Development of 3D Exhibition System for IoT-Oriented Simulation Platform

Wenjun Yang[1,2], Qinghe Du[1,2](✉), Xinlei Xiong[1,2], Li Sun[1,2], and Pinyi Ren[1,2]

[1] Department of Information and Communications Engineering, Xian Jiaotong University, Xian 710049, China
yangwenjun2014@stu.xjtu.edu.cn, {duqinghe,lisun,pyren}@mail.xjtu.edu.cn, xiongxinleixxl@163.com

[2] National Simulation Education Center for Communications and Information Systems, Xian 710049, China

Abstract. This paper develops an exhibition system based on the system-level simulation platform for massive wireless access of IoT. The system appends a complete data output mechanism based on the original simulation platform, which provides a convenient environment for development and debugging, observation of system process and performance evaluation for the NB-IoT simulation platform. The exhibition system includes multiple modules, such as a data processing module, a driving engine module, a drawing module and a 3D scene module. Meanwhile, the system designs multiple interaction modules to restore the simulation details. Finally, this paper completes the debugging of the system, analyzes and discusses the results.

Keywords: NB-IoT · Exhibition system · Qt

1 Introduction

In order to meet the needs of future users for delay and speed, the fifth-generation mobile communication system (5G) [1–3] proposes the objective of high-speed, low-latency and massive access to realize the Internet of Everything. In this context, the Narrow Band-Internet of Things (NB-IoT) has attracted more and more attention around the world. In order to carry out comprehensive evaluation and verification of NB-IoT technology, and provide reference and basis for NB-IoT technology selection, the research team developed a system-level simulation platform for NB-IoT, but had not yet developed a simulation demonstration system and failed to provide a complete data output mechanism. In order to build a convenient environment for development and debugging, observation of

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system working process and performance evaluation for NB-IoT simulation platform, this paper sorts out the function structure of NB-IoT simulation platform and adds a data output module. Based on the simulation record file, this paper designs and implements the 3D demonstration system to match with the simulation platform. And the cross-platform C++ application development framework Qt [4] is used to construct the 3D model. Based on the signal and slot mechanism [5] provided by Qt, the event-driven engine is designed. When the interactive mode of the system is demonstrated, the system perspective, the base station perspective as well as the user perspective are designed for the users to observe. In the analysis and demonstration of the simulation data, the exhibition system designed the real-time rendering curve function, and the observer can analyze the key performance indicators of the simulation platform through observing the curve.

The rest of the paper is structured as follows: Sect. 2 briefly introduces the general structure and function of the NB-IoT simulation platform, and Sect. 3 summarizes the system structure of the exhibition system. Section 4 explains the concrete implementation of the 3D exhibition system, including the structural design and the specific implementation of each function. Section 5 analyzes and discusses the demonstration results, and finally Sect. 6 summarizes the full text and gives conclusions.

2 Simulation Platform for NB-IOT

In order to carry out comprehensive evaluation and verification of NB-IoT technology and provide reference and basis for NB-IoT technology selection, the research team designed and developed NB-IoT system-level simulation platform based on 3GPP TR45.820 [6]. The platform is written in C++, and the modules of service generation module, drive engine module, resource allocation module, channel module, random access module, power control module and coverage type division module are designed and implemented to complete the simulation of capacity of NB-IoT network and the probability of access failure. In order to reduce the probability of access failure and avoid congestion, the backoff mechanism must be optimized. Therefore, in the development process of the simulation platform, a different type of backoff mechanism based on coverage type is proposed. Thanks to this mechanism, the simulation platform can avoid large-scale access failures.

3 System Architecture

The exhibition system is roughly composed of four major functional modules: a data reading module, a data processing module, a 3D scene module and an engine module. System perspective, base station perspective and user perspective are designed in the 3D scene demo module. By switching of the angle of view, the different content in the simulation process can be showed. Three functions of real-time drawing function, 3D scene model and event list function are designed in various perspectives. The real-time drawing function can draw curves in real time for some key indicators during the simulation process, and the user can further deepen the understanding of the simulation through the drawn curves. The 3D scene model is based on the system perspective, the base station perspective and the user perspective respectively establish their own 3D models. As the simulation progresses, some events will trigger the animation effects in the 3D model. The function of event list is a demonstration of some of the key events that occur during the simulation. The engine module connects the above modules in series, and schedules each module by reading the data in the simulation log file, and finally achieves the driving effect on the entire demonstration system. The structure of the specific 3D exhibition system is shown in Fig. 1.

