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BattleSpace Communications Network Planner and Simulator (BCNPS)

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Abstract

With rapid battlespace digitization, appreciation of communications challenges amongst war-fighters has become increasingly critical in any military operation. In order to achieve better battlespace awareness, an advanced communications system capable of projecting dynamic tactical communications environment, in real-time, is needed for operational concept development. Likewise, the dynamic shifts in operational scenarios exemplify the need for minimal response time in coping with changes in new scenarios, failure of which often results in "battlespace blindness" amongst military commanders.

The concept of Battlespace Communications Network Planner and Simulator (BCNPS) System was conceived to suffice the challenges faced by military commanders. This advanced system utilises OPNET, an advanced communication simulation tool, as the core computational engine, and is based on an innovative architecture to overcome the technical difficulties associated with near real time simulations of large tactical networks. The BCNPS System also relies on an Emulator to control the messages generated from the C2 applications, enabling commanders (Man/Hardware-in-the-loop) interaction with the BCNPS System in real-time to gain better awareness of communication conditions across the battlespace.

This paper details the BCNPS concept and exemplifies the use of virtual modelling and simulation environment as a "real-time" platform for communications network planning and operational concept development.

Introduction

The Defence Science and Technology Agency (DSTA) has jointly developed the Battlespace Communication Network Planner & Simulator (BCNPS) System, an advanced communications simulation and emulation test-bed, with the Singapore Armed Forces (SAF) Centre for Military Experimentation (SCME).

The BCNPS System provides a real-time virtual modelling and simulation environment for military commanders to conduct communications network planning and operational concept development.

The BCNPS System utilises OPNET Modeler, an advanced Commercial-off-the-shelf (COTS) communication simulation tool, to provide packet level accuracy communications simulations. The BCNPS System relies on an Emulator to control the messages generated from the C2 applications. The Emulator enables military commanders (Man/Hardware-in-the-loop) interact with the BCNPS System in near real-time to gain better awareness of communication conditions across the battlespace. In addition, the BCNPS System has been modelled specifically for Battalion communications over VHF radios since mobility and volatility of operations are commonly experienced in this military echelon.

The objective of the paper is to describe the approach and architecture adopted in BCNPS. It discusses the usage of OPNET, an advanced communication simulation tool, to suffice the simulation requirements in SAF. It also details the usage of the BCNPS System for cost benefit analysis of communication solutions and operational concept validation prior to physical deployment.

BCNPS System Architecture

The BCNPS System architecture was designed with key consideration for Man/Hardware in-the-loop feature to enable its users to experience communication conditions in their operations. In order to enable this feature, the BCNPS System was designed with customised simulation features for compliancy with the requirement with near real-time simulations.

In addition, there have been several components in the architecture, shown in Figure 1, that supports near real-time simulation and emulation of communication systems whilst preserving flexibility for Man/Hardware in-the-loop interactions. The 2 critical components of the BCNPS System architecture are the Simulation Engine and the Emulator.

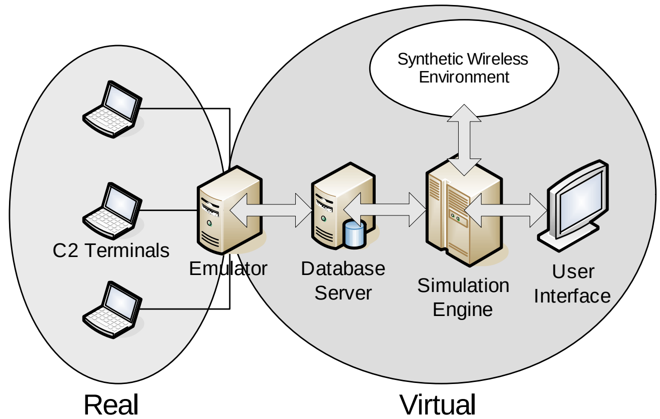

Figure 1: BCNPS Architecture

The Simulation Engine utilises OPNET Modeler and provides the BCNPS System with a synthetic wireless platform where radio and equipment models can be virtually simulated. The Emulator performs as an interface between the C2 terminals and the rest of the system components. The Emulator induces simulated communication effects such as latency and link performance variations.

