Hardware in the loop simulation training system based on HLA architecture

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Abstract. A simulation training system is designed, which uses HLA architecture to realize the coordinated operation of network simulation, hardware in the loop access and electromagnetic computing. The system uses the standardized virtual real access interface to make the communication equipment simulator share the equipment parameters and interactive data with the network simulation model. VRNET is used for network simulation and interacts with the electromagnetic calculation module to form a complex electromagnetic environment. The system can be used in communication simulation training, electromagnetic interference array analysis and other fields.

1. Introduction
Network simulation is a network planning, design and analysis technology, which can test the network and verify the scientific communication scheme. The distributed simulation technology based on high level architecture (HLA)\cite{1}\cite{2} can effectively distribute the simulation functions to multiple platforms, so as to improve the simulation accuracy and allocate the functions reasonably, which provides an effective solution for large-scale planning communication network simulation. For distributed communication network simulation, there are a lot of resources for research, such as the JCSS \cite{3} simulation system developed by the US Department of defense. The system provides a large number of communication device models based on OPNET platform, including HLA interface. VRNET is based on discrete event scheduling algorithm. The network types that can be planned include Link11, Link16, radio, satellite, microwave, IP and upper layer services. This paper designs the simulation training system based on HLA Distributed design, uses VRNET for network planning, and allows the simulator to access the simulation network.

2. System Architecture
The core architecture of hardware in the loop simulation training system is composed of network simulation subsystem, electromagnetic computing subsystem and virtual real access subsystem, and its architecture is shown in Fig. 1.
Based on the virtual network communication model platform VRNET, the network simulation subsystem constructs the network topology through platform model, device model, protocol model and business model. Virtual real access subsystem mainly realizes data sharing between simulator and network simulation model. The simulator parameters are shared with the network simulation model parameters in real time, and the simulator traffic flow information is updated to the network simulation model.

### 3. HLA Ring

The first mock exam is HLA system, which is an open architecture with distributed interactive simulation technology. It will connect different places and different types of simulation devices or systems to implement the combat capability in the same simulation environment. In HLA, Federation refers to the distributed simulation system used to achieve a specific simulation purpose, which is composed of several interacting federates.

HLA is mainly composed of rules, object model template and interface specification. RTI (runtime infrastructure) is the core of HLA. It separates the realization of simulation function, the management of simulation operation and the transmission of underlying data, making each part relatively independent. HLA uses "publish/subscribe" claim management mechanism for data communication. That is to say, each state declares to RTI the data it can generate and orders the data it needs. Table 1-3 shows the information of "publish" and "subscribe" involved in each subsystem of the simulation training system. In table 1-3, the "description" column is the information generated in the "source" row, and the "destination" row is the state that needs to "subscribe" such information.

**Table 1. Network simulation subsystem.**

| Name         | Network simulation subsystem                                                                 |
|--------------|---------------------------------------------------------------------------------------------|
| source       | Network simulation subsystem                                                                |
| destination  | Other HLA state                                                                             |
| description  | Publish the working status of equipment, wireless link status, network performance status    |
|              | and communication service transmission status                                               |
| source       | Electromagnetic computing subsystem                                                          |
| destination  | Network simulation subsystem                                                                 |
| description  | Release electromagnetic environment status                                                  |
Table 2. Virtual real access subsystem.

| Name | Virtual real access subsystem |
|------|-------------------------------|
| 1 source | Network simulation subsystem |
| destination | Virtual real access subsystem |
| description | Publish the working status of equipment, wireless link status, network performance status and communication service transmission status |
| 2 source | Virtual real access subsystem |
| destination | Network simulation subsystem |
| description | Publish the working status of equipment and the transmission status of communication service |

Table 3. Electromagnetic computing subsystem.

| Name | Electromagnetic computing subsystem |
|------|-------------------------------------|
| 1 source | Network simulation subsystem |
| destination | Electromagnetic computing subsystem |
| description | Publish the working status of equipment, wireless link status, network performance status and communication service transmission status |
| 2 source | Electromagnetic computing subsystem |
| destination | Network simulation subsystem |
| description | Publish the electromagnetic calculation status |

4. Network simulation subsystem

The network simulation subsystem is mainly used to simulate the network in complex electromagnetic environment. In VRNET, there are four inter layer model mechanisms: network model, platform model, device model and protocol model. The relationships among the four models are as follows:

![Diagram of VRNET models]

Equipment model is the smallest simulation model with independent function, which is the basic unit of station model. The station model is composed of different equipment models. The network model contains different station models.
5. Electromagnetic calculation subsystem
The electromagnetic computing subsystem is mainly based on the radio wave propagation model to realize the wireless communication link calculation and wireless link communication performance evaluation in the simulation training network.