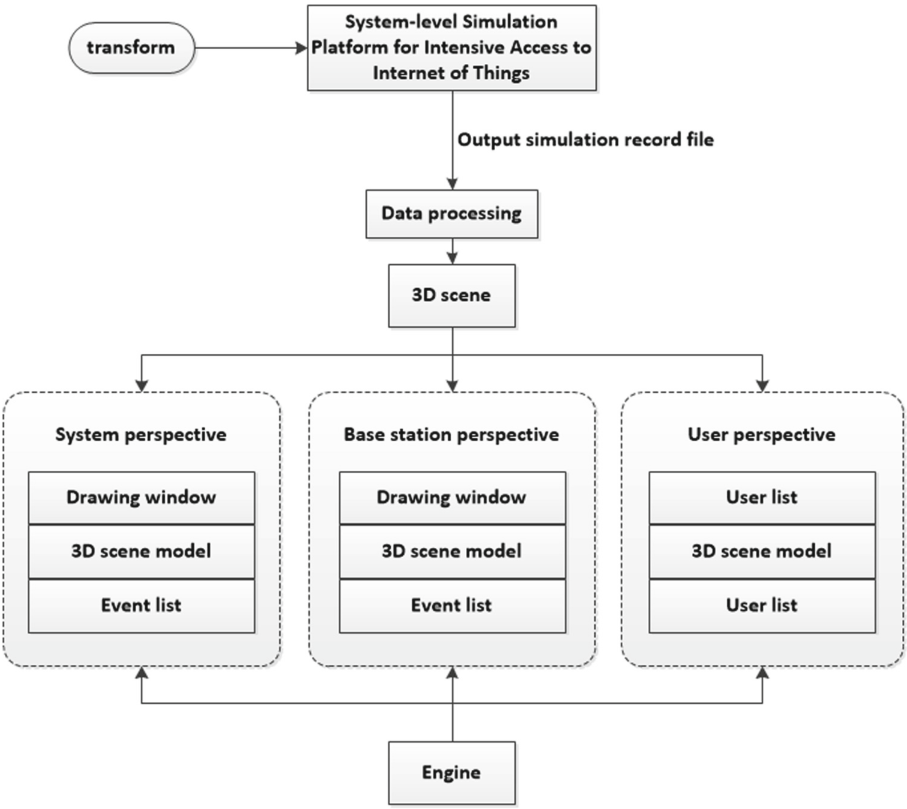

Fig. 1. The structure of the 3D exhibition system.

The operation process of exhibition system: firstly, the simulation record file of the original simulation platform transformation output is input into the exhibition system, and the file is read by the data reading module. Then, the data processing module processes the data of the file, and reads the file according to the format definition of the file, and it specifically reads and stores according to the format of the event structure. Eventually, all data will be stored in the set of events in a structured format. Then the drive engine module detects that the process of data reading is complete and waits for the instruction to start the simulation. Once the instruction of starting the simulation is received, the timer will be triggered. And each time the timer is full, an event will be taken from the set of events. Then the event processing function in which the multiple signals are designed will handle the event. After that, different signals will be emitted according to different types of events, which triggers different slot functions. By designing these slot functions, the 3D scene presentation module is driven.

4 System Implementation

4.1 Engine

The function of the drive engine module is to drive the various function modules to coordinate operation after reading the simulation record file. The engine module used in the exhibition system is the event-driven engine, and the core part of the event-driven engine is the event. After reading the record file and processing the data, the exhibition system gets an set of events, which arranges various events occurring in the simulation process in chronological order. During the simulation process, various functions and operations of the device are stored in the set of events in the form of events. The function of processing event takes the events and executes them in order from the set of events. Firstly, the type of the event is judged, and the corresponding signal is selected according to the different types of the event, and the corresponding slot function is triggered. Then, the engine module continuously processes the event, mobilizes other functional modules, and coordinates the cooperation to complete the demonstration. A detailed schematic diagram of the drive engine is shown in Fig. 2.

