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Experimental Design of Wireless Sensor Network Simulation Teaching Based on OBE Concept

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Abstract: ***In response to the problem that students cannot effectively master the theoretical knowledge of wireless sensor networks, this study proposes an outcome-based education (OBE) guided teaching method and designs a simulation experiment on wireless sensor networks using the NS3 simulation platform. In the experiment, access point (AP) and station (STA) nodes are set up to present different network environments, and the transmission layer protocols (TCP and UDP) are changed to analyze different network performance. Through the analysis of experimental results, students can gain a vivid understanding of the basic knowledge of wireless sensor networks and achieve the expected teaching goals. This teaching method helps improve students' understanding and application ability of wireless sensor network theory, and promotes their learning and research in related fields.***

Keywords: OBE concept, NS3 simulation platform, Wireless Sensor Networks**.**

1. Introduction

Wireless sensor network (WSN) is a self-organizing network that connects sensors through wireless communication technology [1]. In a wireless sensor network, sensors form a multi-hop network in a static or mobile manner, communicate collaboratively, and send processed information to staff [2]. However, in actual teaching experiments, due to the complexity of geographical location, the layout and design of sensors cannot be effectively solved, resulting in the inability to build a real wireless sensor network topology, which is not conducive to students mastering the basic theoretical knowledge of wireless sensor networks. Therefore, in response to this problem, this paper proposes a teaching experiment method based on the OBE concept to design a wireless sensor network through the NS3 network simulation platform.

OBE (Outdoor-based Education), also known as outcome-oriented education, emphasizes student-centeredness. Different from traditional educational concepts, the OBE concept focuses on the student practice process and sets corresponding training goals for it [3]. Teachers can use diversified methods to guide students to achieve the expected teaching effect [4]. In recent years, in the construction of university subject experiments, higher education has gradually shifted from teaching to learning, and the OBE concept has been introduced and widely applied [5]. For example, Cen Qin [6] applied the OBE concept to C language teaching design, established a complete closed-loop control experimental teaching system, and improved students' professional quality. Tan Yongqian et al. [7] integrated the OBE concept into the Internet of Things communication technology experiment, effectively improving students' innovative practical ability. Hu Xiayun et al. [8] proposed a computer network networking experiment case teaching based on the OBE concept, and verified the effectiveness and sustainability of the teaching model through teaching cases. Li Jia [9] proposed a new engineering computer first-class course construction plan based on the OBE concept, introduced high-quality MOOC resources, and reconstructed characteristic teaching resources. Han Ming et al. [10] proposed a hybrid teaching reform of computer network courses based on OBE, which adopted a diversified course assessment method. This teaching method has been widely promoted. In addition, many scholars have proposed related discipline construction reforms based on OBE and achieved good results [11-14]. Therefore, through the analysis of relevant literature, it can be seen that integrating OBE concepts into the design of relevant teaching experiments can effectively improve students' learning ability and achieve the expected teaching goals.

The main work of this paper is as follows:

1) Designed a wireless sensor network simulation teaching experiment process based on OBE concept;

2) The wireless sensor network environment was simulated using the NS3 simulation platform and visualized using the NetAnim tool. Different network performances were analyzed by changing the transport layer protocols (TCP and UDP).

2. Teaching Experiment based on OBE Concept

2.1 Teaching Experiment Design Process

The wireless sensor network teaching experiment needs to be combined with the OBE concept. When designing the experiment, the difficulty of the teaching objectives should be considered, and students should be able to demonstrate their professional qualities in the practice process to form an effective closed-loop teaching system. Students should be able to continuously debug the code according to the requirements of the experimental design and achieve the results of the experimental settings, so as to master the basic theoretical knowledge required for the network simulation experiment. The design process of the teaching experiment is shown in Figure 1.

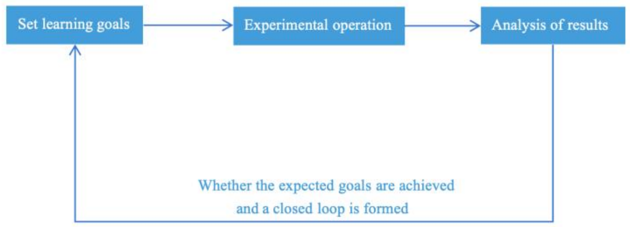

Figure 1: OBE-based wireless sensor network teaching design process

2.2 Experimental Case Design

In this paper, we set a teaching goal to help students effectively master the basic theoretical knowledge of wireless sensor networks through experimental operations. To achieve this goal, we chose the NS3 simulation platform to design experimental cases for wireless sensor networks. By using the NS3 simulation platform, we can ensure that the experimental cases contain the basic components required for wireless sensor networks, making the experiments closer to the actual situation and meeting the teaching goals.

