Implementation of 5G IoT Based Smart Buildings using VLAN Configuration via Cisco Packet Tracer

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Abstract – **This paper aims to present an implementation of 5G IoT smart buildings using virtual network in Cisco Packet Tracer visual simulation tool. The rational of smart buildings is not only to improve wireless connectivity, but also to enhance life quality and safety in various aspects of people's life. The 5G IoT architecture considers security, fire safety, energy management, wide range of smart devices include RFID, lightening, watering plants for any smart buildings. The simulation of VLAN aims to simulate smart devices that can response independently or be controlled by end-users remotely to drive efficiency and effectiveness. Simulation results using Cisco Packet Tracer show that enabling 5G IoT to buildings is a promising and cost-effective approach that pursue the aim of this article in timely and efficient manners.**

Keywords – **Internet of Things, Wireless Communication, Smart City, Safety and Security, VLAN, 5G.**

I. Introduction

Smart buildings can be defined as "Buildings that use technology and processes to become more efficient operationally, protect the health and safety of occupants, improve employee productivity and reduce its impact on the environment" [1]. Safety and health are vital as they aim to protect people in buildings (e.g. homes, factories, schools, hospitals) from possible accidents that may cause injuries, death or damage to property. Most serious accidents that occur due to the lack of effective tools to monitor, detect and act in order to save lives and properties. Besides the lack of implementation of guidelines and policies of safety from authorities. Therefore, the appearance of Internet of Things (IoT) delivers an effective tool for strengthening safety and security supervision for buildings. The smartness and autonomous functioning of IoT are the main drives for supporting surveillance safety and security purposes, as well as comfort, improving energy efficiency, and reducing costs. Smart buildings embrace the Fourth Industrial Revolution (4IR), which has introduced wide range of advanced technologies in comparison to the third industrial revolution. Examples of these technologies are: Artificial Intelligence (AI), Robotics, IoT, Self-driving Vehicles, 3D Printing, Nanotechnology, Drones, Biotechnology, Radio frequency identification (RFID), Quantum Computing, Cloud Computing, and Blockchain. In an easy statement: the third industrial revolution represents simple digitization, while the fourth represents creative digitization based on a mixture of symbiotic interactive technology breakthroughs through innovative algorithms [2, 3].

Papers that reported in the literature are mainly focused only on some aspects of smart implementations (e.g. home, company, college); Let alone considering 5G IoT simulation. Thus, the motivation of this paper is to provide an intensive 5G implementation of IoT to smart building using Cisco Packet Tracer tool from various smart perspectives. Fig.1 shows some of the IoT capabilities that can be implemented in smart buildings. The rest of this paper is organized as follows: Section II presents related study; while III shows the proposed model of IoT smart buildings. Section IV describes the implementation and results. Section V concludes.

Fig. 1. IoT capabilities for Smart Buildings.

II. Related Work

A common trace is that smart integration between devices, where IoT contribute effectively in linking trillions of objects and sensors to serve wide range of applications. IoT is widely considered as one of the main boosters of the 4IR, as it has significantly contributed to make people's life smarter [4, 5]. Researchers around the world are striving in adopting IoT technology in various applications. In [6, 7], highlight the smart city concept, which is becoming an increasingly significant in the current digital era. Smart city could include smart home, smart drones, smart energy grid, smart transportation system, smart schools, smart healthcare, and many more. Any smart platform could be benefited from scalability, integration and interoperation of different IoT services and networks that are run on different hardware to enhance global connectivity. In [5], paper has, also, addressed four aspects of the IoT smartness and its wide applications. These aspects are: Data, Connectivity, Devices, and Services.

Authors in [8, 9], have focused on the implementation of IoT for smart homes. The paper emphasis the applicability of IoT that enabled smart home environment for various things (e.g. lighting, home appliances, computers, security camera, alarms). Researchers in [10, 11] pointed out how IoT can play a vital role in safety and health applications. The processing time, size, cost, and rapid deployment are main advantages of implementing IoT in health sector. Education and learning are from those applications that get benefited from IoT and smart connectivity [12].

Authors in [13] investigate the implementation of IoT for smart campus. Results shows that many applications used IoT efficiently that help in education process, such as: flipped classroom, entrance system, student's feedback, IoT orangery and IoT heating system. Reliability is a vital element with any space-based system when it comes to provides wireless communication services. One of these systems is an Unmanned Aerial Vehicles (UAVs) either drones or aerial platforms. Using advanced UAVs have the advantage of not only cost-effective solution with Line of Sight (LoS) connectivity and low latency and wide footprint cover; but also, IoT empowerment [14-17]. Researchers in [18] discussed implementation of smart factory in the context of 4IR and IoT. Integrated systems between IoT and AI show great potential in enhancing not only productivity of industrial manufacturing, but also safety and security of individuals in such an environment.

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III. PROPOSED MODEL OF IOT SMART BUILDINGS

Papers that reported in the literature are mainly focused only on some aspects of smart implementations (e.g. home, company, college); Let alone considering 5G IoT simulation [19-25]. Therefore, this paper aims to present a 5G implementation of IoT a smart building using Cisco Packet Tracer tool from various IoT smart perspectives. The visual simulation tool is used to create computer Virtual networks via Virtual Local area network (VLAN), as per Fig. 2. Fig. 2 (a) shows group of computers and smart devices that share a communications line wire or wireless link to a server within the same geographical area of a building. Whereas, Fig. 2 (b) shows the heart of this simulation, where this network topology includes: IoT devices, servers connected to the VLAN, routers equipped with Ethernet ports, switches, and cable modem, besides Internet Service Provider (ISP) provider, and 5G mobile network for remote access.

