Communications In The Simulated Battlespace

APLIN, Richard; KLUGE, Claire
The Boeing Company
Richard.J.Aplin@Boeing.com; Claire.Kluge@Boeing.com

Abstract. As Defence moves ever closer to fulfilling its vision of a fully networked battlespace, one of the key challenges is the provision and maintenance of effective C4 networks. In order to better understand the issues and tradeoffs of communications equipment and architecture throughout the battlespace, a vast array of modelling tools have been utilised to simulate the communications of a wide variety of force elements.

Boeing Australia’s Systems Analysis Laboratory (SAL) conducts a range of modelling and simulation (M&S) activities, including human-in-the-loop (HITL) virtual war fighting (VWF) experiments. The facility uses a broad range of isolated simulation applications that provide the capability to simulate specific components of the battlespace. For complete and robust battlespace simulation, it becomes necessary to federate applications to ensure the accurate portrayal of all joint assets and all joint effects. One of the problems experienced in federating tools, are the limitations in compatibility of terrain and shape files, which may prevent high fidelity propagation modelling.

This paper discusses how Boeing Australia has engaged vendors to provide support for common terrain features across multiple tools, including the commercial-off-the-shelf communications modelling tool, QualNet®, available through Scalable Network Technologies (SNT). This engagement has enabled Boeing Australia to federate a number of independent tools with QualNet, facilitating HITL VWF experiments in order to analyse and understand:

1. The effects of terrain (both man-made and natural) on force element communications connectivity during operations in both the urban and rural environment.
2. The effective use of air and space assets to enhance overall coverage and interconnectivity across the battlespace.

The experiments that are conducted, including analysis of their outcomes, will seek to demonstrate the enhancement to the fully networked battlespace of developing communications capabilities such as Wideband Global Satellite System (WGS), Unmanned Aerial Vehicles (UAVs), and the ‘Wedgetail’ Airborne Early Warning and Control (AEW&C) aircraft.

1. INTRODUCTION

Many schools of thought surrounding the revolution of military affairs believe that in future warfare all shooters will be connected via a series of sensors interconnecting the future battlespace. Many western military officials would argue that in the current Network Centric Environment, a fully networked and interconnected battlespace is within reach already. With an influx of communications equipment on the battlefield, communications challenges experienced in warfare are now becoming more prevalent and will continue to do so as the quest for a digitized battlespace progresses. Overcoming these challenges is now vital to the success of commanders at all levels and, therefore, the ability to accurately simulate the modern day C4 architecture for design, analysis and training purposes has become essential.

2. BOEING AUSTRALIA’S SYSTEMS ANALYSIS LABORATORY

Boeing Australia’s Systems Analysis Laboratory (SAL) provides simulation-based military Operations Analysis (OA) enabling analytical insight into complex capability and concept-based problems. The facility uses a broad range of simulation applications that provide the capability to model and simulate different components of the joint battlespace.

As mentioned, simulating the communications architecture of a Network Centric military has become increasingly important. Many warfighting simulation tools provide very basic level communications modelling capabilities with entities being able to communicate between one another on designated frequencies as long as Line-of-Site (LOS) exists between them. Other simulation tools provide very detailed communication modelling capabilities.

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1 QualNet is a registered trademark of Scalable Network Technologies, Inc.
For the remainder of the paper, QualNet will be referred to as QualNet.
including detailed signal degradation algorithms, interference through jamming, bandwidth constraints, routing protocols etc. The advent of dedicated communications effects servers which act as a federate in virtual warfighting experiments and generate the communications challenges experienced during operations is now a necessity if all critical vulnerabilities of a plan are to be assessed. The complexity and accuracy of the communications simulation will depend on the methodology that is required and this will in turn identify the most appropriate communications simulation tool to utilize.

3. COMMUNICATIONS SIMULATION
Over the past five years, a number of literature studies have been undertaken to identify methodologies for communication simulation which would satisfy all communications domains[1]. The general consensus is that communications simulation can be classified into two main types:

- **Effect-based Simulation.** This methodology uses mathematical representations of behaviour, performance and effects for the communication network, applications, and protocols. It is inherently fast, near real-time speed, but does not guarantee accurate results since the formulas serve as generic and not exact representations of communications behaviours.