5.1. Radio wave propagation model
Seven kinds of classical propagation models are used for radio wave propagation attenuation, and the function of automatic matching is provided. The appropriate propagation algorithm can be selected automatically according to the link type and frequency range. Match according to work frequency and service type. When different services communicate with each other, the propagation model is automatically matched according to the service type, which is used to complete the simulation calculation of radio wave propagation of various ultrashort wave and microwave electromagnetic signals based on geographic information. It is suitable for all kinds of transceiver links, and provides the calculation of path loss, propagation delay and coverage level.

| Communication model | Description | Frequency Range |
|---------------------|-------------|-----------------|
| ITU_P.525           | Free space propagation prediction model. | 0-300GHz         |
| ITU_P.526           | It is used to predict the ground diffraction propagation in ultrashort wave band includes smooth ground diffraction, edge obstacle diffraction and other propagation characteristics. | 30MHz-30GHz |
| ITU_P.618           | It is used for propagation prediction of radio communication service between satellite and ground station, including the influence of precipitation, clear sky, ionosphere and tropospheric scintillation on the transmission path. | 1-55GHz         |
| ITU_P.838           | It is used to calculate the transmission attenuation caused by rain according to the relationship between rainfall intensity. | 1-1000GHz |
| Short wave propagation model | It integrates the propagation prediction methods of medium frequency and high frequency sky and ground waves, including a special ionospheric environment database for sky wave calculation. By inputting the predicted time, frequency, longitude and latitude at both ends of the link and the equipment parameters used, the delay and SNR distribution of the link are calculated. | 1.6-30MHz |
| Okumura-Hata        | Communication model of ground mobile services in big cities. | 1.5-2GHz |
| COST-231            | Base station intensive area ground mobile service propagation model, extended Okumura-Hata model. | 0.8-1.8GHz |

5.2. Wireless link communication performance evaluation model
The basic idea of communication evaluation is to compare the signal to interference ratio (SIR) of the receiver front-end of the communication station with the SIR threshold of the communication equipment. When the equivalent interference level (dBm) of the receiver is greater than 10dB, or when the signal to interference ratio of the front end of the receiver is less than the working threshold of the communication station, the communication will be treated as affected. When the equivalent level (dBm) of the receiver is less than 10dB, or when the SIR of the front end of the receiver is greater than the working threshold of the communication station, the communication will not be treated as affected.

A communication link is formed between the transmitter and the receiver, which automatically matches the propagation model. The same network uses the same frequency, and there is no interference within the network. Receiver intermodulation is mainly caused by nonlinear components in the front end of the receiver. The influence of receiver intermodulation interference can be described by equivalent intermodulation interference level. The expression is as follows:

$$P_{IM} = -93 + 2P_N + P_P - 60\log(\Delta f)$$ (1)
Among them, $P_{IM}$ is the equivalent interference level of the receiver (dBm), $P_N$ is the interference signal level of interference signal $f_N$ at receiver input (dBm), who near to the receiver frequency $f_{OR}$. $P_N$ is the interference signal level (dBm) at the input end of the receiver for the interference signal far away from the receiver frequency, and $\Delta f$ is the the normalized percentage of frequency difference of $f_N$ and $f_{OR}$.

$$\Delta f = \frac{|f_N - f_{OR}|}{f_{OR}} \times 100\% \quad (2)$$

When the equivalent intermodulation interference level is greater than 10 dB of receiver sensitivity, the receiver can be considered to be interfered. Link calculation as follows:

1. All receivers create useful links in the network to form multiple useful link schemes;
2. The signal strength of the link receiver is calculated. When the signal strength is greater than the sensitivity, the link can communicate, otherwise not;
3. Calculate the rate of signal to interfere SIR of the link. When the SIR is greater than the threshold, the link is considered to be in normal communication and not interfered. When the SNR is less than the threshold, the link is interfered;
4. Judge the intermodulation interference when there are multiple interference sources.

6. Virtual real access subsystem
The main functions of virtual real access subsystem include simulator and simulation model parameters, which can simulate the transmission data according to the link state. The simulation model has a unique ID, which can correspond to the simulator one by one. Through the virtual real access subsystem, the formatted data packets of the device parameters are transferred, so that the parameters of the simulator and the corresponding simulation model are consistent in real time. In order to improve the real-time communication of the simulator, the virtual real access subsystem processes and forwards the communication data asynchronously. The middle form of model relation is designed, that is, the basic information of model is stored in tables. The virtual real access subsystem receives the real-time updated equipment working status, wireless link status, network performance status and communication service transmission status from the network simulation subsystem, and updates the model information table in real time. After receiving the data from the simulator, the virtual real access subsystem processes and forwards the data in real time according to the table content.

7. Summary
This paper introduces a simulation network architecture based on HLA, which allows the simulator to access the simulation network, and can be used in communication simulation training, electromagnetic interference array analysis and other fields.

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