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Network Centric Simulation Architecture

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Abstract: In the network-centric warfare, modeling and simulation capabilities should be delivered to the battlefront by networking to directly support some key capabilities of the joint command and control. However, current simulation architectures are incompetent for such requirement due to the nonsupport of seamless integration and interoperation with the command and control system. This paper proposes a network centric simulation concept, as well as its architecture and interoperation mechanism with the command and control system. As a new simulation method, network centric simulation relies on the formulized standards and specifications to make the simulation resources discoverable, accessible and understandable, and forms an agile and scalable simulation environment on the information grid infrastructure, in which simulation resources could plug and play, serve on demand, and communicate point to point.

Keywords: network centric simulation (NCS), command and control (C2), architecture, interoperation

1. Introduction

The development of network centric warfare (NCW) concept and global information grid (GIG) technology has significantly influenced the construction method and application pattern of command and control (C2) system[1]. Future C2 system for joint warfare will be built on the military information grid infrastructure[2], and interconnect various intelligence, surveillance and reconnaissance (ISR), force units, weapons, platforms and other information support systems, to form a network centric combat system across the land, sea, air, space and electronic warfare.

Network extends the C2 system boundary and endues the system with more resources, capabilities and flexibilities, however also increases the difficulty in system designing, development and evaluation. As a result, future joint C2 system will rely more heavily on the modeling and simulation (M&S). M&S will act as a component of the C2 mission capability packet (MCP)[3] and its capability will be delivered by network to the battlefront to directly support some key capabilities of the C2 system, such as mission planning, course of action analysis, training and mission rehearsal. To meet above military requirements, the integration and interoperation between M&S and C2 system should be solved.

C2 system and M&S have developed independently for a long term. The interoperation methods in each domain and between two domains have been widely researched. Leslie S. Winters and Dr. Andreas Tolk proposed two perspectives to achieve the interoperability based on the GIG[3]. One is to maintain the current concepts of interoperability as defined by the high level architecture (HLA)[4] and package current M&S applications into application-sized services[5][6]. The other is to develop a novel service-oriented[7] simulation architecture and solve the interoperation problem from the architecture viewpoint. This paper follows the latter perspective and proposes the concept of network centric simulation (NCS), as well as its characteristics, application pattern, architecture and interoperation mechanism with the future joint C2 system.

2. NCS Concept and Characteristics

2.1 NCS Concept

Following the service oriented architecture (SOA), NCS formulizes unified standards and specifications for simulation resource description, accessing, publishing, etc., and relies on the information grid infrastructure to form a simulation resource sharing environment. For a simulation application task, the task-related simulation resources residing on the grid will be recruited to dynamically form a community of simulation task (CoST) to accomplish the simulation goal. NCS is a new method to build and run the simulation application system, but not the simulation of network centric environment, and does not care how to construct the entity models in the simulation application.

In the NCS, simulation resources can be mainly divided into three categories. The first is the basic simulation resource, such as data resource, computing resource and storage resource, which can be visited by the simulation application and other simulation resources. The second is the simulation support resource, including modeling tool, runtime support software, application support software, resource configuration tool, management facility, etc. The third is the simulation application resource, including entity simulation model, simulator, simulation system, and so on. These simulation resources could be the constructive simulation models, virtual simulators or live facilities/systems. The third class of simulation resource can actively access the first and second, and exchange data with other simulation application resources through a service-oriented solution.

A CoST is a community similar to the traditional simulation system or HLA federation, but it is virtual and temporary, i.e., a CoST is dynamically constituted with the task-related simulation resources distributed on the network, runs for specified simulation task, and dismisses at the end of simulation task. A CoST usually consists of multiple simulation resources. To execute different simulation tasks, different CoSTs should be formed. In military domains, the simulation application tasks contain mission planning, course of action analysis, mission rehearsal, embedded training, system/equipment test and evaluation, and so on.

2.2 NCS Characteristics

1) NCS is a service-oriented simulation method

Service is essentially a publishable and accessible functional component or resource. NCS adopts service-oriented technology to design, develop and integrate the simulation system. In NCS, unified specifications for resource description, integration, publishing, etc., are formulized and utilized to enable new system development in a service-oriented manner. Meanwhile, legacy systems and functions can be encapsulated and brought into the service-oriented world. Then, these simulation resources are shared and loosely coupled on the network, and could be invoked to implement a simulation application system. For example, the advancing of simulation clock can invoke the time management service, and the information interaction between two entity-models can be achieved by calling the information publish/subscribe service.

