Smart Hospital System

CSE457- Mobile & Wireless Networks

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Introduction

The integration of Internet of Things (IoT) technology in hospitals, particularly within smart hospital management systems, represents a significant advancement in healthcare infrastructure. This project explores the deployment of IoT devices and systems in a hospital environment, focusing on network topology, departmental functionalities, and specific IoT applications.

Key aspects include segmented Virtual Local Area Networks (VLANs) for efficient communication, IoT devices in the Emergency and Nursing Departments for rapid response and patient monitoring, and patient smart rooms equipped with sensors and interfaces for personalized care. The IT Department plays a critical role in managing the IoT infrastructure, ensuring seamless integration and security.

Additionally, a prototype demonstration showcases the potential applications of IoT technology in patient monitoring and environmental control. Overall, IoT in hospitals holds promise for improving healthcare delivery, enhancing patient outcomes, and advancing healthcare innovation.

Network Topology

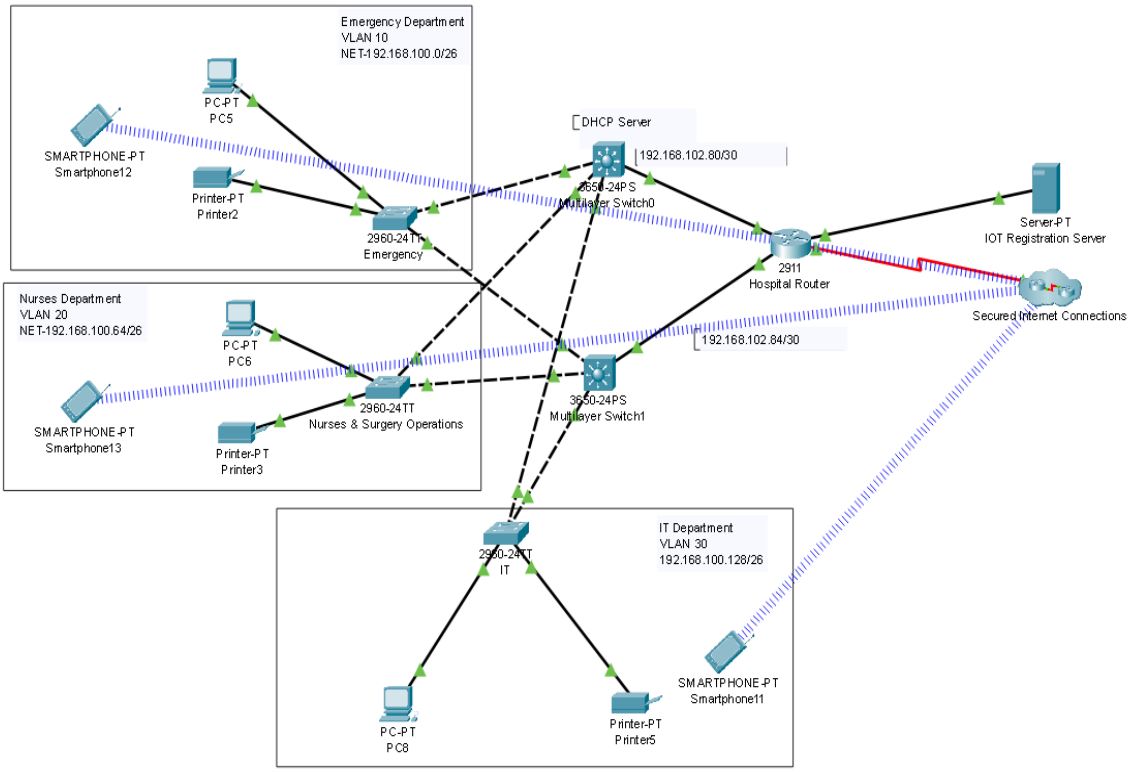

Figure 1 Network Topology

In Our Hospital System, we divided our departments (Emergency, Nursing and IT) into different VLANS; VLAN10, VLAN20 And VLAN30 respectively. So, what are VLANS? and why we did we divide our Network into different VLANs?

VLANs (Virtual Local Area Networks)

VLANs are used to segment a physical network into multiple distinct broadcast domains at the data link layer (Layer 2) of the OSI model. Each VLAN functions as a separate network, allowing for better traffic management because of broadcast messages sent from switches while trying to communicate between devices, security, and network efficiency.

Main Key Points about VLANs

- **Segmentation:** VLANs divide a single physical network into multiple logical networks, which can help reduce broadcast traffic and improve performance.
- **Security:** By isolating network segments, VLANs can enhance security by preventing unauthorized access between different segments.
- **Flexibility:** VLANs allow for logical grouping of devices regardless of their physical location, enabling easier network management and policy implementation.

In our project:

- **Emergency Department:**
  - VLAN 10: 192.168.100.0/26
- **Nurses Department:**
  - VLAN 20: 192.168.100.64/26
- **IT Department:**
  - VLAN 30: 192.168.100.128/26

To Allow Communication between Devices in different VLANs, we use 2 multi-layer switches to enable inter-VLAN Routing. Let's Explain Multi-Layer Switches:

Multi-Layer Switches

Multi-layer switches, also known as Layer 3 switches, combine the capabilities of both traditional switches (Layer 2) and routers (Layer 3). These devices can perform both switching and routing functions, making them ideal for modern network environments that require high performance and flexibility.

Key Features of Multi-Layer Switches:

Layer 2 Switching: Handles traffic within the same VLAN, forwarding frames based on MAC addresses.
Layer 3 Routing: Routes traffic between different VLANs or subnets using IP addresses.
Performance: Typically offers higher performance compared to traditional routers due to specialized hardware designed for switching and routing.
Scalability: Supports large-scale network environments with the ability to manage high traffic volumes and multiple VLANs.

