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Management Information System (MIS)

Computer Based information System Graduation Project II

MGT_420NII

Title: Logical Design for Doctor-Patient Smart Tracking System

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Acknowledgement

We would like to express our deepest gratitude to our respected instructor, **Prof. Adel Ghanam**, and our dedicated Teaching Assistant, **Hend Osama**, for their invaluable support and guidance throughout the course of our graduation project. Over the span of two semesters, their continuous encouragement, insightful feedback, and constant commitment have been crucial in shaping our work and helping us overcome every challenge we faced. Their mentorship has not only enhanced our technical and research capabilities but also inspired us to maintain a high standard of excellence. We are truly thankful for their efforts and proud to have had the opportunity to learn under their supervision.

1 Executive Summary

This project outlines the **Logical Design for a Doctor-Patient Smart Tracking System**, an innovative healthcare solution. It addresses critical *delays in locating medical personnel and patients within hospitals* by integrating Internet of Things (IoT) and Radio-Frequency Identification (RFID) technologies for real-time tracking. The system utilizes smart RFID wristbands with SOS buttons for patients and smart RFID badges for doctors, enabling continuous location monitoring. Its core functions are *real-time patient tracking*, *immediate emergency alerts*, and *constant doctor tracking*.

The proposed IT infrastructure includes *Wi-Fi 6*, an *enterprise router*, *Linux servers*, and *LLRP middleware* for seamless RFID communication. An *ASP.NET web application*, hosted on *AWS*, ensures scalability, reliability, and mobile accessibility for secure, real-time data.

Ultimately, this system aims to enhance patient safety, optimize doctor workflows, and improve overall hospital efficiency through immediate location data and streamlined emergency responses.

2 Business Case

2.1 Project Overview:

The availability of specialized doctors is often a critical issue in hospitals, where delays in locating a required doctors can have serious consequences. For example, in time-sensitive scenarios such as emergencies requiring immediate surgical intervention, the inability to quickly locate a doctor can result in harmful delays to patient care. Similarly, hospitals face challenges in ensuring locating patients.

Siemens Healthineers Egypt offers Real-Time Location Solutions (RTLS) that enable hospitals to track the real-time movement of patients, staff, and medical assets within healthcare facilities *(we will focus on the patients tracking part)*. These systems help improve workflow efficiency, enhance patient experience, support infection control, and streamline clinical operations by providing location-based insights and automated notifications. By integrating wearable tags, sensors, and digital analytics, RTLS supports better bed management, staff coordination, and patient navigation, contributing to safer and more efficient hospital environments (*Spot check patient monitor systems, 2025)*.

Patients Still Need Tracking (Even with Nurses Present) Hospitals are large, complex facilities with multiple departments and floors. Patients are frequently moved for tests (e.g., X-rays, MRI), procedures, or transfers between different units (e.g., from ER to inpatient room) (Hidglobal.com, 2025). During these transitions, or even within a department, a patient might temporarily be out of the direct sight of their primary nurse, or responsibility might shift between staff members. While a nurse might be assigned, delays can occur during patient transport or handoffs between departments, leading to the patient waiting in an unmonitored hallway or a transfer area longer than necessary. Tracking ensures these delays are minimized and patients are always accounted for (Therainalliance.org, 2025).

According to these incidences, introducing our **Logical Design for Doctor-Patient Smart Tracking System** which is an advanced solution for these issues that face hospitals, by integrating Internet of Things (IoT) technology with Radio-Frequency Identification (RFID). This smart system will help in addressing critical challenges in healthcare by enabling hospitals to track both doctors and patients effectively, creating a more comprehensive and smart healthcare. Moreover, by equipping patients with **smart wristbands** and doctors with **smart badges** (smart wearables), the smart system integrates RFID and IoT technologies to enable real-time tracking for both doctors and patients. Furthermore, the smart system could be connected to a **cloud platform**, providing seamless access to data for hospital administrators while reducing the costs associated with maintaining private servers. Thus, adopting the Doctor-Patient Smart Tracking System aligns with Egypt's broader goals of digital transformation in healthcare, as it integrates cutting-edge technology to address critical healthcare issues.

- **References :**

Spot check patient monitor systems. (2025). Philips. Retrieved June 21, 2025, from https://www.philips.com.eg/healthcare/solutions/patient-monitoring/spot-check-monitoring-systems

(2025). Therainalliance.org. Retrieved June 19, 2025, from https://therainalliance.org/rfid-healthcare-patient-tracking/

(2025). Hidglobal.com. Retrieved June 19, 2025, from https://www.hidglobal.com/solutions/rtls-healthcare

References to prove that it is a real business case:

This study highlights the critical delays in emergency department (ED), this research primarily focuses on vulnerable women, children, and patients who need non-trauma consultations. It emphasizes the underlying problems that lead to these delays, like crowding, not being able to locate specialized personnel (like doctors or nurses), and the lack of financing (Researchgate.net, 2019). *We will be focusing on the "not being able to locate specialized personnel (e.g., doctors)" in this research, which helps us in our project to help prove that this is a real business case.*
(https://www.researchgate.net/publication/331537134_Delays_in_arrival_and_treatment_in_emergency_departments_Women_children_and_non-trauma_consultations_the_most_at_risk_in_humanitarian_settings)
This study primarily discusses the inability of patients to reach doctors when needed *(along with other issues, **but** we will be focusing on this part as it is related to our business case)*. It reports that only 36% of patients said they were "always able to speak to a doctor when needed" during a recent overnight hospital stay, a significant drop from 43% in 2011. The findings are based on feedback from 2,885 U.S. patients who were hospitalized overnight between April and November 2023. Only 1 in 3 patients feel they can always reach a doctor when needed, a situation that has worsened since 2011 (Jdpower.com, 2023).
(https://www.jdpower.com/business/press-releases/2023-us-hospital-patient-satisfaction-study?utm)

- **References :**

(2019). Researchgate.net. Retrieved June 19, 2025, from https://www.researchgate.net/publication/331537134_Delays_in_arrival_and_treatment_in_emergency_departments_Women_children_and_non-trauma_consultations_the_most_at_risk_in_humanitarian_settings

(2023). Jdpower.com. Retrieved May 7, 2025, from https://www.jdpower.com/business/press-releases/2023-us-hospital-patient-satisfaction-study?utm

2.2 Project Scope in Terms of Opportunities/Problems:

The Doctor-Patient Smart Tracking System will provide cutting-edge IoT and RFID technologies to tackle critical challenges faced by hospitals, such as: *inability to locate a doctor when needed*, which may lead to serious negative impacts. Therefore, its primary objectives include rapidly locating doctors during emergencies.

Our core problem is that *patients are facing delayed response in emergencies, and inability to locate a doctor when needed* which leads to serious negative consequences.

For instance, Trevigilo-Caravaggio Hospital in Italy uses RFID technology to monitor patients' movements within emergency department, enhancing patient safety and improves efficiency (Rand.org, 2009). Similarly, at Danbury Hospital in Connecticut, the Safe Place Infant Security Solution system is implemented to track newborns babies' location by using RFID technology (PR Newswire, 2013). These real-world examples help in highlighting the potential of the Doctor-Patient Smart Tracking System in improving the hospital procedures.

Problems:

1. **Lack of real-time location tracking:** Difficulty in continuously monitoring the location of doctors and patients within the hospital due to the absence of RFID or Bluetooth-based tracking systems *(Supports FR1 & FR3)*.
2. **Inability for patients to request immediate help:** Patients lack a simple and direct method, such as an emergency button, to trigger alerts and call for urgent assistance during critical situations *(Supports FR1 & FR2)*.
3. **Delayed doctor identification in emergencies:** Inability to quickly determine the real-time location of doctors during emergencies, which leads to life-threatening delays in delivering critical care to patients *(Supports FR3)*.

2.3 Target Beneficiaries:

- **Who will use it:** Patients and Doctors

Patients:

With the Doctor-Patient Smart Tracking System, patients are receiving faster, more efficient healthcare services. Patients are aided in emergencies from rapid responses, and smoother transitions through departments significantly reduce wait times for patients promoting better health outcomes. Thus, tracking patients in real-time allows hospitals to manage the flow of patients more efficiently through various stages of care, this benefits the patient (e.g., admission, waiting for tests, post-op recovery, discharge). This reduces bottlenecks and significantly cuts down on patient wait times, leading to faster admissions and discharges (*RTLS healthcare for best Patient experience, 2025)*.

Doctors:

The system optimizes doctors' workflows by streamlining tasks and minimizing disruptions, enabling them to work more efficiently. Through real-time tracking, doctors can be quickly located and notified during emergencies, ensuring timely intervention in critical cases, which decrease workloads on doctors making it more balanced and fairer (Hafez, 2023).

- **Who will pay for it:** Private Hospital Investment and The Egyptian Ministry of Health, and Population (Example: **Cleopatra Hospital Group** and **Dar Al Fouad**).

Private Hospitals:

Private hospitals, such as *Cleopatra Hospital Group* and *Dar Al Fouad*, can benefit from adopting the Doctor-Patient Smart Tracking System. This investment is in keeping with their goals of efficiency, profitability and enhanced patient satisfaction. Tracking in real time reduces wait time in an emergency and optimizes workflows, enhancing the hospital's brand as a provider of high-quality healthcare. Featured Evaluation Hospitals can treat more patients efficiently, help avoid overcrowding and maintain quality of care by improving capacity management. Automating manual processes decreases administration costs and wastage of resources like misplaced equipment and over-staffing. This system leads to increased patient satisfaction, improved resource use, and higher revenue (Varshneya, 2020).

The Egyptian Ministry of Health and Population:

The system addresses critical challenges in public healthcare while aligning with the ministry's mission to enhance accessibility, efficiency, and cost-effectiveness. It also faster responses to emergencies and facilitate seamless transfers of critical patients in less time through real-time monitoring which can save lives and enhance health outcomes in public hospitals. Automation minimizes the reliance on administrative staffing and avoids wasting resources, such as misplaced equipment or bad schedules (Hafez, 2023).

- **System Administrators**

Although not direct beneficiaries, system administrators play a critical role in ensuring the success of the Doctor-Patient Smart Tracking System:

***Hospital Staff Supervisors**:* Oversee daily usage of the system, ensuring compliance and efficiency within hospital workflows.

Communication Systems Administrators: Manage automated notifications sent to doctors, patients, and hospital staff. Ensure SMS, email, and in-app notifications are delivered properly. And monitors failed notifications and escalate unresolved issues.

Real-Time Monitoring & Alerts Administrator: Oversee emergency alert triggers from IoT devices, RFID tags, and tracking systems. Ensure doctors and hospital staff are immediately notified of emergencies. Escalate cases if a doctor is unavailable. And work with hospital Emergency Response Teams (ERTs) to ensure smooth coordination.

• References :

Varshneya, R. (2020). *Four innovative case studies of RFID application in healthcare*. RFID JOURNAL. https://www.rfidjournal.com/expert-views/four-innovative-case-studies-of-rfid-application-in-healthcare/193087/

Hafez, T. (2023, October 23). *Challenges and progress in Egypt's healthcare system: A 2023 update*. Business Monthly. https://businessmonthlyeg.com/challenges-and-progress-in-egypts-healthcare-system-a-2023-update/

4., I. (2025, February 15). *RTLS healthcare for best Patient experience*. Ripples IoT Pte Ltd; RTLS solutions. https://www.ripplesiot.com/rtls-healthcare/

2.4 Expected Demand Size in Egypt/Region:

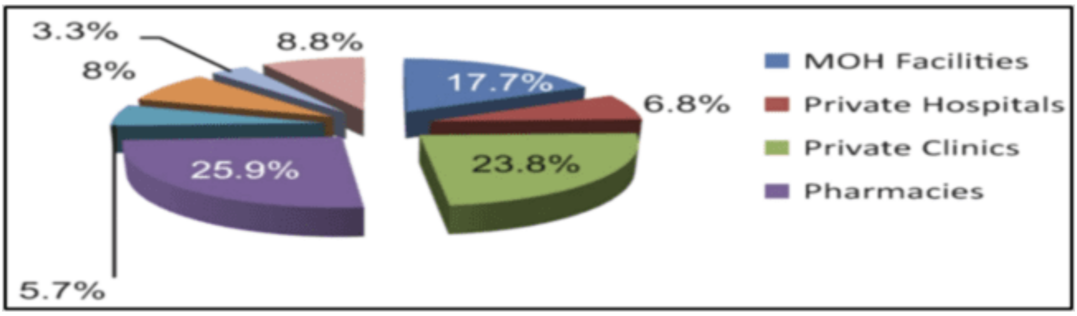

Figure 1
(Source: Smartscraper, 2024)

The above pie chart states that there are 17.7 % of MOH Facilities (Ministry of Health) in all over Egypt, along with 6.8% Private Hospitals, which this is our target beneficiaries list (Who will buy it?) in our system. Moreover, the above pie chart includes Private Clinics 23.8%, Pharmacies 25.9%, but both are not in our target beneficiaries list, so we will not use them in our statistics of the expected demand size in Egypt/Region. There are 69 private hospitals in Giza alone, private healthcare facilities (Private Hospitals) representing 6.8% of Egypt's healthcare landscape, are more likely to adopt advanced tracking systems to enhance operational efficiency and patient care (Smartscraper, 2024).

The adoption of such systems could initially focus on private hospitals and high-tech healthcare facilities in key locations like Cairo, Alexandria, and the New Administrative Capital, which is being developed as a smart and sustainable city. The New Administrative Capital, selected as the Arab Digital Capital in 2021, embodies advanced technological integration and serves as a hub for smart solutions in Egypt. According to market research, the Egyptian IoT healthcare market is growing at a CAGR of 25%, reflecting the country's readiness for digital healthcare solutions (TechSci Research, 2024).

Figure 2
(Source: Advisors, 2025)

According to recent data, the expected Compound Annual Growth Rate (CAGR) for **digitalized and technologically advanced healthcare services in Egypt** increased by **10.79% in 2023** (Advisors, 2025). This significant surge reflects a growing readiness among healthcare institutions—particularly **private hospitals and smart healthcare hubs**—to adopt innovative, tech-driven solutions. This trend directly supports the anticipated demand for our Doctor-Patient Smart Tracking System, as hospitals increasingly seek to improve emergency response times, operational efficiency, and patient safety through smart infrastructure. The CAGR growth suggests a favorable investment climate for IoT-based healthcare tools like RFID-enabled tracking systems, especially in metropolitan areas such as Cairo, Giza, and the New Administrative Capital. Therefore, this upward trend in healthcare digitalization reinforces the **high potential demand** and **market readiness** for implementing our proposed system across Egypt's evolving healthcare landscape.

International success stories like of RFID to track real time location at Trevigilo-Caravaggio Hospital and Danbury Hospital demonstrate the potential impact of this system in Egypt, where ensuring timely care and patient safety is critical. As Egypt moves toward achieving its Vision 2030 goals for digital transformation, technologies like the Doctor-Patient Smart Tracking System will become a necessity, offering a significant opportunity for hospitals to improve care delivery, and meet the increasing demand for smart healthcare systems.

- **References :**

Advisors, M. (2025). *Egypt Healthcare Market research report: Forecast (2025-2030)* [Data set]. https://www.marknteladvisors.com/research-library/egypt-healthcare-market.html

Smartscraper. (2024). *Private hospitals in Egypt - 430 Available (Free Sample)* [Data set]. https://rentechdigital.com/smartscraper/business-report-details/list-of-private-hospitals-in-egyp

Egypt healthcare IoT market size, Trends, Growth, forecast 2026. (2024). Techsciresearch.com. Retrieved October 29, 2024, from https://www.techsciresearch.com/report/egypt-healthcare-iot-market/12792.html

3 Features of the System

3.1 Theoretical Background:

We should acknowledge the two approaches that this smart system could adopt either the De Facto Practices or the Theoretical Academic References. The De Facto Practices refers to the methods, approaches, and even techniques that are widely used and adopted based on the practical experience and knowledge, even though it may not be theoretically and academically approved on, thus the De Facto Practices usually emerges from the experience within an industry (Maggetti, 2012). On the other hand, the Theoretical Academic References is the opposite of the De Facto Practices, as it relays on the academic articles and theories that were theoretically approved on. But in our system, we will work with the Theoretical Academic References.

The theoretical foundation for RFID (Radio-Frequency Identification) tracking of people within a hospital environment is rooted in the advancements of modern tracking technologies, particularly the evolution of IoT (Internet of Things) and RFID systems since the late 20th century (Rosenbaum, 2014). At its core, RFID tracking relies on the principle of using radio waves to automatically identify and track tags attached to objects or, in this case, people. For tracking individuals like patients and doctors in a dynamic hospital setting, **Active RFID** technology is typically adopted (Hawrylak & Hale, 2015). This is because Active RFID tags contain their own power source, allowing them to continuously transmit signals over longer distances (up to 100 meters) (*Passive vs. Active tags in modern manufacturing, 2025)*. This continuous signal transmission is crucial for real-time location tracking of moving assets.

The location determination itself is often achieved through **Wi-Fi-based Real-Time Location Systems (RTLS)**. This involves leveraging the hospital's existing wireless infrastructure, such as Wi-Fi access points, to detect the signals emitted by the RFID-enabled wearable devices (smart wristbands for patients and badges for doctors). By analyzing the signal strength and timing from multiple access points, the system can triangulate or determine the precise location of the person in real-time (Gray et al., 2004).

Furthermore, a critical theoretical aspect involves the **data communication and integration**. Protocols like the Low-Level Reader Protocol (LLRP) standardize the communication between RFID readers and the hospital's central IT systems (*Low level reader protocol, 2010)*. This ensures efficient, secure, and compatible data collection from the RFID tags.

Systems such as the Doctor-Patient Smart Tracking System came into being as the need for more intelligent healthcare solutions increased. To provide real-time location monitoring, these systems integrate modern tracking technologies with smart wearable devices for patients and physicians. For instance, patients wear smart wristbands to ensure security and prevent wandering around, while doctors wear smart badges to facilitate rapid identification and notification in an emergency.

The idea of using tracking systems to improve healthcare operations traces back to early technological initiatives to increase hospital efficiency (Khan, 2017). Hospitals started experimenting with simple electronic systems to keep an eye on patients and improve operations in the middle of the 20th century. These systems had a narrow scope and frequently concentrated on responsibilities like patient documentation. The possibility for real-time tracking and data interaction had increased dramatically with the introduction of IoT and RFID technologies in the late 20th century, opening opportunities for improving hospital operations (Martínez Pérez et al., 2018).

Inventory and equipment tracking was one of the earliest extensive uses of RFID in healthcare, guaranteeing that vital instruments were accessible when needed. As time went on, attention turned to applying these technologies to more complicated problems, like finding medical help in an emergency and protecting patients, especially those who are vulnerable, like those suffering from dementia.

The next phase of medical technology is now represented by the Doctor-Patient Smart Tracking System. It offers smooth real-time data access, boosts operational effectiveness, and improves patient care by combining IoT and RFID. Hospitals are now responsive, effective, and secure thanks to this modern system, which is in line with worldwide trends in digital transformation.

- **References :**

Gray, M. K., Peden, J. J., II, & Chery, Y. (2004). Position detection and location tracking in a wireless network (Patent No. 6674403). In *US Patent* (No. 6674403).

Hawrylak, P. J., & Hale, J. (2015). Data privacy issues with RFID in healthcare. In *Medical Data Privacy Handbook* (pp. 549–567). Springer International Publishing.