Flexibility through the use of Databases

To achieve a flexible and modularised architecture, the BCNPS System employs Structure Query Language (SQL) Database Servers for data depository and extraction. Data from the Simulation Engine are transferred to the database thus allowing the Emulator to retrieve the information at a later instance. An advantage of the database is the minimisation of complex synchronising procedures between the Simulation Engine and Emulator. It is also envisaged that future enhancement to the system can be realised through this generic interface.

In addition, it is important that the unconventional use of the database for real time requires strict policing techniques. For example, data was kept in snapshots; no residue records were stored as voluminous records slow down data retrieval. A sluggish behaviour in the database server will invariably cascade to other time critical system thereby inhibiting the performance of the BCNPS System.

The Simulation Engine

In Fall 2002, Simulation Interoperability Workshop [1] (SIW) held a meeting in Orlando (USA) to discuss the requirements for Communications Modelling and Simulation (Comms M&S) in the US Army simulation programs. At this meeting, it was identified that one single type of communication simulation methodology would probably not be sufficient to meet the requirements of all the domains. From this input, a literature survey of the available Comms M&S approaches was conducted. In general, Communications Simulation, can be classified into two main types - Engineering-based Simulation and the Effects-based Simulation - depending on the levels of resolution and fidelity of the simulation models required.

a. Effect-based Simulation. 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 served as generic and not exact representations of communications behaviours.

b. Engineering-based Simulation. Involves models of high fidelity, accuracy and resolution. Engineering-based models typically mirror systemic behaviours on all seven layers of the OSI (i.e. Open System Interconnection[1]), 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.

The major technical challenge faced in BCNPS System was to design a framework that could effectively synergies the advantages of both the effect-based simulation and the engineering-based simulation, i.e. achieve high simulation fidelity at near real-time speed. OPNET was able to fulfil this requirement through its hybrid simulation [2], an implementation that combines effects-based and engineering-based simulations. Without this near real-time speed capability, the C2 systems plugged into the Emulator would not be able to experience near real-time communication conditions, thus rendering military commanders the inability to make accurate decisions in a dynamic battlespace.

The OPNET Modeler was chosen since the software platform facilitates both effect-based (through the OPNET integrated C/C++ platform) and engineering-based simulation (through OPNET kernel procedures). However, due to OPNET's inherent nature of non real-time simulation, there was a need to customise the OPNET Modeler to suffice real-time simulations. Besides, customised VHF radio and RF propagation models in OPNET environment were also required to enable accurate simulation of wireless effects and equipment. It was possible to obtain a High Level Architecture (HLA) module to provide real-time functionality; however, it has proved to be uneconomical with just 1 simulator engine required for the system.

Near Real-Time Simulations

Without open literatures on time correlation techniques, an ingenious technique (Real-Time Adherence technique) was devised to embed a time

[1] OSI defines the framework for communications which has seven layers: 1-physical, 2-datalink, 3-network, 4-transport, 5-session, 6-presentation and 7-application

controller in the Engineering-based Simulation Engine, OPNET Modeler, for optimal simulation accuracy and synchronisation with real-time speed.

The Real-Time Adherence (RTA) technique comprised of a combination of process models and external functions. As it is virtually impossible to achieve perfect synchronisation between real-time and simulation time, the RTA devised a maximum time deviation interval (Δ) to achieve near real-time simulation.

Prior to simulation commencement, the BCNPS System users define the time interval value in accordance to three factors, namely:

a. the tempo of the simulated scenario, e.g. 5 milliseconds for fast moving forces (aircraft) and 5 minutes for slower moving forces (foot soldiers and vehicular forces),

b. the simulation granularity, and

c. the size of the simulated force.

Mathematically, the time interval is directly proportional to the timeliness of the results (tempo), the fidelity of the simulation results (granularity) and the number nodes in the scenario (size).

In the event where simulation time > Δ, data extraction at the end of Δ is still possible but slight degradations in accuracy are expected, e.g. extracting the previous calculated data. As such, RTA relies on the assumption for an initialisation phase in all simulations to ensure valid data have been deposited in the SQL Database Servers prior to Emulator extracting the information.