Usage of Multi-Layer Switches in VLAN Environments:

1. Inter-VLAN Routing:

Multi-layer switches enable communication between different VLANs by routing traffic at Layer 3. This process, known as inter-VLAN routing, allows devices in separate VLANs to communicate as if they were on the same network.

Configuration for Inter-VLAN Routing:

Creating VLANs:

- vlan 10
  name Emergency
- vlan 20
  name Nurse
- vlan 30

```
    name IT
```

Assigning VLANs to Interfaces

```
interface FastEthernet0/1
  switchport mode access
  switchport access vlan 10

interface FastEthernet0/2
  switchport mode access
  switchport access vlan 20

interface FastEthernet0/3
  switchport mode access
  switchport access vlan 30
```

Configuring SVIs (Switch Virtual Interfaces) for Inter-VLAN Routing

```
interface Vlan10
  ip address 192.168.100.1 255.255.255.192
interface Vlan20
  ip address 192.168.100.65 255.255.255.192
interface Vlan30
  ip address 192.168.100.129 255.255.255.192
```

2. Reducing Network Latency:

Since multi-layer switches can route traffic internally without needing to pass it to an external router, they reduce latency and improve overall network performance.

3. Simplified Network Management:

With a multi-layer switch, network administrators can manage VLANs and routing from a single device, simplifying the network architecture and management.

4. Enhanced Security:

By using VLANs in conjunction with multi-layer switches, administrators can implement granular security policies. For example, access control lists (ACLs) can be applied to SVIs to control traffic between VLANs.

5. High Availability and Redundancy:

Many multi-layer switches support advanced features like redundancy protocols (e.g., HSRP, VRRP) and link aggregation, enhancing network reliability and availability.

Departments

Emergency Department

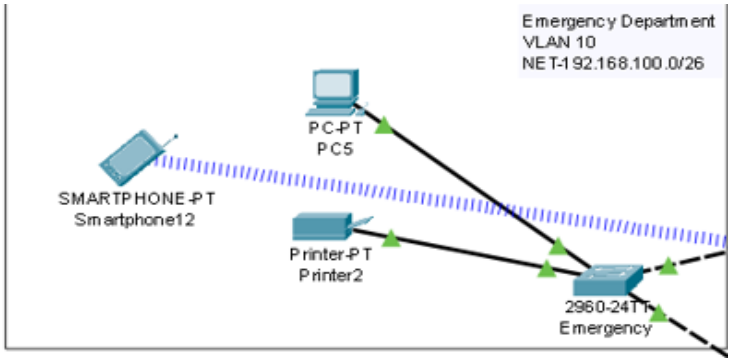

Figure 2 Emergency Topology

In a hospital emergency department network, these devices might be used for the following:

- Smartphones: Used by hospital staff for urgent communication and coordination.

- Communication Devices: Any additional devices used for urgent notifications and alerts.
- Printers: Used to print emergency-related documents, instructions, and communication logs.

Nurses & Surgery Operations Department

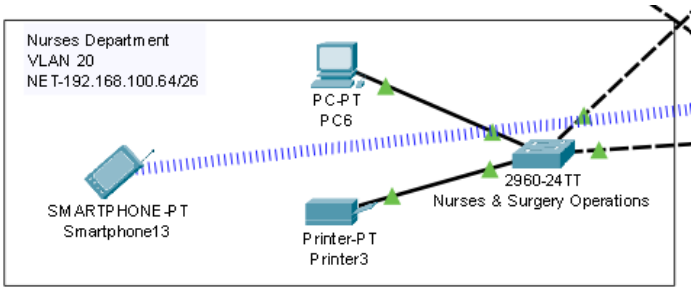

Figure 3 Nurses/Surgery Operations Topology

In a hospital Nurses department network, these devices might be used for the following:

- Smartphones: Hospital staff might use smartphones to communicate with each other, access patient information on the go, and use mobile apps to improve efficiency.
- PCs: Doctors and nurses might use PCs to access patient records, view medical images, and order medications.

- Printers: Printers might be used to print patient records, lab results, and other documents. for department instead of nurses

IT Department

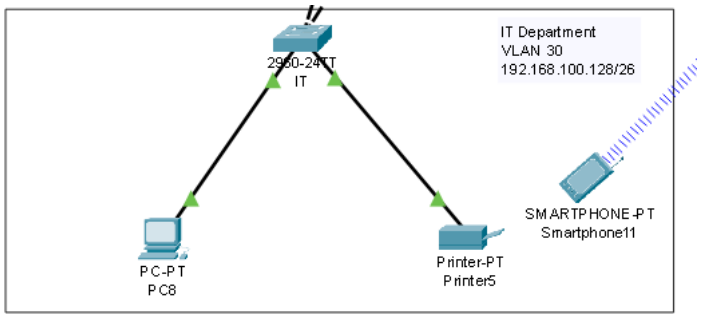

Figure 4 IT Topology

In a hospital IT department network, these devices might be used for the following:

- Smartphones: Used for communication, network monitoring, and managing IT infrastructure via mobile apps.

- PCs: Used for managing the network, handling IT support tickets, and other administrative IT tasks
- Printers: Printers Used to print IT-related documents, network diagrams, and support tickets.

Key Points of the Hospital Network Topology

- VLAN Segmentation.
- Use of Multi-Layer Switches:

  Combines Layer 2 switching and Layer 3 routing.
  Enables efficient inter-VLAN routing.
- Performance and Security:

  Reduced broadcast traffic and improved network efficiency.
  Enhanced security through network isolation and ACLs.
- Scalability and Manageability:

  Easily expandable network architecture.
  Simplified administration with centralized VLAN and routing management.

