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SIMULATING CRISIS COMMUNICATIONS

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ABSTRACT

This paper addresses the need for simulation of voice and data communication demands during civil and military crisis events. Modeling of federal, state, and local civilian agencies in addition to military forces can lead to better planning and execution decisions during the crisis. The need has become particularly acute following recent terrorists attacks on the United States. Preliminary crisis communication modeling capabilities exist in the Network Warfare Simulation (NETWARS) software that has been successfully used to model networks supporting the military's Operation Enduring Freedom. We will examine the software's features, limitations, and potentials.

1 INTRODUCTION

The 2001 terrorist attacks on the United States emphasized the need for a modeling tool capable of measuring the impact of degraded communications on military and civil emergency operations. It is a current hypothesis that military and civil emergency communications infrastructures are incapable of accommodating the burden that will be placed upon them during large-scale crisis situations. On September 11, 2002, there were multiple simultaneous crises, a large number of communication producers and consumers and a wide spectrum of threats and intelligence requirements to accommodate. The Network Warfare Simulation (NETWARS) is a discrete event simulation tool that provides a modeling capability that is well suited to analyze this problem. The NETWARS system has been used successfully by the military to model communication networks supporting Operation Enduring Freedom in Southwest Asia.

The Command, Control, Communications and Computer (C4) Systems Directorate (J-6) of the Joint Staff is currently working with the Defense Information Systems Agency on software that provides this type of rigorous analytical support to investigate the utility and effectiveness of proposed battlefield and civil emergency communications systems and networks (NETWARS Program Management Office, 2000).

The J-6 gained institutional approval for the Network Warfare Simulation (NETWARS) initiative when the Vice Director of the Joint Staff (VDJS) signed the Mission Needs Statement in 1997, and subsequently when the Military Communications Electronics Board (MCEB) in April 1998, and the Global Information Grid (GIG) Steering Group in August 1999 both endorsed the NETWARS program as the primary network-modeling tool for the armed services (NETWARS Program Management Office, 2000). The adoption of NETWARS as the primary network modeling tool for the services is consistent with Joint Vision 2010 and underscores the wide reaching impact of information superiority on emerging operational concepts.

NETWARS provides the joint staff and the services with the capability to model the joint communications systems across the tactical unit level to the joint task force level and above. Prior to the advent of NETWARS the separate military services and government agencies were constrained in their ability to simulate communications systems and networks. Each used specific stovepipe models and simulations to analyze their proposed investments in enhanced digitized communications devices, links, processors, and other communication systems. An assessment of the overall performance of these networks in NETWARS will provide the DoD and federal government with an assessment of the robustness of an integrated network infrastructure (Joint Chiefs of Staff, 2000).

2 NETWARS SIMULATION SYSTEM

The NETWARS simulation system is designed to allow the user to compose or assemble integrated network communications simulation scenarios by combining reusable communications device models, military operational concepts, environmental factors, and other defense information infrastructure objects that have been archived in databases and libraries. This functionality provides the user with the ability to develop, execute, and analyze complex scenarios that include military units, organizations, and equipment that move over three-dimensional terrain while transmitting network communications events over simulated communication

networks that include nodes, links, and protocols. The communications networks allow the user to stochastically model and analyze the dynamic effects of voice, data, and other traffic over the simulated communications infrastructure.

The NETWARS simulation system is used to measure and assess information flow in military communications networks. NETWARS includes a unified modeling and simulation framework, innovative software approaches, and military operational concepts that are designed to provide a simulation system and a common modeling structure to support the sharing of resources, processes, and results in order to provide users with the ability to: study network traffic; perform communications contingency planning to support wargaming and other force-on-force models; evaluate emerging technologies; and reduce the time needed to conduct analyses (NETWARS Program Management Office, 2000).

NETWARS provides the ability to realistically model and simulate network centric battlefield communications to support the analysis of alternative proposed communications infrastructures. This analysis supports budget, high-level acquisition, and policy deliberations by helping to quantify the effects of communications on battle outcome. It also supports the warfighter by providing the ability to support communications planning, assess proposed communications technologies, and evaluate the supportability of operational concepts (NETWARS Program Management Office, 2000) .

Although NETWARS was specifically designed to provide a versatile simulation environment to support the analysis of major regional conflicts, small joint operations, and other military operations that vary widely in scope, size, and resolution; it is also well suited to supporting the wide range of interests among the potential users in the government, commercial, and other non-military domains. The NETWARS architecture is well suited to support the users who need high-resolution communications device models to perform detailed engineering level analysis to assess possible system design changes, as well as the users who need lower resolution communications device models to assess high-level operational alternatives (Joint Chiefs of Staff, 2000).