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Maggetti, M. (2012). *Regulation in practice: The de facto independence of regulatory agencies*. ECPR Press. https://doi.org/10.5167/UZH-66106

Martínez Pérez, M., Dafonte, C., & Gómez, Á. (2018). Traceability in patient healthcare through the integration of RFID technology in an ICU in a hospital. *Sensors (Basel, Switzerland)*, *18*(5), 1627. https://doi.org/10.3390/s18051627

Khan, S. F. (2017). Health care monitoring system in Internet of Things (IoT) by using RFID. *2017 6th International Conference on Industrial Technology and Management (ICITM)*.

3.2 Fishbone Analysis:

Problem statement: The core problem is that *patients are facing delayed response in emergencies, and inability to locate a doctor when needed* which leads to serious negative consequences.

Scenario: As in the emergency timings the patient life is in danger where each second is important to save lives. Furthermore, any delay can lead to patient's death or any other complications for the patient in a critical case.

→ ***Fishbone diagram:***

1. Define the Problem (Head of the Fish):

Delay of doctors in emergency timings where this can lead deterioration of the patient's life.

2. Draw the Basic Structure:

Spine and bones:

A. Identify the Major Categories (Bones):

- Technology & Infrastructure
- Process Inefficiencies
- Environment

B. Brainstorm Possible Causes (Smaller Bones):

1. Technology & Infrastructure:

- RFID/WiFi coverage gaps in critical hospital areas (ER, ICU, OR).
- Signal interference from hospital walls, elevators, and medical equipment.
- Delayed updates in tracking system, causing inaccurate doctor/patient locations.
- Insufficient RFID readers, leading to blind spots in hospital tracking.
- Emergency alerts not always triggered in real-time due to system lags.

Effect:

- Delayed response in emergencies (Doctors & Patients)

2. Process Inefficiencies:

- No automatic doctor-patient assignment system based on proximity.
- Emergency alerts are not prioritized, leading to response delays.
- Manual intervention required to confirm alert validity, slowing down response.
- Tracking system does not integrate well with hospital emergency protocols.
- Doctors/patients' last known location not updated in real-time, delaying action.

Effect:

- Delayed emergency alerts
- Difficulty in locating doctors quickly

C. Human Factors (Staff & patient behaviours affecting system efficiency):

- Doctors forgetting or refusing to wear RFID badges.
- Patients removing or damaging RFID tags, making tracking ineffective.
- Hospital staff not trained to use the tracking system efficiently.
- Doctors turning off notifications due to too many false alarms.
- Lack of enforcement—no strict policy ensuring RFID tags are always used.

Effect:

- Doctors/patients are not accurately tracked
- Emergency alerts may be ignored or missed

D. Hospital Environment (Physical barriers impacting tracking & alerts)

- Crowded emergency rooms blocking tracking accuracy.
- Walls, doors, and equipment interfering with RFID/WiFi signals.
- Lack of clear tracking zones for doctors and patients in hospital layouts.
- Emergency situations causing chaotic conditions, making tracking harder.

Effect:

- Inaccurate tracking of doctors & patients
- Delays in emergency response

3. Analyze the Diagram and Identify Key Problems:

- **Lack of Real-Time Tracking:** Inability to track doctor and patient locations in real-time, leading to delays in care *(Supports FR 1 & FR 3)*.
- **Patient emergency button :**Where the patients have difficulty to trigger an emergency alert *(Supports FR1 & FR 2)*.
- **Determining the location of the doctors**: identifying the doctor's location in critical timings *(Supports FR 3)*.

4. Actionable Steps:

- **Implement Real-Time Location Tracking:** Use RFID or Bluetooth-based tracking systems to monitor the real-time location of doctors and patients within the hospital *(Supports FR1 & FR3)*.
- **Implementing patient emergency button:** it is an easy way to let patients trigger the emergency alert *(Supports FR 1 & FR2)*.
- **Identifying the location of the doctors in emergency:** Tracking doctors in emergency timings as patient life is in danger where each second is important to save lives *(Supports FR3)*.

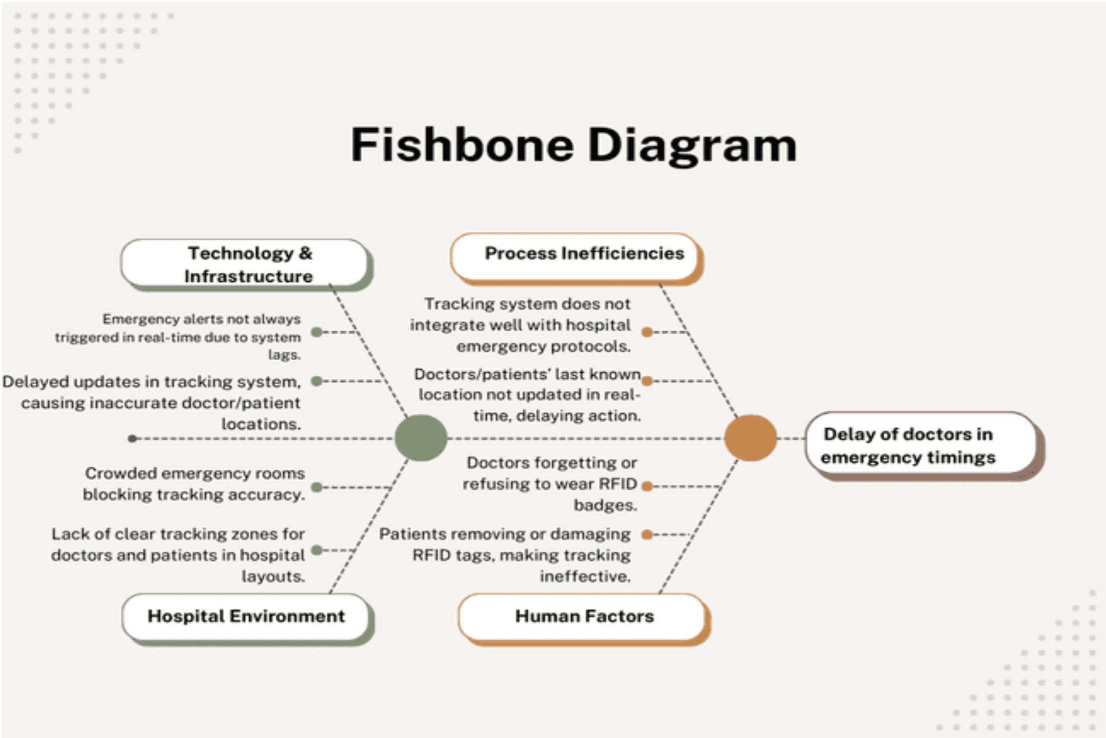

Figure 3
Fishbone Diagram
(Source: Developed by the students)

3.3 Identify Functional Requirnments

3.3.1 Fareeda Mohamed – 225163:

ID	FR.1
Title	Track Patient Location
Description	The system will track the current location of patients to ensure that they are in designated areas within the hospital premises, to ensure continuous tracking, also whenever the patient presses the SOS button, the doctor is immediately notified with the patient's exact location, using wearable smart RFID Tag Wristbands worn by patients ***(BLE Active RFID Wristband, SOS/Panic Button)***.
What	Monitor patients' movements using wearable smart RFID Tag Wristbands worn by patients.
Where	Hospital areas specifically the not allowed areas.
When	Regularly, with continuous updates as every second.
Why	To enhance patient safety, especially for patients who may get in restricted or unsecured areas within the hospital and want to call for immediate help (e.g., **Laboratories, Equipment Rooms)**, also continuous tracking of patients in case of serious and critical situations and they need the assistance of a doctor immediately, so tracking them in crucial *(problem number 1 & 2)*.
Dependency	None
Patient Location Tracking Microservice	Monitors patient movement inside the hospital to enhance safety, and ensure real-time location tracking, when **getting the patient location** for the SOS alert *(will be operation in the microservice integration diagram)*.

3.3.2 Ahmed Mustafa – 223269:

ID	FR.2
Title	Trigger Patient Emergency Alert
Description	The system will allow patients to manually trigger an emergency alert by pressing a physical emergency button called SOS Button embedded in the BLE Active RFID Wristband. Once pressed, the system will detect the patient's real time location using the hospital's RFID tracking infrastructure (RFID Tag Wristband) and will locate the nearest doctor through also the RFID tracking infrastructure (RFID Tag Badge), sending an SOS alert to that nearest doctor.
What	To allow patients to instantly request emergency assistance by simply pressing a physical button on patient wristbands.
Where	Wearable devices (Smart wristbands)
When	Anytime a Patient needs urgent medical care
Why	To reduce emergency response time and ensure patients receive immediate medical care and to enhance hospital efficiency by enabling real-time alerting to nearby doctors and nurses and ensure patients safety *(problem number 2)*.
Dependency	**FR.1**
Trigger Patient Emergency Alert Microservice	Triggered when a patient **presses the SOS button** *(will be operation in the microservice integration diagram)* that is embedded in their RFID wristband that sends their location and sends instant alerts to the nearest available doctor.

3.3.3 Merola Victor – 224329:

ID	FR.3
Title	Track Doctor location
Description	The system will track the current location of doctors Using RFID embedded in Doctor ID RFID badges, to update the doctor's location automatically. Where the alert emergency system notifies doctors of any potential patient emergency.
What	To observe the instant-time location of doctors.
Where	Throughout the hospital premises.
When	Regularly, with continuous updates as every second.
Why	To assure that doctors are located when needed for emergencies to reduce response time to critical conditions *(problem number 1 & 3)*.
Dependency	**None**
Doctor Location Tracking Microservice	It provides real-time updates on the location of doctors inside the hospital to ensure that doctors are accessible during emergencies and helps locating specialists when **getting a notification** *(will be operation in the microservice integration diagram)* from the emergency alert.

3.4 Referantial study for at leat two already marketable systems:

- **Trevigilo-Caravaggio Hospital's Patient Tracking System**

Trevigilo- Caravaggio Hospital in Italy uses RFID technologies ***(Active RFID technology)*** to track patients' location in emergency departments in real time using RFID technologies. This system enhances patient safety and improves efficiency in the emergency department (Rand.org, 2009).

→ **Functional Requirnments of Trevigilo-Caravaggio Hospital's Patient Tracking System:**

1. Assign RFID Tags to Patients

Every patient who enters the emergency department is given an RFID wristband to enable real time location tracking.

2. Track Patient Location

Use RFID readers to track patients' movemnts within the emergency department.

3. Enhance Patient Safety With Automated Alerts

Trigger alerts when a patrient moves out to a restricted area.

4. Integrate with Hospital Information Systrems

Use and synchronize the RFID tracking data with a hospital's Electronic Health Record (HER) to update patient status to keep medical teams alert on the patients and help them find patients quickly.

- **Safe Place Infant Security Solution System (Implemented by Danbury Hospital)**

Danbury Hospital in in Connecticut has implemented the Safe Place Infant Security Solution to track newborns babies by using RFID technology *(**Active RFID** using RTLS)*. This system involves securing lightweight, water- resistant transmitters around infants' ankles, enabling real-time location tracking and enhancing security measures to prevent abductions or misplacements (PR Newswire, 2013).

→ **Functional Requirnments of the Safe Place Infant Security Solution System:**

1. Tracking Infant Locations in Real-Time

Monitors tors the precise location of each infant within the hospital to ensure they remain in authorized zones.

2. Detecting Tampering with RFID Transmitters

Detects any attempts to remove or tamper with the infant's RFID transmitter, ensuring uninterrupted monitoring.

3. Alerting Emergency System

Activates security protocols such as locking doors and alerting staff upon detecting unauthorized infant movement or tampering.

4. Notifying Parents and Staff in Real-Time

Provides real-time notifications to parents and authorized personnel regarding the infant's status and any security events.

5. Integrating System and Training Staff

Ensures seamless integration with hospital protocols and provides training for staff to effectively monitor and respond to alerts.

- **References :**

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3.4.1 Comparative Analysis:

Functional Requirements	Doctor-Patient Smart Tracking System	Trevigilo-Caravaggio Hospital's Patient Tracking System	Safe Place Infant Security Solution System
FR.1 Track Patient Location	✓	✓	✓
FR.2 Trigger Patient Emergency Alert	✓	✓	✓
FR.3 Track Doctor Location	✓	✗	✗
FR.4 Integrate with Hospital Information Systems (e.g., EHR)	✓	✓	✗
FR.5 Notifying Parents and Staff in Real-Time	✗	✗	✓

3.5 Technology Needed:

- **Local Area Network (LAN):**

Application:

1. RFID Reader Integration:

Each HZ100 Long-Reading RFID Reader is connected via *Ethernet cables (Cat6)* to the hospital's LAN infrastructure. This enables real-time transmission of RFID tag signals, originating from wristbands or badges, to the local processing server. The wired LAN ensures stable data flow without interference, which is vital in medical environments where reliability and uptime are non-negotiable.

2. Local Linux-Based Server Communication:

The LAN connects all fixed-position devices (e.g., RFID readers, data storage units, alert display panels) to a central Linux-based server hosted in the hospital's data center. The server processes tracking data, triggers alerts, and updates EHR records instantly. Through LAN, this processing is done with minimal delay, ensuring accurate real-time monitoring.

4. Emergency Alert Handling:

When a patient presses the SOS button, the RFID wristband transmits a signal that is picked up by the nearest reader and sent over LAN to the server. The server processes this emergency and immediately sends a high-priority alert over LAN to wall-mounted alert screens and LAN-connected terminals used by emergency response staff. This ensures instant alert propagation within milliseconds.

5. Redundancy and Failover Mechanism:

In case of Wi-Fi interference or wireless signal degradation, LAN serves as a fail-safe channel, maintaining communication between critical system nodes. This hybrid design enables the system to continue processing patient tracking and emergency alerts even if wireless services experience disruption.

- **Wi-Fi-based Real-Time Location Systems (RTLS):**

WHAT?

Wi-Fi-based RTLS utilizes wireless access points (APs) strategically installed across the hospital to detect signals emitted by wearable devices such as RFID badges for doctors and RFID wristbands for patients. By examining these signals, the system provides real-time location data, ensuring accurate tracking of patients and doctors within the hospital. RTLS enables the immediate identification of doctors during emergencies (Researchgate.net, 2006).

<u>HOW?</u>

Wireless access points (APs) are installed across the hospital at strategic locations to create a comprehensive Wi-Fi coverage map. These APs (**Cisco Catalyst 9130AX Series**) act as receivers to capture signals emitted by wearable devices (**CenTrak Wi-Fi Badge Tags & BLE Active RFID Wristband, SOS/Panic Button).**

Active RFID: Since real-time tracking requires continuous signal transmission, active RFID tags with their own power source (battery) are ideal for our project. These can emit signals over longer distances compared to passive RFID tags. Actice RFID tags are equipped with their own power source, thus allowing them to transmit signals over longer ranges (up to 100 meters or more), while the passive short-range requirements (up to 10-25 feet). They are ideal for tracking moving assets, real- time location systems, and high-value or critical assets in industries like logistics, healthcare, and construction, and can store and transmit more data, *in our project we will use it to track patients and doctors*. Thus, it will be beneficial in our system.

Wi-Fi-Enabled RFID Tags: Integrated with Wi-Fi for compatibility with the hospital's Wi-Fi 6 network.

<u>WHERE to place Wi-Fi 6 Access Points in a Hospital?</u>

1. **Hallways & Corridors**
    - APs here support seamless handover as people move across the building.
    - Ensures seamless handover of signal tracking from one zone to another, important for continuous RTLS triangulation coverage.

2. **Patient Rooms**
    - Ensure continouse tracking of patients through RFID wristbands.
    - Needed for monitoring patient location, movement, and emergency button alerts.

3. **Operating Rooms (ORs) & Intensive Care Units (ICUs)**
    - Must-have for real-time doctor tracking
    - Quick emergency interventions (alerts), and EHR updates.

4. **Emergency Department**
    - Enables fast identification and location tracking of both doctors and patients.

5. **Waiting Areas & Lobbies**
    - Helps monitor patient flow.

6. **Entry/Exit Points**
    - Critical for detecting when a patient enters/exits the building.

7. **Restricted Zones (e.g., Laboratories, Equipment Rooms)**
    - Ensures alerts can be triggered by the patients from these restricted zones, in case the patient had entered these areas.

8. **Elevators and Stairwells**
    - Prevents signal drop and ensures continuity of tracking as individuals (doctors and patients) move vertically in the building.

- **RFID Integration with Electronic Health Record (EHR):**

WHAT?

RFID technology integrates seamlessly with Electronic Health Record (EHR) systems, linking RFID-enabled wristbands and badges to patient and doctors' profiles. RFID integration minimizes errors in data handling, streamlines hospital workflows, and enhances the accuracy of patient care (*Electronic Health Record Management System using RFID, 2023)*.

HOW?

In the Doctor-Patient Smart Tracking System, RFID integration with the Electronic Health Record (EHR) enables real-time tracking of patients and doctors and supports emergency alert functionality. Each patient is assigned an RFID-enabled wristband, and each doctor wears a smart RFID badge, both of which are linked to their respective profiles in the HER *(e.g., when the patient's want to view their profile the integration between the RFID and the EHR will make it happen)*. These RFID devices continuously transmit signals that are detected by strategically placed sensors and readers throughout the hospital. This location data is automatically updated in the EHR, providing real-time visibility of each individual's position within the hospital. When a patient presses an emergency button, the system retrieves their identity and location from the EHR and instantly alerts the nearest available doctor, whose presence is also verified through their RFID badge data. This integration ensures enhanced patient safety and faster medical intervention.

→ ***RFID Integration with EHR placement:***

Active RFID tags embedded in wristbands (patients) *"**BLE Active RFID Wristband, SOS/Panic Button**"*,

and badges (doctors) *"**CenTrak Wi-Fi Badge Tags**"*.

- **Linux-based Operating System (OS):**

WHY?

A **Linux-based operating system** is the best choice for this smart system due to its reliability, scalability, and cost-effectiveness. Linux offers robust support for networking and real-time processing, which is crucial for RTLS, and RFID integrations. It is highly customizable, allowing developers to optimize the system for hospital-specific needs, and it excels in handling large amounts of real-time data with minimal downtime. Additionally, Linux's open-source nature ensures *lower costs* compared to licensing fees for Windows, and its security features make it a safer choice for protecting sensitive medical data. While Windows provides a more user-friendly interface, the flexibility, stability, and efficiency of Linux make it the superior option for this critical application.

HOW?

1. **Wi-Fi-based Real-Time Location Systems (RTLS) and CenTrack Wi-Fi Badge Tags using Linux-based OS:**

The system will rely on Linux's robust support for APIs and communication protocols to continuously collect location signals from Wi-Fi access points (Cisco Catalyst 9130AX Series). With CenTrak Wi-Fi Badge Tags, Linux drivers and libraries will interface with RTLS software to process location data and trigger events (e.g., receive alerts from patients). The open-source nature ensures seamless customization of monitoring dashboards and integration with hospital IT systems (EHR).

2. **RFID Integration with EHR, BLE Active RFID Wristband, and HZ100 Long Reading Integrated RFID Reader via Linux-based OS:**

Linux provides extensive compatibility for RFID reader drivers and integration tools. The **HZ100 Long Reading Integrated RFID Reader** will communicate with hospital systems using open-source libraries (e.g., LLRP Toolkit), allowing efficient handling of data captured from BLE Active RFID Wristband. Linux-based middleware will integrate RFID data directly into the EHR without additional licensing costs.

- **Middleware (e.g., Low-Level Reader Protocol "LLRP"):**

WHAT?

Low-Level Reader Protocol (LLRP) is a standardized communication protocol developed by EPCglobal for controlling and interacting with RFID readers. It defines a **binary message format** transmitted over **TCP/IP**, allowing client applications to manage reader operations such as starting or stopping tag reads, configuring antennas, adjusting read parameters, and receiving tag data. LLRP provides a uniform interface across different RFID reader manufacturers, promoting interoperability and simplifying software integration. It supports detailed control over reader behavior and enables efficient communication between readers and enterprise systems. By abstracting low-level hardware details, LLRP allows developers to build scalable and maintainable RFID applications using consistent message structures and commands (*E-learning "LLRP for RFID", 2007*).