Benefits:

- Improved Efficiency: Department-specific network segments reduce unnecessary traffic.
- Enhanced Security: Isolation and access control between departments.

- Reduced Latency: High-speed routing within the switch.

Hospital Interior

Smart Garden:

- **Lawn Sprinkler:** Lawn sprinklers are devices that spray water onto lawns and gardens. They are connected to a hose or irrigation system. The sprinkler in the diagram appears to be a stationary sprinkler head. Stationary sprinklers spray water in a circular pattern.

Figure 5 Lawn Sprinkler

- **Water Level Monitor:** The water level monitor used to measure the pressure of a fluid in a closed system. In an irrigation system, a pressure gauge can be used to monitor the water pressure in the system. This information can be used to ensure that the sprinklers are receiving enough water pressure to function properly.

Edit	Remove	Yes	TURN-ON Sprinkler	Water Monitor Water Level <= 10.0 cm	Set Sprinkler2 Status to true
Edit	Remove	Yes	Turn-OFF SPRINKLER	Water Monitor Water Level > 10.0 cm	Set Sprinkler2 Status to false

Figure 6 Sprinkler Conditions

Waiting Room:

The waiting room is a vital component of hospital infrastructure, providing a comfortable and welcoming environment for patients and their families. It helps manage patient flow, preventing overcrowding in clinical areas and acting as a buffer for scheduling delays. This organized system enhances operational efficiency and ensures a smooth, orderly process within the hospital.

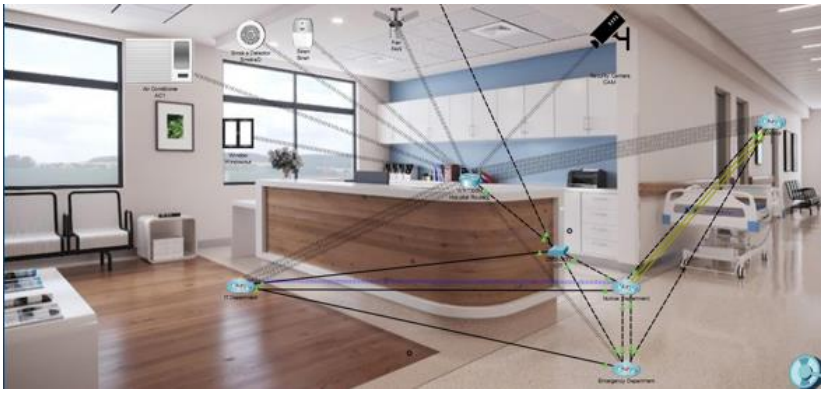

Figure 7 Waiting Room

- **Smoke Detector**: Smoke detectors are essential for fire safety in any building. In a smart hospital, a smoke detector could be part of an Internet of Things (IoT) system that would send an alert to the hospital staff and emergency services if smoke is detected.

- **Siren:** Sirens are a crucial component of a hospital's emergency response system. They are used to warn people of danger because of smoke detector or other security device. By detecting any heat, Siren will turn ON.

    - SmokeD Level < 0.17
    - Set Siren On to OFF
    - Set Windowout On to OFF

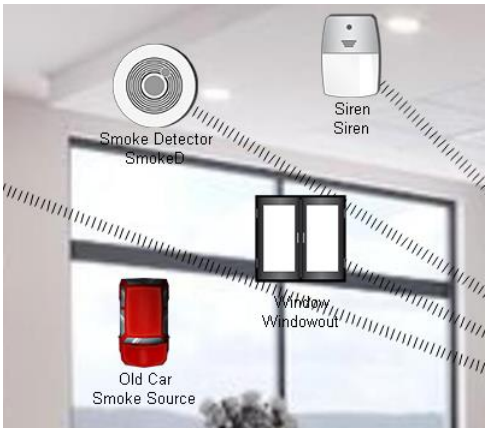

Figure 8 Smoke Detection

Edit	Remove	Yes	SmokeSiren	SmokeD Level >= 0.17	Set Siren On to true Set Windowout On to true
Edit	Remove	Yes	StopSiren	SmokeD Level < 0.17	Set Siren On to false Set Windowout On to false

Figure 9 Smoke Detection Conditions

    - SmokeD Level >= 0.17
    - Set Siren On to true

- Set Windowout On to true

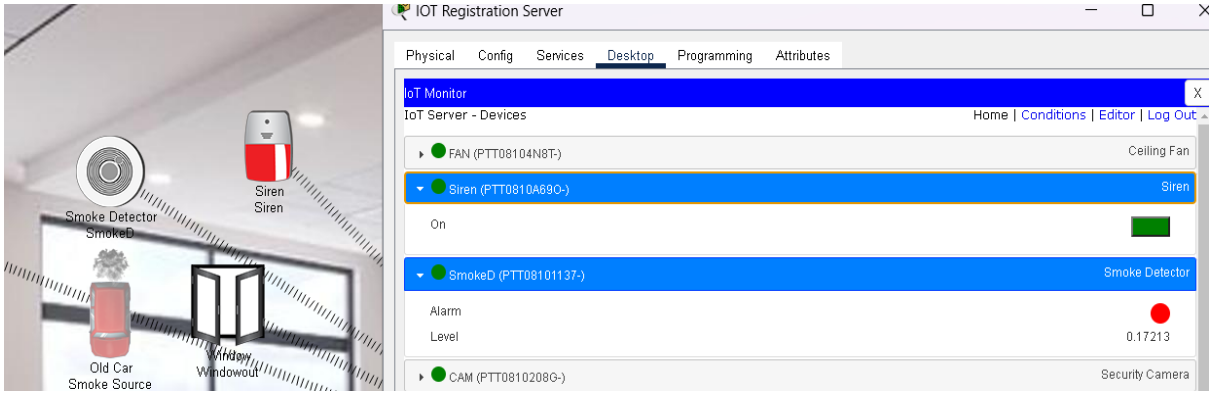

Figure 10 Window opening after detecting smoke

- **Security Camera (CAM)**: Security cameras are used to monitor activity in a hospital and deter crime. In a smart hospital, security cameras could be part of an IoT system that would allow hospital staff to monitor activity remotely from their computers or smartphones. Packet Tracer allows you to simulate the video stream from the security camera being sent to a central monitoring station.