When the simulation starts, the QTimer will be started and the timer will be set to 1 ms. When the timer expires 1 ms, the timeout signal is issued, the slot function "run()" is designed, and the signal "timeout()" is associated with the slot function "run()". When the signal "timeout()" is issued, the slot function "run()" is called. The event execution function is designed in the slot function "run()". Take the event from the set of events and execute it, determine the type of the event firstly, and then send the corresponding signal according to the type of event. The slot function for drawing, the slot function for showing 3D models and the slot function for showing event list will be executed after receiving the signal, and the respective functions are implemented accordingly. The event-driven engine designed by the exhibition system relies on the powerful signal and slot mechanism provided by Qt to complete the scheduling of each functional module.

4.2 Event List

The function of the event list is to reflect the event that is happening in the current exhibition system by displaying the event name and the time of occurrence,

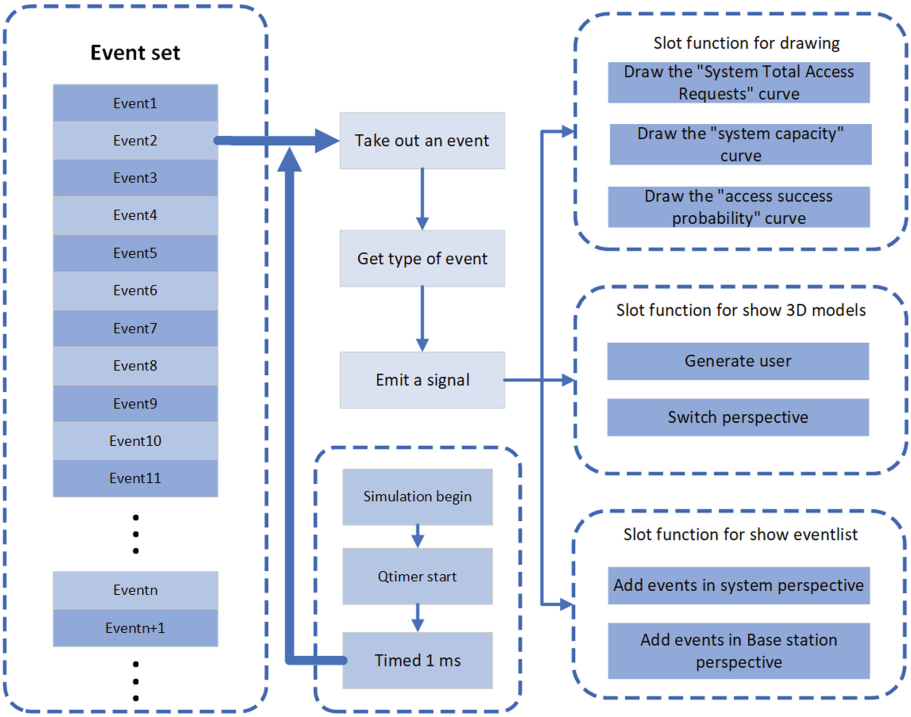

Fig. 2. Engine

visualizing the entire simulation process, and the event list is an indispensable part of the exhibition system. From the perspective of the system, the event list needs to display all events that occur during the entire simulation. From the perspective of the base station, the event list needs to display events related to the base station. Every time an event occurs, the time when the event occurred and the name of the event are displayed in the event list. When the event list is empty, the button for the first empty text is searched from top to bottom, and the name of the event and the time of occurrence are edited into the text of the button. When the event list is full, the event name and the time of occurrence are added to the bottommost button, and all the original text of all the buttons are moved up one space. The event list under the system view and the event list under the base station perspective share the same event list class, and the design principles are basically the same.

4.3 3D Scene Modeling

The 3D scene module is mainly to establish a corresponding 3D model for the simulation application scenario. The model needs to conform to the overall background of the simulation, and the animation effect is added on the basis of the model, so that the simulation process is more vivid. The 3D scene module is mainly divided into two parts: scene modeling and animation effects.

Scenario modeling: a large-scale access cell scenario needs to be built in the exhibition system. Based on the 3GPP TR45.820 recommendation, 52,547 NB-IOT devices need to be deployed in each cell. Considering the limitation of machine performance, the building is not modeled in the cell scene, and the NB-IOT equipment is deployed in a large amount to reflect the characteristics of large-scale access.

Animation effect: When the exhibition system runs, the occurrence of the event needs to reflect the user access action. In actual operation, you also need to be able to select a specific user. Therefore, the animation effect of the user's connection with the base station and the animation effect selected by the user are added.