HOW?

In the Doctor-Patient Smart Tracking System, LLRP will be used to establish direct communication between the **RFID readers**—*such as the **HZ100 Long Reading Integrated RFID Reader***—and the hospital's **Linux-based servers or backend software**. Through LLRP, the system will control various functions of the RFID readers, such as starting or stopping tag reading sessions, configuring read range and antenna behavior, and filtering specific tag data (e.g., identifying whether a tag belongs to a doctor or a patient). When an RFID-enabled wristband or badge is detected, the reader will use LLRP to send detailed tag data—*including ID, timestamp, and location context*—to the central processing system. From there, the data will be integrated into the **Electronic Health Record (EHR)** and **real-time tracking dashboard**, enabling doctors to respond to emergencies, and maintain accurate logs without relying on third-party messaging systems. LLRP ensures that RFID data collection is efficient, secure, and directly compatible with the hospital's internal infrastructure.

Application:

1. **RFID Reader Detection**
   - The hospital is equipped with **HZ100 Long Reading Integrated RFID Readers** installed in key areas (e.g., patient rooms, corridors, ICU).
   - These readers are configured and managed using **LLRP**, which controls their reading range, timing, and tag filtering settings.
2. **Patient Wristband Activation**
   - Each patient wears a **BLE Active RFID Wristband** equipped with an **SOS/Panic Button**.
   - When the patient presses the panic button, the wristband emits a **signal containing the patient's status**.
3. **Signal Capture and LLRP Communication**
   - The RFID reader captures the wristband's signal.
   - Using **LLRP**, the reader sends the captured data (e.g., tag ID, timestamp) to the hospital's **Linux-based server**.
4. **Doctor Badge Detection**
   - At the same time, **CenTrak Wi-Fi Badge Tags** worn by doctors continuously emit signals.
   - RFID readers detect these tags and use LLRP to report their location and availability status to the central system.

5. **Backend Processing and EHR Update**
   - The server processes the incoming data from both patients and doctors.
   - The system cross-references this data with the **Electronic Health Record (EHR)** to determine:
     - The patient's identity and location
     - The nearest available doctor
6. **Response Coordination**
   - Based on real-time LLRP data, the system can **automatically notify the nearest doctor** or display alerts on the hospital's tracking dashboard.

- **Public Cloud Services (e.g., AWS):**

WHAT?

Public cloud services, such as Amazon Web Services (AWS), offer on-demand computing resources over the internet, eliminating the need for organizations to maintain physical hardware. These services provide scalable, reliable, and cost-effective infrastructure to run applications, manage storage, host databases, and more. AWS enables dynamic provisioning of resources, allowing systems to automatically scale up or down based on demand, which helps reduce wasted capacity and improves performance. Unlike traditional hosting models, public cloud services allow users to quickly deploy environments for development, testing, or production, while also offering built-in tools for security, backup, load balancing, and global content delivery *"E-learning : cloud.pdf*" (Bartlett, 2021).

WHY?

Public Cloud Services (e.g., AWS) will be used in this project for several reasons, including the provision of scalable computing capacity, Infrastructure as a Service (IaaS), and Web Application services. Because AWS offers adaptable, dependable, and reasonably priced cloud services that are necessary for real-time data processing, storage, and analytics in the smart tracking system, we will use AWS to host the web application. Additionally, AWS services like AWS Lambda for serverless computing, and Amazon S3 for secure data storage will also make system integration easy. These services reduce the need for on-premise servers and ensure high availability, flexibility, and HIPAA-compliant security for healthcare operations. Because AWS takes care of the underlying infrastructure, backups, and maintenance, these features will lower infrastructure costs and make management easier.

→ ***Note:*** HIPAA, or the Health Insurance Portability and Accountability Act of 1996, is a federal law aimed at simplifying the process of maintaining health insurance, safeguarding the privacy and security of healthcare data, and assisting the healthcare sector in managing administrative expenses

- **ASP.NET (for building the web application)**

WHAT?

ASP.NET is a **framework** used to build and run the **backend of the web application**, including:

- RESTful APIs
- User authentication (via ASP.NET Identity)
- Real-time notifications (via SignalR)
- Backend logic to process RFID data collected through LLRP

WHY?

The web application is developed using **ASP.NET Core MVC** or **ASP.NET Core Web API**, which supports:

- **Model-View-Controller (MVC)** architecture for web pages and user interaction.
- **RESTful APIs** for secure communication with hospital databases and front-end interfaces.
- **Responsive design**, using Razor views or HTML pages, to allow access from any mobile browser.

ASP.NET enables **mobile accessibility**, allowing doctors and patients to log into a **secure, role-based dashboard** via smartphone or tablet and receive real-time alerts and location updates.

Application:

1. A patient presses the **SOS button** on their BLE Active RFID wristband.
2. The **RFID reader** detects the signal and communicates it to the server using **LLRP**.
3. The **ASP.NET backend** receives the data, logs the alert, and retrieves the patient's location and identity.
4. **SignalR** pushes a real-time notification to the **doctor's mobile dashboard**.
5. The doctor clicks the alert and views the **patient's location and status** immediately for a fast response.

→ **Functions Accessed on Mobile via Web App:**

Role	Mobile Features via ASP.NET Web App
Doctor UI	- View emergency alerts (receving emergency alert triggered by patients). - Real-time map of patient locations (showing patient's current location, e.g., room and floor number). - Update Location (e.g., Showing their real-time location).
Patient UI	- View profile (e.g., Name, ID, current location). - Press button (to request immediate doctor assistance).

→ **<u>Hosting and Deployment:</u>**

- The ASP.NET web app is hosted on **AWS (Elastic Beanstalk or EC2)** or **Azure App Service** (*we will use AWS in our project*).
- Mobile access is via a secure **HTTPS URL**, accessible on any device with internet and a browser *(ios or android)*.

→ **<u>How it all comes together:</u>**

Our ASP.NET web application:

- Acts as a central control and monitoring system.
- Delivers a **responsive mobile-friendly interface**.
- Supports real-time tracking, alerts, and doctor-patient interaction.
- Uses ASP.NET features like **MVC**, **Web API**, **SignalR**, and **Identity** to ensure performance, security, and usability on mobile phones.

- **Web Application Accessibility via Mobile Phones**

<u>WHAT?</u>

The web application will be hosted on a **cloud-based infrastructure (AWS)**, ensuring accessibility through any standard web browser on mobile devices, whether Android or iOS. This eliminates the need for a standalone app download while still offering mobile responsiveness and real-time functionality.

<u>HOW?</u>

- **Responsive Web Design (RWD):** The web application will be designed with responsive frameworks (e.g., Bootstrap or Tailwind CSS), enabling the interface to adjust automatically to different screen sizes and orientations.
- **Secure Login Interface:** Doctors and Patients can log in using secure credentials via mobile browser to access tracking dashboards, emergency alerts, and patient status updates.

→ **Use Cases on Mobile Devices**

- **Doctors:**
  - Receive real-time emergency alerts via push notifications (through web notifications or SMS/email integration).
  - Use their mobile dashboard to view patient location, status, and navigate to the emergency area quickly.

- **Patients:**
  - Patients can log in to view their name, ID, current location within the hospital, room number, and admission details, via "Patient" class operation: View_Profile, which is shown explicitly in the Sequence Diagram: Fareeda Mohamed's diagram.
  - Patients can press a virtual SOS button from the mobile web app, which will show the patient where to press on the physical button on the wristband that he/she is wearing.

<u>Technical Implementation:</u>

- **Front-End:** HTML5, CSS3, and JavaScript (React or Angular) to provide dynamic, mobile-friendly UI.
- **Back-End:** Hosted on AWS Lambda or EC2 with APIs that serve mobile requests for location tracking, alert triggering, and status monitoring (*we will use in our project: AWS services like AWS Lambda for serverless computing, and Amazon S3 for secure data storage; mentioned in the cloud computing part*).
- **Communication Protocol:** Uses **REST APIs** for real-time data transmission between IoT devices and the web interface.
- **Security:** Enforced with HTTPS, token-based authentication (e.g., JWT), and role-based access control.

→ ***Example Scenario***

When a patient presses the **SOS button**:

- The RFID wristband transmits the alert.
- The LLRP broker forwards the alert to the cloud server.
- The cloud updates the database and sends a **notification to the doctor's mobile web app** interface.
- The doctor views the alert and **navigates using the web app** to the patient's location.

- **References :**

(2006). Researchgate.net. Retrieved June 10, 2025, from https://www.researchgate.net/publication/228937288_Real_Time_Location_System_over_WiFi_in_a_Healthcare_Environment

Electronic Health Record Management System using RFID: Improving Efficiency and Accuracy in Healthcare. (2023).

(2007). Edu.Eg. Retrieved April 6, 2025, from https://e-learning.msa.edu.eg/pluginfile.php/1101212/mod_resource/content/2/LLRP%20for%20RFID.pdf

Bartlett, J. (2021). Hosting with AWS. In *Building Scalable PHP Web Applications Using the Cloud* (pp. 141–152). Apress.

3.6 IT Infrastructure Proposed:

- **Wi-Fi** *(Supports the 3 FRs):*

HOW?

Wi-Fi technology is essential for **indoor communication** within the hospital, connecting the RFID tags, wearable sensors, and tracking devices with centralized management systems. It facilitates real-time location tracking of both doctors and patients, ensuring immediate updates are available on hospital dashboards. Additionally, Wi-Fi connectivity minimizes reliance on cellular networks, making it a cost-effective solution for internal hospital operations. We choose Wi-Fi 6, especially Cisco Catalyst 9130AX Series, for our project.

WHY?

1. **Higher Device Capacity**
   - Wi-Fi 6 supports more simultaneous device connections using OFDMA (Orthogonal Frequency Division Multiple Access).
   - Ideal for environments like hospitals where hundreds of RFID tags, sensors, and wearables are active.

2. **Low Latency & Faster Response**
   - Enables real-time tracking and alerts with minimal delay, critical for emergencies.
   - Helps RFID readers, wearable sensors, and dashboards update instantly.

3. **Better Coverage & Throughput**
   - Wi-Fi 6 provides improved performance in dense indoor spaces with walls and equipment.
   - Longer range and more stable signals, especially in places like patient rooms and corridors.

4. **Enhanced Security**
   - Supports WPA3 encryption, essential for protecting patient data and medical records.
   - Complies with HIPAA and other healthcare regulations on data security.

5. **Power Efficiency**
   - Devices use Target Wake Time (TWT) to reduce power consumption, extends battery life of active RFID tags.

6. **Optimized for IoT**
   - Designed to handle a large number of low-data-rate IoT devices, like RFID wristbands and CenTrak badges.

→ ***Recommended Model:*** Cisco Catalyst 9130AX Series

- Designed for high-density environments like hospitals
- Supports Wi-Fi 6, OFDMA
- Integrated security and IoT support
- Can be used as both Wi-Fi and Access Points (APs)
- Cisco Catalyst 9130AX Series supports Active RFID

Figure 4
Cisco Catalyst 9130AX Series
(Source: *Cisco, 2024*)

- **From where to buy?**

1. Cisco official website: (https://www.cisco.com/c/en/us/products/collateral/wireless/catalyst-9100ax-access-points/nb-06-cat-9130-ser-ap-ds-cte-en.html)
2. Authorized Cisco resellers such as:

→ **CDW**(https://www.cdw.com/product/cisco-catalyst-9130axi-wireless-access-point/5831887)

OR

→ **Insight**(https://www.insight.com/en_US/shop/product/C9130AXI-B/cisco%20systems/C9130AXI-B/Cisco-Catalyst-9130AXI-wireless-access-point-Bluetooth-WiFi-6/)

When purchasing for a hospital-scale, like our project, it is recommended to:

- Ask for **volume discounts**
- Request **on-site support or installation**
- Ensure access to **warranty and Cisco SmartNet service**

- **Router (e.g., Cisco C8300-2N2S-4T2X)** *(Supports the 3 FRs):*

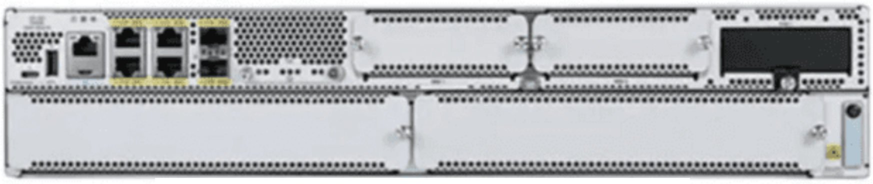

Figure 5
Cisco C8300-2N2S-4T2X
(Source: It-planet.com, 2025)

HOW?

An **enterprise-grade router** Cisco C8300-2N2S-4T2X (specifically designed for **enterprise-level LAN deployment** in environments like hospitals) is installed in the hospital's network control room and configured with:

LAN ports connected to core switches that serve RFID readers, Linux-based servers, and admin terminals. **WAN uplinks** that provide high-speed access to **AWS-hosted services** for web dashboards, EHR integration, and cloud-based alert processing. **Quality of Service (QoS) settings** to prioritize emergency traffic (e.g., SOS alerts) over regular data. **Redundant links** and **failover configurations** to ensure **24/7 availability** of tracking and alerting systems.

Application:

When a patient presses the SOS button, the LAN transmits the signal to the local Linux server. If the doctor's dashboard is running on a cloud-based web app, the router routes that alert through the hospital's firewall and out to AWS. The router (Cisco C8300-2N2S-4T2X) ensures that critical data leaves the hospital securely and reaches the right cloud endpoint with minimal latency.

Requirement	**How C8300-2N2S-4T2X Meets It**
LAN Support	4 embedded 1 Gbps LAN ports, plus NIMs for expansion, fully supports wired connections to RFID readers, servers, and admin stations.
Wi-Fi 6 Infrastructure Integration	Integrates seamlessly with Cisco Catalyst 9130AX APs for wired–wireless collaboration.
Cloud Connectivity	Dual 10G uplink ensures high-throughput, low-latency connection to AWS.

Real-time Emergency Alerts	High forwarding capacity (up to 19.7 Gbps) and QoS ensure real-time SOS alert processing.
Security Needs	Built-in firewall, VPN/IPsec, ACLs secure sensitive health data and emergency alerts.
Scalability	Expandable with SM/NIM slots—perfect for future growth (e.g., PoE LAN modules).
Reliability for Hospital Use	Rack-mountable, redundant power, and Cisco IOS XE ensure robust, 24/7 operation.

- **From where to buy?**

https://it-planet.com/en/p/cisco-c8300-2n2s-4t2x-409822.html?number=10011304000.1&gad_source=1&gad_campaignid=17413131060&gbraid=0AAAAAC89HVTShxcLDxJVyQtms5r0FW-pR&gclid=CjwKCAjw6ZTCBhBOEiwAqfwJd5wazQmPmm0AfjMKF7ZlTC63O5-I0x2mw6kLPDrDmK8vON6tC6xRyBoC54IQAvD_BwE

***For Doctors;* Example Model: "CenTrak Wi-Fi Badge Tags"**, which are lightweight, rechargeable, and support accurate real-time location tracking *(Supports FR 3 "Track Doctor location"& FR 2 "Trigger Patient Emergency Alert"):* (https://centrak.com/solutions/safety)

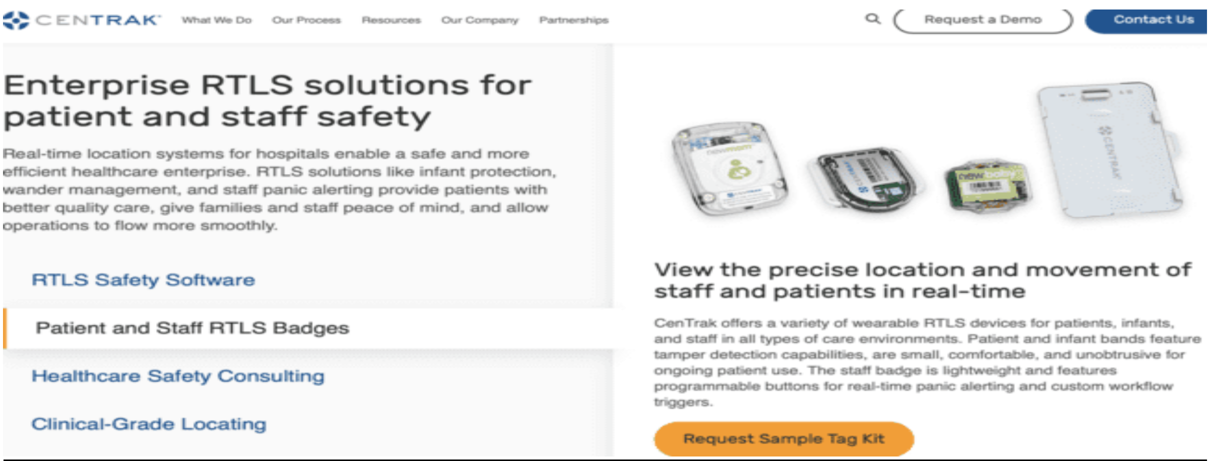

Figure 6
CenTrak Wi-Fi Badge Tags
(Source: CenTrak, 2021)

Features:

1. **Real-Time Location Tracking**
   - Designed for Wi-Fi-based RTLS systems.
   - Continuously emits location data picked up by strategically placed access points (APs) "Cisco Catalyst 9130AX Series", which were installed across the hospital at strategic locations.

2. **Rechargeable Battery**
   - Comes with long-lasting rechargeable batteries, reducing replacement costs and ensuring 24/7 uptime.

3. **Two-Way Communication**
   - Supports bidirectional signaling to receive and send updates, alerts, or acknowledgments, *we will use it in out project to receive alerts*.

4. **Status Indicators**
   - Built-in LED indicators (and sometimes audible alerts) to show status, alert acknowledgment, or battery notifications.

5. **High Location Accuracy**
   - Combines Wi-Fi triangulation with low-frequency signaling to provide room-level accuracy or better.
   - Helps identify precise doctor location during emergencies.

6. **Integration with EHR & RTLS Platforms**
   - Seamlessly integrates with hospital systems like Electronic Health Records (EHR) and dashboards for location and alert tracking.

7. **Network Compatibility**
   - Operates on **standard hospital Wi-Fi** (*like Wi-Fi 6 Cisco Catalyst 9130AX Series*).
   - No need for execlusive infrastructure, it leverages existing hospital networks.

8. **Lightweight and Wearable**
   - Designed to be worn as a badge, similar in size and comfort to a standard ID badge.
   - Includes a clip or lanyard attachment.

9. **Secure Communication**
   - Supports encrypted communication protocols, ensuring safe transmission of sensitive data like doctor locations.

- **<u>From where to buy?</u>**

https://centrak.com/resources/request-sample-kit

***For Patients;* "RFID-Enabled Wristbands"**, Model: **BLE Active RFID Wristband, SOS/Panic Button** *(For FR 1 "Track Patient Location" & FR 2 "Trigger Patient Emergency Alert"):*

(https://gaorfid.com/product/ble-2-45ghz-active-rfid-wristband-w-tamperproof/)

Figure 7

RFID Wristband
(Source: GAO RFID, 2025)

<u>WHY?</u>

The BLE Active RFID Wristband with SOS/Panic Button was chosen because it provides real-time location tracking, emergency alert functionality, long-range signal, and patient safety features, all in a durable, tamperproof, and comfortable design, perfectly suited for hospital use. As well as, offering patient-friendly design and reliable RFID scanning for medical records.