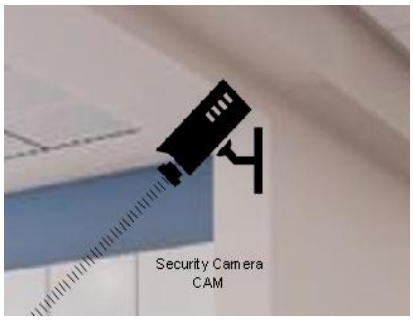

Figure 12 Security Camera Off

`

Figure 11 Security Camera On

- **Air Conditioner (AC1)**: Air conditioners are used to regulate the temperature in a hospital. In a smart hospital, an air conditioner could be part of an IoT system that would allow hospital staff to control the temperature remotely from their computers or smartphones. Packet Tracer allows you to simulate the communication between the air conditioner and a thermostat or temperature control system.

Here are some additional things to keep in mind about using these devices in Packet Tracer for a smart hospital network:

- You would need to configure the devices with appropriate IP addresses and subnet masks so that they can communicate with each other on the network.
- You may need to use additional devices in your Packet Tracer simulation, such as routers, switches, and sensors, depending on the complexity of your smart hospital network design.

- Packet Tracer allows you to simulate different scenarios, such as a smoke detector going off or a security camera detecting motion. This can be helpful for testing the functionality of your smart hospital network design.

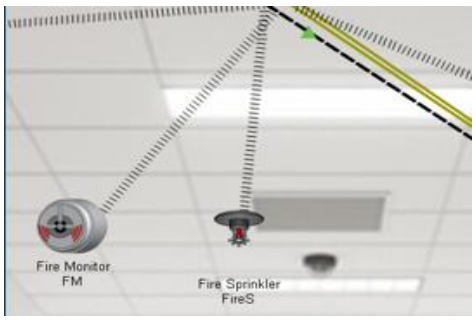

Figure 13 Fire Monitoring

Fire Monitor (FM): Fire monitors are used outdoors to fight large fires. In a smart hospital network simulation, a fire monitor would not be directly connected to the network. However, you could include a fire alarm system that would be connected to the network and could trigger events based on sensor data.

Fire Sprinkler (FS): Fire sprinklers are automatic fire extinguishing systems. In a smart hospital network simulation, a fire sprinkler system wouldn't be directly connected to the network. However, like the fire monitor, it could be triggered by a fire alarm system.

Edit	Remove	Yes	SprinkleON	FM Fire Detected is true	Set FireS Status to true
Edit	Remove	Yes	SprinkleOFF	FM Fire Detected is false	Set FireS Status to false

Figure 14 Fire Sprinkler Conditions

IT Department

The IT Department in hospitals is essential for managing information, optimizing operations, and supporting clinical decision-making where we monitor all the IOT devices as that we server is used from the IT department.

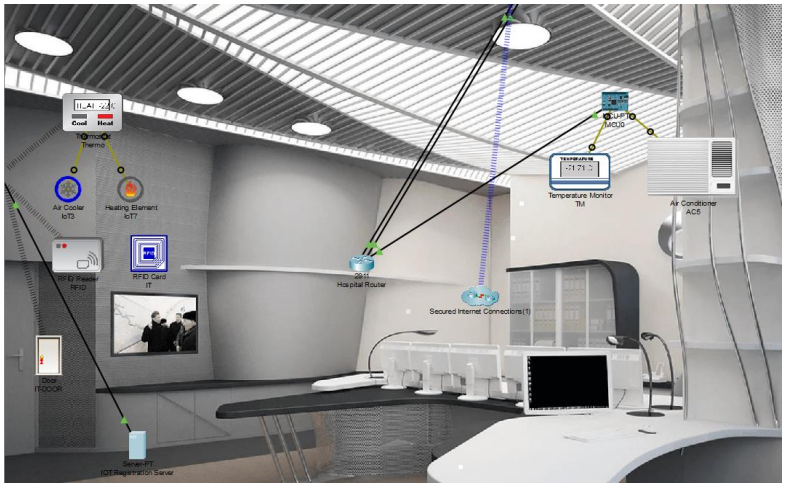

Figure 15 IT Department

IT Room

IOT Registration Server to connect various devices to a network. It manages the registration process, which involves authenticating devices, assigning them unique identifiers, and granting them access to the network or service where it ensures these devices communicate effectively with hospital servers, integrating data with other systems for improved patient outcomes and predictive analytics.