4.4 Drawing Window

Draw the curve of "system capacity": System capacity is defined as the number of data transmissions that can be successfully completed per hour over a 200 kHz bandwidth, as calculated by Eq. (1):

$$N_{syscapacity} = \frac{N_{total} - N_{failure}}{N_{site} \times N_{200\,\mathrm{KHz}}} \times \frac{60 \times 60}{TimeStamp \times 10^{-3}} \tag{1}$$

In the formula:

N_{total}——The total number of transmissions per cell, the data comes from the total number of access requests(double) stored in the "nb-iot data transmission" event.

$N_{failure}$——The number of failed transmissions per cell, the data comes from the number of access failure requests(double) stored in the "nb-iot data transfer" event.

N_{site}——The number of cells set during the simulation, set to 1 during debugging.

$N_{200\,\mathrm{KHz}}$——Number of 200 KHz transmission bandwidths per cell.

Draw the curve of "access success probability": The probability of system random access success can be calculated by Eq. (2).

$$P_{success} = \frac{N_{total} - N_{failure}}{N_{total}} \tag{2}$$

In the formula:

N_{total}——The total number of transmissions per cell, the data comes from the total number of access requests(double) stored in the "nb-iot data transmission" event.

$N_{failure}$——The number of failed transmissions per cell, the data comes from the number of access failure requests (double) stored in the "nb-iot data transfer" event.

5 Results

Based on the recommendations of 3GPP TR45.820, the exhibition system configuration parameters are 1 cell, 3 base stations, 52547 NB-IOT devices, the devices are evenly distributed, and the device is set to a stationary state. Run the exhibition system in the current configuration. The results are shown in Fig. 3.

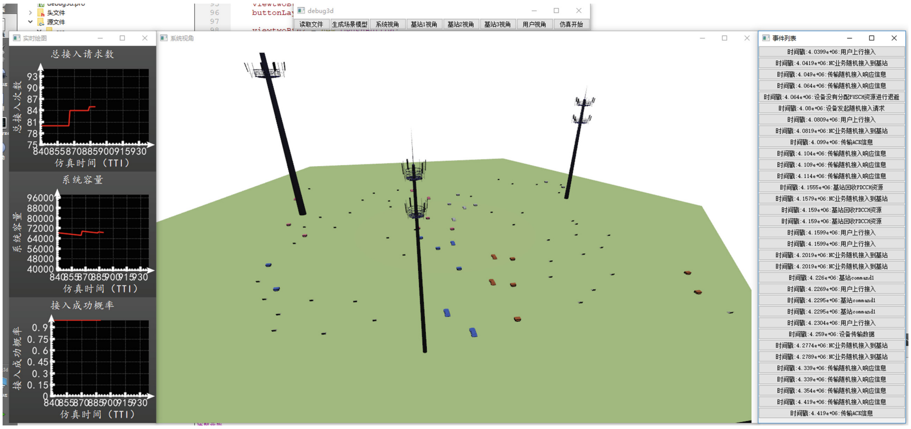

Fig. 3. Operation result

After the simulation starts, the event is displayed in the event list every time an event is executed. At the same time, according to the type of the event, the state of each function module of the exhibition system is updated, some events control the drawing window, and some events control the 3D scene window. Under the scheduling of the drive engine, each functional module cooperates to complete the demonstration.

6 Conclusions

The exhibition system visualizes the simulation platform oriented to the IoT dense access by constructing a 3D model, plotting curves in real time and displaying simulation events, and vividly displaying the simulation process in the 3D model. By plotting the curve, the user can observe the state of the system in real time and control the key performance indicators of the system. The demonstration results show that when the system bandwidth is 20 MHz, the system can support more than 1 million connections, which can meet the needs of millions of connections in the future 5G network. The running result of the demonstration system can also play a feedback role on the development of the simulation platform. When a node has a problem, the time and approximate location of the problem can be found through the exhibition system, which greatly facilitates the debugging program.

Add a few points, the current exhibition system only supports a single cell configuration, and on this basis, the configuration of the cell can be expanded, and the maximum can be expanded to 19 cells. And the number of deployments of multiple NB-IOT devices such as 12857, 25714, 52547, 64285, and 77142 is supported by a single cell. The above test results are obtained under the configuration of 52547 NB-IOT devices deployed. The probability of access failure measured under this configuration is extremely small, indicating that the coverage type-based backoff algorithm proposed by the simulation platform effectively reduces the access failure probability of the system. The currently deployed NB-IOT devices are all static. In the future, when upgrading the simulation exhibition system, we can consider adding a dynamic device model.

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