<u>Features:</u>

1. **Active RFID with BLE (Bluetooth Low Energy)**
   - Active RFID: Has its own power source (battery), allowing for continuous signal transmission over long distances (up to 100 meters).
   - BLE Technology: Operates on Bluetooth 4.0/5.0 chipset, making it compatible with modern hospital IoT systems and Wi-Fi infrastructure.
2. **SOS/Panic Button**
   - Critical for patient safety.
   - Allows patients to immediately send emergency alerts with a single press.
   - The system can instantly identify who, where, and when, and notify the nearest doctor based on

their location data.

3. **Tamperproof Design**
   - Prevents unauthorized removal.
   - Ensures that patients, especially children, elderly, or high-risk cases, stay under continuous monitoring.
4. **Durability & Comfort**
   - Waterproof (IP67 rating): Safe for use during daily hospital routines like bathing or cleaning.
   - Lightweight and compact (23g): Comfortable for extended wear without irritating the patient.
5. **Battery Life and Power Efficiency**
   - Powered by nRF52 chipset and a CR2032 battery.
   - Offers up to 16 months of battery life, minimizing maintenance or replacement costs.
6. **Compatibility and Integration**
   - Broadcasts in the 2.4–2.5 GHz range, making it compatible with:
     - → iBeacon
     - → Eddystone
     - → BLE-compatible readers and gateways
   - Integrates smoothly with the hospital's Wi-Fi network, RTLS, and EHR systems.
   - **From where to buy?**

     https://gaorfid.com/product/ble-2-45ghz-active-rfid-wristband-w-tamperproof/

→ ***Note:*** CenTrak Wi-Fi Badge Tags (Doctors) and BLE Active RFID Wristbands (Patients) have their *own internal antennas* for transmitting signals. These use active RFID technology, meaning they have onboard batteries and transmit signals proactively

For Scanners; Model: **HZ100 Long Reading Integrated RFID Reader** *(Supports the 3 FRs):* (https://www.hopelandrfid.com/product/integrated-rfid-reader/HZ100.html)

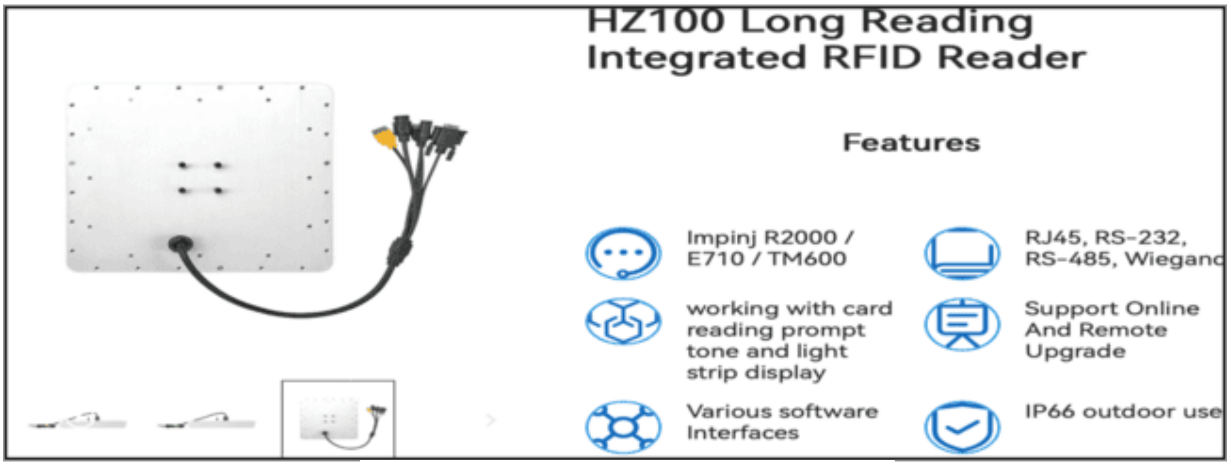

Figure 8
RFID Reader
(Source: *HZ100 Long reading integrated RFID reader, 2024*)

- **From where to buy?**
  https://www.hopelandrfid.com/product/integrated-rfid-reader/HZ100.html#pro4-d

Features:

1. **Long Reading Range**
   - Supports long-distance RFID reading, suitable for detecting active RFID wristbands and badges from up to several meters away. With Active RFID Tags (like BLE RFID wristbands used in our project): Modern RFID readers often boast a maximum range of **1500 feet (457.2 meters**) reading (*What is an RFID reader's maximum range?, 2024).*
   - Ensures coverage of large hospital rooms, corridors, or entry points without requiring dense reader placement.

2. **Dual RFID Support**
   - Compatible with both active and passive RFID technologies, increasing flexibility and allowing integration with multiple types of RFID tags (e.g., BLE wristbands, smart badges).

3. **Hospital IT System Integration**
   - Designed to interface seamlessly with hospital management systems, such as Electronic Health Record (EHR) platforms.
   - Uses standard communication protocols (like TCP/IP) to send data to the central system for location updates and alerts.

4. High-Performance Processing

- Built-in processing power ensures fast signal capture and real-time data transfer.
- Minimizes latency in detecting RFID signals from moving patients or doctors.

5. Network Connectivity

- Supports Ethernet or Wi-Fi communication for flexible installation (*in our project we will use Wi-Fi 6*).
- Enables integration with cloud-based or on-premise systems via middleware like Google Cloud IoT Core or LLRP.

6. Plug-and-Play Compatibility

- Simplified deployment in hospital environments.
- Works with standard APIs and libraries (like LLRP Toolkit) on Linux-based systems, (*which our project uses Linux-based*).

7. Robust and Industrial Design

- Built for reliable operation in healthcare environments where 24/7 performance and resistance to interference are essential.

To determine how many **HZ100 RFID readers** to install in a hospital; Modern RFID readers often boast a maximum range of **1500 feet (457.2 meters) (https://www.rfidjournal.com/ask-the-experts/what-is-an-rfid-readers-maximum-range/)**, significantly extending coverage for robust and continuous signal acquisition for precise indoor location data**,** so the recommended reader placement strategy, as per the following assumption, is as follows:

→ *Assumption:* for a **medium hospital** that has 4 floors, each with:

- 20 patient rooms per floor
- 1 OR suite, 1 ICU per floor
- Long corridors (~100–120 meters) per floor
- Staff/admin rooms, emergency zone

1. Corridors (100-120 meters long)

- A single reader can effectively cover multiple corridors or even the main corridors of an entire floor. One strategically placed reader per main corridor cluster would be sufficient for real-time tracking along the entire length.

Calculation: 1 reader per main corridor/floor x 4 floors = **4 readers**.1 corridor = 3 readers x 4 floors = 12 readers

2. **Patient Rooms**
   - With such a long range, a single reader can cover a significantly larger number of patient rooms, potentially an entire wing or a large section of a floor. For detailed room-level accuracy, we can still aim for a reasonable density, but far less than before. Assuming one reader can cover 5 rooms for better accuracy within the much larger range.

Calculation: (20 rooms per floor ÷ 5 rooms per reader) x 4 floors = **16 readers**

3. **Emergency Department**
   - While the range is vast, the need for high accuracy and triangulation in critical areas remains. Three strategic points are still beneficial for precise location determination, even if each reader's detection footprint is much larger and overlaps considerably.

Calculation: 3 readers (maintaining the triangulation setup for high accuracy).

4. **ICU + Operating Rooms (ORs)**
   - Given the critical nature and often contained environment of these units, a single reader per critical zone should provide ample and reliable coverage without the need for additional redundancy based purely on range.

Calculation: 1 reader per zone x 4 zones (2 ORs + 2 ICUs) = **4 readers**

5. **Nurse stations + Reception + Admin**
   - A single powerful reader can cover a large open area encompassing multiple administrative or nurse station zones on a floor.

Calculation: 1 reader per floor x 4 floors = **4 readers**.

6. **Entry/Exit Points + Elevators/Stairwells**
   - Readers can now cover multiple adjacent entry/exit points or vertical shafts (elevators, stairwells) across several floors. Strategic placement at main access points and centralized vertical pathways would be sufficient.

Calculation: 2 readers for main hospital entry/exit points (e.g., ground floor) + 2 readers for central elevator/stairwell banks (covering multiple floors vertically) = **4 readers**.

→ **Total Estimated Number of HZ100 Readers:**

Area	Readers
Corridors	4
Patient Rooms	16
Emergency Department	3
ICU + Operating Rooms	4
Nurse/Admin Stations	4
Entry/Exit/Elevators	4
Total	**35**

→ ***Note:*** HZ100 Long Reading Integrated RFID Readers, include *built-in antennas*, making them suitable for hospital-wide real-time tracking. These readers support long-range detection (up to 100 meters with active tags in in open, unobstructed environments) and are strategically placed around the hospital, such as in corridors, patient rooms, emergency departments, ICUs, and elevators.

→ *Here are some photos for a visual representation of how the RFID readers will be strategically placed throughout the hospital environment:*

Entry/Exit:

Corridor:

Patient Room:

Emergency Department:

ICU + Operating Rooms:

Nurse/Admin Stations:

Elevators:

→ ***How the Chosen RFID Meet Requirnments:***

1. **Real-Time Tracking of Doctors and Patients** *(Supports FR1 "Track Patient Location" & FR3 "Track Doctor Location"):*
   - Active RFID Tags (used in both wristbands and badges) have their own power source, enabling continuous signal transmission.
   - These tags can emit signals over long distances (up to 100 meters), which is ideal for real-time tracking within a hospital.

2. **Accurate Indoor Location *Detection*** *(Supports FR1 "Track Patient Location"& FR3 "Track Doctor Location"):*
   - The Wi-Fi-enabled RFID tags (e.g., CenTrak Wi-Fi Badge Tags), and RFID-Enabled Wristbands (e.g., BLE Active RFID Wristband, SOS/Panic Button) are compatible with the hospital's Wi-Fi 6 infrastructure.
   - They ensure precise location detection when combined with strategically installed Access Points (APs).

3. **Seamless Integration with EHR Systems** *(Supports FR1 "Track Patient Location"& FR3 "Track Doctor Location"):*

- RFID devices (both wristbands and badges) are linked to digital patient and doctor profiles within the Electronic Health Record (EHR).

4. **Emergency Response Support** *(Supports FR1 "Track Patient Location"& FR2 "Trigger Patient Emergency Alert "& FR3 "Track Doctor Location")***:**
    - The RFID wristbands for patients include an SOS/Panic Button, allowing patients to send immediate alerts during emergencies.
    - The system uses RFID location data to identify and notify the nearest doctor via their badge data.

5. **Data Reliability and Safety** *(Supports FR1"Track Patient Location")***:**
    - Tamperproof Design of wristbands ensures patients remain continuously monitored.

- **The Role of the Cloud:**

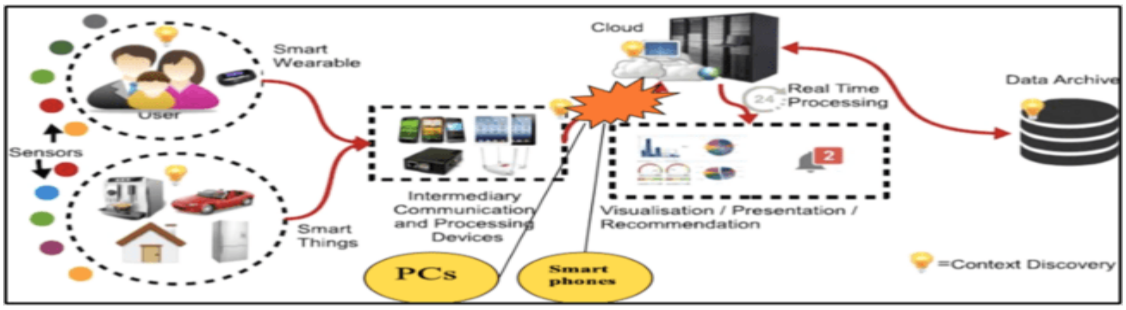

Figure 9
3 Tier Architecture
(Source: *The Moodle, E-Learning*)

<u>Diagram Illustration:</u>

Tier 1:

This layer involves the RFID wristbands and badge tags worn by patients and doctors (smart wearable devices). These smart wearable devices constantly track movement and status. They function alongside sensors and antennas located across the hospital to collect real-time data.

- **<u>Components:</u>**
    - BLE RFID Wristbands (with SOS button)
    - CenTrak Wi-Fi Badge Tags
    - Antennas (within the badges and wristbands)

Tier 2:

This is the intermediary communication layer, where all collected data is transmitted via the hospital's secure Wi-Fi network (Cisco Catalyst 9130AX). The data is processed through LLRP protocol and forwarded to the Linux-based server for real-time interpretation.

- **Components:**
  - Cisco Wi-Fi Infrastructure
  - LLRP Protocol
  - Smart devices (mobile phones, PCs) for hospital doctors and patients

Tier 3:

The processed data is uploaded to the AWS Cloud, where the Web Application presents real-time dashboards and notifications for tracking and emergency management (the 3rd tier act as both the application and database server). In the above diagram it stores information in a data archive (which our system does not do).

- **Components:**
  - AWS Cloud Platform
  - Linux Server
  - Web Application

Doctor-Patient Smart Tracking System – IT Infrastructure Architecture:

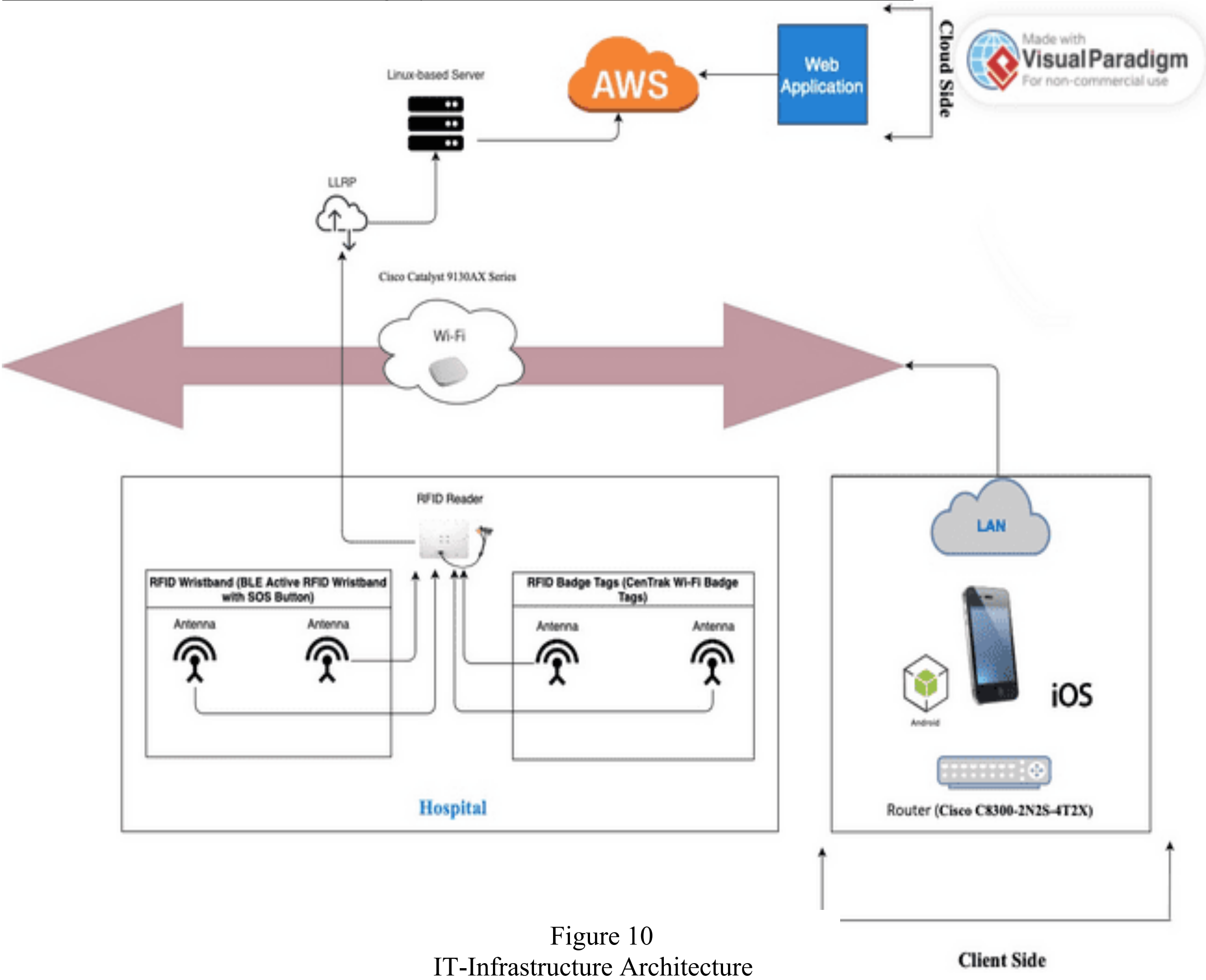

Figure 10
IT-Infrastructure Architecture
(Source: Developed by the Students)

→ ***Architecture Illustration:***

The IT infrastructure architecture of the Doctor-Patient Smart Tracking System integrates advanced technologies to ensure real-time tracking, emergency responsiveness, and secure data flow between hospital systems and the cloud. At the core, RFID wristbands (with SOS buttons) worn by patients and CenTrak Wi-Fi badge tags worn by doctors continuously transmit location signals, which are captured by RFID readers and antennas strategically installed throughout the hospital. These signals are processed through the Low-Level Reader Protocol (LLRP) and transmitted over a high-performance Wi-Fi 6 network supported by Cisco Catalyst 9130AX Series access points. The system's central router, the Cisco Catalyst C8300-2N2S-4T2X, serves as the backbone of the network—providing high-speed LAN connectivity for RFID readers, Linux-based servers, while also ensuring secure cloud communication with AWS. The LAN infrastructure offers low-latency wired connections to fixed-position systems, while mobile dashboards and alerts are accessible through iOS and Android devices connected via Wi-Fi. This hybrid infrastructure ensures continuous monitoring, instant alerting, and seamless data synchronization between client-side operations and cloud-hosted web applications, creating a scalable, secure, and efficient digital healthcare environment.

→ ***Traceability of IT Infrastructure with the Functional Requirements:***

IT Infrastructure	**Which FR does it supports**
Wi-Fi (Cisco Catalyst 9130AX Series)	**Supports FR1 (Track Patient Location):** These access points detect signals from patient wristbands to provide real-time location data for patients within the hospital. **Supports FR2 (Trigger Patient Emergency Alert):** Wi-Fi facilitates the transmission of emergency alerts from patient wristbands. **Supports FR3 (Track Doctor Location):** It detects signals from doctor badges to provide real-time location data for doctors.
Router (Cisco C8300-2N2S-4T2X)	**Supports FR1 (Track Patient Location):** Serves as the network backbone, ensuring stable data flow for all location tracking information, including patient movements. **Supports FR2 (Trigger Patient Emergency Alert):** Prioritizes and routes emergency alert data (e.g., SOS button presses) from the hospital network to cloud services and doctor dashboards with minimal latency. **Supports FR3 (Track Doctor Location):** Ensures high-speed connectivity for real-time doctor location data and the delivery of patient emergency notifications to doctors.