- **Engineering-based Simulation.** This methodology involves models of high fidelity, accuracy and resolution. Engineering-based models typically mirror systemic behaviours on all seven layers of the Open System Interconnection Model, including the detailed control processes of the communications protocol. Because of the layer-by-layer detailed simulations, Engineering-based models usually run on discrete-event simulators (DES). Therefore, Engineering-based simulations, using DES, provide a high level of fidelity but incur the longest run-times.

Over the past decade many M&S tools have been developed which satisfy one or both methodologies. Examples include OPNET® by OPNET Technologies, QualNet by Scalable Network Technologies, and Network Effects Server (NES) created by Boeing and QinetiQ. In order to successfully model the entire battlespace, the SAL identified a need to procure a communications M & S tool and selected QualNet as their preferred tool. Although QualNet can be used successfully to span both communications simulation methodologies described above, it has been used predominantly by Boeing Australia for Engineering-based simulation.

4. QUALNET
QualNet is a Commercial Off the Shelf (COTS) communications modelling tool from Scalable Network Technologies, that allows end-users to simulate and emulate communication architectures, and to predict the performance of the network and protocols.

QualNet can be used as a stand-alone M&S tool, or can be used as a communications effects server in a federation, as described in the following sections.

4.1 Using QualNet Standalone
QualNet has been used by the SAL as a standalone modelling tool to successfully model both wired and wireless communications architectures. One such example is the systems engineering support provided to Project AIR5333 (Project Vigilare).

Project AIR5333 (Project Vigilare) is designed to upgrade the Australian Air Defence System and will provide two new ground-based air defence, command, control and communication systems at RAAF Base Tindal in the Northern Territory, and at RAAF Base Williamtown in NSW.

As the successful tenderer, Boeing Australia have used QualNet to reduce the associated technical and schedule risks that are inherently involved in such a large-scale integration project. The capability to experiment with different network design options has been provided via the creation and use of a model in QualNet that represents the proposed Vigilare Regional Operations Centre (ROC) local area network (LAN). The model in QualNet is flexible enough to deal with rapid changes in links, hardware (such as switches and routers) and levels and types of traffic, and has provided Vigilare engineers with a capability that enables them to undertake rapid "what if" analysis to test the likely impact of technical decisions.

4.2 Using QualNet In A Federation
Many simulation tools contain limited capability to facilitate communication effect-based simulation. However, the fidelity of the communications effects model is generally inadequate for experiments that need to analyse issues and tradeoffs of communications equipment/architectures in a networked joint battlespace. To meet this need, the SAL have successfully used QualNet within federations to successfully model the communications effects of entities generated in other federates. Entities that are generated and controlled in another simulation tool are represented in QualNet as radios, after synchronization of scenarios, and the power of QualNet is used to determine whether communications between entities are successful or not.

One such example of how QualNet has been used in a federation is provided in Section 5.

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1 OPNET is a registered trademark of OPNET Technologies, Inc.
5. FEDERATING WITH QUALNET

5.1 Interfacing With Other Federates

QualNet contains a High Level Architecture (HLA) interface that may be used to interface QualNet with other federates. Interfacing with QualNet over a HLA standard RPR-FOM can be achieved at two different levels:

- QualNet as a passive listener in the federation: In this scenario, the other federate(s) sends HLA ApplicationSpecificRadioSignal interactions that stimulate the communications modelling in QualNet. QualNet listens to the HLA interactions, however its propagation computation cannot affect the outcome of the other federate.

- QualNet as an active participant in determining the communications effects in the federation: In this scenario, the other federate(s) sends HLA ApplicationSpecificRadioSignal interactions that stimulate the communications modelling in QualNet. QualNet monitors for these interactions then returns results for those communications to the client federate in real-time via HLA Data interactions.

In order for QualNet to be an active participant, changes to the other federate are often required. Without any modifications, the individual federate(s) will compute their own propagation and communications network traffic log.

To improve the capability of the SAL to conduct HITL and VWF activities that accurately model communications effects, Boeing have contracted MAK Technologies, Presagis and SNT to develop plug-ins that will enable QualNet to act as a communications effects server for VR-Forces and S-Mission.

Successful collaboration between the vendors has resulted in providing the SAL with a significantly enhanced communications modelling capability. The plug-ins have allowed HLA ApplicationSpecificRadioSignal interactions generated in VR-Forces and/or S-Mission to be read by QualNet and transmitted to the desired recipient if a successful path between the two entities is established.