HLA adopts object-oriented rules to construct simulation system, and depends on the federate object model (FOM) to solve the integration and interaction problems. In HLA, reuse and interoperation are limited within the federation, while the NCS achieves larger-domain reuse and interoperation with a novel designing rule.

2) NCS environment has the information grid[8] technology characteristics

NCS environment is distributed, heterogeneous, dynamic and autonomous. 1) Simulation resources on the network have different kinds, functions, interfaces and locations. 2) Simulation resources can freely join or resign the NCS environment according to their states. For example, in-service resources may exit due to malfunction, and outside resources may enter successively on demand. Therefore, the NCS environment has good expansibility. 3) Each simulation resource belongs to certain handler. The resource handler has the highest management authority and independent management capability, and decides whether to share the resource. While the simulation resource is shared, it is not only managed by its owner, but also subjects to the management of the NCS environment for reuse and interoperation.

3) NCS agrees to dynamically construct and execute task-oriented simulation

Compared with traditional simulation methods, NCS is superior in the dynamic construction and execution of task-oriented simulation application. For a specified simulation task, task-related entity model, simulator and other required resource will be queried, located and organized by the configuration tool to form a CoST. Then, the CoST runs under the support of simulation support resources, including simulation runtime support software, simulation application common support software, simulation management facility, and so on.

In the NCS, the construction of CoST is the process of dynamically organizing and configuring the simulation resources on the network, while such pattern can't be supported by traditional simulation method. HLA-based simulation system must follow the Federation Development and Execution Process (FEDEP), and the developed federation can only meet the pre-set simulation function. Static FOM confines the flexibility and adaptability of the simulation federation. Fixed resource assignment does not allow the federation to dynamically invoke and manage the simulation resources. As a result, during HLA-based simulation system running, the resources can not be dynamically loaded, shared and organized.

3. NCS Application Pattern and Architecture

3.1 NCS Application Pattern

NCS supports a novel simulation application pattern. The designers can rely on the service-oriented simulation support environment to organize the task-related resources for dynamically constructing and running various CoSTs. A CoST is formed according to the simulation task, and its members are distributed on the network, including simulation basic resource, simulation application resource, simulation support resource, operational system, etc. For example, the CoST for planning, as shown in Figure 1, is composed of C2 model, C4I model, ISR model, computer generation force (CGF) model, simulation support resource, and so on. A CoST can be viewed as a loosely-coupled federation, of which the members can freely enter and exit, i.e., if suiting the requirements, the simulation resource can join or resign the CoST at any moment or location. In the NCS environment, multiple CoSTs can coexist and a simulation resource can simultaneously serve for multiple

CoSTs. In Figure 1, the CoSTs for planning and training run at the same time on the information grid infrastructure, and the simulation resource register service plays parts in both CoSTs.