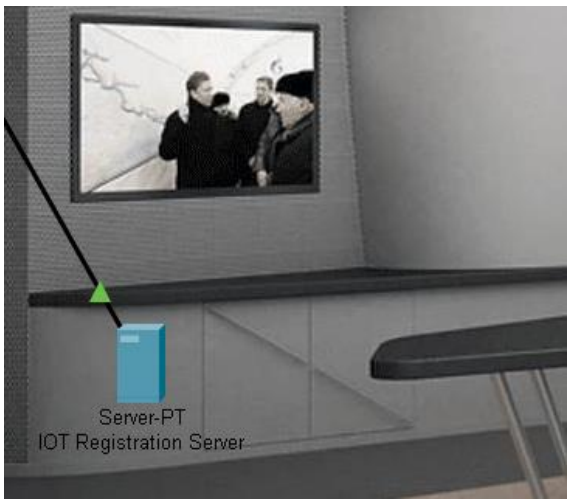

Figure 17: Server in IT Department

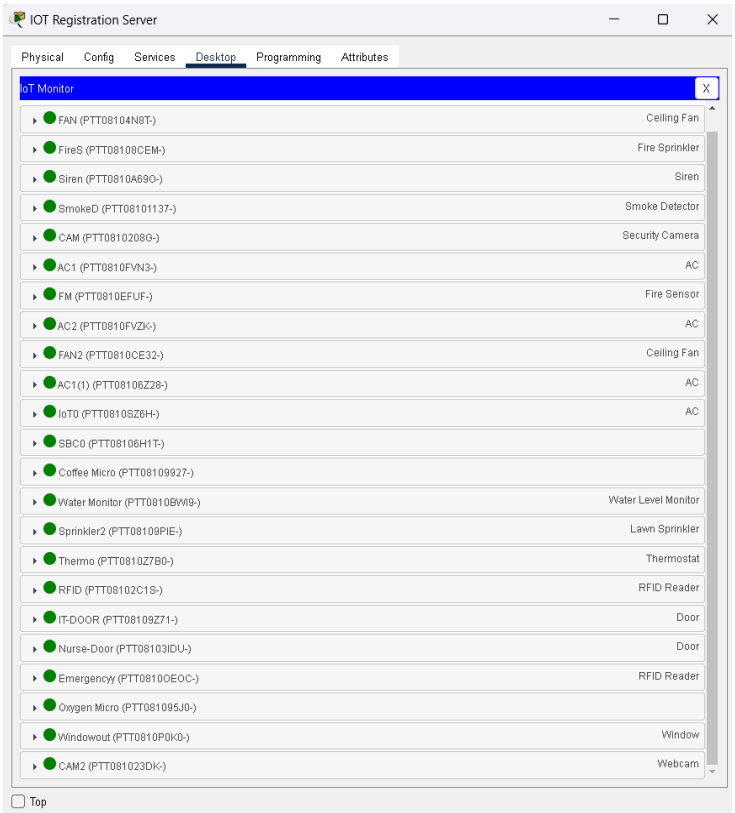

Figure 16: IOT devices in Server

IOT Temperature Monitoring

The temperature monitor helps where it keeps checking the room temperature and sends the readings to the microcontroller and the microcontroller

keeps checking if it got higher than a predetermined threshold if it exceeded that threshold the microcontroller turns on the Air conditioner until it goes below a certain temperature when it goes below that temperature it turns the air conditioner off.

MCU0

Specifications Physical Config Programming Attributes

Blink (JavaScript) - main.js

Open New Delete Rename Import

main.js

Reload

```
1  var air=0;
2  var ter=A0;
3
4  function setup() {
5      pinMode(air, OUTPUT);
6      pinMode(ter, INPUT);
7      Serial.println("Blinking");
8  }
9
10 function loop() {
11     var t=analogRead(ter);
12     var te=(((t-30)*(5/8))/2).toFixed(2);
13     Serial.println(te);
14
15     if (te>=20){
16         digitalWrite(air,HIGH);
17         Serial.println("AC ON");
18     }
19     else{
20         digitalWrite(air,LOW);
21         Serial.println("AC OFF");
22     }
23     digitalWrite(1,HIGH);
24     delay(1000);
25     digitalWrite(1, LOW);
26     delay(500);
27 }
28
```

Figure 19: Code in the Microcontroller

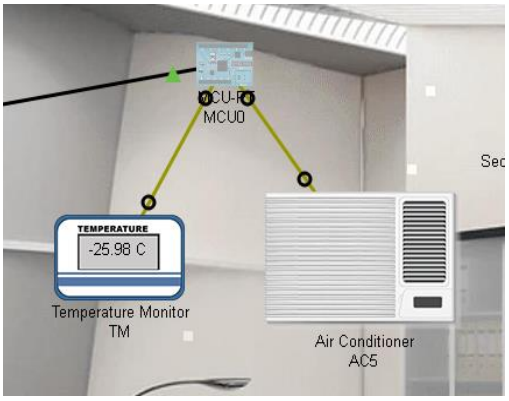

Figure 18 Temperature Monitoring

Security: ***RFID for authentication***

RFID (Radio-Frequency Identification) Reader reads Card ID takes the correct the Card IDs from the server where we add it in the server. The RFID reader opens the door only if the Card ID matches the IDs provided by the server if it doesn't match it won't open the door.

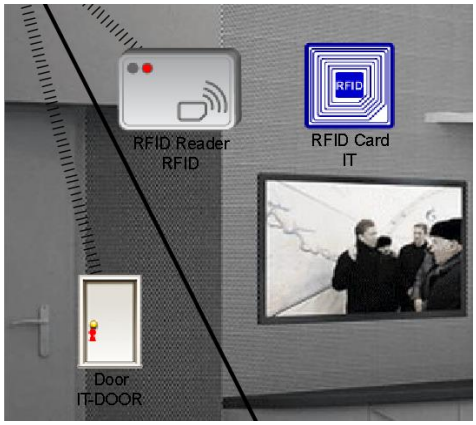

Figure 20 RFID with no Card ID

Edit	Remove	Yes	IT_ID-valid	RFID Card ID = 100	Set RFID Status to Valid
Edit	Remove	Yes	IT_ID-invalid	RFID Card ID != 100	Set RFID Status to Invalid

Figure 21 RFID Conditions

Figure 22 RFID with valid ID

Edit	Remove	Yes	IT-Door unlock	RFID Status is Valid	Set IT-DOOR Lock to Unlock
Edit	Remove	Yes	IT-Door lock	RFID Status is Invalid	Set IT-DOOR Lock to Lock