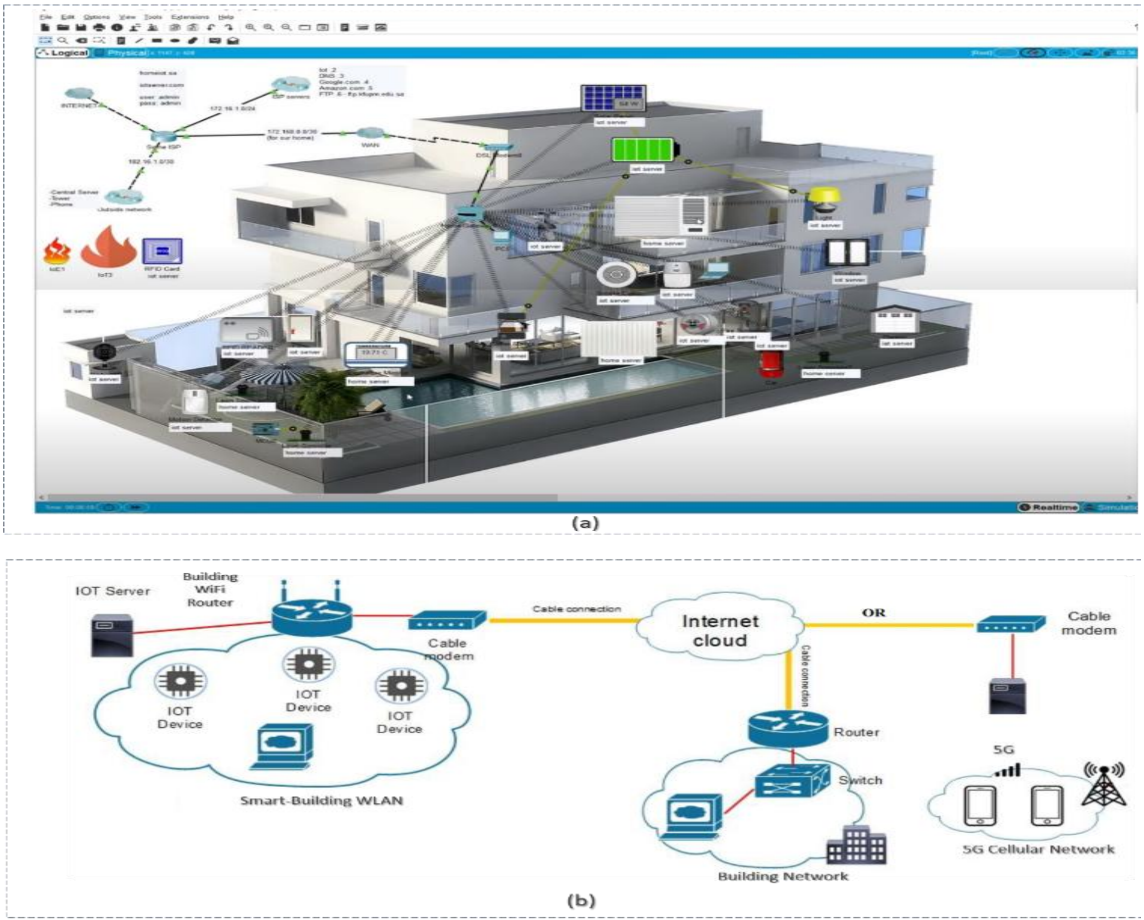


Fig. 2. (a) IoT Architecture for Smart Building using Packet Tracer, (b) Smart- Building network topology.

The proposed model focuses on providing an entirely working network layers operating different Cisco components. The network layers were constructed using a mixture of router, wireless router, switches, backbone connection, internet connection clouds, 5G antennas and IoT devices via pre-defined tools and functions in Cisco Packet Tracer. There are four main steps of the proposed scenario, as Fig 3 shows. In this selected configuration, a vital performance indictor has been considered called “Routing Information Protocol (RIP)”. Where, RIP is a dynamic routing protocol which uses hop count as a routing metric to find the best path between the source and the destination network. The RIP, also, could give more performance details such as: ping test, environmental variables.

