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WLAN simulations using Huawei eNSP for e-laboratory in engineering schools.

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Abstract:
A wireless LAN (WLAN) is a wireless computer network that links two or more devices using wireless communication to form a local area network (LAN) within a limited area such as a home, school, computer laboratory, campus or office building. WLAN technology is one of the main contents of a computer network and telecommunications engineering course. For many sub-*Saharan African countries, it is very scarce to find telecommunication lecturers with a PhD grade and this has an impact on quality of the training provided to students in telecommunications fields. Another problem is the lack of means to buy and install telecommunication equipment for laboratory experimentations where students can learn and improve their skills during their training program in a university. To overcome this problem, a possible solution could be the design of simulations and tests using simulation software like Huawei eNSP and implement remote labs based on that for universities without telecommunications lecturers. In order to enable students to have a better understanding of WLAN, this paper proposes two experimental implementations of WLAN on the simulation platform Huawei eNSP, which builds the experimental environment, realizes the interconnection of network by configuring Access Controller(AC) and Access Points (AP), and mobile users can roam in the wireless signal coverage area. At the same time, Wireshark is used to capture packets in different interfaces, and then analysis of the principle of wireless access point control and configuration protocol is done as well as verification of the process of wireless terminal roaming. Through these experiments, the students' understanding of WLAN technology principle is enhanced. Their practical ability and data analysis ability are also exercised. This solution can be used in real a lab or remotely between a lecturer and his or her students.*
Key Word*: WLAN, simulation, e-laboratory, eNSP, Access Controller, Access Point.*

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I. Introduction

With the rapid development of wireless communication technology, WLAN is more and more widely used. Almost all equipment has WLAN connectivity available. We can cite some equipment as examples: Televisions, printers, mobile phones, laptops and desktops. WLAN is everywhere and can also be used for smart home initiative [1] [2]. WLAN is defined as a LAN in narrow sense, which is based on the standard of 802.11 series of IEEE, using high frequency radio frequencies (such as 2.4 GHz or 5 GHz band radio electromagnetic wave) as transmission medium. WLAN in our daily life refers to the narrow definition of WLAN. 802.11 series standards which have become the mainstream technical standards of WLAN because of their relatively simple implementation technology, reliable communication, high flexibility and relatively low implementation cost. Huawei eNSP simulator embedded the solution for implementing the WLAN simulation. Based on that and the advantages of e-learning like accessing updated contents when ever wanted, learning by one's own speed of learning instead of following the speed of the whole group, saves time as a student does not need to travel to the training venue, the learner can learn at the comfort of his own place; accessing the content an unlimited number of times[3]; a set of simulation labs can be developed to improve the quality of training for schools and universities especially for sub Saharan Africa countries. With the recent apparition of Corona virus 19 which has obliged governments to order social restrictions and confinement, and the implementation of e-learning to support education system, this kind of simulation solution based on free software can be very important. In this paper, we are trying to show how we can build simulations based on eNSP software to support e-learing for engineering schools, for this purpose, this paper will be organized as follow, in section 2 we will present an e-learning solution, the simulation software and some simulations guides and architectures. In section 3, we will present the result of the simulation and the packets captured using Wireshark and after we will make a conclusion.

II. Material And Methods

II.1 WLAN principle

IEEE 802.11 series is a general standard for WLAN. The WLAN standard announced by IEEE (the Institute of Electrical and Electronics Engineers) in 1997 is suitable for the communication between wired stations and wireless users or between wireless users. It defines the MAC (media access control) layer and the physical layer. The wireless terminal is connected to the network after running 802.11 protocol access AP (Wireless Access Point). The access process includes scanning, link authentication, identity authentication and association. AP is the HUB in the traditional wired network, and it is also the most commonly used device in the construction of small wireless local area networks. AP is equivalent to a bridge connecting wired networks and wireless networks. Its main function is to connect various wireless network clients together and then connect wireless networks to Ethernet.

WLAN has two basic architectures namely FAT Access Point architecture and FIT access point architecture [4].

a) FAT AP (FAT Access Point) architecture.

In this architecture, the AP cannot only transmit a radio frequency to provide a wireless signal for wireless terminal access, but also independently complete security encryption, user authentication and user management and other management functions. FAT AP is often the most suitable choice to use in scenarios such as home WLAN or small business WLAN.

b) FIT AP (FIT Access Point) architecture.

In this case the AP has no control function except providing radio frequency signals. In order to realize the function of WLAN, besides FIT AP, AC (Access Controller) which has the function of management and control is also needed. The main function of AC is to manage and control all FIT APs in WLAN. AC cannot transmit radio frequency signals, and cooperate with FIT AP to complete WLAN functions. It's generally applicable to large and medium-sized scenarios. According to the different regions and throughput controlled by AC, AC can appear in the convergence layer or core layer, while FIT AP is generally deployed in access layer and enterprise branch.

Compared with home WLAN application scenarios, enterprises with larger number of users use centralized control to build WLAN networks. AC centralizes the management and control of associated APs in the network. CAPWAP (Control and Provision of Wireless Access Points) protocol runs between AP and AC, which makes APs being configured and managed from AC by establishing CAPWAP tunnel. In this paper we will do the simulation based on FIT AP architecture with Access controllers.

II.2 e-learning presentation

E-learning refers to a learning system that we can obtain through the internet using an electronic device. We also call it **online learning** or **online education** [5]. The *'E'* in E-learning stands for *'Electronic'*. Hence, the original term '**electronic learning'**. This means with an Internet connection or via the Internet.

The term may also refer to a network that can provide knowledge and skills to one or more individuals. The network can provide the knowledge or skills either to everyone simultaneously or individually.

The challenges of education exist in many factors such as students, teachers, campuses, and ministry of government, as following:

- Outdated teaching contents, boring courses, and less learning channels;
- Teaching facilities are backward, and Self-improvement is difficult;
- Lack of excellent teachers, and waste of resources;
- Unbalanced distribution of resources and backward education in depressed areas;

Because of so many challenges that traditional education faces, it needs a series of new technologies to push the development of education. The following figure presents the position of e-learning in the society.

E-learning solution includes: Online Learning, Digital library and e-Management systems. Each system can be implemented individually [6].

Online Learning solution builds a highly efficient communication cloud platform for teachers and students, which could integrate e-board, terminals, and voice systems. It can realize classroom to classroom, classroom to family online and offline, multi-media interactive remote education. Sharing the teacher's resource and knowledge which let the students from different regions to enjoy the same education resources. Students can access remote real time classes from remote classrooms, home, or trips via mobile terminals, and interact with teachers and classmates through voice and e-board [6]. Many authors have developed new or different approaches for e-laboratory, we have B. Barros, et al in [7] who worked on a virtual collaborative experimentation for an approach combining remote and local labs, C. Colwell et al in [8] proposed the usage of remote laboratories to extend access to science and engineering G. Gercek and N. Saleem in [9] proposed to transform traditional labs into virtual computing labs for distance education.

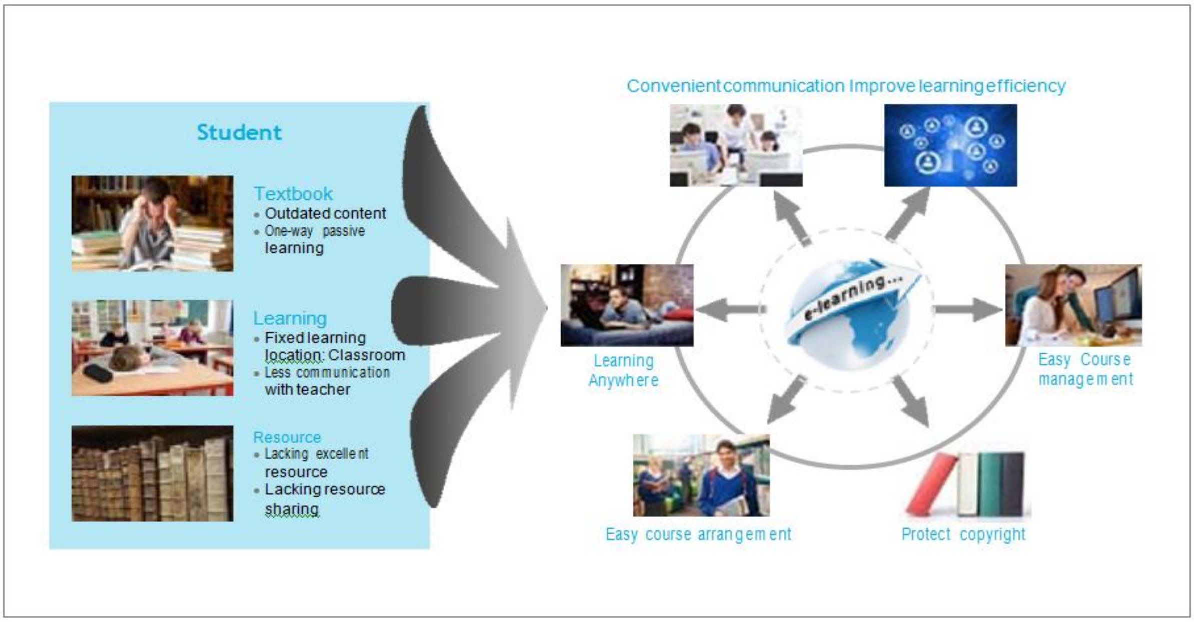


Figure 1: position of e-learning in the society [6]

The importance of e-lab and simulation in virtual environments has been proved to be very important by author in [10]. The usage of software during the training program of engineering students even in e-learning scenario has an impact on the development of learners' practical skills through stimulation of experimental applications which they do not always need physical equipments [10]. So to develop the e-learning for engineering schools, e-laboratories are very important [11] [12]. And to build this king solution, we can use software like Huawei eNSP simulation tool, which combined with appropriate practice guide could be very powerful and strengthen the quality of engineering training especially in sub Saharan African countries where qualified lecturers in the telecommunications field are scarce. For the rest of the paper, we will first present the simulation tool eNSP and then sample of simulations which can be implemented in eNSP.

II.3 eNSP presentation

eNSP (Enterprise Network Simulation Platform) is a free, scalable graphical enterprise network simulation software platform provided by Huawei. It mainly simulates routers, switches, firewalls, wireless local area networks and other devices on corporate networks. Its interface is user-friendly, and it can perfectly present the equipment in its operation in real time, supports the scaling of a large-scale network, and gives users the possibility of modeling a network without real equipment available. At the same time, the real network card can be used to tie up with the real network equipment, which can display the protocol interaction process more intuitively and make it easier for users to learn network technology. eNSP helps overcome the limitation of insufficient network teaching resources such as devices and networks for students and teachers. eNSP provides a network-based simulation platform that is easy to use and supports extendable graphical user interfaces (GUIs). Students and technical engineers can quickly learn network basics, simulate a network, and learn about Huawei Data communication products. eNSP is very useful for students, teachers and technical engineers and appropriated for e-learning or e-lab because of the lack of specialized lecturers in some sub Saharan African countries.

a) Students

Students can use the interesting and flexible eNSP to simulate a network and perform tests on the network. eNSP is helpful for students' jobs, further education, and obtaining certificate. Students can obtain the same experience of performing tests on an actual network from eNSP, helping them become network professionals.

b) Teachers

Teachers can use the simulative, visible, and collaborative eNSP to teach. eNSP allows students to create virtual networks and perform packet-related tests on the networks. In this way, students can better understand the principles of packet flowing and network protocols.

From this software we can use routers, switches, firewall, servers, access points and access controllers. Table 1 presents some objects in eNSP simulation software.

Table no 1: Objects in eNSP

Types of routers	Ports	Types of switches	Ports
AR201	8 fast Ethernet(FE) ports	S5700	24 Ethernet ports 2 GE ports, 1 console port
AR1220	16 FE ports available 2 GE ports	S3700	24 ports GE 1 console port
AR2220	48 GE ports available 8 FE ports 4 serial ports	CE6800	
AR2240	96 GE ports available 64 FE ports available 8 serial ports		
AR3260	192 GE ports available 64 FE ports available 8 serial ports		

Figure 2 and figure 3 present respectively the home page and empty simulation page of eNSP when you run it.