2.2.1 Introduction to NS3 Simulation Platform

NS3 (Network Simulator 3) is an open source project launched in 2006. It supports both C++ and Python languages and mainly runs on Linux. The basic model structure of NS3 includes network model, physical layer model, MAC layer model and application layer model. The functions and composition of these models are as follows:

(1) Network model: It consists of channels, network devices, protocol stacks, and application devices. They are connected together through node installation to build network topology and realize communication functions between networks [16].

(2) Physical layer model: It consists of modulation module, channel module, receiver module and transmitter module. This model simulates the real physical layer behavior in NS3 and is used for data transmission between application devices.

(3) MAC layer model: mainly composed of channels and MAC protocols, used to allocate and coordinate data transmission resources between nodes.

(4) Application layer model: It consists of applications and transport protocols (such as TCP, UDP, etc.) and is used to simulate the sending process of applications in the network.

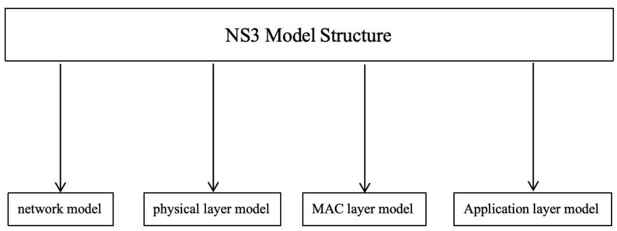

Figure 2: NS3 model structure diagram

2.2.2 Experimental Case

In the experiment, the topology structure is designed with one AP node and three STA nodes. AP (Access Point) node refers to the wireless access node, which is mainly used to form a wireless LAN; while STA (Station) node is each client that accesses the wireless LAN, such as computers, mobile phones, etc. Figure 3 shows the topology of the experimental case.

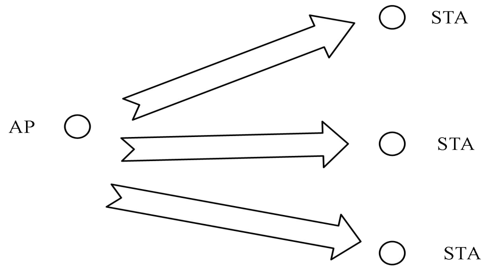

Figure 3: Experimental case topology diagram

In Figure 3, the AP node acts as the transmitter and the STA node acts as the receiver. The AP node sends 4 64-byte data packets to the STA node every second. In this experimental case, four scenarios are set: AP and STA are stationary, and the transport layer transmits the UDP protocol; AP and STA are stationary, and the transport layer transmits the TCP protocol; AP moves, STA is stationary, and the transport layer transmits the UDP protocol; AP moves, STA is stationary, and the transport layer transmits the TCP protocol. The process code for setting up the experimental environment is as follows:

(1) Create 1 AP and 3 STAs

```
NodeContainer allNodes;
NodeContainer wifiStaNodes;
wifiStaNodes.Create (3);
allNodes.Add (wifiStaNodes);
NodeContainer wifiApNode ;
wifiApNode.Create (1);
allNodes.Add (wifiApNode);
```

(2) Create Wi-Fi channels, physical layer, and MAC protocols

```
YansWifiChannelHelper channel =
YansWifiChannelHelper::Default ();
YansWifiPhyHelper phy = YansWifiPhyHelper::Default ();
phy.SetChannel(channel.Create());
 WifiHelper wifi;
 wifi.SetRemoteStationManager ("ns3::AarfWifiManager");
 WifiMacHelper mac;
 Ssid ssid = Ssid ("ns-3-ssid");
mac.SetType ("ns3::StaWifiMac",
    "Ssid", SsidValue (ssid),
 "ActiveProbing",BooleanValue (false));
  YansWifiChannelHelper channel =
YansWifiChannelHelper::Default ();
 YansWifiPhyHelper phy = YansWifiPhyHelper::Default ();
 phy.SetChannel (channel.Create ());
 WifiHelper wifi;
 wifi.SetRemoteStationManager ("ns3::AarfWifiManager");
mac.SetType ("ns3::ApWifiMac",
    "Ssid", SsidValue (ssid));
```

