allocation	Complex	O	D
Data Link			
Data unit (frame) - frame/fragment/reassembly:			
frame_format	Complex	M	S
Acknowledgement (error handling):			
ack_timeout	Real	M	D
ack_nak	Complex	M	S
Link flow control			
link_flow_ctrl	Complex	M	D
Network			
Routing / Switching:			
interfaces	Complex		
Transport			
Message fragmentation/reassembly:			
fragment_format	Complex	M	S
Message to connection management:			
trans_conn_mgt	Complex	M	D
End-to-end flow control:			
end_flow_ctrl	Complex	M	D
Session			

Attribute	Type	M/O	S/D
End-to-end connection establishment and management:			
sess_conn_mgt	Complex	M	D
Presentation			
Data translation:			
data_translation	Complex	M	S
translation_delay	Real	M	D
Compression:			
data_compression	Complex	M	S
compression_delay	Real	M	D
Encryption:			
data_encryption	Complex	M	S
encryption_delay	Real	M	D
Application			
User-defined application data			

4.10 ATM Communication Layers Device

The following table lists the minimum set of attributes for communications device models with Asynchronous Transfer Mode (ATM) device functionality.

Attribute	Type	M/O	S/D
Common attributes			
interfaces	Complex		
data_fwd_rate	Real	M	D
switching_info	Complex	M	D
data_buffers	Complex	M	D
error_correction	Complex	M	D
AAL_framing	Complex	M	S
qos_provisioning	Complex	M	S
flow_control	Complex	M	D
connect_mgt	Complex	M	D
data_translation	Complex	M	S
translation_delay	Real	M	D

5. HLA Reference FOM Representation of Model Classes

The work presented in the previous section formed the basis for the HLA Reference FOM. This work is presented in detail in [3]. The tabular format, syntax and terminology that were used follow that of the HLA Object Model Template (OMT). The HLA Object Model Development Tool (OMDT) was used to create the Reference FOM representation of the model classes.

The current Reference FOM contains definitions of the initial set of network element classes, the respective minimum attributes, and message handling interactions. Datatype definitions include representative enumerated and complex types along with cardinality specifications. Other attributes and parameters were set as the OMDT default values.

6. Summary and Conclusions

The JCS has a requirement for a simulation environment to support JTF communications burden analyses. Rigor in the modeling environment is required to accurately identify areas of the network for improvement. Confidence in the results is required to provide the warfighter with a higher degree of trust in the communication plans. Modeling flexibility and robustness are required to provide planners with the capability to experiment with a variety of scenarios in order to optimize plans for deployment. In order to fulfill these requirements, a variety of reusable, interoperable, validated models must be available. This work supports the validation process by providing developers with a minimum set of attributes that are essential for models. In addition, this standard provides a common modeling framework to enhance reusability and interoperability of communication models, and to support potential federations of C4ISR simulations.

7. References

[1] *AN/WSC-3(V) Operation and Maintenance Instructions*, E-Systems, 31 May 1987.

[2] *Jane's Military Communications 1996-97*, Jane's Information Group, Inc., 1996.

[3] *C4ISR Communication Modeling Standard*, Navy Modeling and Simulation Management Office, December 1999.

8. Author Biographies

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