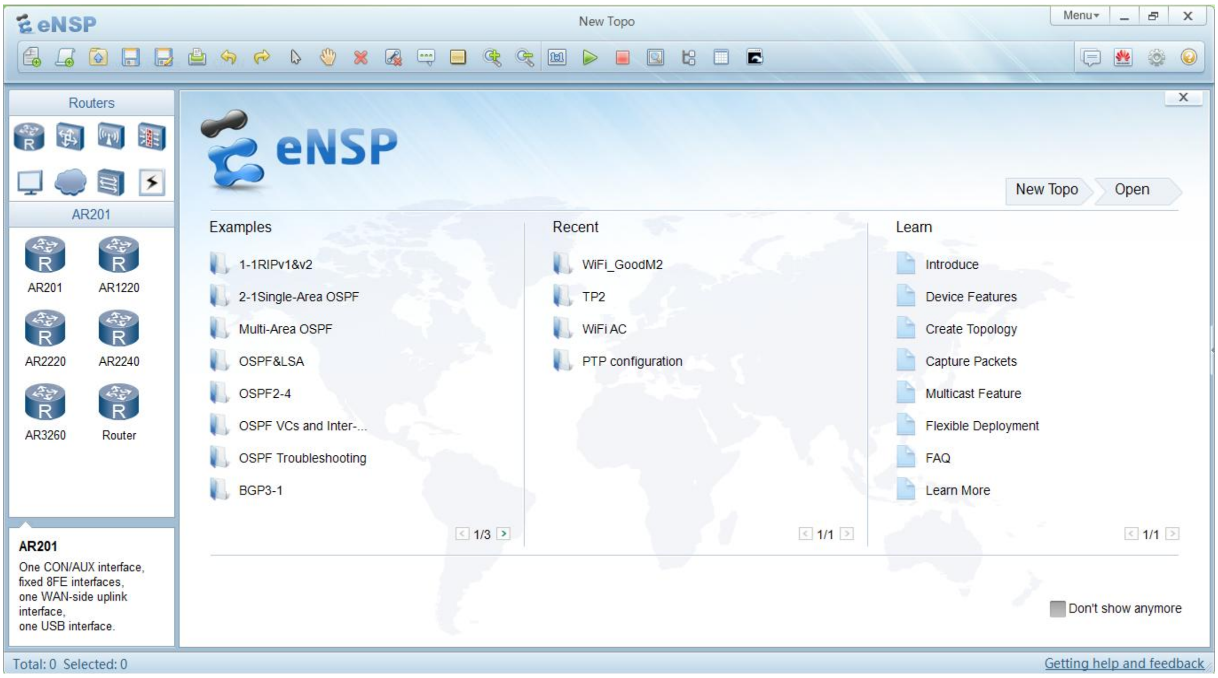


Figure 2: Home page of eNSP software.

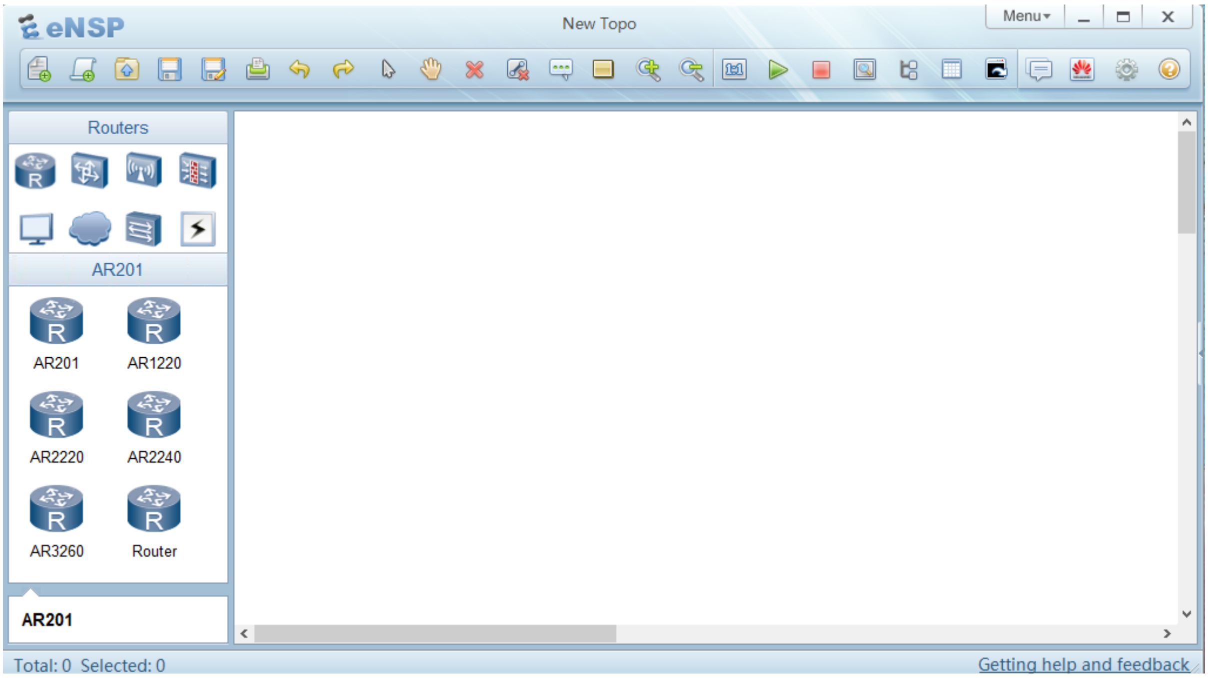


Figure 3: Empty simulation page of eNSP software.

II.4 Network simulation

For this simulation we will used the following equipment embedded in eNSP:

- Access Control AC6605
- Access Point AP6010
- Laptops
- Mobile phone with Wi-Fi

II.4.1 Experimental purpose

The purpose of this simulation experiment is to make students understand the basic principle of WLAN [13] and the process of CAPWAP session establishment [14], master the configuration method of AC and AP first, then in the case of a more complex network, master the configuration method of AC, aggregation switch, access switch and AP in a Layer 2 Inline Networking (Tunnel Forwarding) and also and understand the roaming state of mobile clients.

In a desire for an educational approach, we will present step by step the configuration methodology for the case of a simple network containing an AC and an AP. Then we will show how to add 2 other APs to the network. And finally, for the case of a more complex network (WLAN Services in a Layer 2 Inline Networking (Tunnel Forwarding)), we will no longer take up the whole process, but will just present the results obtained when the simulation is well functional, this is to avoid unnecessarily inflating the number of pages of this paper.

II.4.2 Network architectures for the simulation

In this paper, we will implement two scenarios, the first one is a simple one based on one AC and some APs and the second one which is a little more complex will involve one AC, one Aggregation switch, one Access switch and many AP, this second scenario can be implemented in practice in a small school or faculty with many departments. For each department an access switch can be deployed and all of the access switches would be connected to one aggregation switch for internet access.

The following figures present the simulation architectures

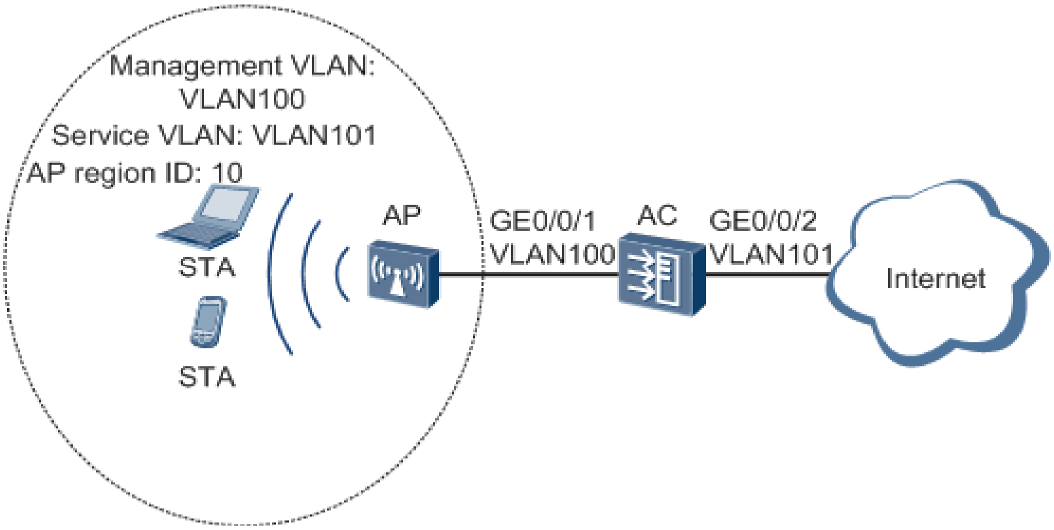


Figure 4: WLAN service configuration networking on a small-scale network

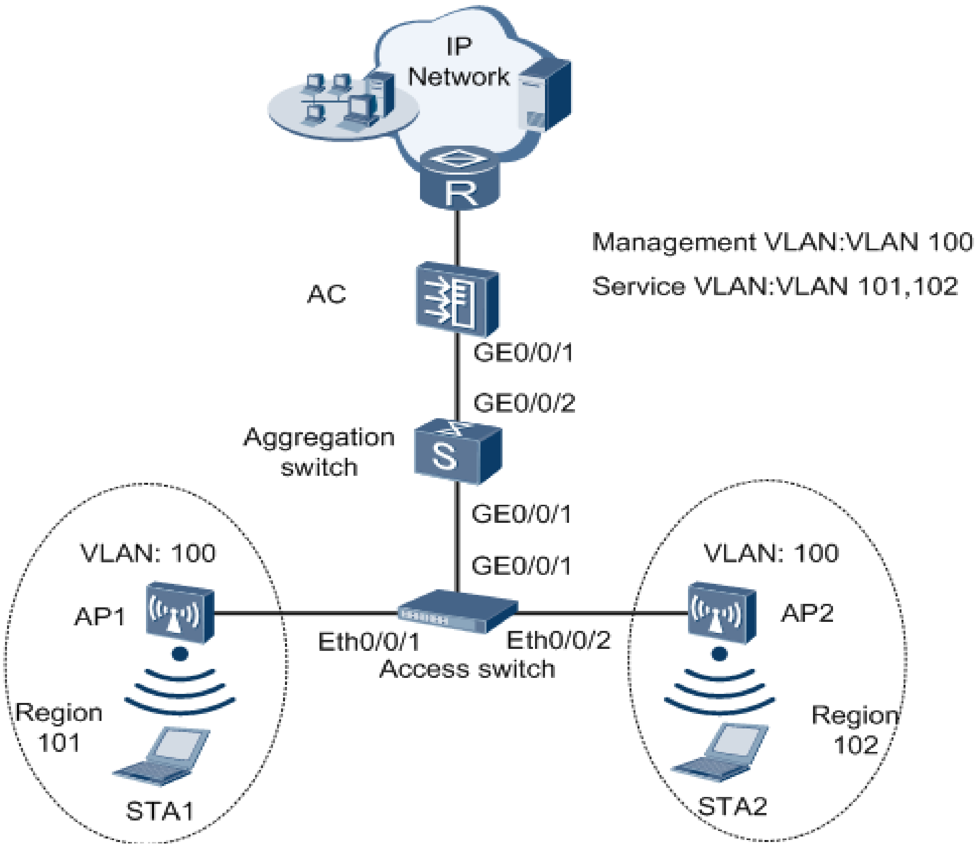


Figure 5: WLAN Services in a Layer 2 Inline Networking (Tunnel Forwarding)

II.4.3 Simulation procedure for WLAN service configuration networking on a small-scale network.

a) Networking Requirements

As shown in figure 5, the AP is directly connected to the AC. For example, a school needs to deploy WLAN services for a department so that teachers and students can access the school's internal network from anywhere at any time inside their department.