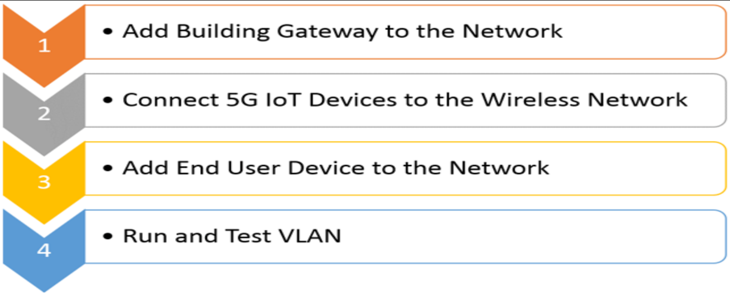
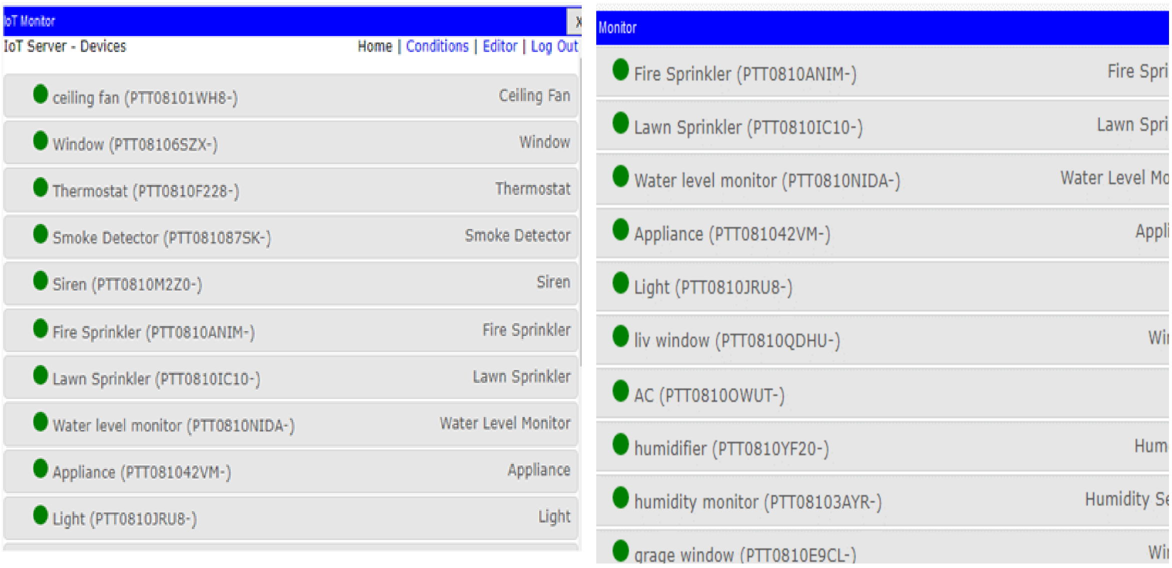


Fig. 3. Four main steps of the proposed scenario.

IV. Implementation and Results

This article seeks to provide a proof of concept virtual prototype network for 5G IoT network that can monitor and display in real time possible. This subsection presents implementation of the proposed 5G IoT smart buildings using Cisco Packet Tracer. A new released cisco packet tracer has been used, which include different smart objects used for smart buildings such as siren, smart window, smart light, fire sprinkler and different smart IoT devices and sensors are involved. Thus, to control these devices a Multi-Chip Unit microcontroller (MCU-PT) is considered and linked to home Gateway for sake of registering and controlling smart objects, respectively, as Fig. 4 (a) and (b) show. The virtual model of smart building system is designed, where home gateway connects multiple wireless devices wirelessly and provides automatic addressing to devices connected to the gateway. Then, a control unit which could be a smartphone is used as an interface medium for controlling and monitoring the performance of smart objects.



(a) (b)

Fig. 4. Registered IoT devices and sensors to the home Gateway.

The proposed 5G IoT architecture for smart building integrates different types of smart sensors and devices (e.g. CCTV cameras, Internet modems, humidity monitor, humidifier, smoked detector, light, siren, fire sprinkler, windows, water level monitor with lawn sprinkle, water drain, AC, fan, Thermostat, RFID, and solar panels as Fig. 4 shows most of these smart devices. Fig. 5 shows smart building gateway obtain IP address from ISP server in Cisco Packet Tracer. While, Fig. 6 demonstrates IoT server device conditions smartphone interface.

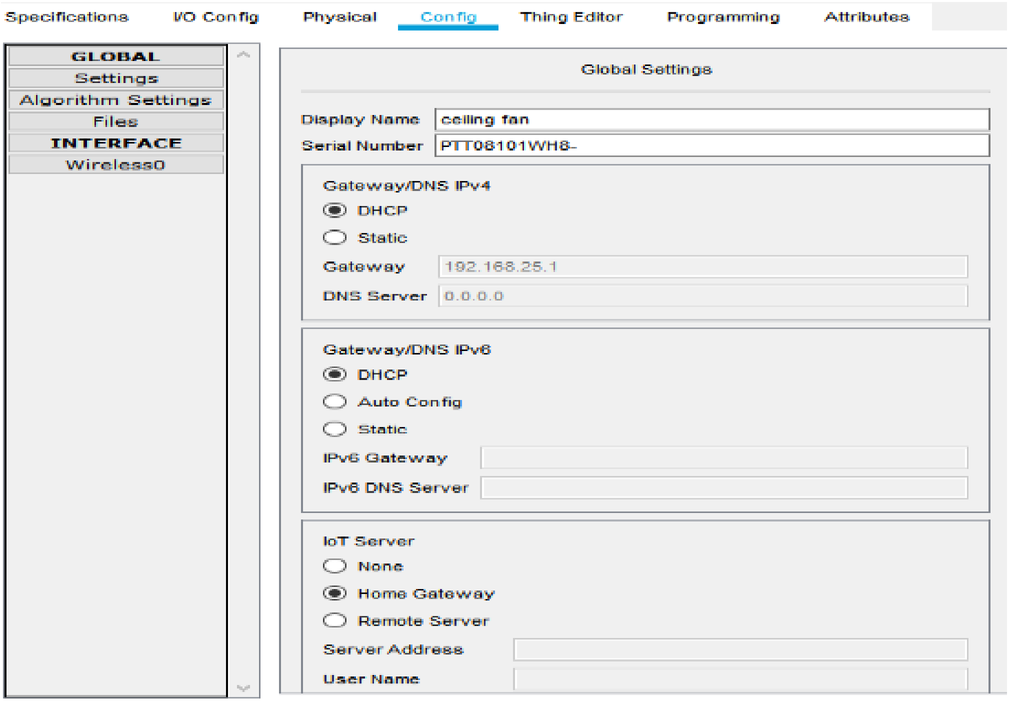


Fig. 5. Smart building gateway obtain IP address from ISP server.