3 NETWARS FUNCTIONAL ARCHITECTURE

The NETWARS simulation system is a scenario centric software application that that is tightly coupled to the commercially available OPNET Modeler network communications simulation. NETWARS extends OPNET Modeler functionality by providing a separate and customized graphical user interface (GUI) that enables the military to approach communications network simulation and analysis from the perspective of a military communications scenario that includes military organizational hierarchies and military communications equipment. The NETWARS functional architecture is illustrated in Figure 1.

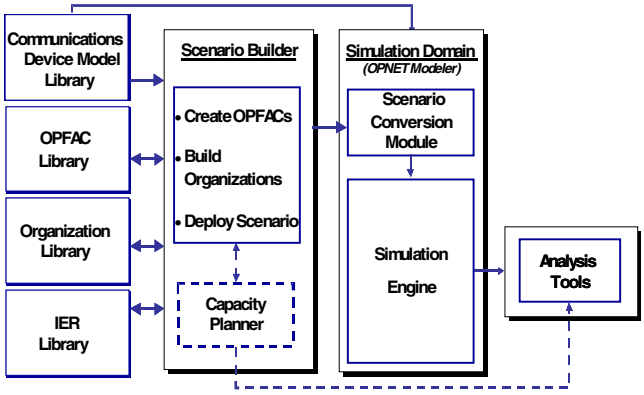

Figure 1. NETWARS Functional Architecture (NETWARS Program Management Office, 2000, p. 12)

The NETWARS Scenario Builder and Analysis Tools are the GUIs that provide the points of access that enable users to construct, execute, and analyze communications network simulations. Various libraries and databases facilitate the use of unique military communications device models by the Scenario Builder and the Simulation Domain.

3.1 Libraries

Libraries of simulation components are used to support the construction and execution of NETWARS simulation scenarios that contain detailed network representations and operational scenarios. The NETWARS simulation system includes libraries that store communications device model, operational facility (OPFAC), organization, and information exchange requirement (IER) data.

3.1.1 Communications Device Model Library

NETWARS communications device models are OPNET based simulation components that implement the NETWARS Model Development Guide (Sukumar & Dyer, 2000) interface specifications. Communications device models represent the logic, attributes, and operational characteristics (routing schemes, number of ports, protocols, priorities) of commercial or military communications equipment. The NETWARS Scenario Builder provides users with the ability to incorporate references to communications device models into OPFACs and scenarios. The NETWARS Toolkit Simulation Domain uses these references to expose the actual communications device models to the OPNET Modeler's simulation engine during simulation execution (NETWARS Program Management Office, 2000). NETWARS communications device models are tightly coupled with the commercial OPNET Modeler.

3.1.2 OPFAC Library

NETWARS introduces the OPFAC construct that allows collections of communications devices to be collocated, grouped together, and represented in the NETWARS GUI as a single object that represents a military organization, headquarters, vehicle, or other military construct. NETWARS uses the IER construct to specify communications demands. The Scenario Builder and Analysis Tools GUIs use OPFACs that are arranged in organizational hierarchies as the primary scenario building block and analysis components (NETWARS Project Standards Working Group, 1999). A notional example of a sample OPFAC is shown in Figure 2.

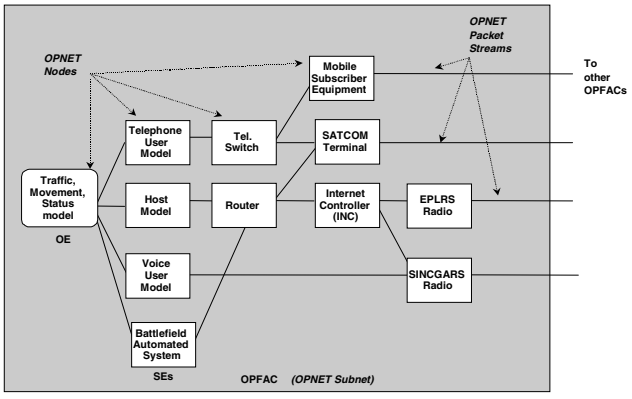

Figure 2. Notional OPFAC Example (NETWARS Project Standards Working Group, 1999, p. 6)

The OPNET Modeler's integrated GUI does not directly support the functional grouping of communications devices and the hierarchical treatment of military organizations that is supported by the Scenario Builder.