CenTrak Wi-Fi Badge Tags (For Doctors)	**Supports FR2 (Trigger Patient Emergency Alert):** These badges enable doctors to receive real-time notifications about patient emergencies, facilitating quick response. **Supports FR3 (Track Doctor Location):** Continuously emit location data, allowing the system to accurately track doctors' positions within the hospital.
BLE Active RFID Wristband, SOS/Panic Button (For Patients)	**Supports FR1 (Track Patient Location):** Provides continuous, real-time location tracking for patients and features a tamper-proof design for constant monitoring. **Supports FR2 (Trigger Patient Emergency Alert):** Features an SOS/Panic button that allows patients to send immediate emergency alerts, identifying their location and notifying the nearest doctor.
HZ100 Long Reading Integrated RFID Reader (For Scanners)	**Supports FR1 (Track Patient Location):** Detects signals from patient wristbands across long ranges (up to 100 meters) to capture and transmit their location data. **Supports FR2 (Trigger Patient Emergency Alert):** Captures the emergency signals transmitted by patient wristbands and forwards them to the central system. **Supports FR3 (Track Doctor Location**): Detects signals from doctor badges, enabling the system to track doctors' locations in real-time.

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4 Business Processes

4.1 Data Flow Diagram (DFD):

According to (Bentley et al., 2000), Data Flow Diagram (DFD) is a graphical representation of the flow of the data within a system, it visually maps out the processes, data stores, data flows and external entities interacting with the system, and how information passes through the system.

» ***DFD Symbols:***

» ***Processes:*** Represent operations or actions performed on data.

» ***Data Flows:*** Indicate the movement of data between entities, processes, or data stores.

» ***External Entities:*** Represent sources or destinations of data outside the system.

» ***Data Stores:*** Represents a physical data store in the system.

4.1.1 Data Flow Diagram (DFD) Context Level:

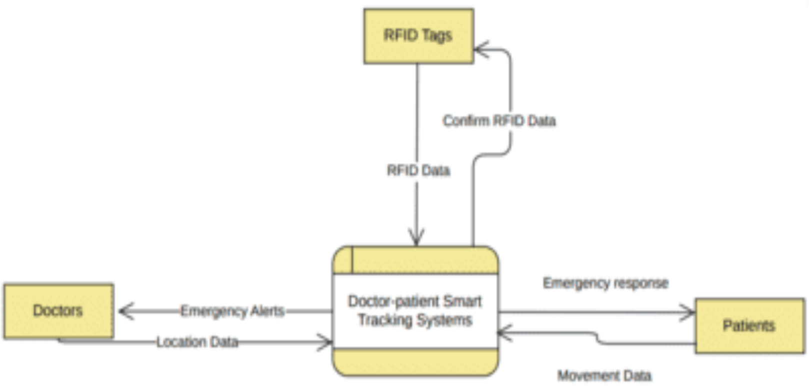

Figure 11
DFD Context Level
(Source: Developed by the Students)

4.1.2 Documentation of the Data Flow Digaram (DFD) Context Level:

Process ID	0
Title	Doctor-Patient Smart Tracking System
Description	The system monitors and tracks the real-time movement of doctors and patients using RFID tags and sensors, ensuring safety, availability, and emergency management. It facilitates data flow between hospitals, doctors, patients, RFID systems, sensors, system administrators, and regulatory bodies.

Entity	Doctors
Data Flow	• Location Data → Doctor-Patient Smart Tracking System • Emergency Alerts ← Doctor-Patient Smart Tracking System

Entity	Patients
Data Flow	• Movement Data → Doctor-Patient Smart Tracking System • Emergency response ← Doctor-Patient Smart Tracking System

Entity	RFID Tags
Data Flow	• RFID Data → Doctor-Patient Smart Tracking System • Confirm RFID Data ← Doctor-Patient Smart Tracking System

4.1.3 Data Flow Diagram (DFD) Level 0:

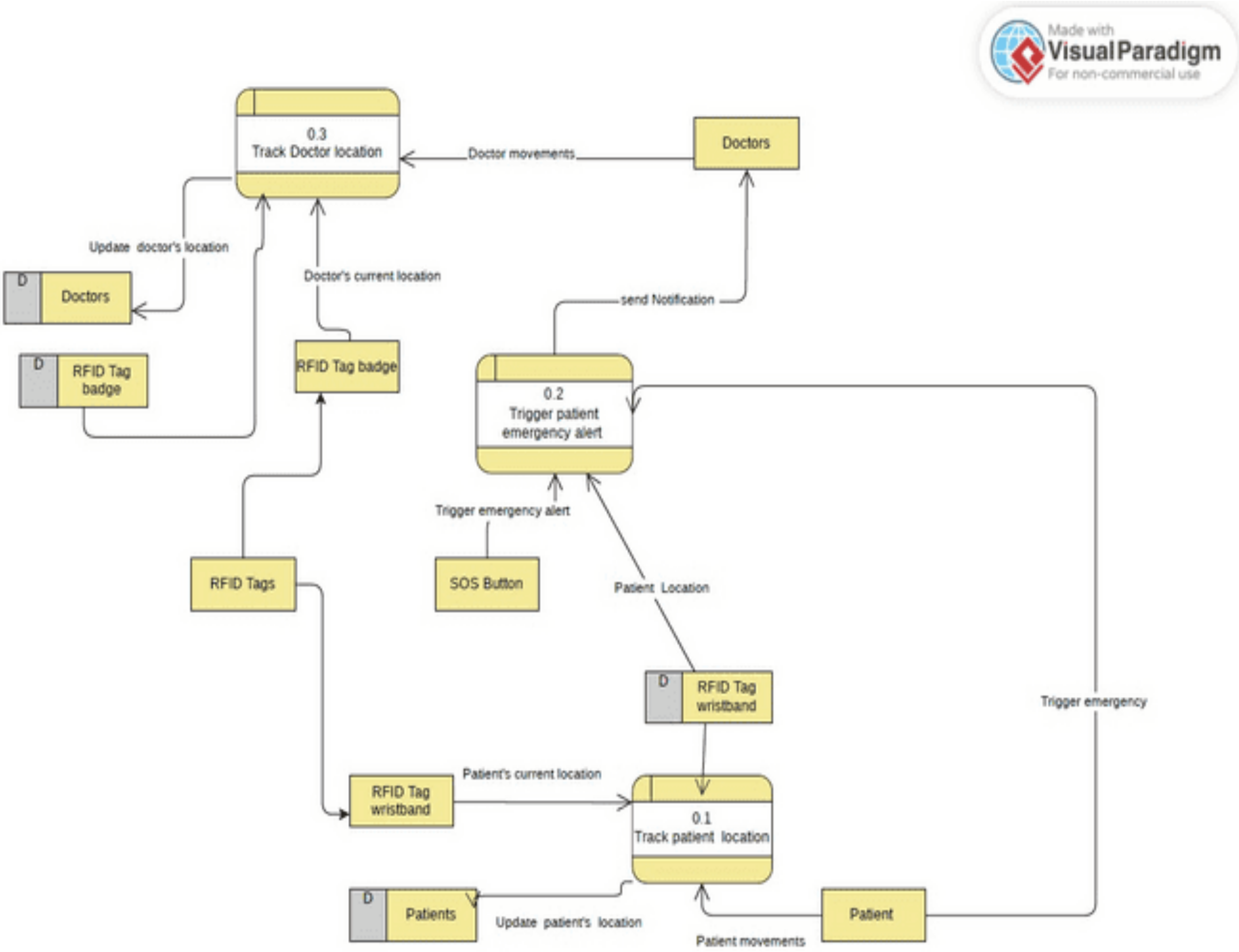

Figure 12
DFD Level 0
(Source: Developed by the Students)

4.1.4 Documentation of the Data Flow Diagram (DFD) Level 0:

» ***Processes:***

Process ID	0.1
Title	Tracking Patients' Locations
Description	Uses RFID tag wristbands to track patients' real-time locations, aiding in managing their presence and ensuring timely medical assistance.

Process ID	0.2
Title	Trigger patient emergency alert
Description	Patients use SOS button where it is an easy way to trigger an emergency alert. As it provides wearable devices or bedside buttons for patients to call for help. Ensure the button is accessible to patients with limited mobility. Include a confirmation mechanism to prevent false alarms.

Process ID	0.3
Title	Tracking Doctors' Locations
Description	Monitors the real-time location of doctors within the hospital using RFID tag badges to ensure efficient allocation of resources and tracking of movements.

» ***External Entities:***

Title	Doctors
Description	Refers to the medical staff whose movements and availability are tracked using RFID tags.

Title	Patients
Description	Refers to individuals receiving medical care, tracked using RFID wristbands for real-time location updates.

Title	RFID Tag Badge
Description	A badge used to track doctors' location in the hospital.

Title	RFID Tag Wristband
Description	A wristband used to track patients' location in the hospital.

Title	SOS Button
Description	A sensor used to trigger an emergency alert. As it provides wearable devices or bedside buttons for patients to call for help

» ***Data Store:***

Title	RFID Tag Badge
Description	A badge used by doctors to update their Locations.

Title	RFID Tag Wristband
Description	A wristband used by patients to track their location.

Title	Doctors
Description	Includes doctors' info (name, ID, contact info, speciality, availability status)

Title	Patients
Description	Includes patients' info (name, ID, contact info, history, medical condition)

4.2 Entity Relationship Diagram (ERD):

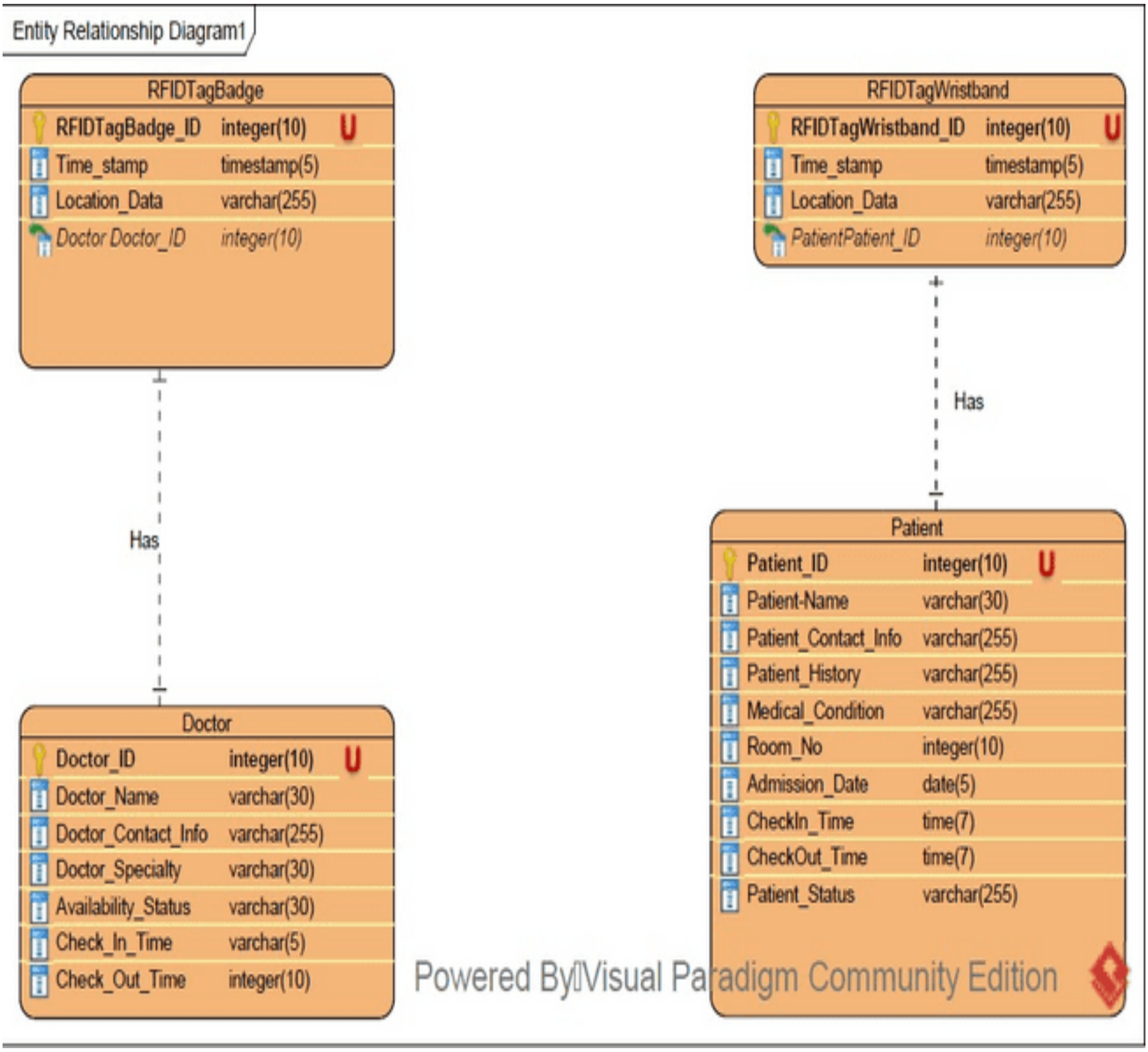

Figure 13
ERD
(Source: Developed by the Students)

4.2.1 Documentation of the Entity Relationship Diagram:

1- Doctor
Foreign Key: RFIDTagBadgeID
Primary Key: Doctor_ID
Attributies: Doctor_ID, Doctor_Name, Doctor_Contact_Info, Doctor_Specialty, RFIDTagBadge_ID
Relations: • **Doctor & RFID Tag Badge**: *One to One Relationship*: Each doctor is assigned only one RFID tag badge, and each RFID tag badge is linked to only one doctor.

2- RFID Tag Badge
Foreign Key:
Primary Key: RFIDTagBadge_ID
Attributies: RFIDTagBadge_ID, Time_stamp, Location_Data
Relations: • RFID Tag Badge & Doctor: *One to One Relationship*: Each RFID tag badge is linked to one doctor, and each doctor has only one RFID tag badge.

3- Patient
Foreign Key: RFIDTagWristband_ID
Primary Key: Patient_ID
Attributies: Patient_ID, Patient_Name, Patient_Contact_Info, Patient_History, Medical_Condition, Room_No, Admission_Date, CheckIn_Time, CheckOut_Time, Patient_Status, RFIDTagWristbandID
Relations: • Patient & RFID Tag Wristband: *One to One Relationship*: Each patient is assigned one RFID wristband, and each wristband is linked to only one patient.

4- RFID Tag Wristband
Foreign Key:
Primary Key: RFIDTagWristbandID
Attributies: RFIDTagWristbandID, Timestamp, LocationData
Relations: • RFID Tag Wristband & Patient: *One to One Relationship*: Each RFID tag wristband is assigned to one patient, and each patient has only one RFID wristband.

- **References :**

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5 The System Services

5.1 The OOAD Steps and Role of the UML Modeling:

Object-Oriented Analysis and Design (OOAD) is a structured methodology used in software engineering that focuses on analyzing and designing systems through object-oriented principles such as encapsulation and inheritance (Booch et al., 1990). The main objective of OOAD is to develop systems that are modular, maintainable, and scalable by modeling real-world entities as objects that integrate both data (attributes) and behavior (methods). The phases of OOAD include Object-Oriented Analysis (OOA), Object-Oriented Design (OOD), and Object-Oriented Programming (OOP). The analysis phase (OOA) focuses on understanding the problem domain by identifying system requirements, key objects, and actors involved. This phase produces a conceptual model that reflects the system's real-world components and interactions. The design phase (OOD) refines this conceptual model, defining the architecture, classes, and object interactions, thereby providing a blueprint for implementation. Finally, the programming phase (OOP) involves translating the design into actual code using object-oriented languages like Java, Python, or C++.

UML is an integral part of OOAD, guiding developers through each phase by providing the necessary tools to model, design, and implement object-oriented systems. Its ability to represent both high-level requirements and detailed designs makes it indispensable for successful software development. UML offers a diverse set of diagrams such as use case diagrams, which model the system's functionality by illustrating how external actors (such as users or devices) interact with the system to achieve goals, making them essential for capturing high-level requirements.

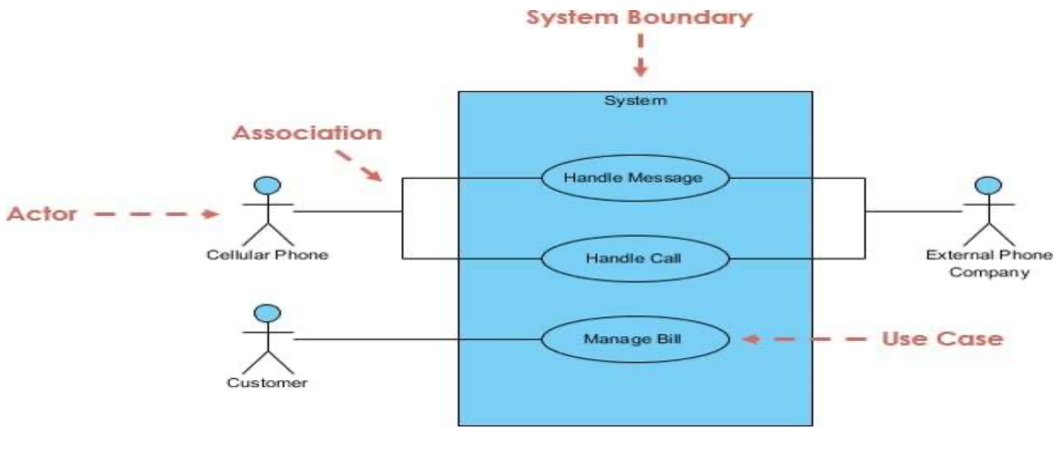


Figure 14
Use Case
(Source: *What is Use Case Diagram?, 2024*)

Class diagrams provide a static view of the system by representing classes, attributes, methods, and relationships (like associations or inheritance), defining the building blocks of the system.

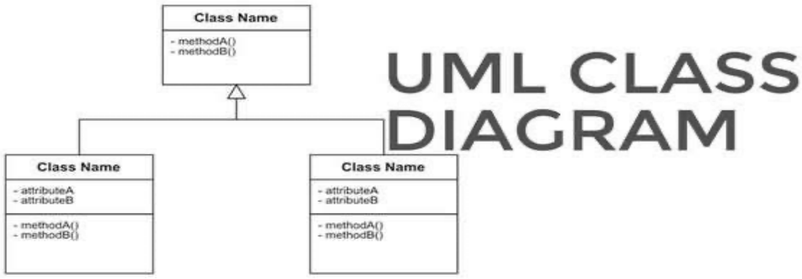


Figure 15
UML Diagram
(Source: *Intro to UML 2.5 diagram types and templates, 2021*)

Sequence diagrams focus on object interactions over time, detailing how objects communicate through message exchanges, making them useful for modeling specific scenarios such as login processes or data retrieval.