IoT Monitor

IoT Server - Device Conditions

Home | Conditions | E

Actions	Enabled	Name	Condition	Actions
Edit Remove	Yes	Turn on the ceiling fan	Thermostat Temperature >= 23.0 °C	Set ceiling fan Status to Low Set Window On to false Set AC On to true Set liv window On to false
Edit Remove	Yes	Turn off the ceiling fan	Thermostat Temperature is between 15.0 °C and 22.0 °C	Set ceiling fan Status to Off Set Window On to true Set AC On to false Set liv window On to true
Edit Remove	Yes	Alarm	Smoke Detector Level >= 0.03	Set Siren On to true
Edit Remove	Yes	Fire Sprinkler	Smoke Detector Level >= 0.045	Set Fire Sprinkler Status to true
Edit Remove	Yes	Turn on lawn Sprinkler	Water level monitor Water Level <= 5.0 cm	Set Lawn Sprinkler Status to true
Edit Remove	Yes	Turn off lawn sprinkler	Water level monitor Water Level >= 20.0 cm	Set Lawn Sprinkler Status to false
Edit Remove	Yes	turn off the alarm	Smoke Detector Level <= 0.02	Set Fire Sprinkler Status to false Set Siren On to false
Edit Remove	Yes	turn on humidifier	humidity monitor Humidity is between 60 % and 75 %	Set humidifier Status to true
Edit Remove	Yes	open grage window	Siren On is true	Set grage window On to true
Edit Remove	Yes	close grarge window	Siren On is false	Set grage window On to false
Edit Remove	Yes	open drain	Water level monitor Water Level >= 20.0 cm	Set water drain Status to true
Edit Remove	Yes	close drain	Water level monitor Water Level < 20.0 cm	Set water drain Status to false
Edit Remove	Yes	close windows	Thermostat Temperature < 14.0 °C	Set Window On to false Set liv window On to false

Fig. 6. IoT server device conditions smartphone interface.

Fig. 7 (a) and (b) and Fig. 8 highlight the performance of the RIP, which takes care of routing to know where and how the data is going to be sent. RIP protocol automatically routes the traffic via using a tracert command. Where, by default RIP uses the route that has low hops counts between source and destination. Fig. 9 shows the ping the ISP IP Address from Host for testing. It shows a success pinging with maximum value of 7ms. Fig. 10 demonstrates microcontroller MCU-PT, where it used to fully control the IoT device functions via programming environment with different language like JavaScript here.

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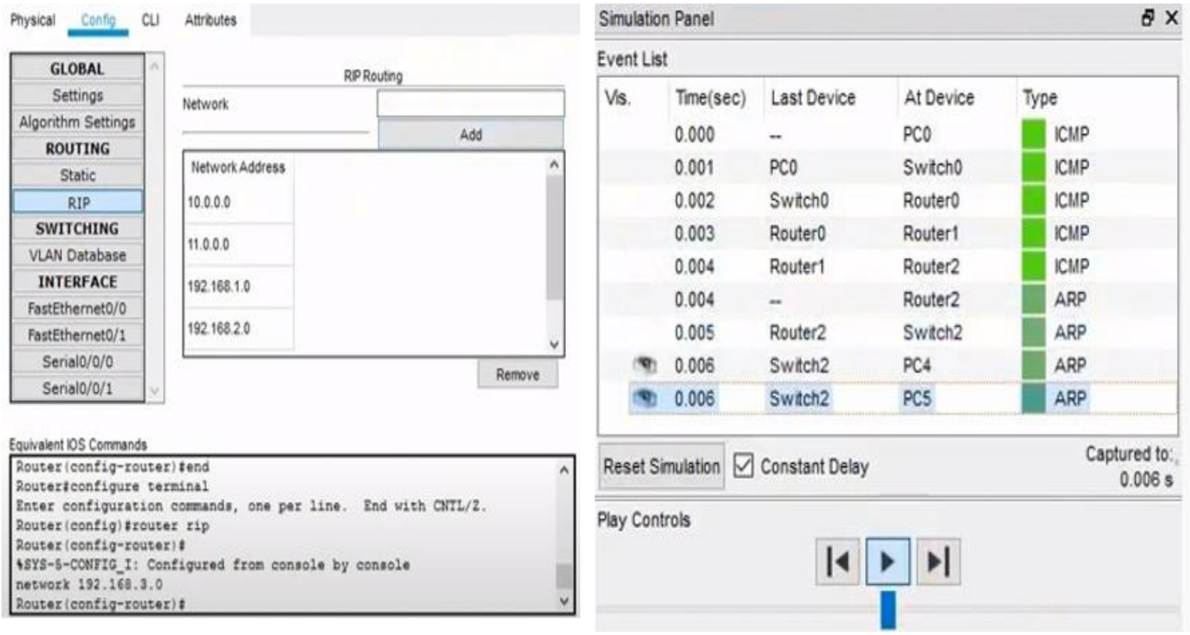

(a) (b)

Fig. 7. Example RIP setup of a router.

Routing Table for Router

Type	Network	Port	Next Hop IP	Metric
C	11.0.0.0/8	GigabitEthernet0/0	---	0/0
L	11.0.0.1/32	GigabitEthernet0/0	---	0/0
R	12.0.0.0/8	GigabitEthernet0/1	15.0.0.2	120/1
R	13.0.0.0/8	GigabitEthernet0/1	15.0.0.2	120/2
R	13.0.0.0/8	GigabitEthernet0/2	18.0.0.2	120/2
R	14.0.0.0/8	GigabitEthernet0/2	18.0.0.2	120/1
C	15.0.0.0/8	GigabitEthernet0/1	---	0/0
L	15.0.0.1/32	GigabitEthernet0/1	---	0/0
R	16.0.0.0/8	GigabitEthernet0/1	15.0.0.2	120/1
R	17.0.0.0/8	GigabitEthernet0/2	18.0.0.2	120/1
C	18.0.0.0/8	GigabitEthernet0/2	---	0/0

Fig. 8. Routing table after applying the RIP protocol of the smart building.