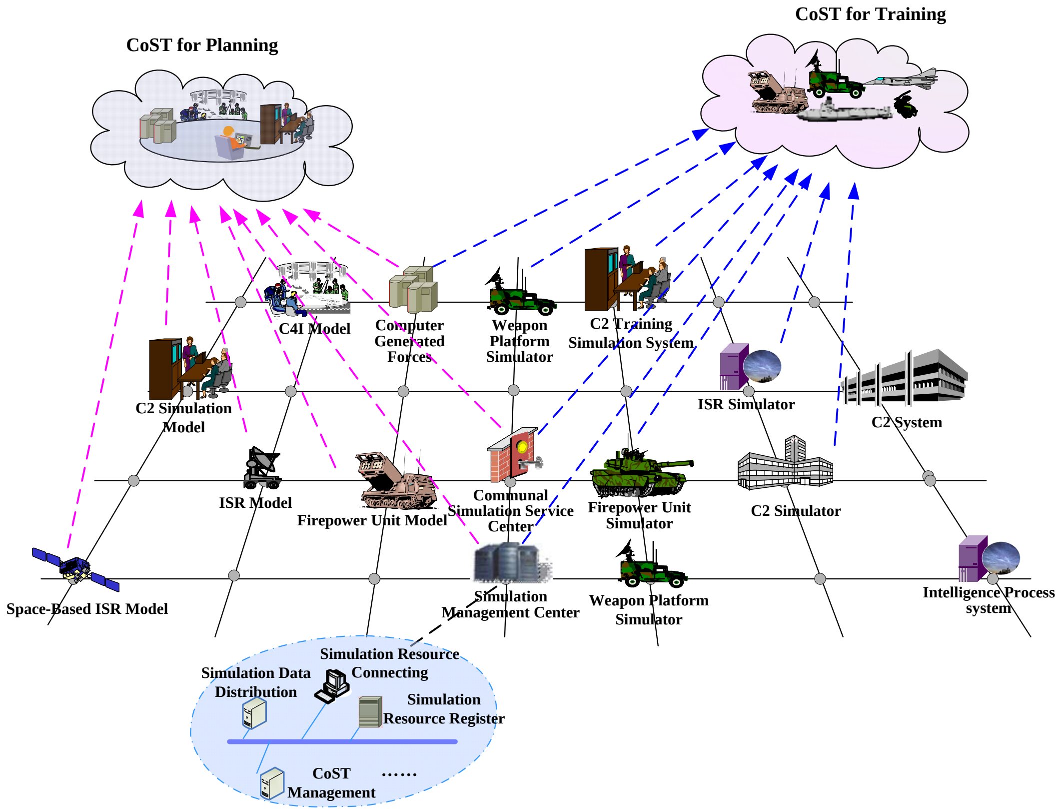

Figure 1 NCS application pattern

The implementation process of a CoST is shown as follows. Firstly, conforming to the security system and standard specifications, the users define the simulation task by the simulation configuration tools, search the available simulation resources on the network, and configure the information interaction relationships between them; Secondly, according to the defined simulation task, the located simulation resources are integrated into a CoST in the way of service composition. Lastly, under the monitoring and managing, the CoST runs to accomplish its simulation task.

3.2 NCS Architecture

NCS architecture is hierarchical, as shown in Figure 2, which includes the layers of information grid infrastructure, simulation core service, simulation common service and simulation application service. Besides, it also includes the contents of simulation service management and simulation resource specifications.

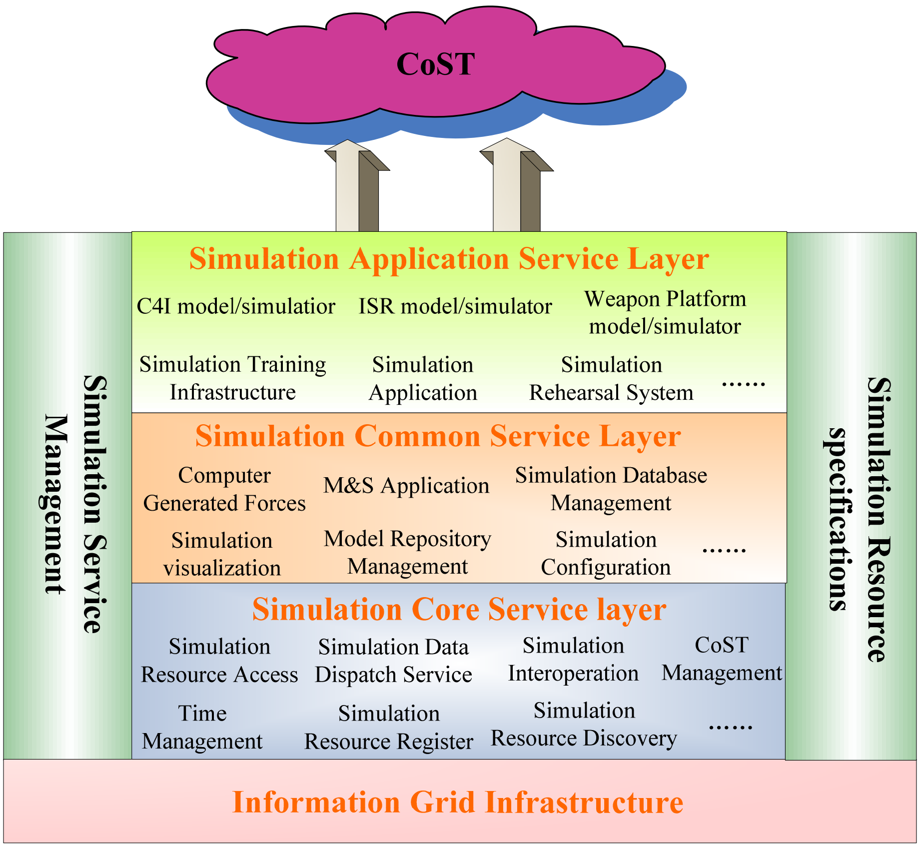

Figure 2 NCS architecture

1) Simulation application service layer

This layer provides various simulation application resources, including C4I model/simulator, ISR model/simulator, weapon platform model/simulator, simulation rehearsal system, simulation training facility, etc. The simulation resources in this layer can be configured to compose various CoSTs for different simulation tasks.