Figure 23 Door Conditions

Registration Server

IOT Registration Server

Physical | Config | Services | Desktop | Programming | Attributes

IoT Monitor

IoT Server - Device Conditions

Home | Conditions | Editor | Log Out

Actions	Enabled	Name	Condition	Actions
Edit Remove	Yes	SprinkleON	FM Fire Detected is true	Set FireS Status to true
Edit Remove	Yes	SprinkleOFF	FM Fire Detected is false	Set FireS Status to false
Edit Remove	Yes	SmokeSiren	SmokeD Level >= 0.17	Set Siren On to true Set Windowout On to true
Edit Remove	Yes	StopSiren	SmokeD Level < 0.17	Set Siren On to false Set Windowout On to false
Edit Remove	Yes	TURN-ON Sprinkler	Water Monitor Water Level <= 10.0 cm	Set Sprinkler2 Status to true
Edit Remove	Yes	Turn-OFF SPRINKLER	Water Monitor Water Level > 10.0 cm	Set Sprinkler2 Status to false
Edit Remove	Yes	AC-ON	Thermo Temperature > 10.0 °C	Set PTT08102JNQ- On to 1
Edit Remove	Yes	AC-OFF	Thermo Temperature <= 10.0 °C	Set PTT08102JNQ- On to 0
Edit Remove	Yes	IT_ID-valid	RFID Card ID = 100	Set RFID Status to Valid
Edit Remove	Yes	IT_ID-invalid	RFID Card ID != 100	Set RFID Status to Invalid
Edit Remove	Yes	Nurse_ID-valid	PTT08107G79- Card ID = 200	Set PTT08107G79- Status to 0
Edit Remove	Yes	Nurse_ID-invalid	PTT08107G79- Card ID != 200	Set PTT08107G79- Status to 1
Edit Remove	Yes	IT-Door unlock	RFID Status is Valid	Set IT-DOOR Lock to Unlock
Edit Remove	Yes	IT-Door lock	RFID Status is Invalid	Set IT-DOOR Lock to Lock
Edit Remove	Yes	Nurse-Door unlock	PTT08107G79- Status is 0	Set Nurse-Door Lock to Unlock
Edit Remove	Yes	Nurse-Door lock	PTT08107G79- Status is 1	Set Nurse-Door Lock to Lock

Add

Figure 24 Conditions in Registration Server

Nursing Department

The nursing department stands to gain significant advantages from the implementation of the IoT system. Real-time monitoring of patients who accommodate in smart rooms with sensors and smart devices empowers nurses to proactively address potential health concerns. Additionally, the system manages workflows through environmental monitoring as well.

The primary responsibility of the Nursing Department is to provide direct patient care. Nurses often use PCs and other devices to communicate with other healthcare professionals, such as doctors, specialists, or pharmacists, through email, messaging systems, or teleconferencing tools via the hospital network.

In addition to that, they access electronic health records or electronic medical records systems to update patient information or other medical data.
Furthermore, nurses are trained to respond to medical emergencies and provide immediate care in critical situations through the alarms that are setup in the department which are all connected to their corresponding patients' rooms. These alarms are configured along with the patients' vitals monitors (Oxygen, Pulse rate, and others) to provide the patients with fast and efficient aid at any time.

The department is also equipped with RFID readers to control access to restricted areas like medication storage rooms or intensive care units within the department. This allows authorized individuals only to access said areas as part of security measures implemented in the hospital.

Figure 25 Nursing Department

Emergency Department

Emergency Departments serve as the critical entry point for a vast number of patients within a hospital. Operating 24/7, they provide immediate medical attention to individuals experiencing a wide range of sudden illnesses or injuries, some of which can be life-threatening. EDs are prepared to handle time-sensitive medical emergencies like cardiac arrests, strokes, severe allergic reactions, and major trauma. Their life-saving interventions can significantly improve patient outcomes.

Upon arrival, patients are triaged by healthcare professionals to prioritize care based on the severity of their condition. Triage ensures that patients with the most critical needs receive immediate attention while others are treated in order of urgency.

Not only that, but also EDs handle trauma cases resulting from accidents, natural disasters, or other emergencies. They have the resources and expertise to provide timely treatment and prevent further complications.

In this project, the ED is represented in a simple manner consisting of several host devices as well as an RFID reader for authorisation and identification.

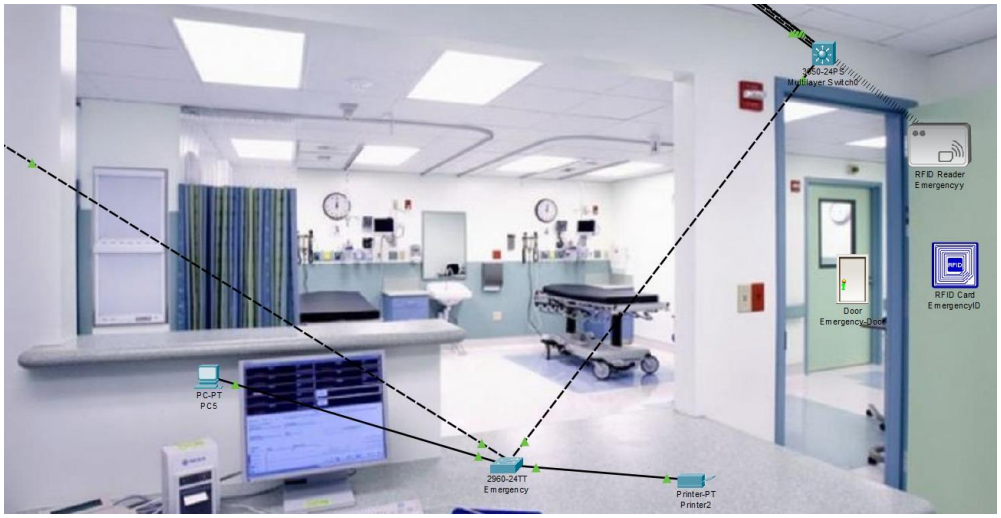

Figure 26 Emergency Department

Patient Smart Room

A patient smart room is a technologically advanced environment within healthcare facilities that utilizes sensors, interactive interfaces, monitoring devices and telemedicine capabilities to optimize patient care and comfort. These rooms continuously monitor environmental conditions and patient health parameters, allowing for real-time adjustments and early detection of health issues.