Command Prompt

```
Reply from 192.168.1.2: bytes=32 time=0ms TTL=128
Reply from 192.168.1.2: bytes=32 time=5ms TTL=128

Ping statistics for 192.168.1.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 6ms, Average = 3ms

PC>ping 192.168.1.2

Pinging 192.168.1.2 with 32 bytes of data:

Reply from 192.168.1.2: bytes=32 time=6ms TTL=128
Reply from 192.168.1.2: bytes=32 time=2ms TTL=128
Reply from 192.168.1.2: bytes=32 time=7ms TTL=128
Reply from 192.168.1.2: bytes=32 time=6ms TTL=128

Ping statistics for 192.168.1.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 2ms, Maximum = 7ms, Average = 5ms

PC>
```

Fig. 9. Example RIP setup of a router.

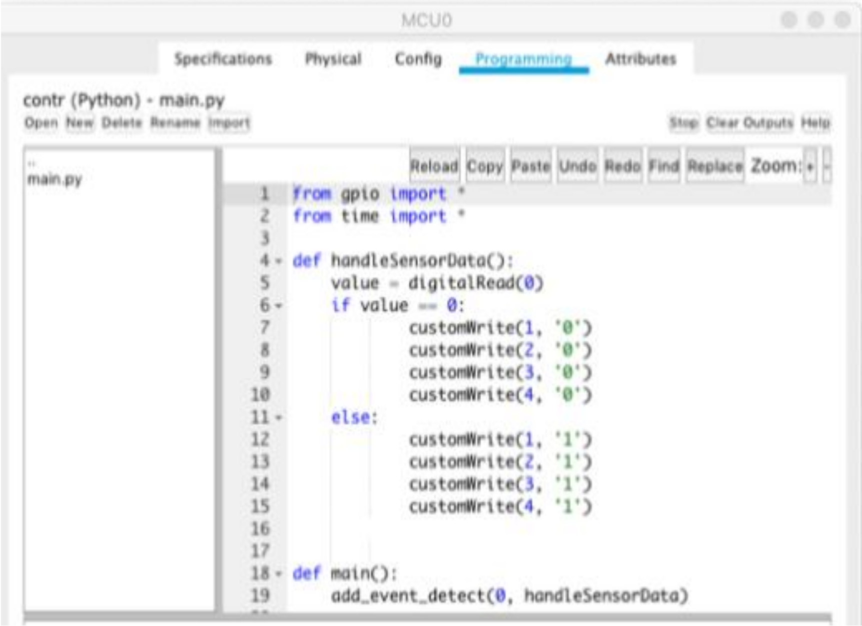

Fig. 10. Microcontroller MUC programming environment.

Fig. 11 to Fig. 21 show smart applications in various types of scenarios, where 5G IoT implemented using Cisco Packet Tracer. Fig. 11 shows the flowchart of fire alarm system simulation process. Fig. 12 illustrates the implementation of fire scenario, which is importance for safety and security of individuals as well as properties. When a fire is detected, alarming system includes siren, alarm sound and red light are working automatically to warn people via visual and audio appliances. In case of smoke level is more than specific threshold, then fire sprinkler and window will be opened. All these functions are programmed and controlled via Microcontroller MCU.

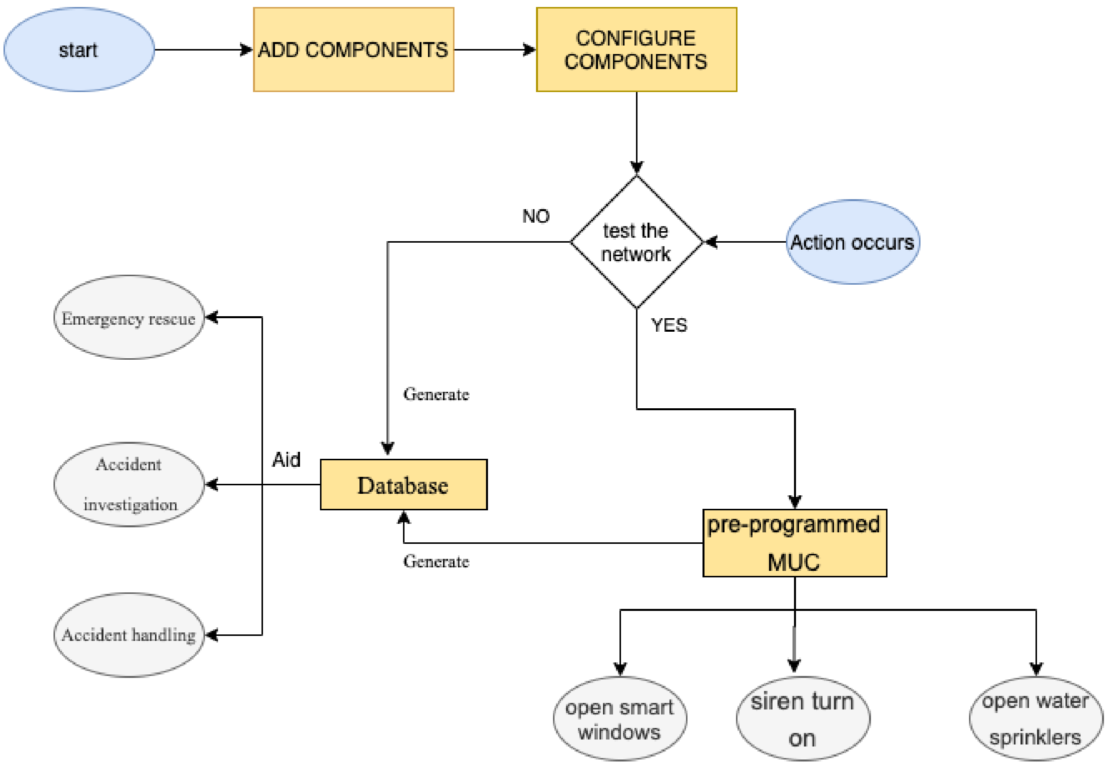

Fig. 11. Flowchart of fire alarm system simulation process.