(3) Create and install network devices

```
NetDeviceContainer staDevices;
staDevices = wifi.Install(phy, mac, wifiStaNodes);
 NetDeviceContainer apDevices;
apDevices = wifi.Install(phy, mac, wifiApNode);
```

(4) Install the protocol stack

```
InternetStackHelper stack;
stack.Install (allNodes);
```

(5) Allocating IP addresses

```
Ipv4AddressHelper address;
address.SetBase ("10.1.1.0","255.255.255.0");
Ipv4InterfaceContainer apInterface;
apInterface = address.Assign(apDevices);
Ipv4InterfaceContainer staInterfaces;
staInterfaces = address.Assign(staDevices);
```

(6) Set the receiving end and the sending end. Here we take UDP as an example.

```
for(int i=0;i<=2;i++)
{
 PacketSinkHelper sinkHelper ("ns3::UdpSocketFactory", InetSocketAddress (Ipv4Address::GetAny (), 9));
 ApplicationContainer sinkApp = sinkHelper.Install (wifiStaNodes.Get(i));
 sinkApp.Start (Seconds (1.0));
 sinkApp.Stop (Seconds (15.0));
OnOffHelper server ("ns3::UdpSocketFactory", (InetSocketAddress (staInterfaces.GetAddress(i), 9)));
 server.SetAttribute ("PacketSize", UintegerValue (payloadSize));
server.SetAttribute("OnTime",StringValue("ns3::ConstantRandomVariable[Constant=1]"));
server.SetAttribute("OffTime",StringValue("ns3::ConstantRandomVariable[Constant=0]"));
server.SetAttribute ("DataRate", DataRateValue (DataRate (dataRate)));
ApplicationContainer clientApps = server.Install (wifiApNode.Get(0));
clientApps.Start(Seconds(2.0));
clientApps.Stop (Seconds (15.0));
```

In the experimental case, the nodes adopted the Random Walk2D Mobility Model and used the NS3 visualization tool NetAnim to intuitively display the communication between the AP node and the STA node. Figures 4 to 7 show the visualization effects of the four scenarios respectively.