Patients can control room features, communicate with healthcare providers remotely, and receive personalized care tailored to their needs. In addition, patients' vitals are

monitored 24/7 through their wearable devices. When a crisis occurs, alarms are triggered to notify the medical staff who immediately intervene to aid the patients and provide them with treatment.
In this system, the patient room was equipped with a health monitoring system, as well as environment controls and other appliances for the comfort of the patient.
Firstly, the health monitoring system consists of several monitoring devices, which are:

- **Body Temperature Sensor**
  This device measures the patients' body temperature and is connected to an RGB LED to indicate if temperature readings are normal or abnormal (Green for normal, Red/Blue for abnormal/crisis).

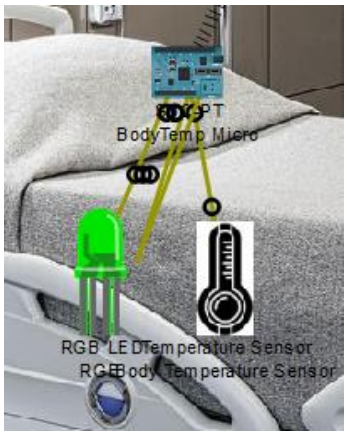

Figure 29 Normal Temperature

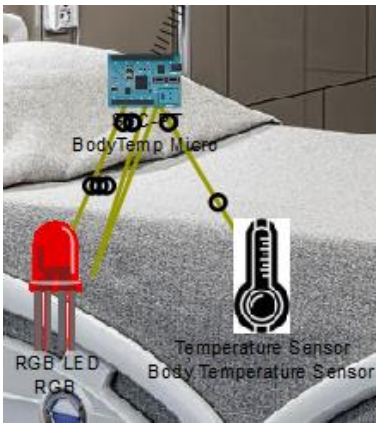

Figure 28 Abnormal Reading (Red)

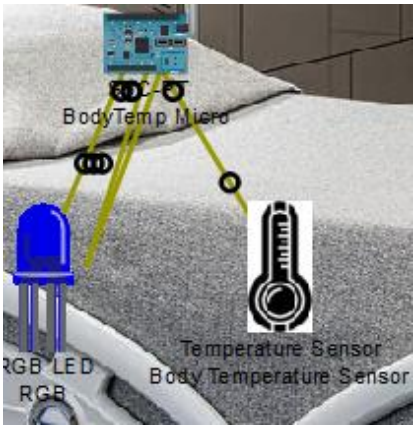

Figure 27 Abnormal Reading (Blue)

- **Oxygen Monitor**
  This device tracks the oxygen level in patients' blood -which normally lies between 95%-100%- and triggers an alarm which lies in *the Nursing Department* to alert the medical staff so that they could interfere.
- **Pulse Rate Monitor**
  This device monitors the patients' heart rate and similarly to the Oxygen Monitor, it triggers the alarm which is corresponding to that patient.

Figure 30 Oxygen & Pulse Rate Monitors

Together, these devices prioritize patient well-being and health through advanced technology integration.

On the other hand, the patient room is equipped with other devices to facilitate patients' activities and help them settle in a comfortable, safe environment. This is achieved through the following devices:

- **Smart Air Conditioning**
  To adjust room temperature according to the surrounding environment and the patient's preferences. This was implemented by turning on/off heating/cooling elements based on temperature sensor readings.

- **Smart Door/Sanitization**
  To automatically interact with individuals who come nearby. This was implemented by connecting a smart door that automatically opens when an individual triggers a motion sensor.

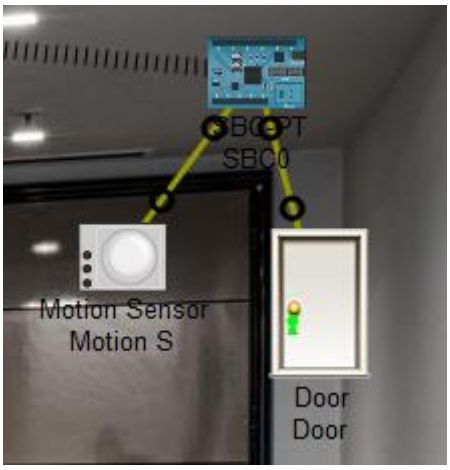

Figure 31 Smart Door

- **Appliances**
  To provide the patient/visitor with a friendly, comfortable environment. This was implemented by providing each room with a coffee maker.

To summarize, these rooms provide an innovative approach to healthcare delivery, leveraging technology to create personalized, responsive, and efficient care environments that prioritize patient well-being and satisfaction.