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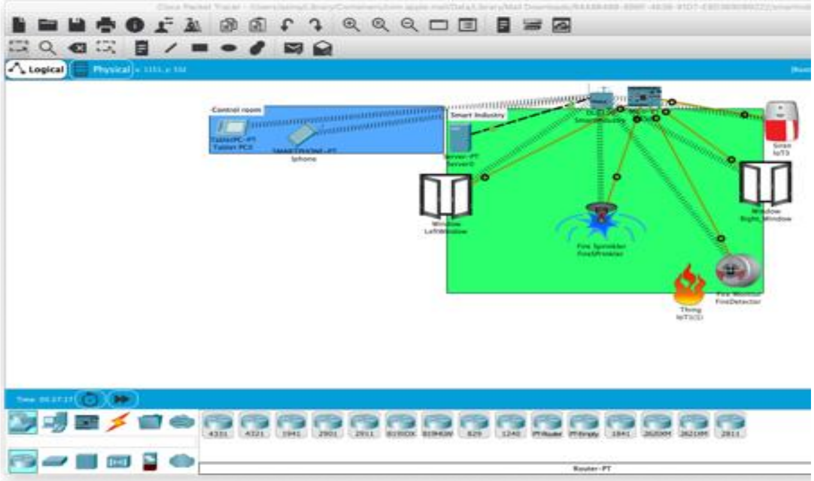

Fig. 12. Implementation of fire alarm system using Packet Tracer.

Fig. 13 shows a solar-powered system that used to provide buildings with is eco-friendly source of energy. The figure presents solar panels, and some IoT devices (e.g. AC, coffee machine and the light system) that can benefit from such a smart system. Another smart application is presented in Fig. 14, which shows implementation of RFID. The RFID is used here as a smart card system that manage the access for authorized people to a building's facilities. The figure shows RFID card connection, where in order to open any door, an authorized card must be swiped to the card reader. If the card is unauthorized the door will remain locked.

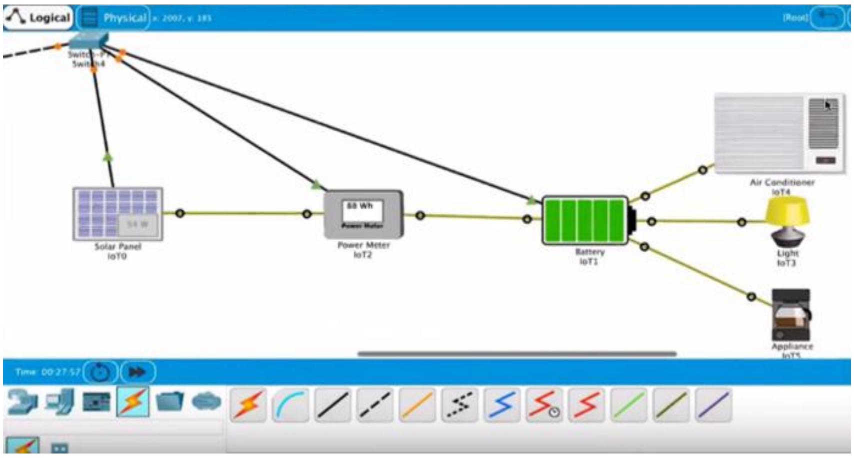

Fig. 13. Solar panel system connection.

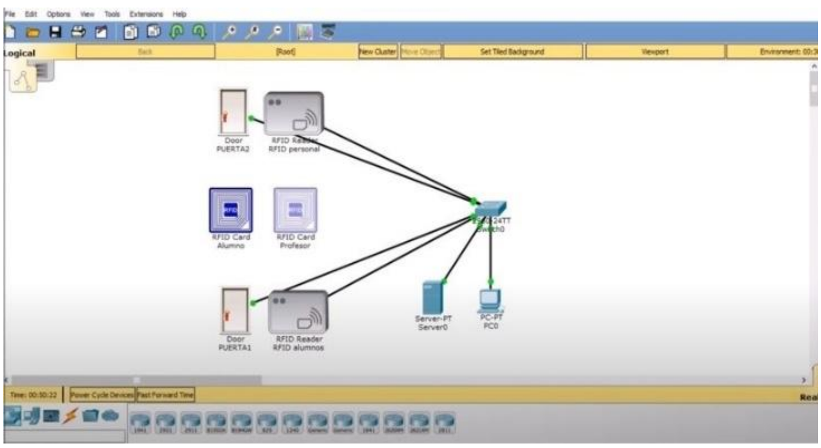

Fig. 14. RFID system for smart access.

Fig. 15 illustrates the implementation of watering plants and grass using the lawn sprinkler. From Fig. 16, it can be seen that sprinkler works or not based on the water level threshold. Moreover, Fig. 17 shows that to make the lawn sprinkler automation more realistic and efficient, the environmental variable of a garden is changing during raining. Thus, in case of rainfalls level increased in the garden, water sensor can detect a higher amount of water and not starting the sprinklers.