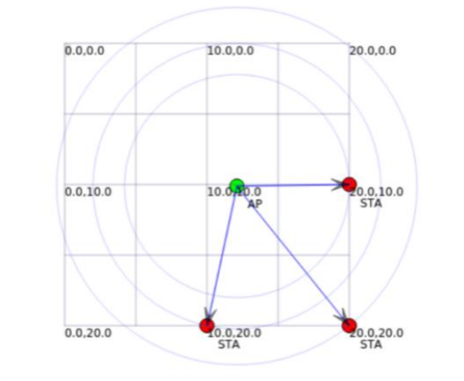

Figure 4: AP moves STA static transmission UDP

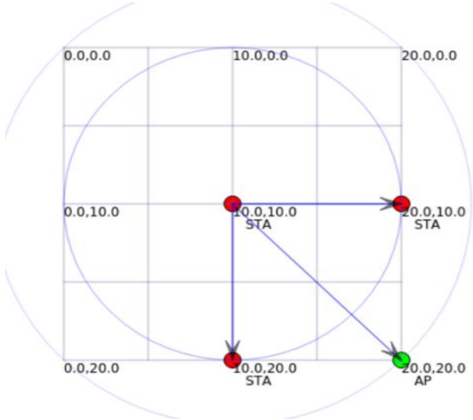

Figure 5: AP is stationary STA is stationary transmitting UDP

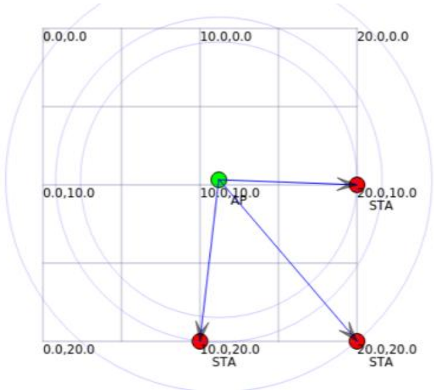

Figure 6: AP moving STA static transmission TCP

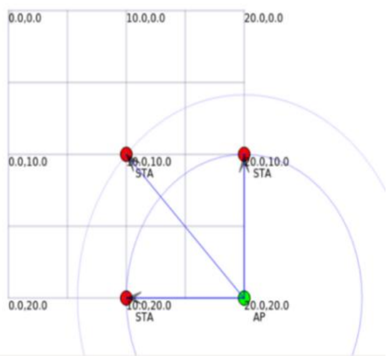

Figure 7: AP is stationary STA is stationary TCP transmission

2.3 Experimental Design and Results Analysis

The experimental results are shown in Figures 8 to 11. Figure 8 shows the performance of UDP transmission when the AP is moving and the STA is stationary; Figure 9 shows the performance of UDP transmission when the AP is stationary and the STA is stationary; Figure 10 shows the performance of TCP transmission when the AP is moving and the STA is stationary; and Figure 11 shows the performance when the AP is stationary and the STA is stationary.

```
--------Total Results ----------
total sent packets   :153
total received packets :153
total lost packets :0
packet delivery ratio :100%
total  delay: 69ms
```

Figure 8: UDP transmission performance when AP is moving and STA is stationary

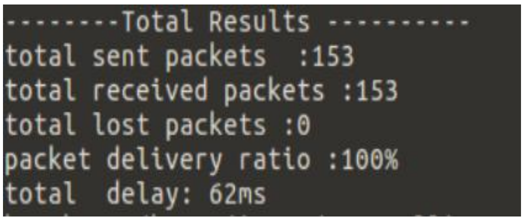

Figure 9: UDP transmission performance when AP and STA are stationary

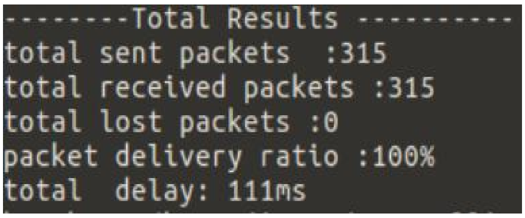

Figure 10: TCP transmission performance when AP is moving and STA is stationary

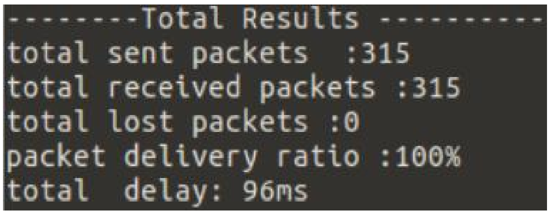

Figure 11: TCP transmission performance when AP and STA are stationary

By observing Figures 8 and 9, it can be concluded that when the transport layer protocol is UDP, the overall network delay is small. Among them, when the AP node moves, the delay increases by 7ms compared to when it is stationary. This is because when the AP node moves, the distance between nodes will change, resulting in a longer time for the data packet sent from the AP node to reach the STA node. By observing Figures 10 and 11, it can be concluded that when the transport layer protocol is TCP, the overall network delay is large. When the AP node moves, the delay increases by 15ms compared to when it is stationary. The delay in both cases is higher than the delay when the transport protocol is UDP. This is because TCP involves a retransmission mechanism, while UDP does not involve retransmission when transmitting data packets. When the transport protocol is TCP, more data packets are sent than when the transport protocol is UDP. This is related to the transmission mechanism of TCP, because TCP has designed confirmation responses and timeout retransmission mechanisms to ensure the reliability of transmitted data, so more data packets need to be transmitted. In summary, through analysis, it can be concluded that the performance loss in UDP mode is smaller than that in TCP, but the transmission reliability is weaker; when the transport protocol is TCP, the performance loss is larger but the transmission reliability is higher. These two transmission modes have their own different characteristics.

3. Conclusion

This paper proposes a wireless sensor network simulation teaching experiment based on the OBE concept, verifies and analyzes the performance of network topology in different scenarios through NS3 simulation, and visualizes it through NetAnim. By building experimental topology and systematically analyzing experimental results, students not only exercise their practical ability, but also effectively master the basic theoretical knowledge of wireless sensor networks, achieving the expected teaching objectives.

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