The following requirements must be met:

- A WLAN named **test** is available.
- Department users are assigned IP addresses on 192.168.11.0/24.

Figure 6 presents the network diagram when built in eNSP simulator

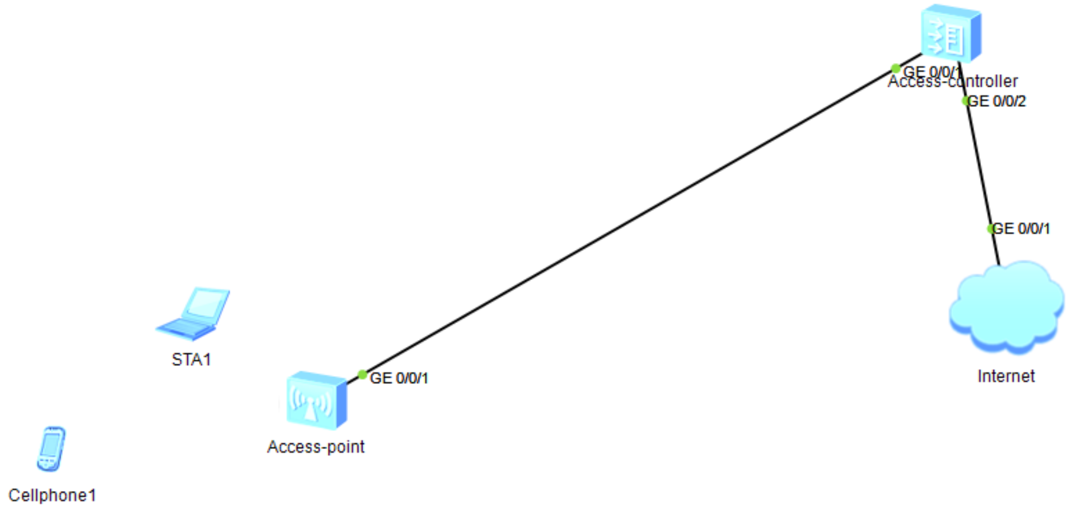


Figure 6: Simulation built in eNSP

b) Configuration Roadmap

The configuration roadmap is as follows:

1. Configure the AP, AC, and upstream device to implement Layer 2 interconnection.
2. Configure the AC as a DHCP server to assign IP addresses to STAs and the AP from an IP address pool of an interface.
3. Configure the AC system parameters, including the country code, AC ID, carrier ID, and source interface used by the AC to communicate with the AP.
4. Set the AP authentication mode and add the AP to an AP region.
5. Configure a VAP and deliver VAP parameters to the AP so that STAs can access the WLAN.

a. Configure a WMM profile and radio profile on the AP, retain the default settings of the WMM profile and radio profile, bind the WMM profile to the radio profile to enable STAs to communicate with the AP.

b. Configure a WLAN-ESS interface so that radio packets can be sent to the WLAN service module after reaching the AC.

c. Configure a security profile and traffic profile on the AP, retain the default settings of the security profile and traffic profile, configure a service set, bind the WLAN-ESS interface, security profile, and traffic profile to apply security policies and QoS policies to STAs.

Configure a VAP and deliver VAP parameters to the AP so that STAs can access the Internet through the WLAN.

c) Procedure

1. Configure the AC so that the AP and AC can transmit CAPWAP packets.

Configure the AC: add interface GE0/0/1 to management VLAN 100.

```
<AC6605> system-view
[AC6605] sysname MAGOUDAYA-GABNO
[MAGOUDAYA-GABNO] vlan batch 100 101
[MAGOUDAYA-GABNO] interface gigabitethernet 0/0/1
[MAGOUDAYA-GABNO-GigabitEthernet0/0/1] port link-type trunk
[MAGOUDAYA-GABNO-GigabitEthernet0/0/1] port trunk pvid vlan 100
[MAGOUDAYA-GABNO-GigabitEthernet0/0/1] port trunk allow-pass vlan 100
[MAGOUDAYA-GABNO-GigabitEthernet0/0/1] quit
```

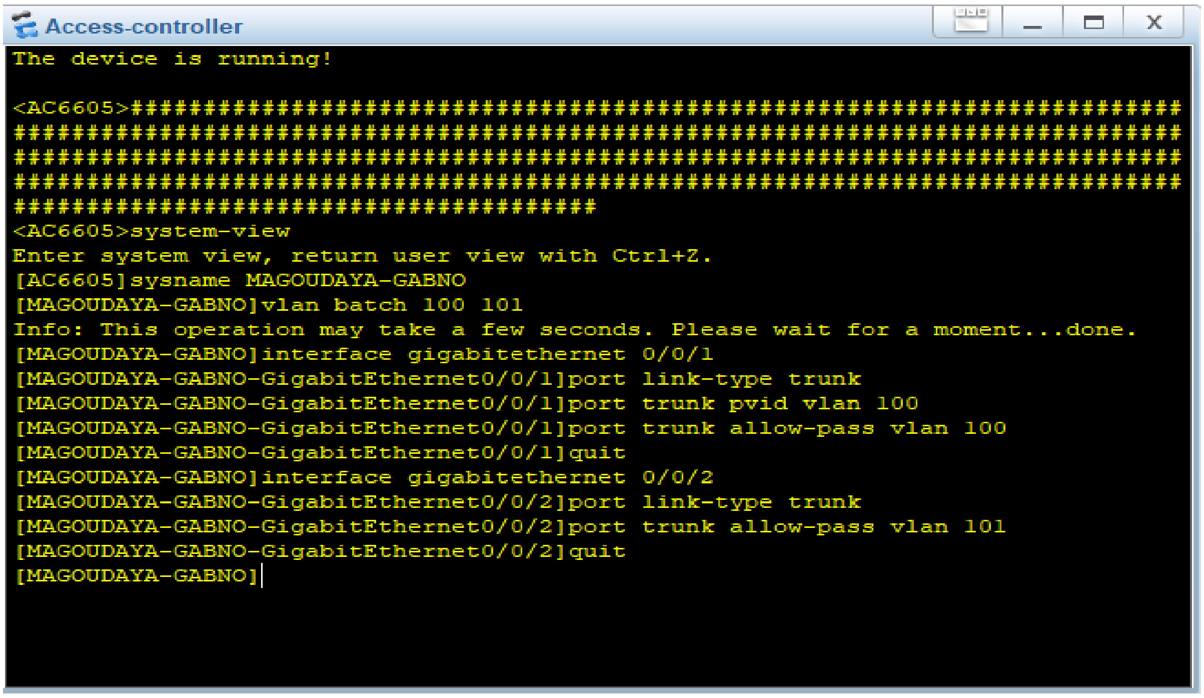


Figure 7: Command run in eNSP

2. Configure the AC to communicate with the upstream device.
   # Add AC uplink interface GE0/0/2 to service VLAN 101.
   [MAGOUDAYA-GABNO] **interface gigabitethernet 0/0/2**
   [MAGOUDAYA-GABNO -GigabitEthernet0/0/2] **port link-type trunk**
   [MAGOUDAYA-GABNO -GigabitEthernet0/0/2] **port trunk allow-pass vlan 101**
   [MAGOUDAYA-GABNO -GigabitEthernet0/0/2] **quit**
3. Configure the AC as a DHCP server to allocate IP addresses to STAs and the AP.
   # Configure the AC as the DHCP server to allocate an IP address to the AP from the IP address pool on VLANIF 100, and allocate IP addresses to STAs from the IP address pool on VLANIF 101.
   [MAGOUDAYA-GABNO] **dhcp enable**
   [MAGOUDAYA-GABNO] **interface vlanif 100**
   [MAGOUDAYA-GABNO-Vlanif100] **ip address 192.168.10.1 24**
   [MAGOUDAYA-GABNO-Vlanif100] **dhcp select interface**
   [MAGOUDAYA-GABNO-Vlanif100] **quit**
   [MAGOUDAYA-GABNO] **interface vlanif 101**
   [MAGOUDAYA-GABNO-Vlanif101] **ip address 192.168.11.1 24**
   [MAGOUDAYA-GABNO-Vlanif101] **dhcp select interface**
   [MAGOUDAYA-GABNO-Vlanif101] **quit**
4. Configure AC system parameters.
   # Configure the country code.
   [MAGOUDAYA-GABNO] **wlan ac-global country-code cn**
   Warning: Modify the country code may delete configuration on those AP which use
   the global country code and reset them, continue?[Y/N]:**y**
   # Configure the AC ID and carrier ID.
   [MAGOUDAYA-GABNO] **wlan ac-global ac id 1 carrier id other**
   Warning: Modify the carrier ID or AC ID may cause all of the AP offline, continu
   e?[Y/N]:**y**
   # Configure the source interface.
   [MAGOUDAYA-GABNO] **wlan**
   [MAGOUDAYA-GABNO-wlan-view] **wlan ac source interface vlanif 100**
5. Manage the AP on the AC.
   # Check the AP type ID after obtaining the MAC address of the AP.
   [MAGOUDAYA-GABNO-wlan-view] **display ap-type all**
   All AP types information:

```
ID    Type
------------------------------------------------------------------------------
17    AP6010SN-GN
19    AP6010DN-AGN
21    AP6310SN-GN
23    AP6510DN-AGN
25    AP6610DN-AGN
27    AP7110SN-GN
28    AP7110DN-AGN
29    AP5010SN-GN
30    AP5010DN-AGN
31    AP3010DN-AGN
33    AP6510DN-AGN-US
34    AP6610DN-AGN-US
------------------------------------------------------------------------------
Total number: 13
```

Add the AP offline based on the AP type ID. Assume that the AP type is AP6010DN-AGN, and the MAC address of the AP is 00e0-fc87-4530.

```
[MAGOUDAYA-GABNO-wlan-view] ap-auth-mode mac-auth
[MAGOUDAYA-GABNO-wlan-view] ap id 0 type-id 19 mac 00e0-fc87-4530
[MAGOUDAYA-GABNO-wlan-ap-0] quit
```

Configure an AP region and add the AP to the AP region.

```
[MAGOUDAYA-GABNO-wlan-view] ap-region id 10
[MAGOUDAYA-GABNO-wlan-ap-region-10] quit
[MAGOUDAYA-GABNO-wlan-view] ap id 0
[MAGOUDAYA-GABNO-wlan-ap-0] region-id 10
[MAGOUDAYA-GABNO-wlan-ap-0] quit
```

After powering on the AP, run the **display ap all** command on the AC to check the AP running status. The command output shows that the AP status is normal.

```
[MAGOUDAYA-GABNO-wlan-view] display ap all
```

6. Configure WLAN service parameters.

Create a WMM profile named **wmm**.

```
[MAGOUDAYA-GABNO-wlan-view] wmm-profile name wmm id 1
[MAGOUDAYA-GABNO-wlan-wmm-prof-wmm] quit
```

Create a radio profile named **radio** and bind the WMM profile **wmm** to the radio profile.

```
[MAGOUDAYA-GABNO-wlan-view] radio-profile name radio id 1
[MAGOUDAYA-GABNO-wlan-radio-prof-radio] wmm-profile name wmm
[MAGOUDAYA-GABNO-wlan-radio-prof-radio] quit
[MAGOUDAYA-GABNO-wlan-view] quit
```

Create WLAN-ESS interface 1.

```
[MAGOUDAYA-GABNO] interface wlan-ess 1
[MAGOUDAYA-GABNO-Wlan-Ess1] port hybrid pvid vlan 101
[MAGOUDAYA-GABNO-Wlan-Ess1] port hybrid untagged vlan 101
[MAGOUDAYA-GABNO-Wlan-Ess1] quit
```

Create a security profile named **security**.

```
[MAGOUDAYA-GABNO] wlan
[MAGOUDAYA-GABNO-wlan-view] security-profile name security id 1
[MAGOUDAYA-GABNO-wlan-sec-prof-security] quit
```

Create a traffic profile named **traffic**.

```
[MAGOUDAYA-GABNO-wlan-view] traffic-profile name traffic id 1
[MAGOUDAYA-GABNO-wlan-traffic-prof-traffic] quit
```

Create a service set named **test** and bind the WLAN-ESS interface, security profile, and traffic profile to the service set.

```
[MAGOUDAYA-GABNO-wlan-view] service-set name test id 1
[MAGOUDAYA-GABNO-wlan-service-set-test] ssid test
[MAGOUDAYA-GABNO-wlan-service-set-test] wlan-ess 1
[MAGOUDAYA-GABNO-wlan-service-set-test] security-profile name security
[MAGOUDAYA-GABNO-wlan-service-set-test] traffic-profile name traffic
```

[MAGOUDAYA-GABNO-wlan-service-set-test] **service-vlan 101**
[MAGOUDAYA-GABNO-wlan-service-set-test] **forward-mode tunnel**
[MAGOUDAYA-GABNO-wlan-service-set-test] **quit**

7. Configure a VAP and deliver VAP parameters to the AP.
   # Configure a VAP.
   [MAGOUDAYA-GABNO-wlan-view] **ap 0 radio 0**
   [MAGOUDAYA-GABNO-wlan-radio-0/0] **radio-profile name radio**
   [MAGOUDAYA-GABNO-wlan-radio-0/0] **service-set name test**
   [MAGOUDAYA-GABNO-wlan-radio-0/0] **quit**
   # Commit the configuration.
   [MAGOUDAYA-GABNO-wlan-view] **commit ap 0**
   Warning: Committing configuration may cause service interruption, continue?[Y/N]
   :**y**
8. Verify the configuration.
   After the configuration is complete, run the **display vap ap 0 radio 0** command. The command output shows that the VAP has been created.