3.1.3 Organization Library

An organization is a NETWARS simulation component that represents the behaviors and communications equipment of a complex military organization like a military command post. Organizations are formed by combining a set of OPFACs together with customized network links and relationships. The individual OPFACs in a NETWARS organization are designed to model subsets of the behaviors and communications equipment of the complex aggregate military organization. At the conceptual level the organization approach treats the separate OPFACs as subsystems of the larger complex military organization.

3.1.4 IER Library

An IER is a NETWARS simulation component that represents an elemental communications requirement between sending and receiving OPFACs. These communications requirements represent scenario specific mission centric voice or data communications that are exchanged between two OPFACs. The NETWARS Scenario Builder automatically invokes the appropriate IERs in the library database both during simulation construction and scenario execution (Atamna & Dyer, 2000).

3.2 Scenario Builder

The Scenario Builder provides the user with semi-automated methods to support scenario and data development. It enables the user to construct or assemble scenarios, which are represented as networks of OPFACs that are enhanced with additional information that describes relationships, traffic, and the operational situation (Atamna & Dyer, 2000). It also provides the user with the ability to construct generic organizations, OPFACS, and IERs that are reusable to support the creation of diverse scenarios.

NETWARS implements the modular composable approach to simulation scenario definition by allowing users to assemble scenarios by extracting previously developed representations of existing interoperable reusable communications device model, scenario, OPFAC, organization, and IER components that have been previously archived in libraries. This composable approach for scenario development is designed to reduce the time and cost associated with creating scenarios and performing analysis (Joint Chiefs of Staff, 2000).

Scenarios are constructed by positioning simulation components on a computer-generated map. The user constructs a scenario by instantiating units, specifying relationships between units, assigning IERs, deploying units on the map, visualizing networks and links on the map, assigning positions and movements, selecting deployment, choosing the time slice, creating scenario description files, and storing study text descriptions. Units are represented in NETWARS simulation as communications subnetworks (Atamna & Dyer, 2000). Scenarios incorporate deployment plans, organizational structures, units, OPFACS, IERs, simulated communications device models, and network representations into files that provide the Simulation Domain and the Scenario Builder's Capacity Planner with appropriate representations of the simulated infrastructure (NETWARS Program Management Office, 2000).

The Scenario Builder stores the completed scenario in a textual representation in a simulation description file (SDF). SDF files contain information that specifies the simulated network topology in terms of OPFAC instances and IER traffic loading information. SDFs also contain OPFAC instance information like timed mobility and status that specifies the operational scenario. The syntax for SDF files incorporates features like intuitive variable names, indentation, punctuation, and normalization that make it easy for a user to examine and review the scenario

for correctness. NETWARS users can use a text editor application program to examine and change any SDF file that was created by the Scenario Builder (Dyer & Stewart, 2000). The SDF file is the interface between the Scenario Builder and the Simulation Domain (NETWARS Project Standards Working Group, 1999).

3.2.1 Capacity Planner

The Capacity Planner is a tool within the NETWARS software designed to support rapid planning and to help reduce the time required to conduct a NETWARS simulation study. The NETWARS Capacity Planner trades off accuracy against the value of timely analysis.

The Simulation Domain and the Capacity Planner are both designed to analyze the same communications network infrastructure that is contained in the user specified simulation scenario. However, unlike the Simulation Domain, the Capacity Planner uses simple IER demand matrices as the foundation of heuristic optimization techniques to provide a quick assessment and representation of network traffic. This simplification provides the user with the ability to gain insights into projected network performance during the simulation construction process. These insights might cause the user to modify the proposed network before the user completes the more detailed simulated network traffic representations that are needed by the Simulation Domain. This early detection provides the user with an opportunity to improve the chances that the architecture representation in the full-scale simulation scenario will satisfy network performance specifications. This early detection can eliminate scenario modification iterations, and reduce the time required to complete a communications simulation study.

3.3 Simulation Domain

The NETWARS Toolkit Simulation Domain executes NETWARS simulation scenarios and archives statistics that characterize the simulation architecture's performance. The NETWARS Toolkit Simulation Domain is composed of the Scenario Conversion Module and the OPNET Modeler Simulation Engine.

3.3.1 Scenario Conversion Module

The Simulation Domain includes a Scenario Conversion Module that converts textual NETWARS scenario representations into the format that is used by the commercial OPNET Modeler simulation engine. It does this by extracting the organizational representations and information flows from the SDF File and the IER library and converting them into discrete events between sender and receiver OPFAC pairs. The Scenario Conversion Module further manipulates the SDF contents and the converted information by assembling it into a binary OPNET Modeler executable scenario that is used by commercial OPNET Modeler simulation engine.