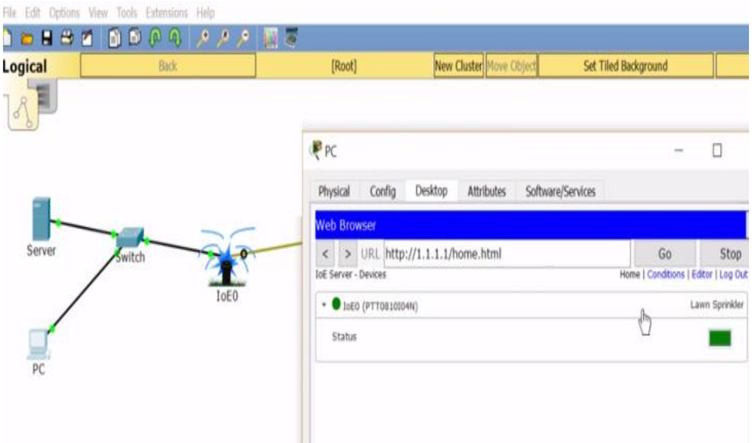

Fig. 15. Watering plants using the lawn sprinkler Packet Tracer.

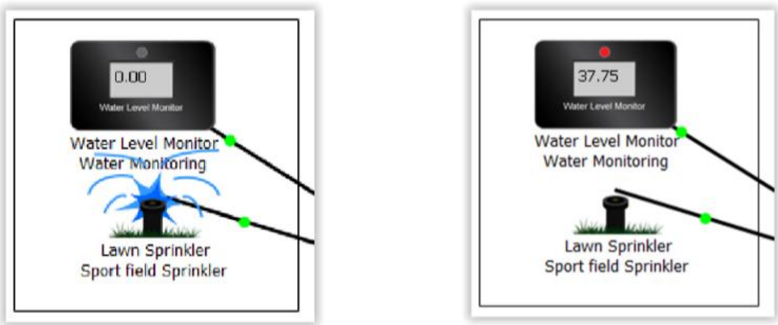

Fig. 16. Water sprinkler function based on the water level threshold.

Fig. 17. Environmental variables for Smart water sensor.

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Fig. 18 shows a comprehensive configuration of smart building simulation that has been set up in the IoT home gateway network on the Cisco packet tracer. There are some smart electronic devices that can be controlled and monitored according to system testing, configuration and condition settings on electronic devices specified in the smartphone system, making it easier in designing and implementing in building the smart building network. Figures 19-21 demonstrate the environmental variables, and behaviour of IoT devices during sunlight. Clearly, during daytime solar panels taking advantage from sun and store power. Lights, AC, and other sensors respond to this positively for sake of efficiency and comfort; Besides improving energy efficiency, reducing energy use costs.

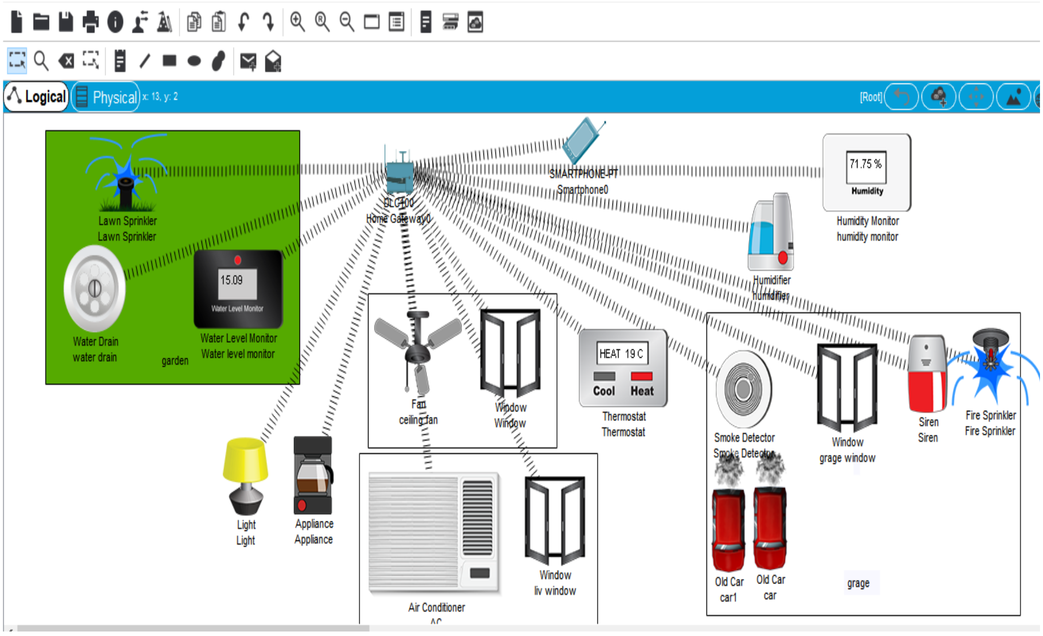

Fig. 18. Comprehensive configuration of smart building simulation using packet tracer.