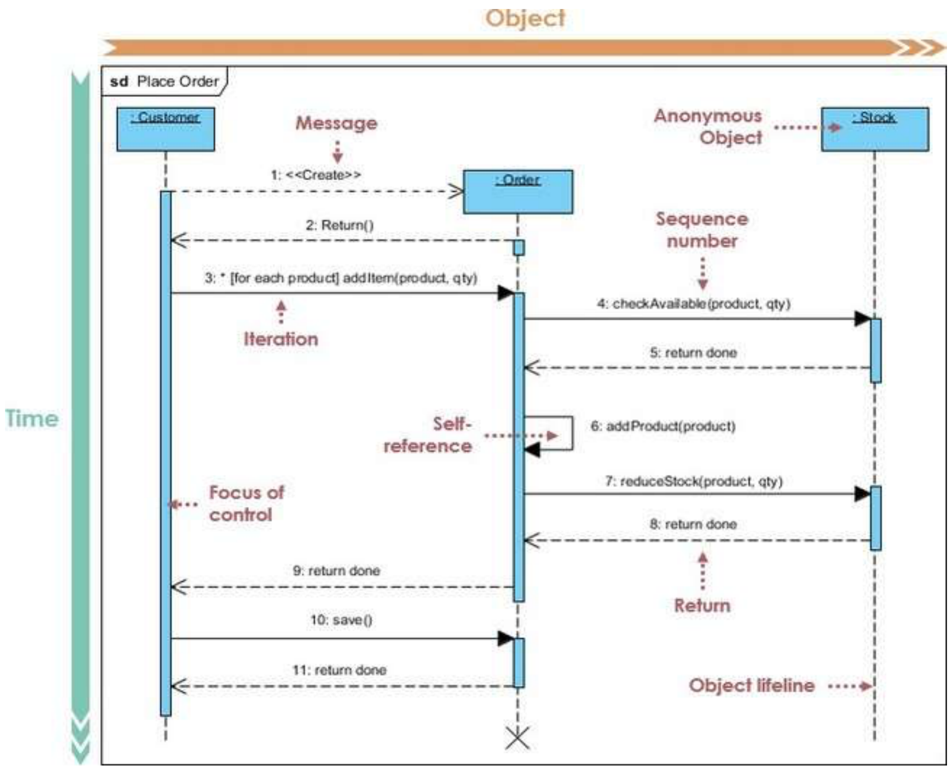
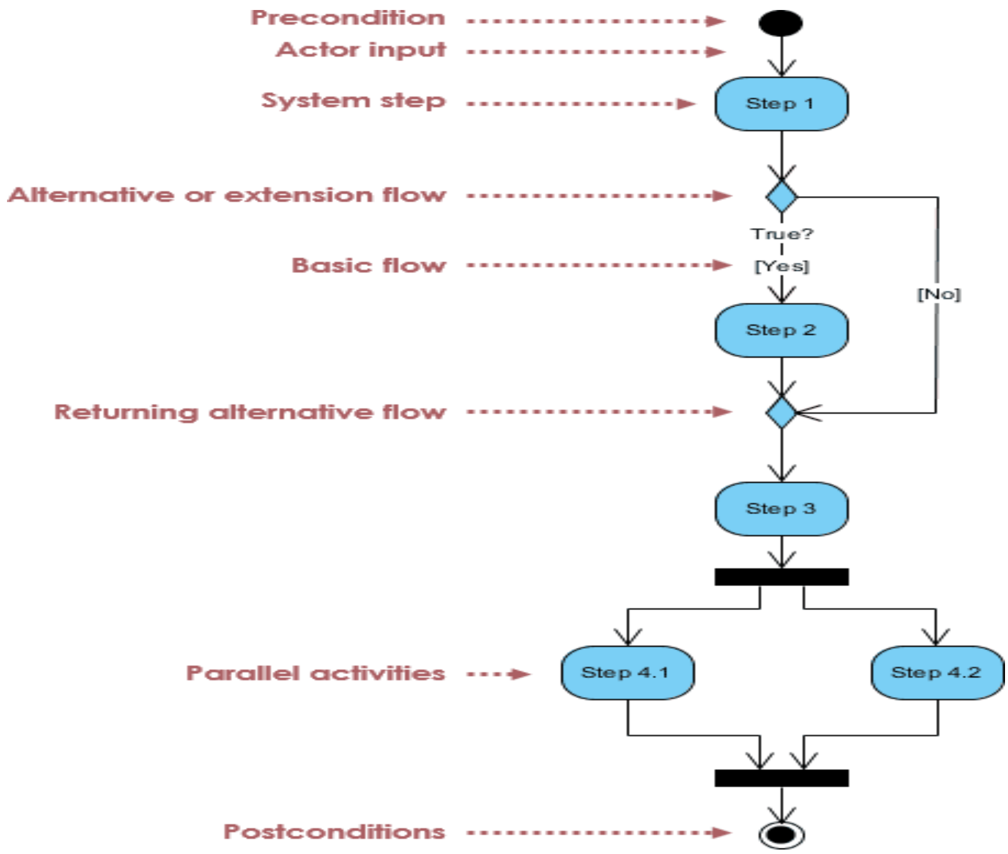


Figure 16
Sequence Diagram
(Source: *Understanding sequence diagrams, 2023*)

Activity diagrams represents the flow of control and decision points within processes, visualizing workflows or algorithms in a step-by-step manner. Together, these diagrams enhance clarity, communication, and system architecture, ensuring consistency across all phases of development (Object Management Group [OMG], 2022).



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5.2 Use-Case Model:

5.2.1 Fareeda Mohamed – 225163:

Use-Case for Track Patient Location Microservice & Documantation

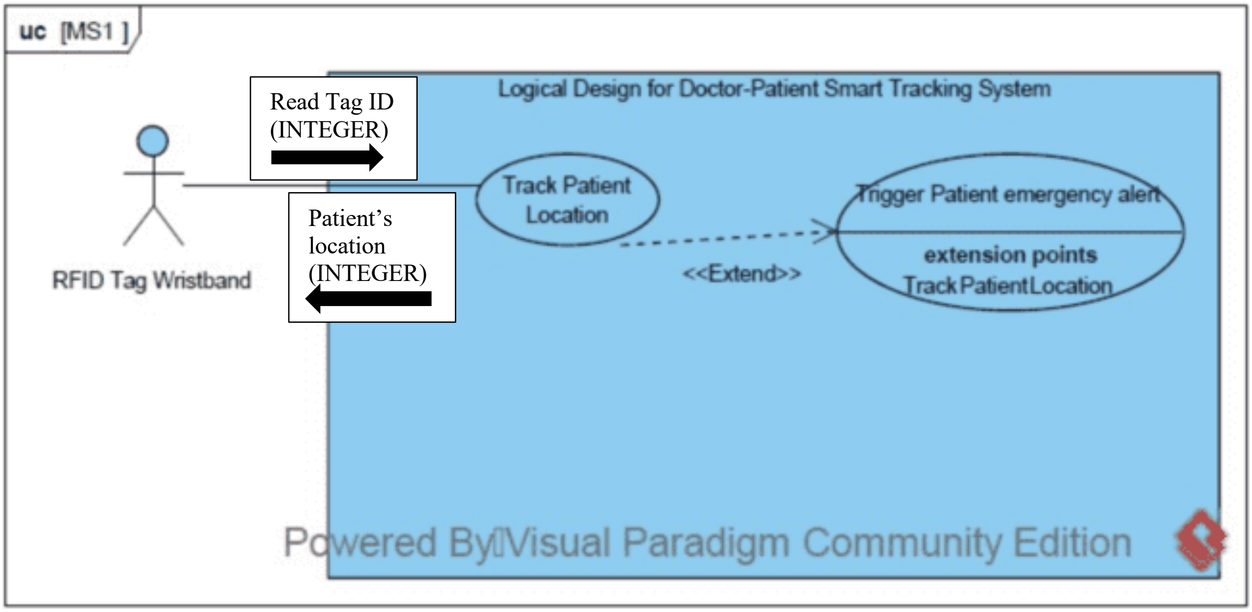


Figure 18
Use-Case Model
(Source: Developed by the Students)

→ ***Detailed Scenario:***

Use Case Name	Track Patient Location
Actor(s)	RFID Tag Wristband
Type	Primary
Cross Reference	Track Patient Location Microservice (Microservice 1)
Data Type	Read Tag ID (Integer) Patient's Location (Integer)
Brief Description	The use case enables real-time tracking of patients using RFID Tag Wristbands (actor), to monitor movements and ensure safety, also the patient **could** trigger an emergency alert (extend use case). The system continuously updates the patient's location.
Flow of Events	**Basic Flow:** The use case begins when a **patient** (will be a class) is equipped with an **RFID Tag Wristband** (will be a class), to allow **Real-time Tracking** (will be a class).

	1. The RFID Tag Wristband relays **Tag ID**, **Timestamp**, and **Location Data** (will be attributes) to the system, to be able to **read the tag** as well as **getting the location** and continuously **updating the new location** (will be operations). 2. The Patient should have his/her **ID**, and **Name** (will be attributes), so when the patient wants to **view profile** (will be operation) it will contain all the patient's data (e.g. name, ID, his/her current location), also the patient should be able to **press button** (will be operation), this button is the SOS button in the RFID Wristband, which triggers the emergency alert in case of danger/require immediate assistant. 3. The system continuously updates the patient's **real-time movements** (attribute), to efficiently **track the patient's location** (will be operation). **Alternative Flows:** • **RFID Connection Failure:** If the RFID connection is lost or data mapping is incorrect, the system displays an error message. The system operator can choose to restart tracking or escalate to technical support, at which point the use case ends. • **Invalid or Missing Tag Data:** If the system receives invalid or incomplete RFID tag data, it prompts the system operator to revalidate or reassign the wristband. The operator can either provide corrected data or cancel tracking, ending the use case.
Special Requirements	The RFID Tag Wristband **must** be active and properly linked to a valid patient record.
Pre-Conditions	– The system **must** have access to real-time tracking sensor data. – Patients **must** be equipped with functioning RFID Tag Wristbands.
Post-Conditions	The system continuously updates the patient's real-time location for monitoring purposes during the session. No historical movement data is stored after the session ends (The active time period during which the patient is wearing the RFID Tag Wristband and the system is connected and tracking).
Extension Points	None.

5.2.2 Ahmed Mustafa – 223269:

Use-Case for for Trigger Patient Emergency Alert Microservice & Documantation

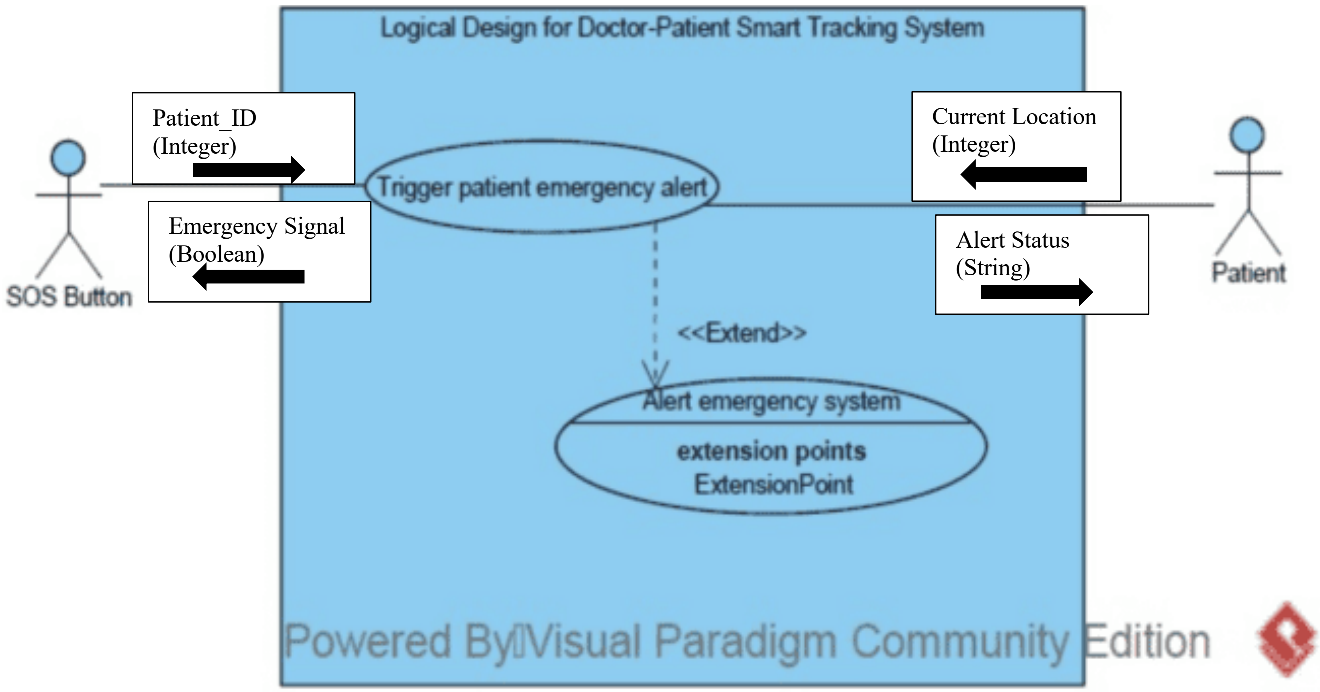


Figure 19
Use-Case Model
(Source: Developed by the Students)

→ ***Detailed Scenario:***

Use Case Name	Trigger Patient Emergency Alert
Actor(s)	SOS Button, Patient.
Type	Primary
Cross Reference	Relies on the emergency alert that will be triggered from **FR1**.
Data Type	Patient ID (Integer) Emergency Signal (Boolean) Current Location (Integer) Alert Status (String)
Brief Description	This use case allows **patients** (actor) to manually trigger an emergency alert through the **SOS Button** (actor), which is embedded in their BLE RFID Wristband. Once triggered,

	the system detects the patient's location and identifies the nearest available doctor to respond. This ensures rapid response and enhances patient safety in critical conditions.
Flow of Events	**Basic Flow:** 1. The **Patient** (will be a class) presses their **SOS Button** (will be a class), which is embedded in their **RFID Wristband** (will be a class), to **Request Emergency Assistance** (will be an operation), using their **PatientID, Name, and Status** (will be attributes). 2. This triggers the SOS Button to execute its internal **Press Button** (will be an operation), followed by activating the **Trigger Patient Emergency Alert** operation (will be an operation). 3. The SOS Button sets **Emergency Signal** (will be a Boolean attribute) to true and updates its **Status** and **Button ID** (will be attributes) then sends the alerts to the **emergency alert** (will be a class) in the hospital. 4. The RFID Wristband **Transmits the location** (will be operation) of patients in real time including **LocationData, WristbandID, and Timestamp** (will be attributes) to the emergency alert. 5. The Emergency Alert receive the alert and uses its **Alert ID, Timestamps and Alert Status** (will be attributes) to process the emergency signal to **Find the Nearest Doctor** (will be an operation) for immediate response. **Alternative Flows:** If the SOS Button fails to respond or the press is not recognized due to device malfunction, the system will display an error or retry again. If the issue persists, the alert process is terminated, and technical support is notified.
Special Requirements	The system must be connected to real-time tracking infrastructure.
Pre-Conditions	patients must wear RFID wristbands with a built-in SOS button.
Post-Conditions	Once an alert is triggered, the patient receives immediate medical care.
Extension Points	None.

5.2.3 Merola Victor – 224329:

Use-Case for Track Doctor Location Microservice & Documantation

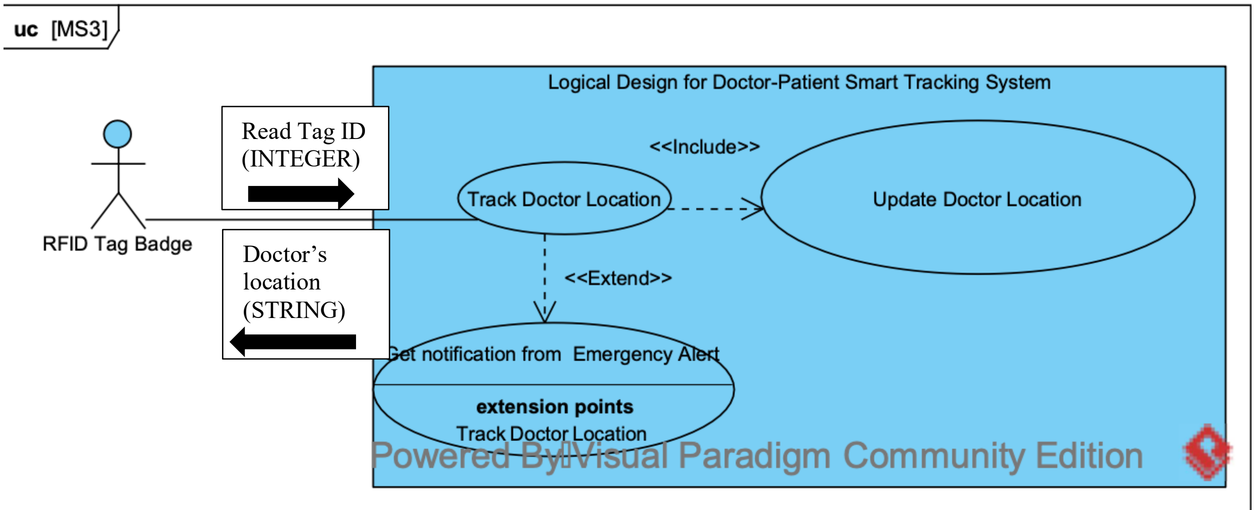


Figure 20
Use-Case Model
(Source: Developed by the Students)

→ ***Detailed Scenario:***

Use-Case Name	Track Doctor Location
Actor(s)	RFID Tag Badge
Type	Primary
Cross Reference	Relies on the emergency alert coming from **FR2**, that will be carrying the patient's location (e.g., floor number, room number). This will not always occur.
Data Type	Read Tag ID (INTEGER) Doctor's location (STRING)
Brief Description	The use case permits the real-time tracking location of doctors by utilizing the RFID Tag badge (as an actor), to track the movements of the doctors as if there any emergency occurs the doctor's location should be known. The system regularly updates the doctor's location.
Flow of events	**Basic flows:** The use case starts when the doctor (as a class) is wearing RFID Tag badge (as a class) to track doctor's location. 1. Once the doctor logs into the system, the system sync his/her Name,ID, activity status

	(attributes). 2. As well as the doctor wear the RFID Tag Badge, it sends Tag ID, Timestamp and Doctor's current location (as an attributes) to the system. To read the Tag (as an operation) and get doctor's location (as an operation). 3. The RFID Tag track doctor's location (as an operation) regularly. 4. RFID Tags within the hospital transmit location data (as an operation). 5. The Doctor location tracking (as a class) update doctor's location (as an operation) continuously. As the locationID and TimeStamp (as an attributes). 6. Alerts are generated for specific conditions (e.g., emergency response). where the doctors get a notification from emergency alert (as an operation). 7. Logs are updated with movement details for future analysis. **Alternative flows:** If loss of connectivity, incorrect data synchronization, or device unavailability occurs: **1. The administrators should do Local Caching by** Store location updates locally and sync when connectivity is restored. **2.Fallback to Last Known Location through** displaying the last recorded position with a Timestamp. **3.Battery Optimization Alerts**: Notify doctors when battery is low. **4.Manual Override**: Allow staff to manually update a doctor's location (e.g., room number 401, floor number 3) **5. Backup Servers**: Use cloud + on-premises sync to prevent total system failure.
Special Requirements	The RFID Tag Badge must be active and properly working.
Pre-Conditions	– The system must have access to real-time - RFID data. – Doctors must enable location tracking on their devices.
Post-Conditions	– The doctor's movement data is recorded and utilized for operational and emergency planning.
Extension Point	None