5.2 Terrain Correlation

The effectiveness of QualNet to calculate accurate communication effects is dependent on the propagation models used to compute path loss between entities and the quality and consistency of the terrain data modelled. If QualNet is used in a federation to compute communications delivery between entities simulated in another federate (e.g. VR-Forces, S-Mission, VBS2), it is essential that all tools in the federation share the same terrain data. Without this consistency, the communications effects modelled in QualNet may not be representative of the real environment.

One of the problems that have hindered the usefulness of QualNet in a federation has been the lack of ability for QualNet to support various terrain formats. The version of QualNet distributed to Australia only supports Digital Elevation Model (DEM) and Digital Terrain Elevation Data (DTED) for ground elevation data terrain, plus a SNT-proprietary XML format to represent 3D urban terrain (buildings). Although Compact Terrain Data Base (CTDB) is also available to US customers, this feature is not available to Australia due to ITAR laws.

To improve the capability for the SAL to conduct joint war gaming experiments with realistic communications effects, all tools need to support a consistent set of terrain formats. To achieve this goal, Boeing has contracted various vendors to introduce new capability to support additional terrain formats. One such example is support for ESRI shape files. ESRI shape files store building footprints, building heights, foliage and other attributes. The ESRI data is then overlaid on the ground elevation data (e.g. DEM), to provide a terrain set that represents the real environment.

If all work remains on schedule, Boeing will take delivery in the first quarter of 2008, of patches to VR Forces, VBS2 and QualNet that provide support for ESRI shapefiles.

The shapefile data will be fed into QualNet’s urban propagation models, along with instantaneous positions of sources, destinations, and interfering transmissions. This will provide Boeing Australia with a significant capability to accurately simulate the effects of terrain in an urban environment in mobile wireless networks.

5.3 Passive Nature Of QualNet

As indicated in Section 5.1, QualNet is currently only capable of listening for RPR-FOM 1.0 PhysicalEntity objects, and outputting RPR-FOM 1.0 Data interactions to the federation. Therefore, all entities in the federation are controlled in other tools.

Looking ahead, it is the intention of the SAL to modify the QualNet source code to create PhysicalEntity objects or other object classes representing the QualNet nodes.

5.4 Support For DIS

QualNet currently only provides communications effects over HLA. For QualNet to federate with a tool using DIS, a DIS/HLA Gateway is required. The tool used by the SAL is the MAK Gateway Release 4.3.

\* MAK Technologies is a registered trademark of MAK Technologies, Inc.
6. EXPERIMENTATION

The SAL regularly use QualNet federated with other simulation tools to conduct virtual war fighting (VWF) experiments. This enables Boeing Australia to explore the impact of various technologies, concepts, platforms, systems and weapons on the connectivity of a deployed military force under controlled conditions.

Examples of the analyses that may be conducted include:

- The effects of terrain (both man-made and natural) on force element communications connectivity during operations in both the urban and rural environment.
- The effective use of ground assets (radars, communications relays) to enhance overall coverage and interconnectivity across the battlespace.
- The effective use of air assets (Wedgetail, UAVs, etc) to enhance overall coverage and interconnectivity across the battlespace.
- The effective use of space assets (e.g. Wideband Global Satellite System) to enhance overall coverage across the battlespace.
- Evaluate emerging technologies prior to defence procurement

An example experiment that has been conducted by the SAL that outlines the use of QualNet when federated with other simulation tools is discussed in the following paragraphs.

6.1 Scenario

A Company-sized Australian Special Operations element in Afghanistan is patrolling south through Oruzgan Province. Two of the platoons and the company headquarters have moved through a village and then progressed through a large mountain pass approximately 2 km to the south which acts as a bottleneck to any force moving through the region. As the lead elements of the third platoon approach the village they are attacked from the north-west by a small Taliban element with small arms, RPG and heavy machine gun fire. They have taken one priority-one casualty who requires immediate air-medical evacuation (AME) and are running low on ammunition prior to a large re-supply that evening. Having consulted the latest Close Air Support (CAS) schedule for possible assets in the area, it is identified that a French F-16 may be able to be diverted to assist. Due to the mountain range that lies between the platoon and its company headquarters it is likely that communications on the LOS company command net will be impacted significantly. The company commander’s intent is to allow the platoon commander in contact to call in Air Support, co-ordinate an AME for the injured soldier and dispatch a platoon to the village to provide assistance and also to conduct a hasty clearance of the village to clear out any further enemy combatants.