2) Simulation common service layer

This layer provides common services for simulation applications, including the CGF tool, modeling tool, simulation database management, simulation visualization toolkit, model library management tool, simulation configuration tool, etc. The simulation resources in this layer can be utilized to establish new simulation application resource and configure the simulation task model.

3) Simulation Core service layer

This layer is independent of the simulation application requirement, but just provides the simulation runtime support core service, including simulation resource accessing, resource registration, simulation interaction, time management, simulation data distribution, etc.

4) Information grid infrastructure

Information grid infrastructure provides basic service for the NCS, including communication, resource scheduling, resource monitoring and resource management. Besides, it also provides the computing resource, storage resource, network resource, etc.

5) Simulation service management and simulation resource specifications

Simulation service management is responsible for monitoring and managing the simulation resources in the CoST to keep it running in order. Simulation resource specifications prescribe the unified standard specifications for the simulation resource development, publishing, sharing and integration.

In the NCS environment, simulation resource is publishable, discoverable and accessible with the services of resource register and discovery. As long as relating to the simulation task and meeting the NCS interface specification and security requirement, the simulation resources can plug and play (PnP), serve on demand, and dynamically compose a CoST in spite of where it is. The simulation resource nodes in a CoST can do point-to-point communication.

4. Interoperation Mechanism between NCS and C2 system

Due to the long-term independent development of M&S and C2 system, there are various differences between their architectures, standard specifications and data models. Existing methods to solve the interoperation problems mainly rely on the agent technology to transform the interface, protocol and data. These methods are deficient due to low efficiency and partial loss of interoperability. The following part proposes an interoperation mechanism from the architecture viewpoint, which can realize seamless integration and interoperation between the NCS and C2 system.

Both the future M&S and C2 system are founded on a common information grid infrastructure, adopt the network-centric and service-oriented architecture, and utilize the same standards and component models. Simulation-based capabilities like training, decision support would be registered, published and shared as services through utilizing the registration, discovery and metadata catalog services in the information grid infrastructure. Similarly, the MCPs in future C2 system could also be registered, published and shared in the form of service. Therefore, under the support of information grid infrastructure, M&S and future C2 system can realize interoperation by service invocation, as shown in Figure 3. This enables a seamless integration and interoperation of simulation-based systems with future C2 systems.