6 Class Diagram

6.1 Fareeda Mohamed – 225163:

Class-Diagram for Track Patient Location Microservice & Documantation

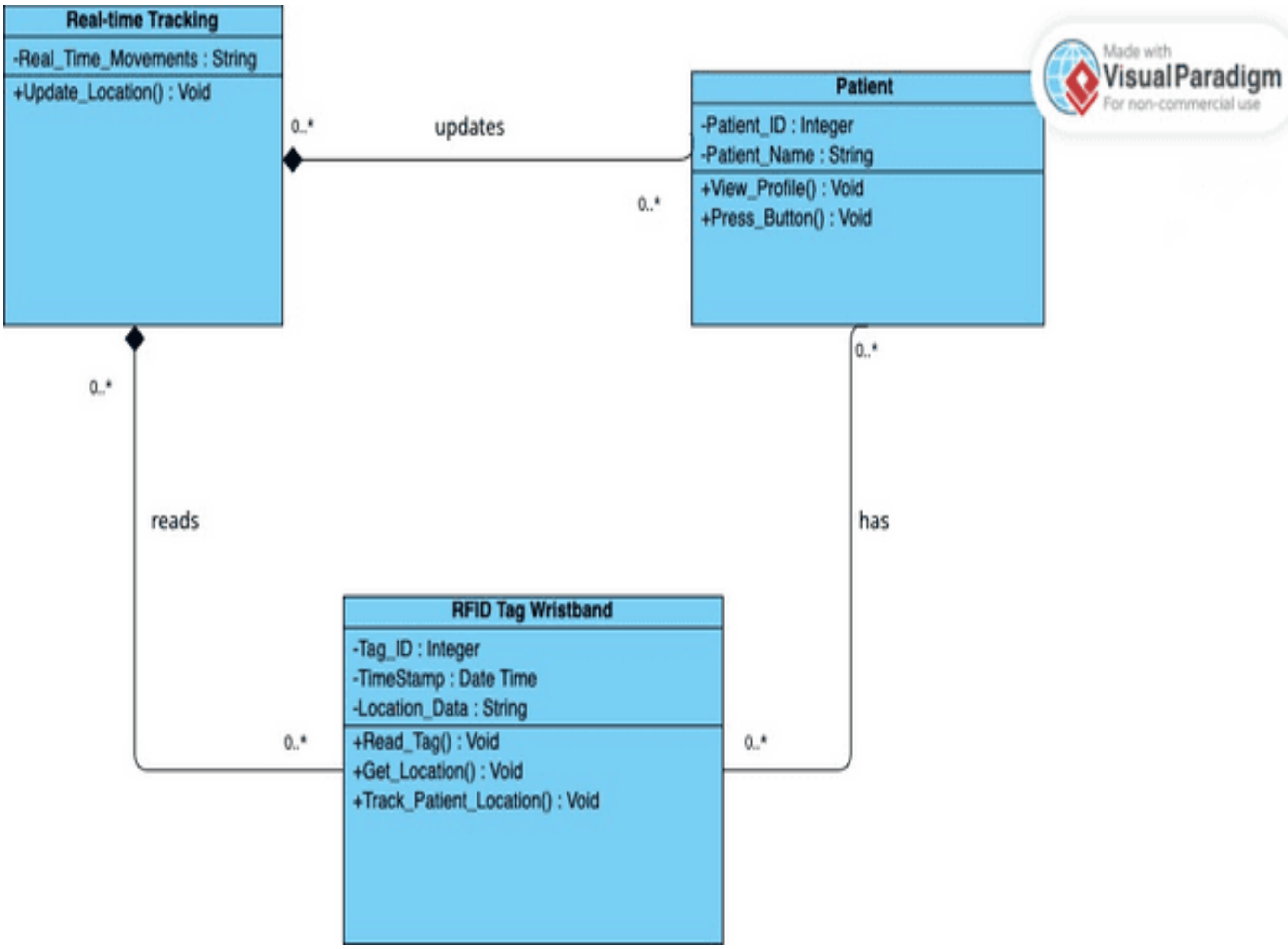


Figure 21
Class-Diagram
(Source: Developed by the Students)

Class: Patient	
Attributes	
Patient_ID (Primary Key)	Each patient must have a unique identification number within the system.
Patient_Name	The full name of the patient registered in the hospital.
Associations	
Patient and RFID Tag Wristband	None or many patients can have none or many RFID Tag Wristbands, and none or many RFID Tag Wristbands can be worn by none or many patients.
Patient and Real-time Tracking	None or many patients location can be updated by none or many Real-time Tracking(s), and none or many Real-time Tracking(s) can track none or many patient.
Operations	
View_Profile	Views the patient's profile (e.g. the patient's name and ID, the patient's current location).
Press_Button	The patient presses the button which triggers the emergency alert, in case of danger/require immediate assistant.

Class: RFID Tag Wristband	
Attributes	
Tag_ID (Primary Key)	Unique identifier for the RFID wristband tag.
TimeStamp	Includes the date and time of the last location update or tag read.
Location_Data	Views the location information associated with the tag.
Associations	
RFID Tag Wristband and Patient	None or many RFID Tag Wristbands belongs none or many patients, and none or many patients can have none

	or many RFID Tag Wristbands.
RFID Tag Wristband and Real-time Tracking	None or many RFID Tag Wristbands can provide location data to none or many Real-time Tracking(s), and none or many Real-time Tracking(s) can be updated through none or many RFID Tag Wristbands.
Operations	
Read_Tag	Reads the tag ID to identify the wristband.
Get_Location	Retrieves the current location data from the wristband.
Track_Patient_Location	Initiates tracking of the patient's current location using RFID Tag Wristband and updates the patient's location accordingly.

Class: Real-time Tracking	
Attributes	
Real_Time_Movements	Represents the data of the patient’s real-time movement location that is being updated overtime from the RFID Tag Wristband class.
Associations	
Real-time Tracking and Patient	None or many Ral-time Tracking(s) can update the location of none or many patients, and none or many patients location can be updated by none or many Real-time Tracking(s).
Real-time Tracking and RFID Tag Wristband	None or many Real-time Tracking(s) reads data from none or many RFID Tag Wristbands to monitor real-time movements.
Operations	
Update_Location	Continuously updating the patient’s location (via RFID Tag Wristband).

6.2 Ahmed Mustafa – 223269:

Class-Diagram for Trigger Patient Emergency Alert Microservices & Documentation

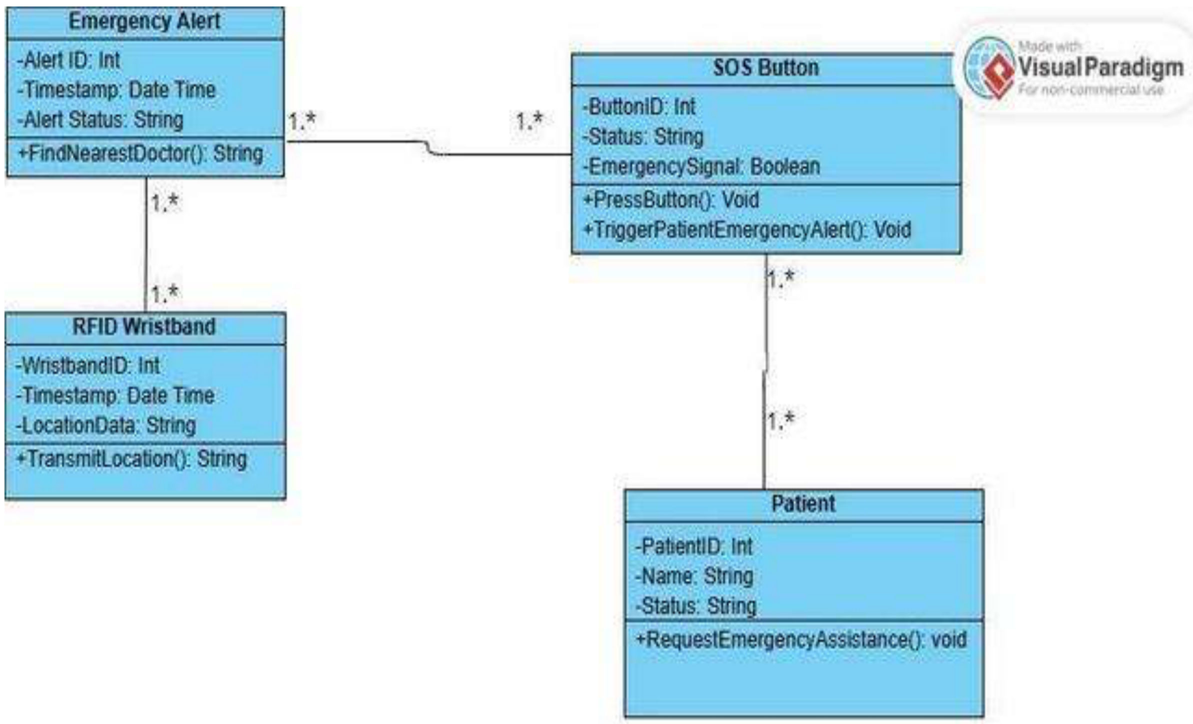


Figure 22
Class-Diagram
(Source: Developed by the Students)

Class: Emergency Alert	
Attributes	
Alert ID (Primary Key)	Unique identifier for the emergency alert
Timestamp	Time and date when the alert was triggered.
Alert Status	Current status of the emergency (e.g., “Active”, “Resolved”).
Associations	
Emergency Alert and SOS Button	An emergency alert is triggered by one or more SOS button presses.
Emergency Alert and RFID Wristband	An alert uses location data from one or more wristbands.
Operations	
Find Nearest Doctor	Identifies and returns the nearest available doctor for the emergency.

Class: SOS Button	
Attributes	
Button ID (Primary Key)	Unique identifier assigned to the SOS button.
Status	Represents whether the button is active or inactive.
Emergency Signal	Indicates if an emergency signal is currently being sent.
Associations	
SOS Button and Patient	Each button is assigned to one patient.
SOS Button and Emergency Alert	Each SOS button can trigger multiple emergency alerts.
Operations	
Press Button	Activates the emergency button manually.
Trigger Patient Emergency Alert	Sends Patients alert to initiate the emergency alert process.

Class: Patient	
Attributes	
Patient ID (Primary Key)	Each patient must have a unique identification number within the system.
Name	The full name of the patient registered in the hospital.
Status	Indicates the current condition of the patient.
Associations	
Patient and SOS Button	Each patient can be linked to multiple SOS buttons, and each SOS button can also be shared by multiple patients.
Operations	
Request Emergency Assistance	The patient Initiates an emergency call by interacting with the SOS button.

Class: RFID Wristband	
Attributes	
Wristband ID (Primary Key)	Unique identifier assigned to each RFID wristband.
Timestamp	Includes the time when the wristband last transmitted its location.
Location Data	Data representing the current location of the wristband.
Associations	
RFID Wristband and Emergency Alert	Each emergency alert uses one wristband to obtain the patient’s location.
Operations	
Transmit Location	Sends the wristband's current location data to the system.

6.3 Merola Victor – 224329:

Class-Diagram for Track Doctor Location Microservice & Documantation

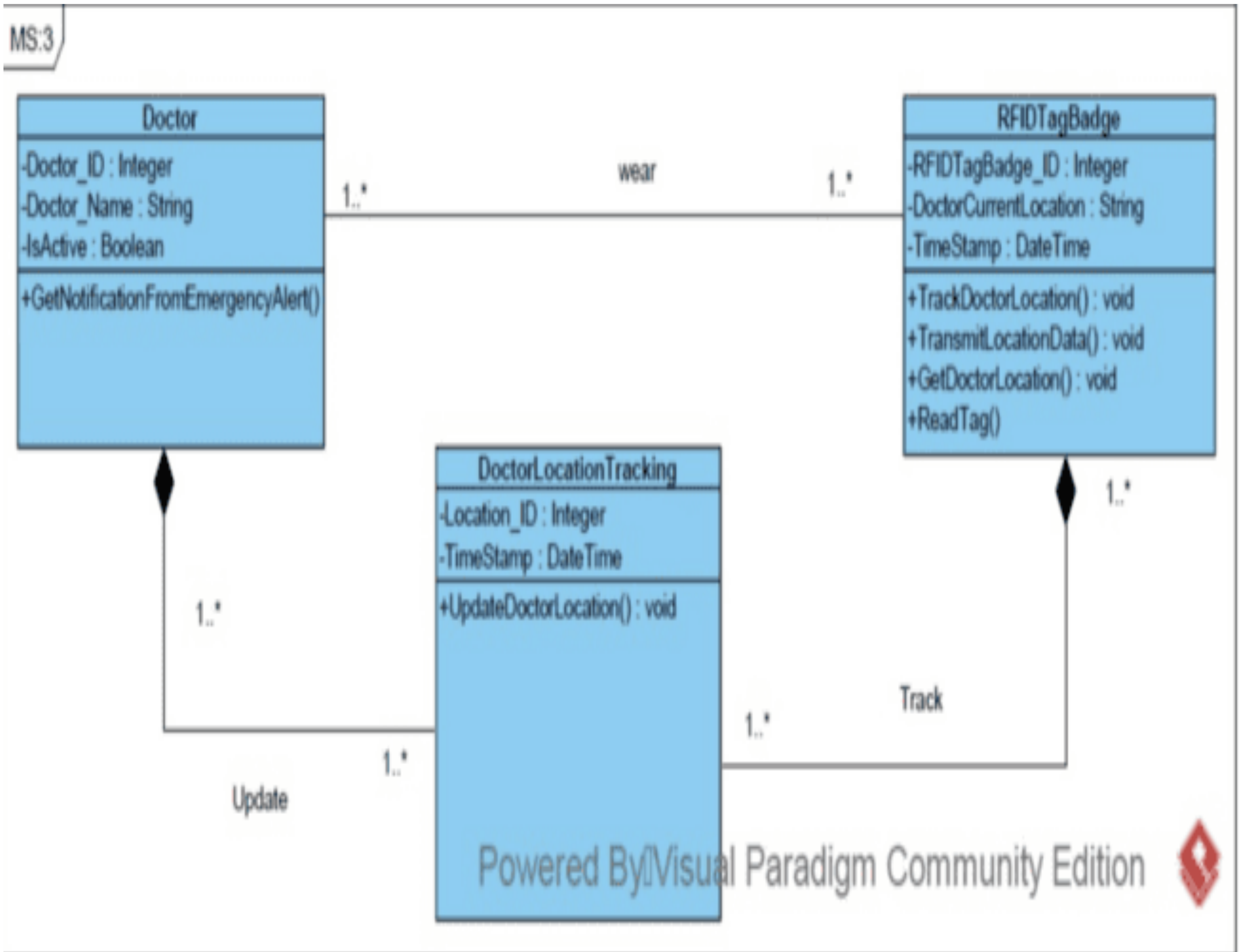


Figure 23
Class-Diagram
(Source: Developed by the Students)

Class: Doctor	
Attributes	
Doctor-ID (Primary Key)	Each Doctor must have a unique identification number within the system.
Doctor-Name	The full name of the Doctor that is working in the hospital.
IsActive	Indicates the doctor’s current condition whether he/she on a break or busy.
Associations	
Doctor and RFID Tag Badge	Each doctor wear one RFID Badge, and each badge belongs to one doctor.
Doctor and Doctor LocationTracking	Doctor can be located in one place, and a place can include many doctors.
Operations	
GetNotificationFromEmergencyAlert	The doctor will receive an emergency alert as when the patient press on the button where the patient’s location will be known

Class: RFIDTagBadge	
Attributes	
RFIDTagBadge-ID (Primary Key)	Each RFID Badge must have a unique identification number within the system.
DoctorCurrentLocation	Indicates the current location of the doctor.
Time-Stamp	Indicates the time of current location of the doctor.
Associations	
RFID Badge and DoctorLocationTracking	RFID badges track the doctor location
RFID Tag Badge and Doctor	Each badge belongs to one doctor, and each doctor wear one RFID Badge.
Operations	
TrackDoctorLocation	The doctor’s location should be known as an emergency

	may occur
TransmitLocationData	The location data will be transmitted
GetDoctorLocation	Retrieves the doctor's current location.
ReadTag	Reads the tag ID to identify the Badge.

Class: DoctorLocation	
Attributes	
Location-ID (Primary Key)	Each Doctor's location must have a unique identification number within the system.
Time-Stamp	Indicates the time of current location of the doctor.
Associations	
Doctor locationTracking and Doctor	Doctor can be located in one place, and a place can include many doctors.
Doctor locationTracking and RFIDTagBadge	Doctor's location is tracked by RFID Tag Badge.
Operation	
UpdateDoctorLocation	The doctor's location should be updated as an emergency may occur

Class: DoctorLocationTracking	
Attributes	
Location-ID (Primary Key)	Each Doctor's location must have a unique identification number within the system.
Time-Stamp	Indicates the time of current location of the doctor.
Associations	
Doctor locationTracking and Doctor	Doctor can be located in one place, and a place can include many doctors.
Doctor locationTracking and RFIDTagBadge	Doctor's location is tracked by RFID Tag Badge.
Operation	
UpdateDoctorLocation	The doctor's location should be updated as an emergency may occur

7 Sequence Diagram

7.1 Fareeda Mohamed – 225163:

Sequence-Diagram for Track Patient Location Microservice & Documantation

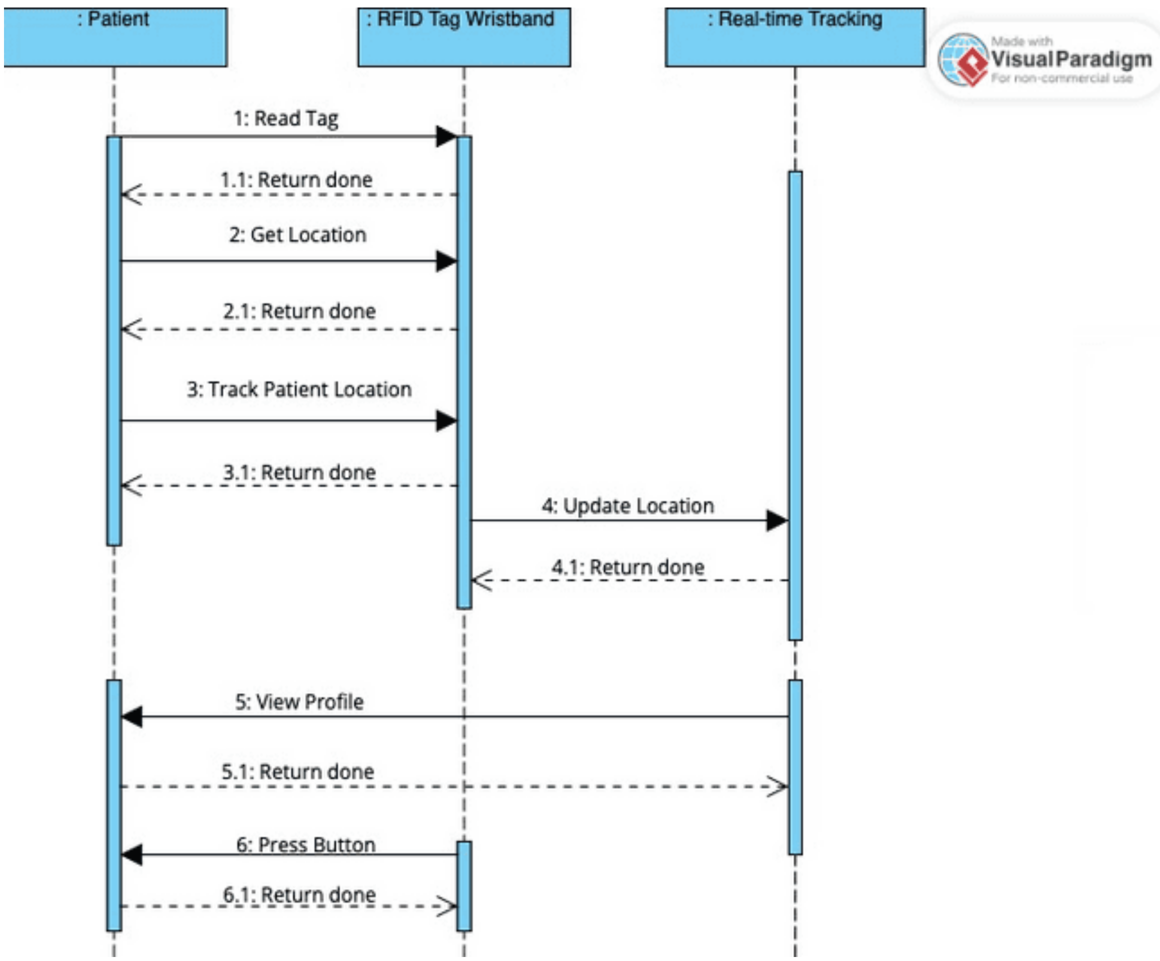


Figure 24
Sequence Diagram
(Source: Developed by the Students)

Description	This sequence diagram illustrates the interaction between the objects: Patient, RFID Tag Wristband, and Real-time Tracking. The process begins when the RFID Tag Wristband worn by the patient is read and is continuously reading the patient's location using the help of the object named Real-time Tracking.
Sequence Flow	1. The object RFID Tag Wristband starts by initiating a request to read the Tag worn by the patient. 2. The object Patient sends a confirmation back "Return done" indicating the tag has been successfully read. 3. Then the object RFID Tag Wristband send a request to Get Location. 4. The object Patient then acknowledges this request and returns a "Return done" through the Tag worn by the patient with the intended request which was getting the location. 5. The object RFID Tag Wristband is then taking the patient's location (Track Patient Location) from the object called Patient to start the continuous tracking of the patient's movement (this helps in continuously updating the location of the patient which will be forwarded to the object Real-time Tracking later on "operation number 4"). 6. Then the object Patient sends all the needed data which is the current patient's location through a "Return done". 7. Then the object Real-time Tracking starts on updating the location, followed by a "return done" from the object RFID Tag Wristband. 8. Then the object Patient can view the patient's profile through the operation called "View Profile", this contains the patient's Name and ID, also the patient's Current Location. 9. Finally, the object Patient can "Press Button", which triggers the emergency alert, in case of danger/require immediate assistant, followed by a "Return done".