6.2 Desired Outcome

The purpose of the experiment was to:

- Identify the optimal communications repeater type and location to maintain communications between all company elements during the contact and subsequent urban clearance.
- Analyse the impact of terrain, both natural and man-made on communications with and without a communications repeater.
- Evaluate the benefits of switching between LOS communications and SATCOM.
- Evaluate the communications architecture in use and provide possible improvements to equipment and procedures.

6.3 Measures Of Effectiveness

In order to quantify the effectiveness of different options/alternatives, the following Measures of Effectiveness (MOE) were defined:

- Percentage of time that the Company Headquarters have connectivity with the deployed force (third platoon) whilst they are:
  - Traversing rural terrain.
  - Traversing urban terrain.
- Percentage of time that the third platoon members maintain connectivity with each other whilst traversing urban terrain.

6.4 Tools

The following simulation tools were federated to conduct the experiment:

- **VR-Forces®** VR-Forces by MAK Technologies is a simulation toolkit for generating and executing battlefield scenarios. Its primary use is as a Computer Generated Forces application, though it can also be used to undertake low-level behavioural studies through the use of its Artificial Intelligence Module, B-Have by Kynogon. In the scenario, VR-Forces is used to model the friendly forces, their reaction to contact, radio transmissions within the platoon and to the company headquarters and then to co-ordinate the CAS and AME.
- **S-Mission®** S-Mission by Presagis is a simulation toolkit for generating and executing computer generated forces in a military or civilian scenario. It features an integrated behaviour editor and model editor that provide the capability to add, edit, or
customize simulated entities, behaviors, rules, sounds, and dynamics. In the sample scenario, S-Mission was used by the SAL to define and control the small Taliban element that ambushes the third Australian Special Operations platoon. The behaviour of the enemy forces is scripted in S-Mission’s behavior editor based upon a set of predefined rules.

- **Virtual Battlespace 2 (VBS2)**: VBS2™ by Bohemia Interactive is a fully interactive, three-dimensional simulation and training tool providing a premium synthetic environment suitable for a wide range of military experimentation purposes. It offers both virtual and constructive interfaces onto high-fidelity, realistic terrain models to provide a high-degree of realism. In the scenario, VBS2 was used to view the entire experiment in 3D, fly the helicopter used in the AME and carry-out the clearance of the village by the supporting platoon.

- **QualNet®**: QualNet was used to model the communications effects between friendly forces in the scenario. This includes communications between the three platoons, Company Headquarters, AME, and CAS.

**Figure 1**: The SAL federate QualNet with various tools to create a robust model of the communications networks in a digitized battlefield.

### 6.5 Terrain

In order to realistically model the effects of terrain on the connectivity of the network, all tools identified in Section 6.2 model a consistent set of terrain data that consists of:

- **DEM.** DEM data is used for ground elevation, which has a direct impact how QualNet calculates the path loss for wireless signal propagation between nodes.

- **ESRI Shape Files.** Shapefile data is used to geographical features (e.g. roads, buildings, foliage)

- **Image.** An aerial image of the area of interest is overlaid on the DEM and shape files.

### 6.6 Results

The scenario was run using different options of communications equipment, technologies and configurations. The results for each option were then analysed against the defined MOEs.

The overall results of experiments such as the one detailed above provide Boeing Australia and its customers with a deeper analytical insight into complexities and issues associated with achieving a fully networked battlespace.

### 7. CONCLUSIONS

As a fully, network-centric force becomes increasingly obtainable, the ability to model the communications networks which facilitate a digitized battlefield is essential. Boeing Australia’s SAL seeks to conduct M&S of the entire modern and future battlespace through the use of a vast array of commercial tools, continually enhanced through vendor interaction. Its choice of QualNet as its communications modelling tool provides an Engineering-based simulation capability which not only provides high-quality modeling capabilities but also enables realistic, high-fidelity simulation of communications effects during Virtual Warfighting Experiments.

### REFERENCES

1. LTC Low, Jin Phang; Yong-Pheng Chua, Anthony; et al., (2005) “BattleSpace Communications Network Planner and Simulator (BCNPS)”, 10th International Command and Control Research and Technology Symposium

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4 Virtual Battlespace and VBS2 are registered trademarks of Bohemia Interactive Australia.