The Emulator

The Emulator plays a complementary role to the Simulation Engine by enabling BCNPS users connect C2 applications to the system, thus achieving a man-in-the-loop operation. The primary interface was the RS-232 standard requiring handshaking with baud rates kept at the maximum rate.

As mentioned earlier, the Emulator relies on the Simulation Engine to provide information such as data-rates and link qualities via the SQL Database Server. Upon obtaining results from the Simulation Engine, appropriate actions like delay and link performance variations will be applied.

Through the Emulator, military users can perform role-playing of any fighting units in the scenario and experience the communication environment through a virtual simulation battlespace. Figure 2 illustrates the virtual simulation battlespace through the Emulator.

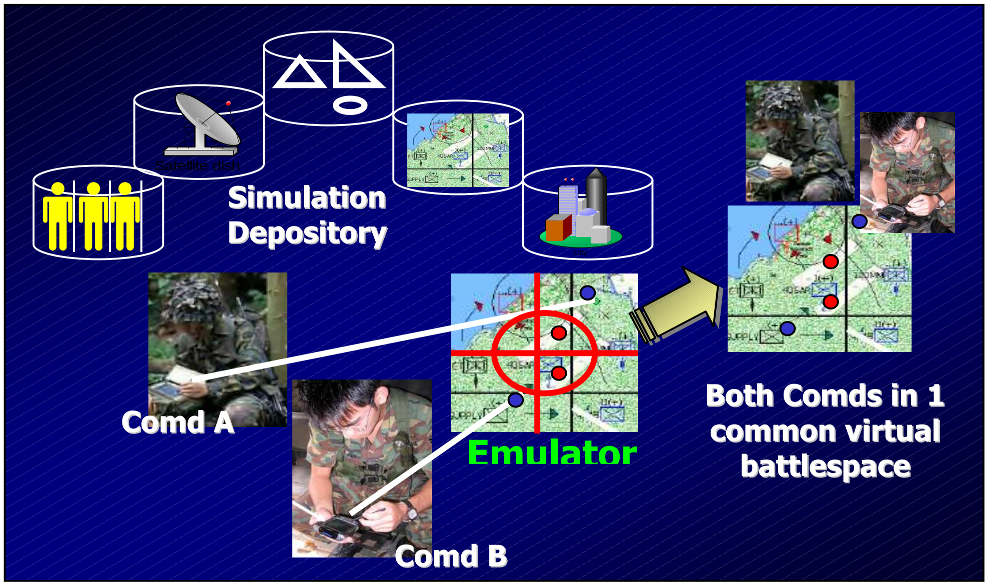

Figure 2: Virtual simulation battlespace through the Emulator

Usage Of BCNPS System

In recent military planning exercises, the BCNPS System was used as an experimental test-bed for communications network design and validation of operational communication plans. Through BCNPS System, the military commanders were able to conduct communication coverage planning and auditing of these plans with "what-if" scenarios for network vulnerability assessment.

In addition, the mocked-up exercises with the BCNPS System provided the military commanders the opportunity to experience the simulated communication conditions. The military commanders were able to drive-through the planned scenario and respond effectively to the communication inhibitors in the scenario without incurring mammoth costs and resources, as would in actual exercises.

Also, the C2 application developers benefited from the BCNPS System as they were able to conduct evaluation and testing of the application protocols in a controlled communication environment prior to actual software rollout. Furthermore, these C2 developers would be able to appreciate the communication constraints and challenges, especially in tactical military echelon, thus effectuating optimum application protocols that address the need for efficient application protocols in bandwidth constrained operational scenarios.

Conclusion

In short, the Battlespace Communication Network Planner & Simulator (BCNPS) System has been developed as a near real-time communication experimental test-bed for the purpose of pre-deployment planning, training and protocol evaluation. With the advancement in advanced communications simulators, e.g. OPNET, and computing hardware, the BCNPS System can harness these technological advancements to provide operational advantages to military commanders in terms of cost effective and accurate battlespace information prior to actual battlefield engagements.

Further enhancements and evolutions to the BCNPS System are in the pipeline to support large-scale war-gaming exercises and also to provide economical communication test-beds for evaluation of emerging technology on military tactics and operational capabilities.

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