The figure 8 presents the implementation of some commands in eNSP

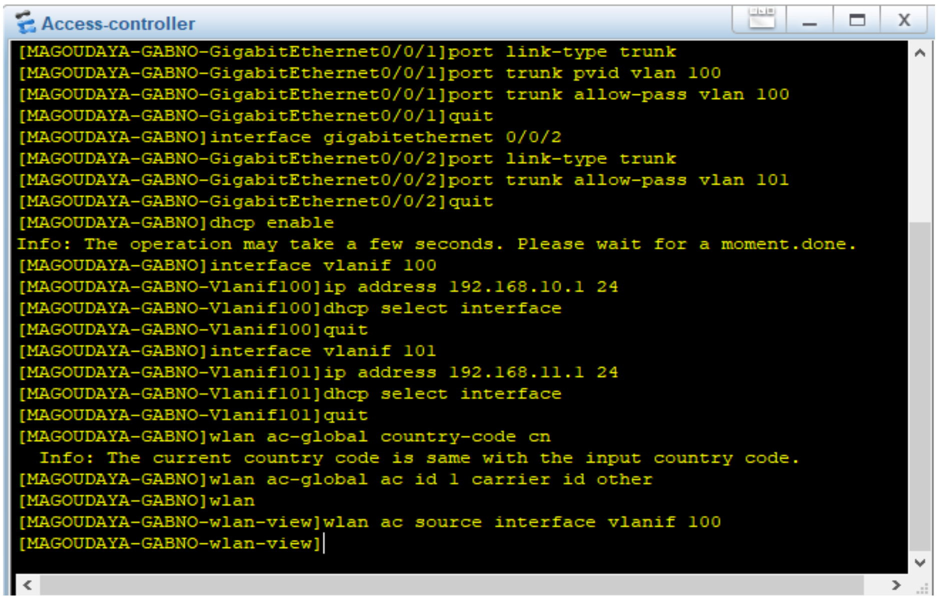


Figure 8: Implementation of some commands in eNSP

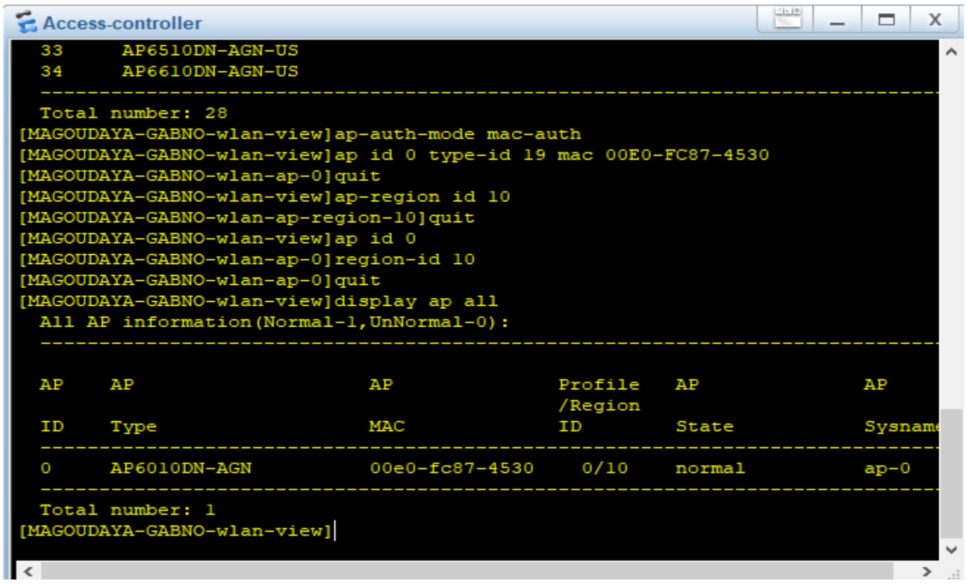
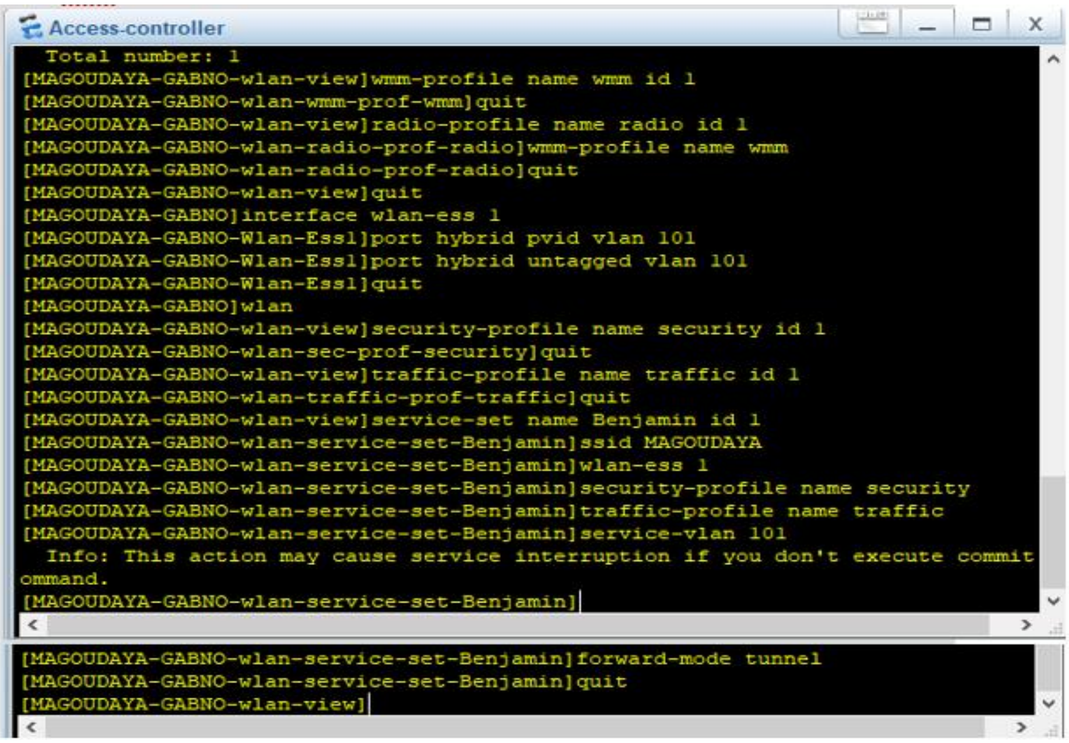


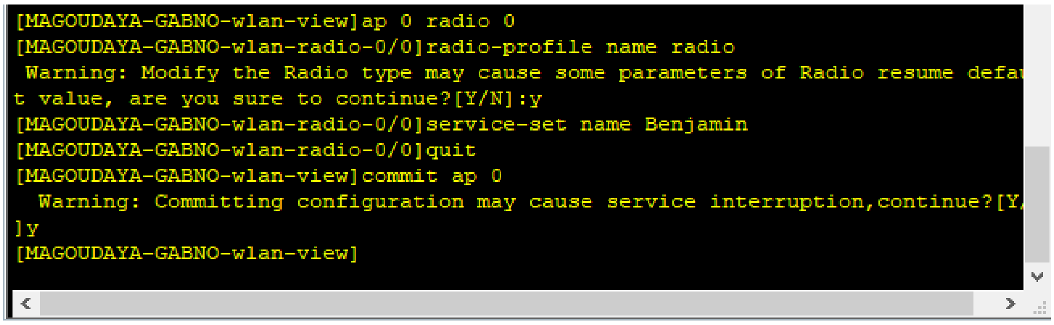
Figure 9: Implementation of some commands in eNSP: AP MAC adress




```
  Total number: 1
[MAGOUDAYA-GABNO-wlan-view]wmm-profile name wmm id 1
[MAGOUDAYA-GABNO-wlan-wmm-prof-wmm]quit
[MAGOUDAYA-GABNO-wlan-view]radio-profile name radio id 1
[MAGOUDAYA-GABNO-wlan-radio-prof-radio]wmm-profile name wmm
[MAGOUDAYA-GABNO-wlan-radio-prof-radio]quit
[MAGOUDAYA-GABNO-wlan-view]quit
[MAGOUDAYA-GABNO]interface wlan-ess 1
[MAGOUDAYA-GABNO-Wlan-Ess1]port hybrid pvid vlan 101
[MAGOUDAYA-GABNO-Wlan-Ess1]port hybrid untagged vlan 101
[MAGOUDAYA-GABNO-Wlan-Ess1]quit
[MAGOUDAYA-GABNO]wlan
[MAGOUDAYA-GABNO-wlan-view]security-profile name security id 1
[MAGOUDAYA-GABNO-wlan-sec-prof-security]quit
[MAGOUDAYA-GABNO-wlan-view]traffic-profile name traffic id 1
[MAGOUDAYA-GABNO-wlan-traffic-prof-traffic]quit
[MAGOUDAYA-GABNO-wlan-view]service-set name Benjamin id 1
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]ssid MAGOUDAYA
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]wlan-ess 1
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]security-profile name security
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]traffic-profile name traffic
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]service-vlan 101
  Info: This action may cause service interruption if you don't execute commit
ommand.
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]

[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]forward-mode tunnel
[MAGOUDAYA-GABNO-wlan-service-set-Benjamin]quit
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 10: Implementation of some commands in eNSP: WLAN-ESS,configuration



```
[MAGOUDAYA-GABNO-wlan-view]ap 0 radio 0
[MAGOUDAYA-GABNO-wlan-radio-0/0]radio-profile name radio
 Warning: Modify the Radio type may cause some parameters of Radio resume defau
t value, are you sure to continue?[Y/N]:y
[MAGOUDAYA-GABNO-wlan-radio-0/0]service-set name Benjamin
[MAGOUDAYA-GABNO-wlan-radio-0/0]quit
[MAGOUDAYA-GABNO-wlan-view]commit ap 0
  Warning: Committing configuration may cause service interruption,continue?[Y/
]y
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 11: VAP configuration and validation.

After the execution of all these commands we can see the network appear in eNSP as shown on figure 12.