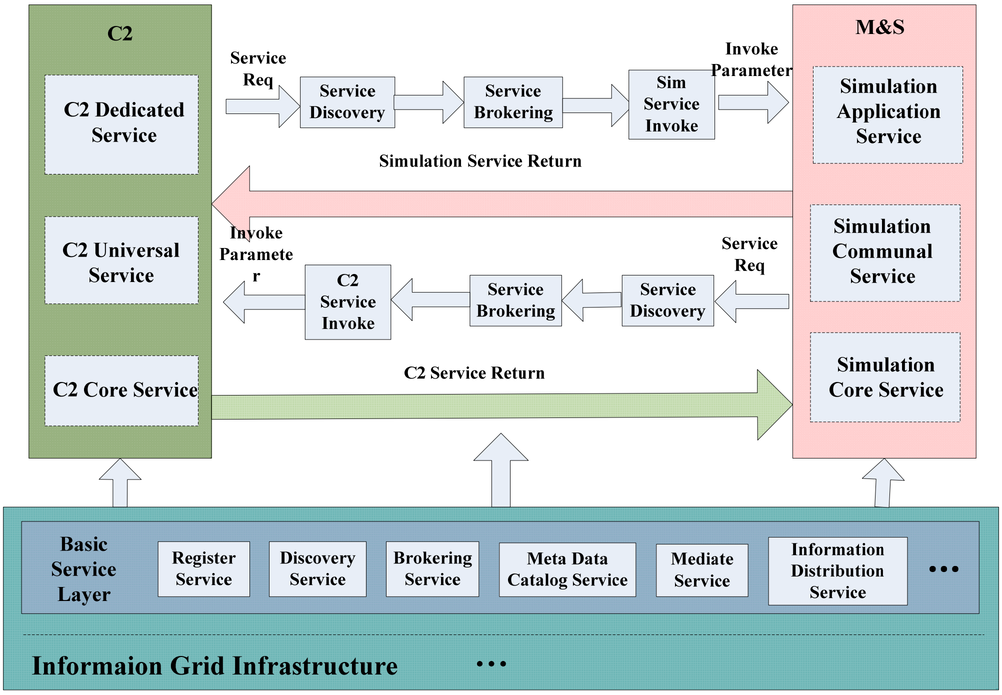

Figure 3 Interoperation mechanism between NCS and C2 system

Operation plan evaluation by simulation rehearsal is an example that the C2 system requires M&S to provide some key capabilities. In this case, the C2 system could deliver service request containing the characteristic information of simulation rehearsal service. The basic service layer provides the ability of discovering, brokering, locating and utilizing the required simulation resources. Lastly, the simulation rehearsal service returns the rehearsal result to the C2 system. Simulation force constitution during editing operation scenario is an example that the simulation system needs C2 system to provide service. Although both the C2 system and simulation system have defined the plan-related and scenario-related data objects in detail, such as force buildup data, equipment data and battlefield environment data, their description modes are different. As a result, the structure and semantics of scenario-related data must be understood by each other during interaction.

NCS can utilize the metadata catalog service and transform services in the basic service layer to analyze the published data in both C2 and M&S, abstract the concept model, and establish an authoritative data exchange model including the battle management language (BML) and common ontology. In this way, the simulation system and C2 system can understand each other about the data, concept, operational regulations and operation actions in all the lexical、grammatical and semantic layers.

Then, a bottom-up agreement at the three layers will ensure an ultimate interoperation between the simulation system and C2 system.

5. Conclusions

NCS is a novel M&S method agreeing with the NCW. This paper proposes the NCS concept, architecture and its interoperation mechanism with the C2 system. Further research will be focused on the designing, developing and validation of the proposed concept and method. Through constructing the NCS prototype system, the proposed concept and method will be validated and improved.

Conferences

[1] David S. Alberts, John J. Garstka, Richard E. Hayes, David A .Signori. Understanding Information Age War[E] .

[2] Global Information Grid. DoD Chief Information Officer Guidance and Policy Memorandum, No.8-8001. http://www.defenselink.mil/nii/org/cio/doc.

[3] Leslie S. Winters, Dr. Andreas Tolk: The Integration of Modeling and Simulation with Joint Command and Control on the Global Information Grid, Spring Simulation Interoperability Workshop, San Diego. CA. April 2005.

[4] The Institute of Electrical and Electronics Engineers: IEEE Standard 1516 for Modeling and Simulation (M&S) High Level Architecture (HLA)-Framework and Rules, http://www.ieee.org, 2000.

[5] Don Brutzman, Michael Zyda, Morse. Extensible Modeling and Simulation Framework (XMSF) Challenges for Web-Based Modeling and Simulation[R]. Technical Challenges Workshop, Strategic Opportunities Symposium. Monterey, CA: Findings and Recommendations Report, 2002.

[6] Arnold Buss, John Ruck. Joint Modeling and Analysis Using XMSF Web Services[C]. Proceedings of the 2004 Winter Simulation Conference. Monterey, CA: Simulation Interoperability Workshop, 2004.

[7] Dirk Krafzig, Kar1Banke, Dirk Slama. Enterprise SOA Service-Oriented Architecture Best Pacrtices. Upper Saddle River: Prentice Hall PTR.

[8] Foster, C. Kesselman, S.Tuecke. The Anatomy of the Grid: Enabling Scalable Virtual Organizations[J]. International Journal of Supercomputer Application, 2001, 15(3): 200~222.

[9] Michael R. Hieb, Andreas Tolk, William P. Sudnikovich. Developing Extensible Battle Management Language to Enable Coalition Interoperability, European Simulation Interoperability Workshop, June 2004.
[10] Andreas Tolk, Michael R. Hieb. Building & Integrating M&S Components into C4ISR Systems for Supporting Future Military Operations, ICGCMS ’03, August 2002.