The NETWARS Toolkit EMA implementation is designed to automatically convert the textual representation of a NETWARS scenario into the binary format that is used by the OPNET Modeler (NETWARS Project Standards Working Group, 1999).

3.3.2 Simulation Engine

The OPNET Modeler Simulation Engine uses the output from the Scenario Conversion Module to generate the simulated network topology by representing each OPFAC instance as an OPNET mobile subnetwork. Each instantiated mobile subnetwork includes the appropriate communications device model representations. The Simulation Domain archives the results of the simulation execution in textual representations in a series of output data files. These output files are the interface between the Simulation Domain and the Analysis Tool (NETWARS Project Standards Working Group, 1999).

3.4 Analysis Tool

The user subsequently interacts with the Analysis Tool GUI to evaluate the results of the simulation execution in order to draw conclusions about the adequacy of the simulated communications infrastructure to satisfy a given set of measures of effectiveness (MOE).

The Analysis Tool provides users with the ability to view and analyze the results of a simulation execution by providing the ability to manipulate, filter, and display a predefined set of measures of performance (MOPs) or statistics, and MOEs in various graphical formats (Atamna & Dyer, 2000). The Analysis Tool generates these MOPs by importing, filtering, and post-processing the set of text output files that were generated and archived by the Simulation Domain during simulation execution (Joint Chiefs of Staff, 2000).

MOPs provide the user with insight into the projected performance of the simulated communications infrastructure to help determine if it would be sufficiently robust to support military operations (Joint Chiefs of Staff, 2000). The NETWARS Analysis Tool provides users with access to the following set of MOPs (Atamna & Dyer, 2000, pp. 51-52):

1. IERs Sent
2. Number of blocks
3. Perishability
4. Speed of service
5. Link throughput (forward)
6. Link throughput (reverse)
7. Broadcast net utilization
8. Connection latency

9. Grade of service
10. Message completion rate
11. Message error rate
12. Call completion rate
13. Blocking probability
14. End-to-end delay

MOPs serve as the basis for evaluating MOEs that allow the analyst to describe the performance of specific simulated communications systems components and to draw conclusions about the adequacy of the simulated communications infrastructure to satisfy a given set of MOEs. A typical MOE could involve the identification of the communications infrastructure components (e.g., over-utilized links, links with excessive contention, routers or switches that have reached or exceeded capacity) that caused bottlenecks that limited the performance of the simulated system (Atamna & Dyer, 2000).

4 EXAMPLE USAGE CRISIS EVENT (TERRORIST ATTACK AGAINST THE U.S.)

As an example, NETWARS can be used to model the following equipment, organizations and information.

1. Communications
   a. Radio
   b. Cellular
   c. Telephone
   d. Data
   e. Satellite
2. Organizations
   a. National Command Authority (NCA)
   b. Federal Emergency Management Agency (FEMA)
   c. Federal Aviation Administration (FAA)
   d. Military
   e. Police
   f. Fire and Rescue
   g. Medical
   h. Civilian/Media/Commercial
3. IER Profiles
   a. Normal
   b. Event
   c. Response
   d. Management

The simulation professional would develop a scenario to include all organizations and communication equipment. These organizations would be given relationships to other organizations such as the FEMA reporting to the NCA. Each organization would contain models of its organic communication capabilities to include packet switch, circuit switch, cellular, satellite, and radio. Each organization would be placed in a specific geographic location corresponding to the scenario. Movement of organizations and assets can also be modeled over a specific period of time. Traffic loading via the IERs would simulate volume during the scenario's timeline. Planned outages and unanticipated failures can be assigned to any device within the simulation and can be activated at specific times during the scenario timeline. These parameters can be entered into the simulation to recreate or plan for a crisis event. Most activities associated with the terrorist attack against the U.S. could be simulated to include air traffic, emergency response, cellular blocking, and military/government communications.

5 CONCLUSION

The requirement for information superiority demands that military and civil authorities cooperate, collaborate, and interoperate. Their historical approach for independently developing communications systems and networks is inconsistent with evolving operational requirements. Future communications development and procurement actions must be properly coordinated between the diverse organizations to achieve the required level of interoperability. Cultures need to evolve away from isolationism toward the common goal of cooperation and collaboration. The NETWARS simulation system provides a communications modeling environment that is fostering the required convergence of cultures by helping to revolutionize procedures to procure and effectively employ communication assets.

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