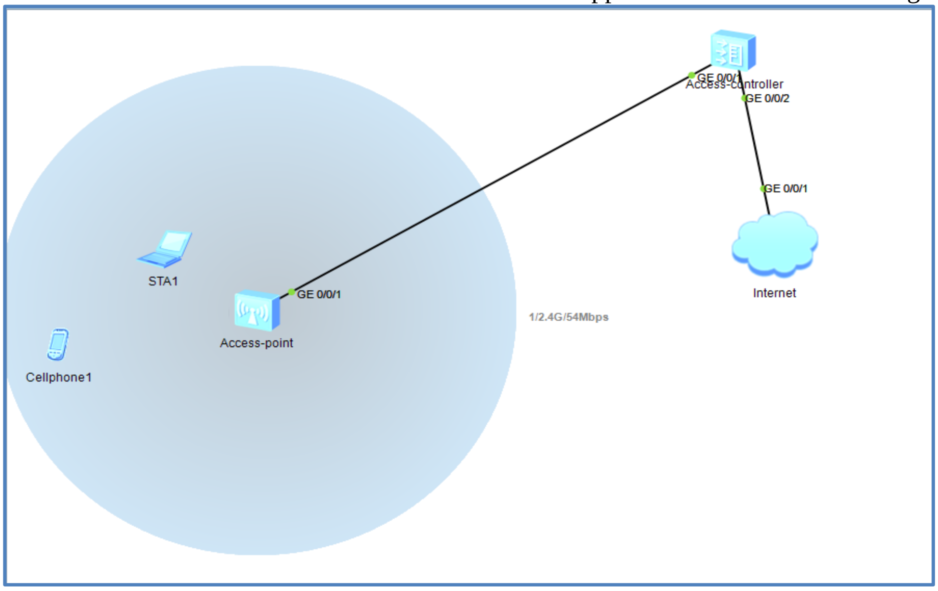
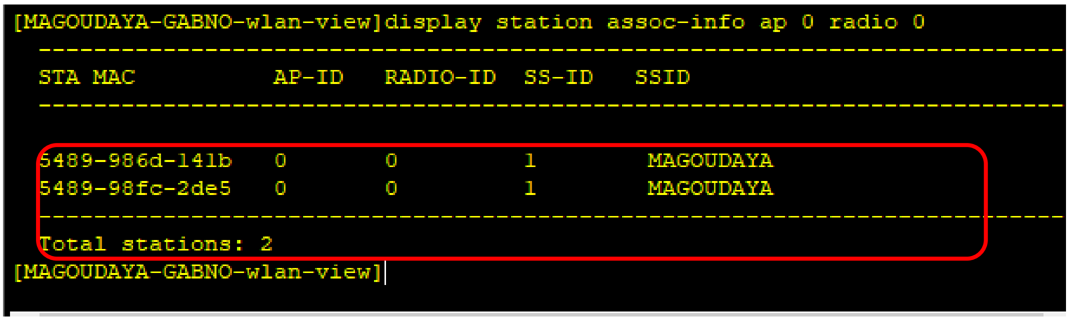


Figure 12: Result of the simulation

But after this step the terminal cannot access the Wi-Fi network because there are not connected, we have to manually connect the terminal on the Wi-Fi network. After connecting the devices and when we run the command "**display station assoc-info ap 0 radio 0**", we can get the result shown in figure 11.



```
[MAGOUDAYA-GABNO-wlan-view]display station assoc-info ap 0 radio 0
 ------------------------------------------------------------------------
 STA MAC          AP-ID   RADIO-ID  SS-ID   SSID
 ------------------------------------------------------------------------

 5489-986d-141b    0        0          1        MAGOUDAYA
 5489-98fc-2de5    0        0          1        MAGOUDAYA
 ------------------------------------------------------------------------
 Total stations: 2
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 13: Association of station

d) Network expansion from 1 to 3 Access point.

If we want to expand the network from one department to 2 others departments, we can run some command on the AC and easily get the result. In this case the network diagram in eNSP would be as in figure 11

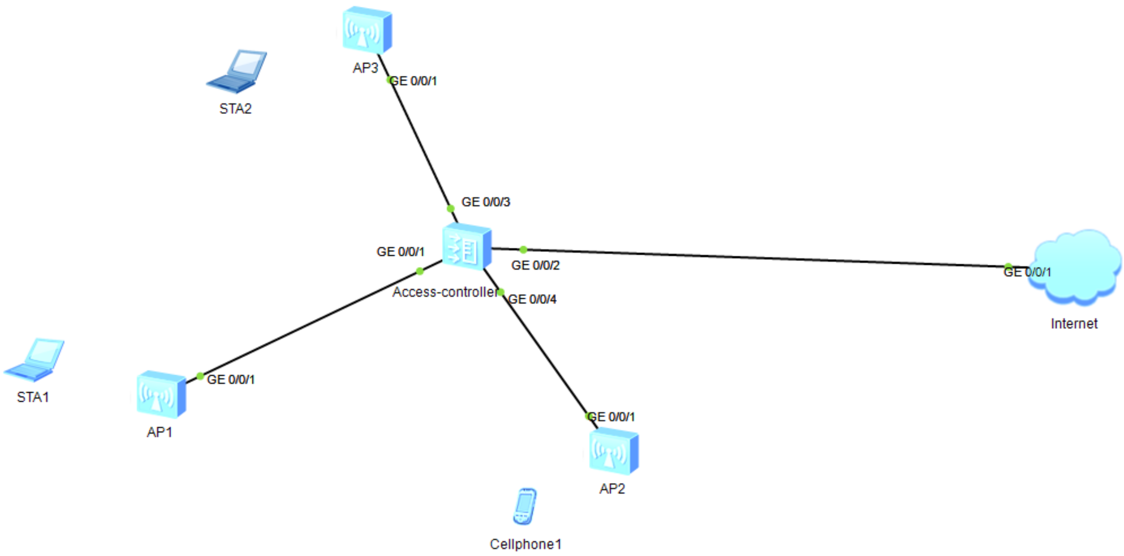


Figure 14: Network diagram for expansion from one AP to 3 AP

a) First of all, we put the interfaces gigabit Ethernet 0/0/3 and 0/0/4 in the VLAN 100

interface gigabitethernet 0/0/3
port link-type trunk
port trunk pvid vlan 100
port trunk allow-pass vlan 100
quit

interface gigabitethernet 0/0/4
port link-type trunk
port trunk pvid vlan 100
port trunk allow-pass vlan 100
quit

b) Then we create the AP inside the controller

wlan
ap id 1 type-id 19 mac 00E0-FC90-4ED0
quit

ap id 2 type-id 19 mac 00E0-FCBF-6630
quit

c) We add the AP to the mm ESS

ap id 1
region-id 10
quit

ap id 2
region-id 10
quit

ap 1 radio 0
radio-profile name radio
service-set name test
quit

ap 2 radio 0
radio-profile name radio
service-set name test
quit

commit ap 1
commit ap 2

```
[MAGOUDAYA-GABNO]interface gigabitethernet 0/0/3
[MAGOUDAYA-GABNO-GigabitEthernet0/0/3]port link-type trunk
[MAGOUDAYA-GABNO-GigabitEthernet0/0/3]port trunk pvid vlan 100
[MAGOUDAYA-GABNO-GigabitEthernet0/0/3]port trunk allow-pass vlan 100
[MAGOUDAYA-GABNO-GigabitEthernet0/0/3]quit
[MAGOUDAYA-GABNO]interface gigabitethernet 0/0/4
[MAGOUDAYA-GABNO-GigabitEthernet0/0/4]port link-type trunk
[MAGOUDAYA-GABNO-GigabitEthernet0/0/4]port trunk pvid vlan 100
[MAGOUDAYA-GABNO-GigabitEthernet0/0/4]port trunk allow-pass vlan 100
[MAGOUDAYA-GABNO-GigabitEthernet0/0/4]quit
[MAGOUDAYA-GABNO]
```

Figure 15: Ethernet trunk configuration

```
[MAGOUDAYA-GABNO]wlan
[MAGOUDAYA-GABNO-wlan-view]ap id 1 type-id 19 mac 00E0-FC04-1D10
[MAGOUDAYA-GABNO-wlan-ap-1]ap id 2 type-id 19 mac 00E0-FC08-6570
[MAGOUDAYA-GABNO-wlan-ap-2]quit
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 16: Adding APP based on their MAC address inside the controler

Now we can add the VAP of the newly added AP in the same region with AP0.

```
[MAGOUDAYA-GABNO-wlan-ap-1]region-id 10
[MAGOUDAYA-GABNO-wlan-ap-1]quit
[MAGOUDAYA-GABNO-wlan-view]ap id 2
[MAGOUDAYA-GABNO-wlan-ap-2]region-id 10
[MAGOUDAYA-GABNO-wlan-ap-2]quit
[MAGOUDAYA-GABNO-wlan-view]ap 1 radio 0
[MAGOUDAYA-GABNO-wlan-radio-1/0]radio-profile name radio
 Warning: Modify the Radio type may cause some parameters of Radio resume defa
t value, are you sure to continue?[Y/N]:y
 [MAGOUDAYA-GABNO-wlan-radio-1/0]service-set name Benjamin
 [MAGOUDAYA-GABNO-wlan-radio-1/0]quit
 [MAGOUDAYA-GABNO-wlan-view]ap 2 radio 0
 [MAGOUDAYA-GABNO-wlan-radio-2/0]radio-profile name radio
  Warning: Modify the Radio type may cause some parameters of Radio resume defa
 t value, are you sure to continue?[Y/N]:y
 [MAGOUDAYA-GABNO-wlan-radio-2/0]service-set name Benjamin
 [MAGOUDAYA-GABNO-wlan-radio-2/0]quit
 [MAGOUDAYA-GABNO-wlan-view]
```