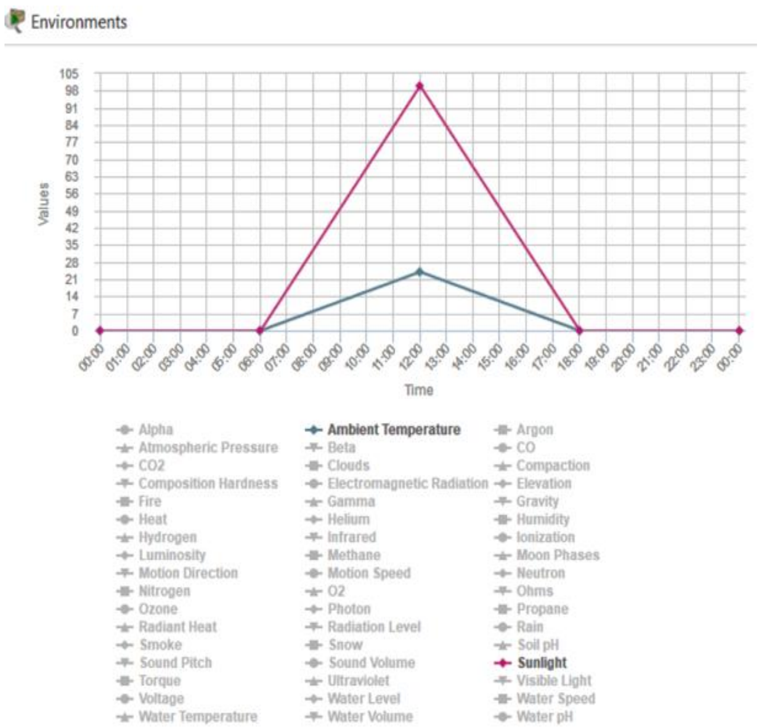

Fig. 19. Environmental variables for smart building during sunlight.

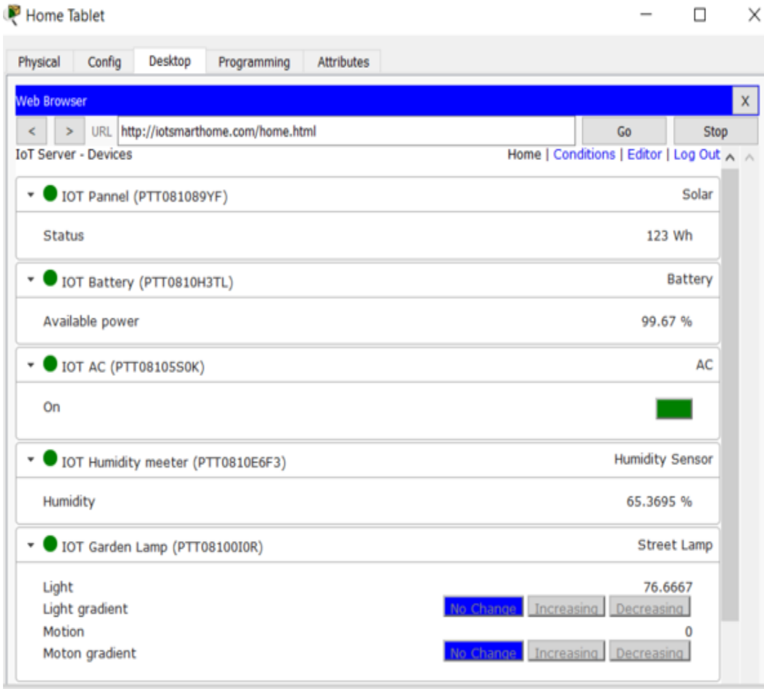

Fig. 20. Behavior of IoT devices during daytime.

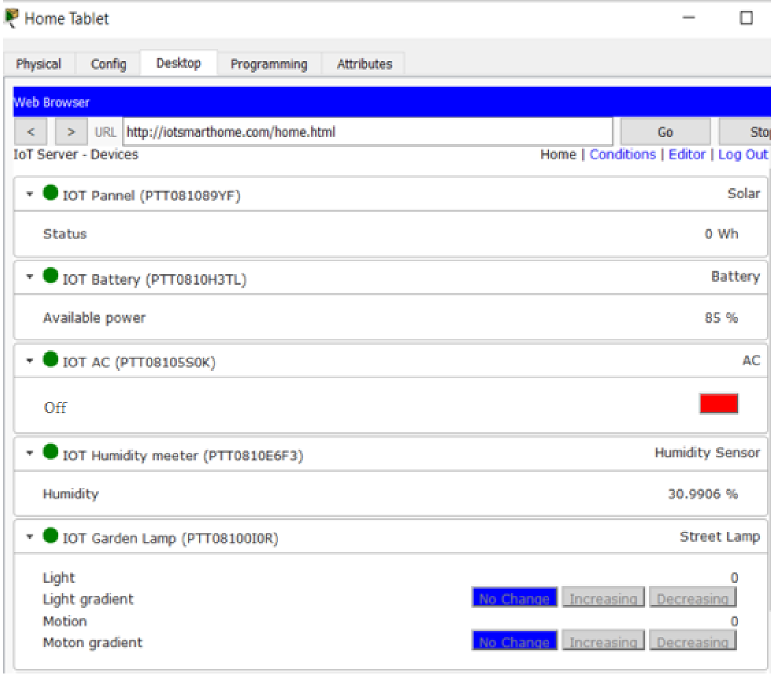

Fig. 21. Behavior of IoT devices during daytime.

V. Conclusion and Future Work

In the era of digital societies, one need is to create smart buildings that can bring comfort, efficiency, safety and security. With this design, simulation, and implementation of 5G IoT smart buildings that considered in this paper using virtual network in Cisco Packet Tracer tool. The 5G IoT architecture considers security, fire safety, energy management, smart devices include RFID, lightening, watering plants for smart buildings. The VLAN simulation results show that enabling 5G IoT to buildings prove that there is a great potential to apply this model in real life in various domains for sake of security, comfort, improving energy efficiency, and reducing costs.

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