Prototype

For the prototype we used the Arduino UNO microcontroller along with a variety of sensors to simulate a mini hospital.
The components used:

- Arduino UNO
- HC-05 Bluetooth Module
- HC-SR04 Ultrasonic Sensor
- MQ-2 Fume Sensor
- MAX30100 Heart Rate and Oximeter Sensor
- I2C LCD
- Buzzer

We used the HC-05 Bluetooth module to send a message to the nurses in the case that the patient's vitals are under a certain threshold. The patient's vitals are also sent in real time to the I2C LCD display in order for the nurse to monitor the vitals all the time. The patient's vitals are measured using the MAX30100 Heart Rate and Oximeter Sensor. For the prototype the heart rate and oxygen level was the only thing monitored, but in a real world environment more vitals may be needed to be monitored. We also used an HC-SR04 Ultrasonic sensor in order to detect any person getting close. Its applications may involve opening the door when someone gets close, or a device that sprays alcohol at the hands when a hand is detected. For this prototype we simulated the detection of a nearby object by an LED lighting up.
We also used an MQ-2 Fume sensor which would be put all over the hospital in order to detect any gas leakage. For this prototype we put a buzzer that turns on whenever fumes are detected. The prototype is shown in the figure below:

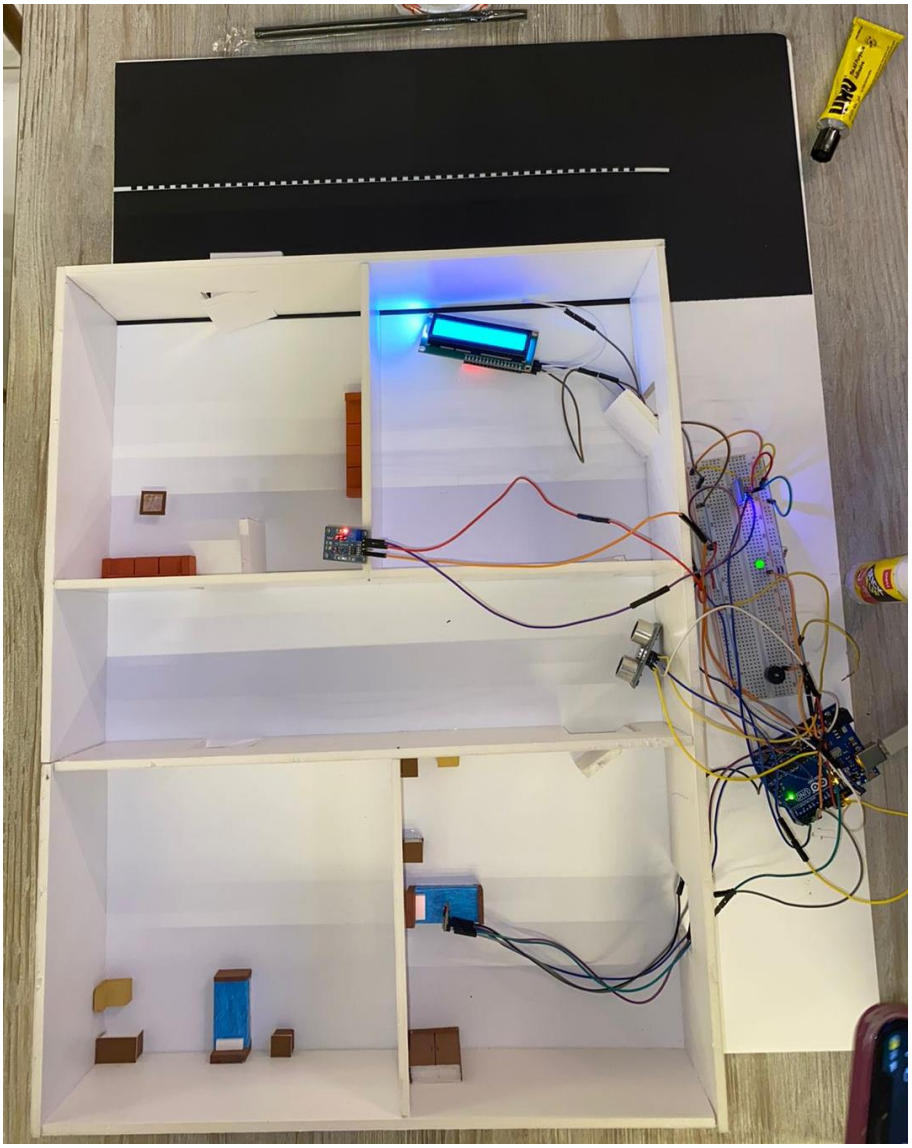

Figure 32 Prototype

Conclusion

To conclude, the project explores the integration of IoT technology in hospitals, focusing on network topology, departmental functionalities, and specific IoT applications. It includes VLAN segmentation, multi-layer switches for inter-VLAN routing, and the deployment of IoT devices in departments like Emergency, Nursing, and IT. Patient smart rooms with sensors for personalized care are highlighted, along with a prototype demonstrating IoT applications in patient monitoring and environmental control. To Simplify, IoT in hospitals promises improved efficiency, enhanced security, and personalized patient care, transforming healthcare delivery.

Q&As

What is the primary function of IoT devices in a hospital?

A) Entertainment for patients
B) Monitoring patient health metrics
C) External communications
D) Staff scheduling
Answer: B) Monitoring patient health metrics

Which technology is commonly used by IoT devices in hospitals to ensure secure data transmission?

A) Bluetooth
B) RFID
C) HTTPS
D) SMS
Answer: C) HTTPS

What is a significant benefit of using IoT devices in healthcare?

A) Reduced need for staff
B) Increased operational costs
C) Enhanced patient care through real-time data
D) Decreased data accuracy
Answer: C) Enhanced patient care through real-time data

Which of the following is a challenge associated with the deployment of IoT devices in hospitals?

A) Increased patient satisfaction
B) Reduced equipment costs
C) Data privacy concerns
D) Simplified management practices
Answer: C) Data privacy concerns

IoT devices in hospitals can help manage which of the following?

A) Only patient health monitoring
B) Only hospital equipment tracking
C) Both patient health monitoring and hospital equipment tracking
D) Neither patient health monitoring nor hospital equipment tracking
Answer: C) Both patient health monitoring and hospital equipment tracking