Figure 17: Adding the AP in the same region with AP0

```
[MAGOUDAYA-GABNO-wlan-view]commit ap 0
  Warning: Committing configuration may cause service interruption,continue?[Y/N
]y
[MAGOUDAYA-GABNO-wlan-view]commit ap 1
  Warning: Committing configuration may cause service interruption,continue?[Y/N
]y
[MAGOUDAYA-GABNO-wlan-view]commit ap 2
  Warning: Committing configuration may cause service interruption,continue?[Y/N
]y
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 18: Commit the AP configuration

Then we can verify the configuration on the graphical interface of eNSP. Figure 19 shows the coverage area of each AP. We can see that all AP are running and the WiFi service is available inside the coverage area. At this stage we have not yet connect and register the terminal to each AP, figure 20 shows how we can connect the terminals and figure 21 shows the WiFi connectivity between each terminal and the AP where he is connected.

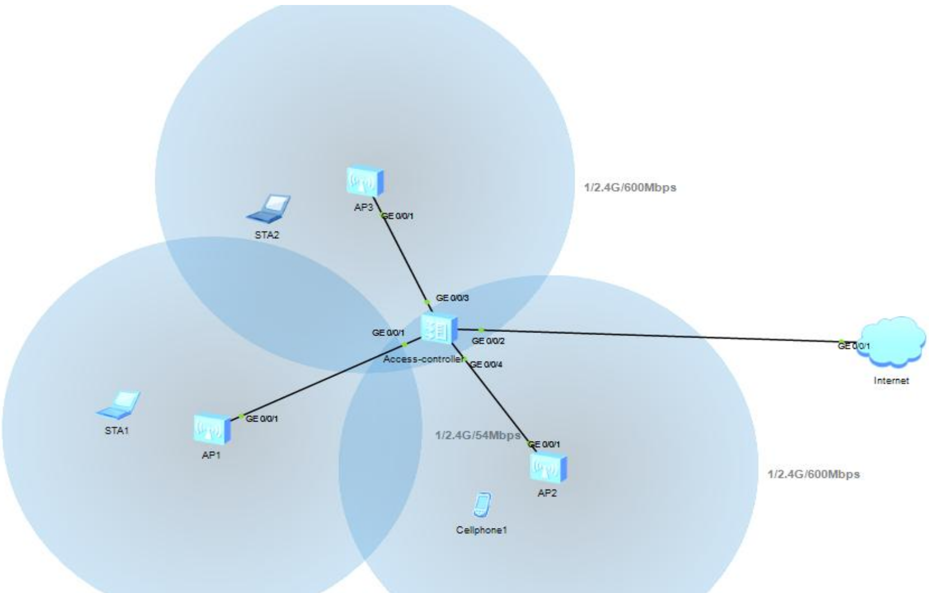


Figure 19: AP visualization

When the network is on as we can see on the coverage area of each AP, we have to connect the terminals, and for that we should double click each terminal, then check the Wi-Fi service availability, the SSID as configured on the AC and finally click on connect for the terminal to be registered to the network. Figure 20 shows how one phone (Cellphone 1) and two stations (STA1 and STA2) are connected to the Wi-Fi network

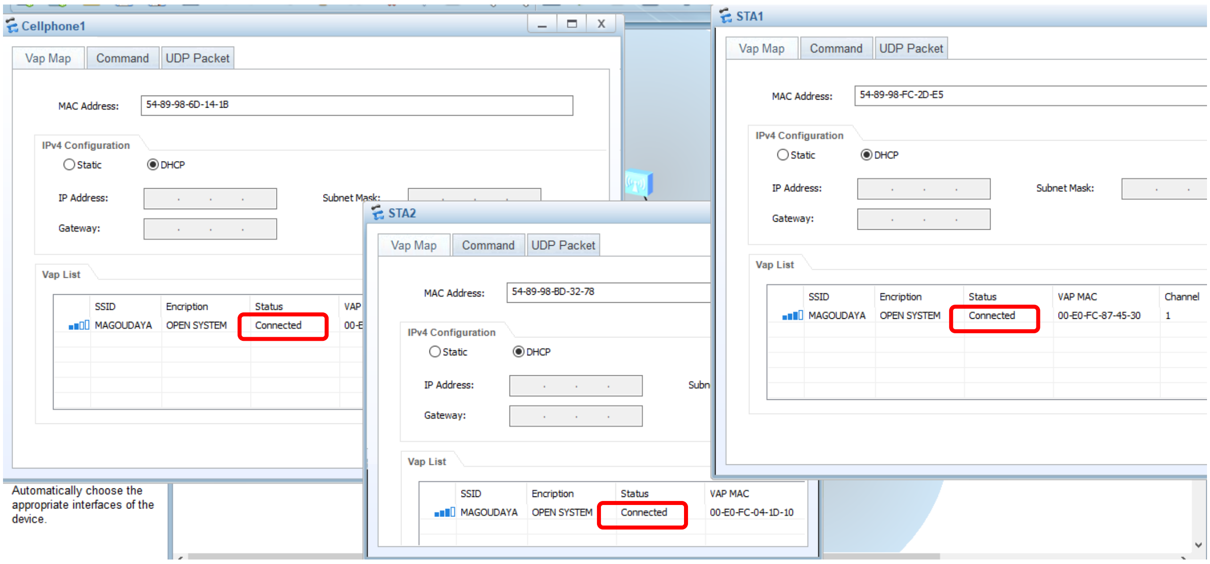


Figure 20: Connection of terminals to the configured Wi-Fi network

Once the equipments are connected, we have a Wi-Fi connectivity which is display between the AP and the terminals on eNSP simulator; later through **Wireshark** packets captured we can clearly see that Wi-Fi connectivity is effective between AP and terminals (see figure 27).

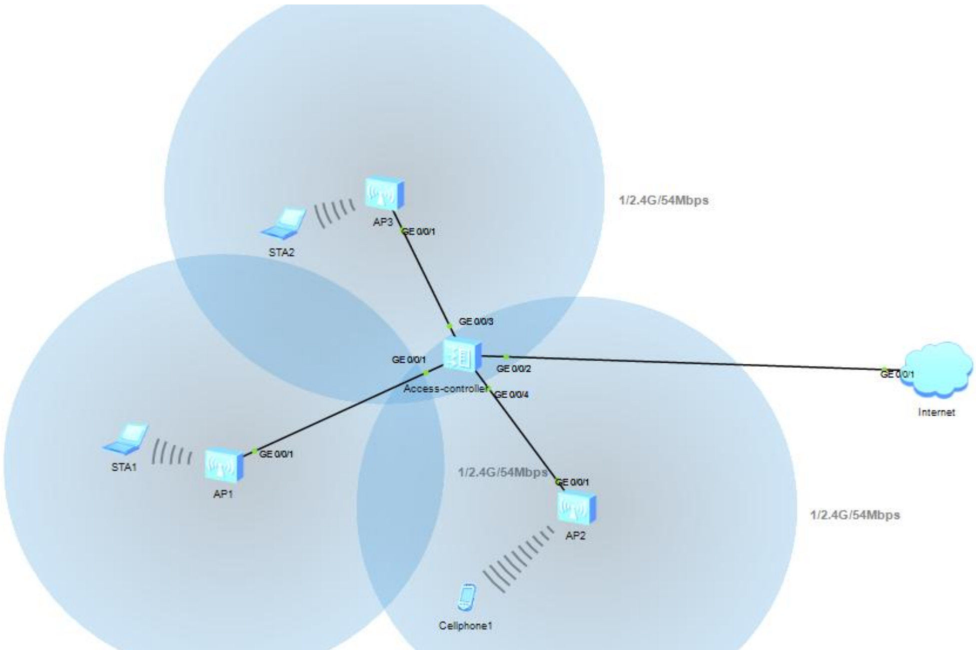


Figure 21: Equipments association to the AP

After all these, we can run the command **« display vap ap 0 radio 0". The output of the command shows that the** VAP are created for each AP.

```
[MAGOUDAYA-GABNO]wlan
[MAGOUDAYA-GABNO-wlan-view]display vap ap 0 radio 0
  All VAP Information(Total-1):
  SS: Service-set      BP: Bridge-profile      MP: Mesh-profile
  ------------------------------------------------------------------------
  AP ID  Radio ID  SS ID  BP ID  MP ID  WLAN ID  BSSID           Type
  0      0         1      -      -      1        00E0-FC87-4530  service
  ------------------------------------------------------------------------
  Total: 1
[MAGOUDAYA-GABNO-wlan-view]display vap ap 1 radio 0
  All VAP Information(Total-1):
  SS: Service-set      BP: Bridge-profile      MP: Mesh-profile
  ------------------------------------------------------------------------
  AP ID  Radio ID  SS ID  BP ID  MP ID  WLAN ID  BSSID           Type
  1      0         1      -      -      1        00E0-FC04-1D10  service
  ------------------------------------------------------------------------
  Total: 1
[MAGOUDAYA-GABNO-wlan-view]display vap ap 2 radio 0
  All VAP Information(Total-1):
  SS: Service-set      BP: Bridge-profile      MP: Mesh-profile
  ------------------------------------------------------------------------
  AP ID  Radio ID  SS ID  BP ID  MP ID  WLAN ID  BSSID           Type
  2      0         1      -      -      1        00E0-FC08-6570  service
  ------------------------------------------------------------------------
  Total: 1
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 22: AP configured on the AC

The command **display station assoc-info** on the AC shows that the equipments connected to the APs.

```
Access-controller
[MAGOUDAYA-GABNO-wlan-view]display station assoc-info ap 0 radio 0
  ------------------------------------------------------------------------
  STA MAC           AP-ID   RADIO-ID   SS-ID   SSID
  ------------------------------------------------------------------------

  5489-98fc-2de5    0       0          1        MAGOUDAYA
  ------------------------------------------------------------------------
  Total stations: 1
[MAGOUDAYA-GABNO-wlan-view]display station assoc-info ap 1 radio 0
  ------------------------------------------------------------------------
  STA MAC           AP-ID   RADIO-ID   SS-ID   SSID
  ------------------------------------------------------------------------

  5489-98bd-3278    1       0          1        MAGOUDAYA
  ------------------------------------------------------------------------

  Total stations: 1
[MAGOUDAYA-GABNO-wlan-view]display station assoc-info ap 2 radio 0
  ------------------------------------------------------------------------
  STA MAC           AP-ID   RADIO-ID   SS-ID   SSID
  ------------------------------------------------------------------------

  5489-986d-141b    2       0          1        MAGOUDAYA
  ------------------------------------------------------------------------
  Total stations: 1
[MAGOUDAYA-GABNO-wlan-view]
```

Figure 23: Station association information

II.4.3 Simulation procedure for WLAN Services in a Layer 2 Inline Networking (Tunnel Forwarding).
The networking diagram to consider is the one of figure 5.

a) Networking Requirements

As shown in figure 5, the AC connects to the upper-layer network and to AP1 and AP2 through the aggregation switch and access switch. The AC and APs communicate through a Layer 3 network. The networking simplifies the network structure of large networks and applies to campus users. The high-efficient tunnel forwarding mode is used in this networking for data packet management. Deploying a wired network requires a large number of cables and consumes much labor and costs. A wired network is also inflexible for users. To reduce cable layout and save human resources, users can deploy a WLAN that improves network flexibility and maintainability.

b) Data Plan

Table no 2: Data planning for Layer 2 inline Networking.

Configuration Item	Data
WLAN security	WEP open system authentication and no encryption
WLAN service set	Name: huawei-1 SSID: huawei-1 WLAN virtual interface: WLAN-ESS 0 Data forwarding mode: tunnel forwarding
	Name: huawei-2 SSID: huawei-2 WLAN virtual interface: WLAN-ESS 1 Data forwarding mode: tunnel forwarding
Management VLAN for APs	VLAN 100
Service VLANs for Aps	AP1: VLAN 101 AP2: VLAN 102
Regions	AP1: 101 AP2: 102
AC carrier ID/AC ID	other/1
Management IP address pool for APs	192.168.10.2 to 192.168.10.254/24
Gateway address for Aps	192.168.10.1/24 (The gateway is on the AC.)
Public IP address pool for STAs on AP1	192.168.11.2 to 192.168.11.254/24
Public gateway address for STAs on AP1	192.168.11.1/24 (The gateway is on the AC.)
Public IP address pool for STAs on AP2	192.168.12.2 to 192.168.12.254/24
Public gateway address for STAs on AP2	192.168.12.1/24 (The gateway is on the AC.)
DHCP server	The AC functions as the DHCP server for APs and STAs.

c) Configuration Procedure

1. Connect network devices according to figure 5 and ensure connectivity between the AC and the IP backbone network.
2. Configure the access switch and aggregation switch so that APs can communicate with the AC at Layer 2.
3. Configure the WLAN service on the AC.
4. Deliver the WLAN service to APs and verify the configuration.

<u>Procedure</u>

1. Configure the access switch.

Configure the access switch to transparently transmit packets of management VLAN and tag AP management packets with management VLAN 100. Configure the AP and AC to communicate in VLAN 100.

```
<Quidway> system-view
[Quidway] vlan 100
[Quidway] interface ethernet 0/0/1
[Quidway-Ethernet0/0/1] port link-type trunk
[Quidway-Ethernet0/0/1] port trunk pvid vlan 100
[Quidway-Ethernet0/0/1] port trunk allow-pass vlan 100
[Quidway-Ethernet0/0/1] port-isolate enable
[Quidway-Ethernet0/0/1] quit
[Quidway] interface ethernet 0/0/2
[Quidway-Ethernet0/0/2] port link-type trunk
[Quidway-Ethernet0/0/2] port trunk pvid vlan 100
[Quidway-Ethernet0/0/2] port trunk allow-pass vlan 100
[Quidway-Ethernet0/0/2] port-isolate enable
[Quidway-Ethernet0/0/2] quit
[Quidway] interface gigabitethernet 0/0/1
[Quidway-GigabitEthernet0/0/1] port link-type trunk
[Quidway-GigabitEthernet0/0/1] port trunk allow-pass vlan 100
```

[Quidway-GigabitEthernet0/0/1] **quit**

2. Configure the aggregation switch.
   # Configure the aggregation switch to transparently transmit packets of management VLAN.
   <Quidway> **system-view**
   [Quidway] **vlan batch 100**
   [Quidway] **interface gigabitethernet 0/0/1**
   [Quidway-GigabitEthernet0/0/1] **port link-type trunk**
   [Quidway-GigabitEthernet0/0/1] **port trunk allow-pass vlan 100**
   [Quidway-GigabitEthernet0/0/1] **port-isolate enable**
   [Quidway-GigabitEthernet0/0/1] **quit**
   [Quidway] **interface gigabitethernet 0/0/2**
   [Quidway-GigabitEthernet0/0/2] **port link-type trunk**
   [Quidway-GigabitEthernet0/0/2] **port trunk allow-pass vlan 100**
   [Quidway-GigabitEthernet0/0/2] **quit**
3. Configure the AC.
   a. Configure the AC so that APs and the AC can transmit management packets.
      # Add GE0/0/1 to VLAN 100.
      <AC6605> **system-view**
      [AC6605] **sysname AC**
      [AC] **vlan batch 100 101 102**
      [AC] **interface gigabitethernet 0/0/1**
      [AC-GigabitEthernet0/0/1] **port link-type trunk**
      [AC-GigabitEthernet0/0/1] **port trunk allow-pass vlan 100**
      [AC-GigabitEthernet0/0/1] **quit**
   b. Configure the AC to communicate with upstream devices.
      Configure a route to the upper-layer network on the AC according to service requirements.
   c. Configure the AC as the DHCP server for APs and STAs.
   d. [AC] **interface Vlanif 100**
   e. [AC-Vlanif100] **ip address 192.168.10.1 24**
   f. [AC-Vlanif100] **dhcp select interface**
   g. [AC-Vlanif100] **quit**
   h. [AC] **interface Vlanif 101**
   i. [AC-Vlanif101] **ip address 192.168.11.1 24**
   j. [AC-Vlanif101] **dhcp select interface**
   k. [AC-Vlanif101] **quit**
   l. [AC] **interface Vlanif 102**
   m. [AC-Vlanif102] **ip address 192.168.12.1 24**
   n. [AC-Vlanif102] **dhcp select interface**
   o. [AC-Vlanif102] **quit**
   p. Configure global parameters on the AC.
      # Configure the AC ID, country code, carrier ID, and source interface.
      [AC] **wlan ac-global country-code cn**
      Warning: Modify the country code may delete configuration on those AP which us
      e the global country code and reset them, are you sure to continue?[Y/N]:**y**
      [AC] **wlan ac-global ac id 1 carrier id other**
      [AC] **wlan**
      [AC-wlan-view] **wlan ac source interface vlanif 100**
   q. Configure APs and enable them to go online.
      # Set AP authentication mode to MAC address authentication.
      [AC-wlan-view] **ap-auth-mode mac-auth**
      # Query the AP device type.
      [AC-wlan-view] **display ap-type all**

      # Add AP1 and AP2 of the AP6010DN-AGN type offline according to the obtained device type ID (**19**).
      [AC-wlan-view] **ap id 1 type-id 19 mac 60de-4476-e360**
      [AC-wlan-ap-1] **quit**
      [AC-wlan-view] **ap id 2 type-id 19 mac dcd2-fc04-b500**
      [AC-wlan-ap-2] **quit**

Add APs to AP regions.

[AC-wlan-view] **ap-region id 101**
[AC-wlan-ap-region-101] **quit**
[AC-wlan-view] **ap-region id 102**
[AC-wlan-ap-region-102] **quit**
[AC-wlan-view] **ap id 1**
[AC-wlan-ap-1] **region-id 101**
[AC-wlan-ap-1] **quit**
[AC-wlan-view] **ap id 2**
[AC-wlan-ap-2] **region-id 102**
[AC-wlan-ap-2] **quit**

Check whether APs have gone online.

[AC-wlan-view] **display ap all**
[AC-wlan-view] **quit**

r. Configure WLAN-ESS interfaces.

[AC] **interface wlan-ess 0**
[AC-Wlan-Ess0] **port hybrid pvid vlan 101**
[AC-Wlan-Ess0] **port hybrid untagged vlan 101**
[AC-Wlan-Ess0] **quit**
[AC] **interface wlan-ess 1**
[AC-Wlan-Ess1] **port hybrid pvid vlan 102**
[AC-Wlan-Ess1] **port hybrid untagged vlan 102**
[AC-Wlan-Ess1] **quit**

s. Configure WLAN service parameters.

Configure WMM profiles and radio profiles, retain the default settings of the profiles, and bind the WMM profiles to the radio profiles.

[AC] **wlan**
[AC-wlan-view] **wmm-profile name huawei-ap1**
[AC-wlan-wmm-prof-huawei-ap1] **quit**
[AC-wlan-view] **wmm-profile name huawei-ap2**
[AC-wlan-wmm-prof-huawei-ap2] **quit**
[AC-wlan-view] **radio-profile name huawei-ap1**
[AC-wlan-radio-prof-huawei-ap1] **wmm-profile name huawei-ap1**
[AC-wlan-radio-prof-huawei-ap1] **quit**
[AC-wlan-view] **radio-profile name huawei-ap2**
[AC-wlan-radio-prof-huawei-ap2] **wmm-profile name huawei-ap2**
[AC-wlan-radio-prof-huawei-ap2] **quit**

Create a security profile and retain the default settings: open system authentication and no encryption.

[AC-wlan-view] **security-profile name huawei-ap**
[AC-wlan-sec-prof-huawei-ap] **quit**

Configure a traffic profile and retain the default settings.

[AC-wlan-view] **traffic-profile name huawei-ap**
[AC-wlan-traffic-prof-huawei-ap] **quit**

Configure service sets for AP1 and AP2, and set the data forwarding mode to tunnel forwarding.

[AC-wlan-view] **service-set name huawei-1**
[AC-wlan-service-set-huawei-1] **ssid huawei-1**
[AC-wlan-service-set-huawei-1] **wlan-ess 0**
[AC-wlan-service-set-huawei-1] **service-vlan 101**
[AC-wlan-service-set-huawei-1] **security-profile name huawei-ap**
[AC-wlan-service-set-huawei-1] **traffic-profile name huawei-ap**
[AC-wlan-service-set-huawei-1] **forward-mode tunnel**
[AC-wlan-service-set-huawei-1] **quit**
[AC-wlan-view] **service-set name huawei-2**
[AC-wlan-service-set-huawei-2] **ssid huawei-2**
[AC-wlan-service-set-huawei-2] **wlan-ess 1**
[AC-wlan-service-set-huawei-2] **service-vlan 102**
[AC-wlan-service-set-huawei-2] **security-profile name huawei-ap**

```
[AC-wlan-service-set-huawei-2] traffic-profile name huawei-ap
[AC-wlan-service-set-huawei-2] forward-mode tunnel
[AC-wlan-service-set-huawei-2] quit
```

t. Configure VAPs and deliver configurations to the APs.

```
[AC-wlan-view] ap 1 radio 0
[AC-wlan-radio-1/0] radio-profile name huawei-ap1
[AC-wlan-radio-1/0] service-set name huawei-1
[AC-wlan-radio-1/0] quit
[AC-wlan-view] commit ap 1
  Warning: Committing configuration may cause service interruption,continue?[Y/N] y
[AC-wlan-view] ap 2 radio 0
[AC-wlan-radio-2/0] radio-profile name huawei-ap2
[AC-wlan-radio-2/0] service-set name huawei-2
[AC-wlan-radio-2/0] quit
[AC-wlan-view] commit ap 2
  Warning: Committing configuration may cause service interruption,continue?[Y/N] y
```

4. Enable radio calibration to allow APs to automatically select optimal channels.
   # Configure radio calibration. By default, the radio mode and power mode are both **auto** in the radio profile, and the radio calibration mode is **manual**. The configuration procedure is therefore not provided here. If the radio calibration mode is **manual**, run the **calibrate manual startup** command to manually trigger radio calibration.

```
<AC6605> system-view
[AC6605] wlan
[AC6605-wlan-view] calibrate manual startup
```

Run the **display actual channel-power all** command to check the channel and power of a radio. Assume that there are three online APs on the AC. The command output shows that AP channels have been automatically assigned through the radio calibration function.

```
[AC6605-wlan-view] display actual channel-power all
  ---------------------------------------------------------
   RADIO CHANNEL POWER-LEVEL POWER( dBm) CHANNEL-BANDWIDTH
  ---------------------------------------------------------
   1/0   1    10     17     20MHz
   2/0   11    9     18     20MHz
   3/0   6     8     18     20MHz
  ---------------------------------------------------------
```

APs finish radio calibration one hour after the radio calibration is manually triggered. After that, change the radio calibration mode to scheduled calibration and configure the APs to start radio calibration at 3:00 am.

```
[AC6605-wlan-view] calibrate enable schedule time 03:00:00
```

Commit the configuration.

```
[AC6605-wlan-view] commit ap 1
  Warning: Committing configuration may cause service interruption,continue?[Y/N
 ]y
[AC6605-wlan-view] commit ap 2
  Warning: Committing configuration may cause service interruption,continue?[Y/N
 ]y
[AC6605-wlan-view] commit ap 3
  Warning: Committing configuration may cause service interruption,continue?[Y/N
 ]y
```

Configure a calibration channel set to specify the channels on which the AP implements radio calibration. This example configures a calibration channel set for the 2.4 GHz radio, which consists of channels 1, 5, 9, and 13.

```
[AC6605-wlan-view] calibrate 2.4g 20mhz channel-set 1,5,9,13
```

To configure a calibration channel set for the 5 GHz radio, run the **calibrate 5g 20mhz channel-set** *channel-value* command.

5. Test the WLAN service configuration.
   - The WLANs with the SSID **huawei-1** or **huawei-2** are available for wireless PCs after the configuration is complete.
   - The wireless PCs obtain IP addresses after they associate with the WLANs.

- Wireless users can login to the corresponding web pages.

After following this procedure, we can get the result showing the AP providing Wi-Fi connectivity to terminal as in figure 24 and 25.

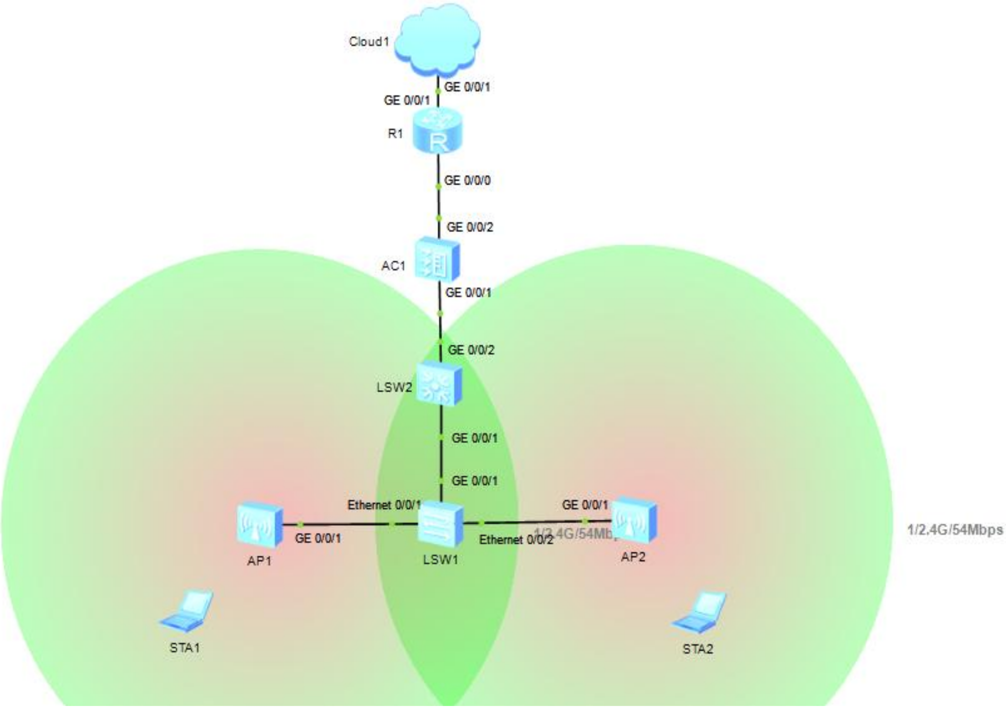


Figure 24: Result got after equipment configuration

It is then possible to connect the terminals as shown in figure 25 for them to register inside a network. And after that we can see the connection between the terminal and the AP as presented in figure 26.

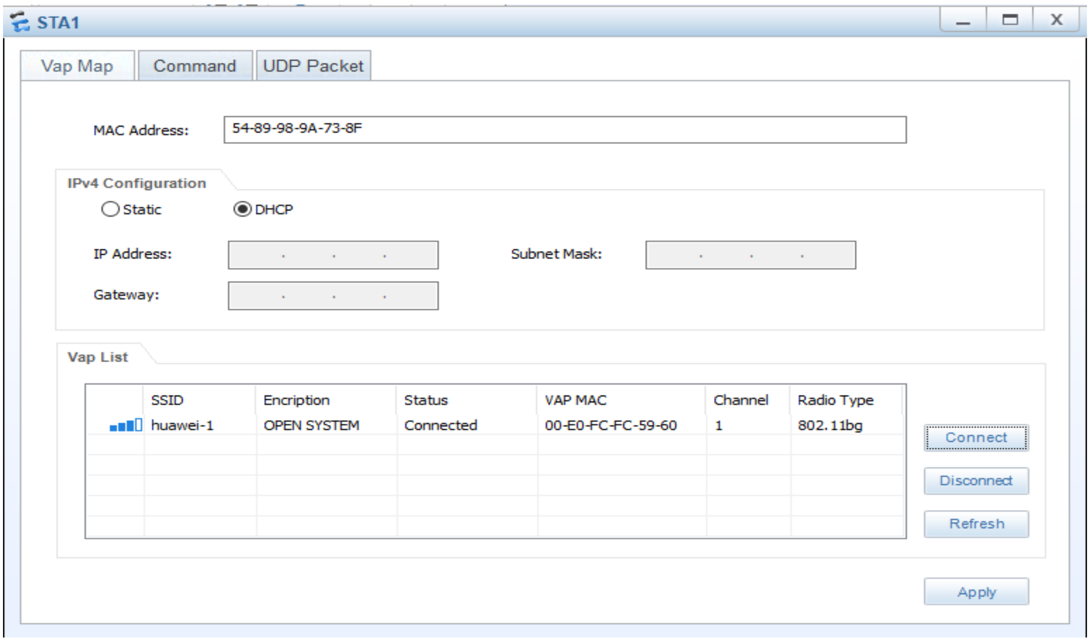


Figure 25: Connection of terminal to the Wi-Fi network

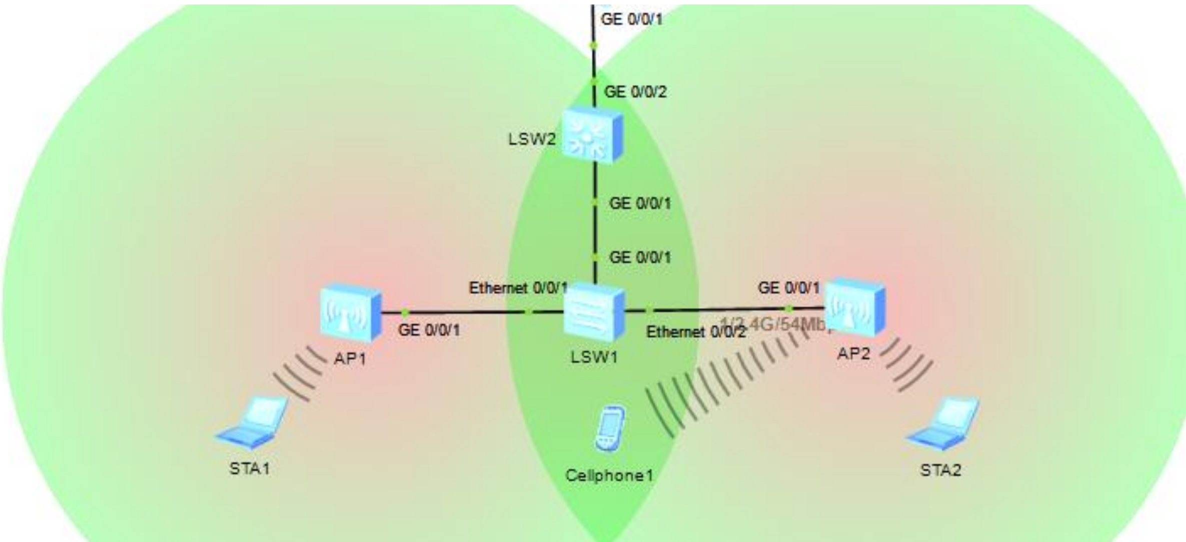


Figure 26: Wi-Fi connectivity between AP and terminals

III. Result and discussion

After the implementation of the simulation as present in section 2, we can use **Wireshark** software to capture packets in different interfaces and confirm that all the protocols are normally running on the equipment.
With **Wireshark**, we observe the traffic going through the gigabit Ethernet interface and also on the Wi-Fi interface. Figure 27 and 28 are given as examples.

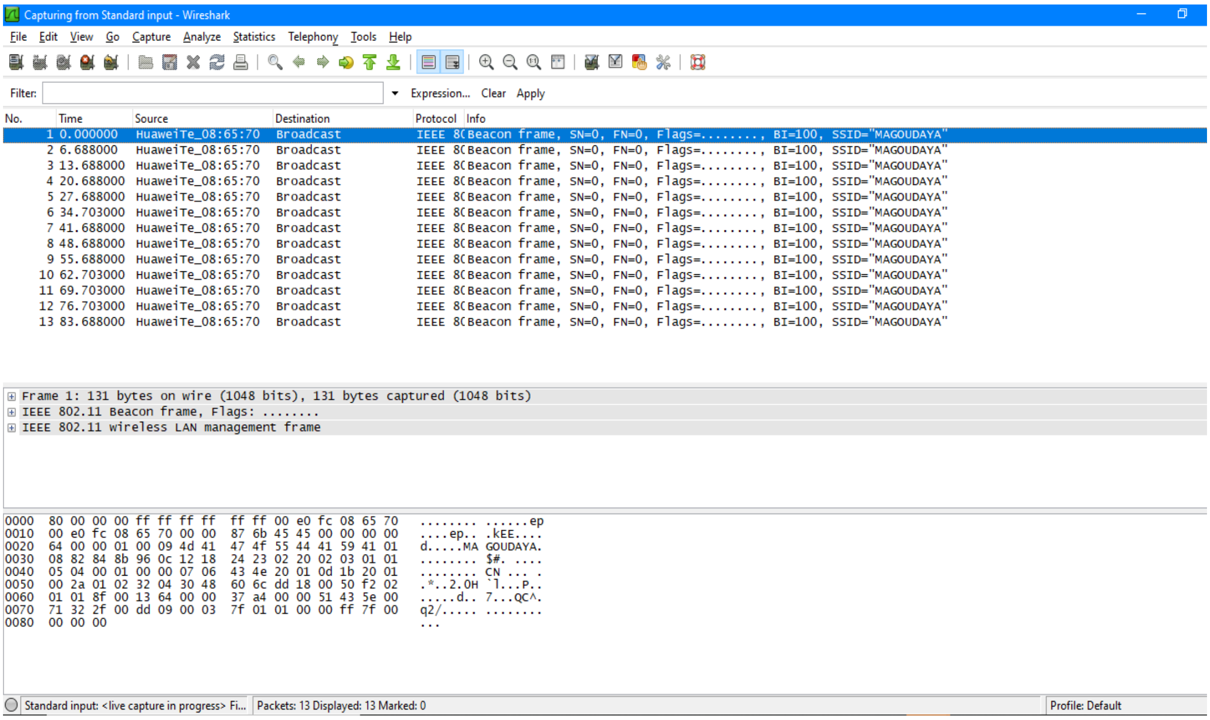


Figure 27: Wireshark packet capture on Wi-Fi interface

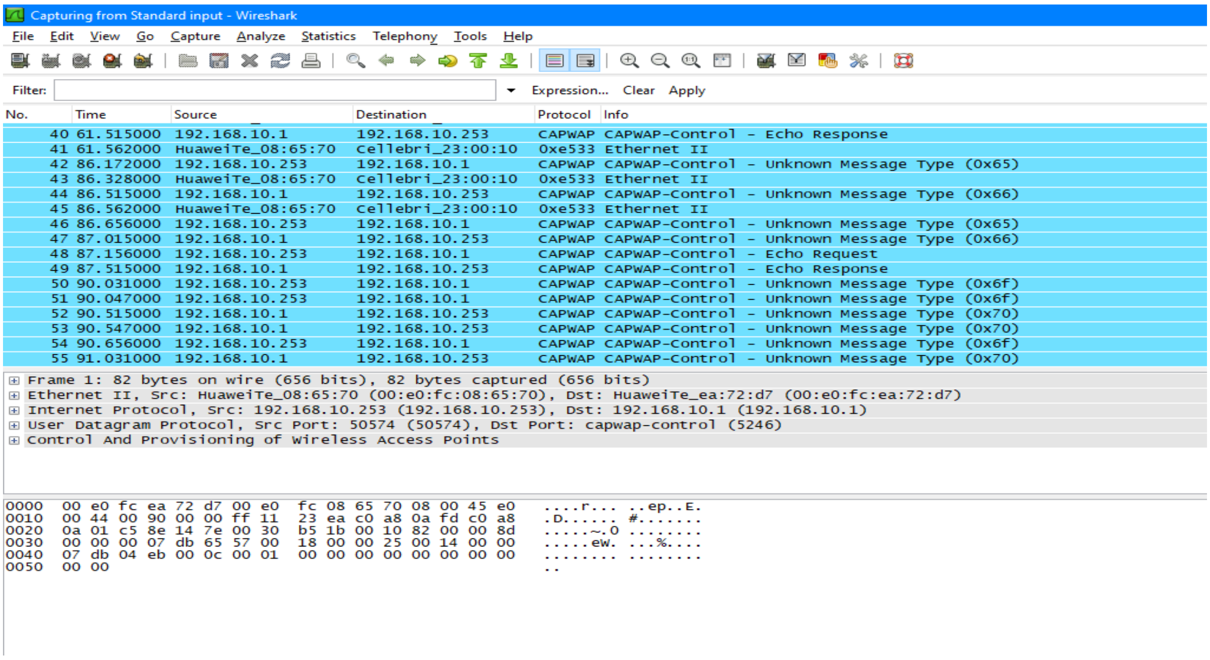


Figure 28: CAPWAP protocol running between AC and AP

We can see that CAPWAP protocol is effectively running between the AC and each AP, the DHCP is active and each terminal can get an IP address from the DHCP server.

Through this simple labs procedures and guides, students can well understand how to build from a simple network to a complex one and capture packets in different interfaces to check the network configuration. They can also learn how to use Wireshark to test and analyze the running of CAPWAP protocol between AC and AP; understand better the concept of FIT AP where the configuration and management is done at the AC level and so one. eNSP software is then suitable for teaching and for remote lab especially during period of crisis where some social restrictions are done (We can take corona virus 19 pandemic as an example).

IV. Conclusion

Implementation of e-learning and remote lab is a big challenge for some countries especially with the pandemic of Corona virus; sub Saharan African countries as well as Cameroon are facing this challenge. In this paper, we have tried to show the importance of e-learning and especially the e-lab operation for the training of engineers in schools or faculties. We have also presented eNSP as free and simple software which can be used for network simulation. By building simple simulation scenarios that can be run on eNSP, engineering students can improve their skills and become more qualified. Because of the simplicity of eNSP, it can be integrated in a concept of remote labs as it is in real labs. After all these, we have proposed, simulated and tested some simulations using eNSP.

From the above experiments presented, we can verify the session establishment process of CAPWAP (AP once power on acquires IP address from AC through DHCP), terminal connection to AP and terminal getting IP address from AP and so one.

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