7.2 Ahmed Mustafa – 223269:

Sequence-Diagram for Trigger Patient Emergency Alert Microservices & Documentation

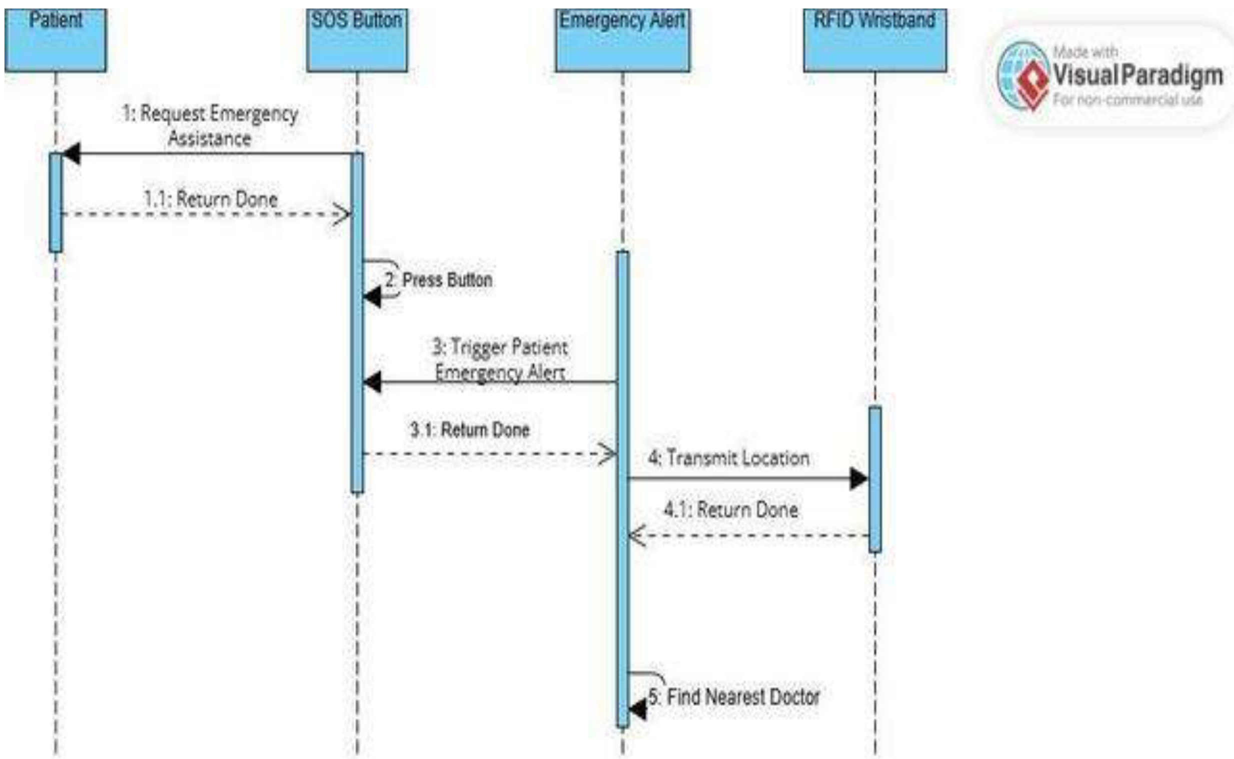


Figure 25
Sequence Diagram
(Source: Developed by the Students)

Description	This sequence diagram illustrates the interaction between the Patient, SOS Button, Emergency Alert, and RFID Wristband. The process begins when the patient manually requests emergency assistance and ends with the system logging the alert and identifying the nearest doctor.
Sequence Flow	**1. SOS Button → Patient:** The patient initiates the process by manually requesting emergency help due to a medical emergency. **1.1 Patient → SOS Button:** A confirmation is returned to the patient. (1.1 Return Done) **2. SOS Button → SOS Button (Self call)** The SOS Button embedded in the patient's RFID wristband is pressed to confirm and trigger the emergency alert. **3. Emergency Alert → SOS Button:** The SOS Button activates the patient Emergency Alert to begin the emergency response process. **4. SOS Button → Emergency Alert:** A confirmation is returned indicating the alert was triggered. **5. RFID Wristband → Emergency Alert:** The RFID Wristband automatically transmits the patient's real-time location when the SOS button is pressed. This location data is sent to the Emergency Alert to determine where the emergency occurred. **6. Emergency Alert →RFID Wristband** The patient's location is received by the emergency alert **7. Emergency Alert → Emergency Alert (Self call)** The emergency alert performs a search and identifies the nearest available doctor based on the patient's location, triggering a notification to medical staff for immediate response.

7.3 Merola Victor – 224329:

Sequence-Diagram for Track Doctor Location Microservice & Documantation

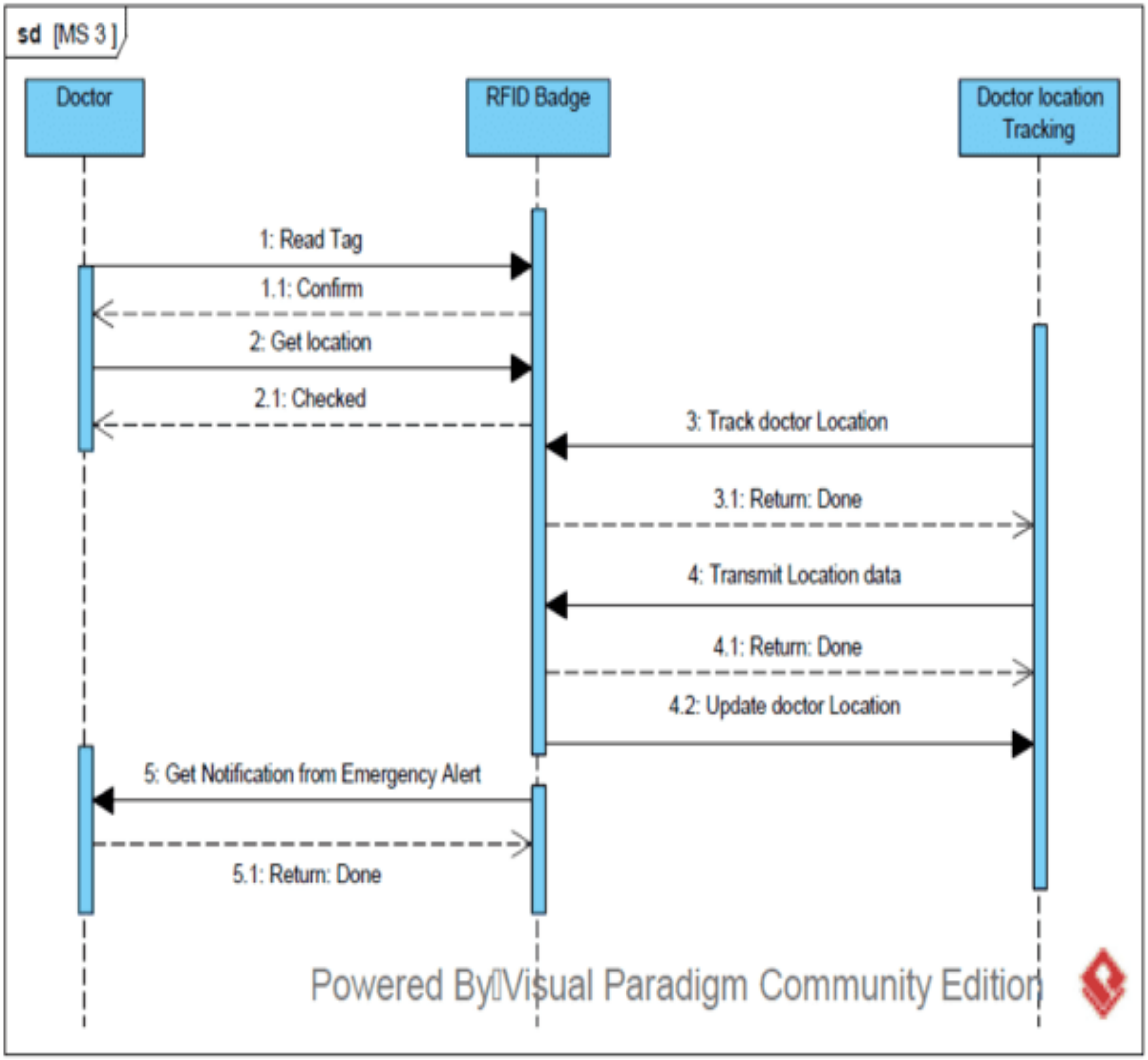


Figure 26
Sequence Diagram
(Source: Developed by the Students)

Description	This sequence diagram illustrates the interaction between the objects: Doctor, RFID Tag Badge, and Doctor Location. The process begins when the RFID Tag Badge worn by the doctor is read and is continuously reading the doctor's location.
Sequence Flow	1. The class RFID Tag starts by sending a request to read the Tag worn by the doctors. 2. The class doctor sends a confirmation message "confirm" indicating the tag has been successfully read. 3. Then the class RFID Tag Badge send a request to get current location (this helps in continuously getting the location of the doctor which will be forwarded to the class Doctor Location). 4. The class Doctor sends a confirmation message "Checked" through the Tag worn by the doctors with the intended request which was getting the current location. 5. The class RFID Badge is tracking the doctor's location and sending the location to the Doctor location Tracking class. 6. Then the class RFID Tag Badge transmit all the location data which is the current doctor's location. 7. The object doctor location Tracking is updating doctors' location; for example, whenever a doctor moves to a new place it automatically updates the location in the doctor location class. 8. The object Doctor will get notification from emergency alert where the patient's location will be known for the doctor.

8 Microservices Integration

As a middleman, the Message Broker (LLPR) receives messages from one service and forwards them to the right recipient. This enhances the application's overall reliability and effectiveness by enabling services to operate independently and sequentially. Because each service is contained within a separate container, it offers isolation and facilitates deployment and scalability.

→ The following diagram shows the microservices integration through a message broker (this will be the LLRP in our system), **BUT** in this project we will not use the left side of this diagram (Container, API-Gateway, and Timer):

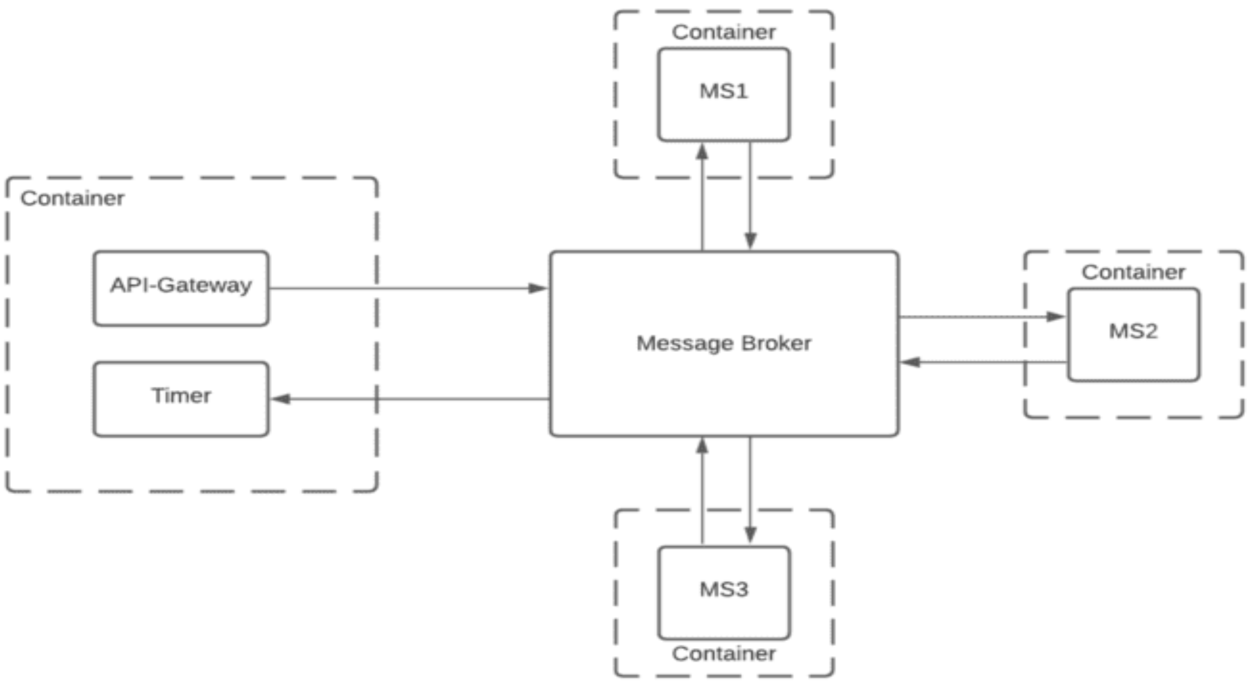


Figure 27
Microservices Integration
(Source: "*E-learning : Microservices Integration*"
Antonio, 2021)

- **References :**

Antonio, B. F. C. (2021). *Message brokers in a microservice architecture*. Diva-portal.org. Retrieved June 11, 2025, from https://www.diva-portal.org/smash/get/diva2:1585173/FULLTEXT01.pdf

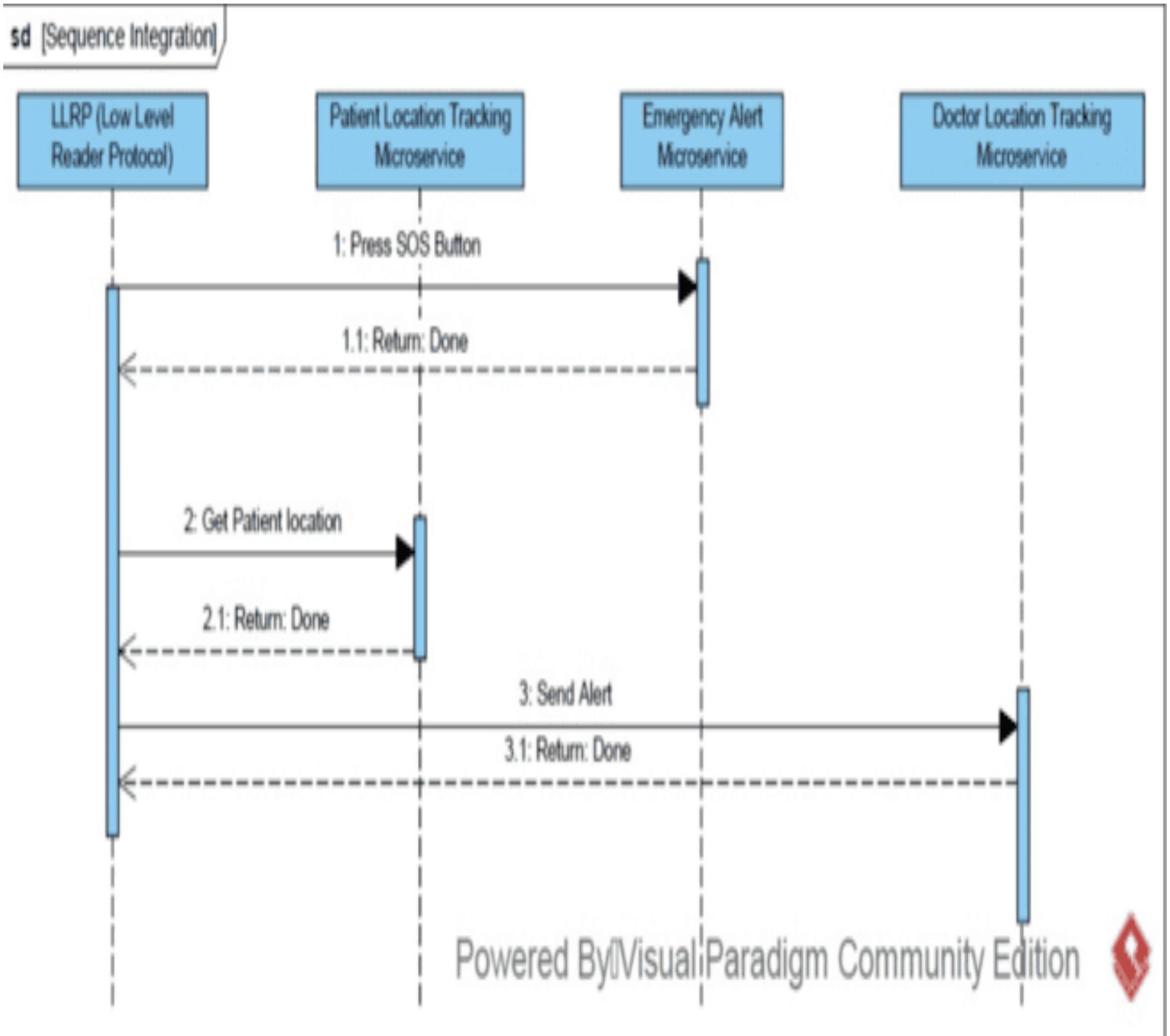


Figure 28
Microservices Sequence Integration
(Source: Developed by the Students)

Description	This sequence illustrates the interaction between three independent microservices in the Doctor-Patient Smart Tracking System which are Patient Location Tracking Microservice, Patient Emergency Alert Microservice, and Doctor Location Tracking Microservice, all coordinated through a **LLRP**, which is the communication protocol/broker for RFID.
Sequence Flow	1. **LLRP → Patient Emergency Alert Microservice:** “Press SOS Button” The **SOS button** is triggered by the patient, thus triggering an emergency alert. This action initiates the emergency handling sequence. 1.1: Then the Patient Emergency Alert Microservice acknowledges this operation with a “Return done”, confirms that the SOS trigger was received. 2. **LLRP → Patient Location Tracking Microservice:** “Get Patient Location” Upon the SOS alert, the LLRP will request the paient’s location from the microservice called Patient Location Tracking, which handels the real-time tracking of patients to collect it and then send it to the doctor later on. 2.1: Then the Patient Location Tracking Microservice acknowledges with a “Return done”, which returns the acquired location. 3. **LLRP → Doctor Location Tracking Microservice:** “Send Alert” When the LLRP collected the required location (patient’s location) when pressed on the SOS button, then it sends to the Doctor Location Tracking Microservice an alert to the nearest doctor. 3.1: Then the Doctor Location Tracking Microservice acknowledges this alert with a “Return done”, which ensures that the alert was sent successfully.

9 Activity Diagram

9.1 Fareeda Mohamed – 225163:

Activity-Diagram for Track Patient Location Microservice & Documantation

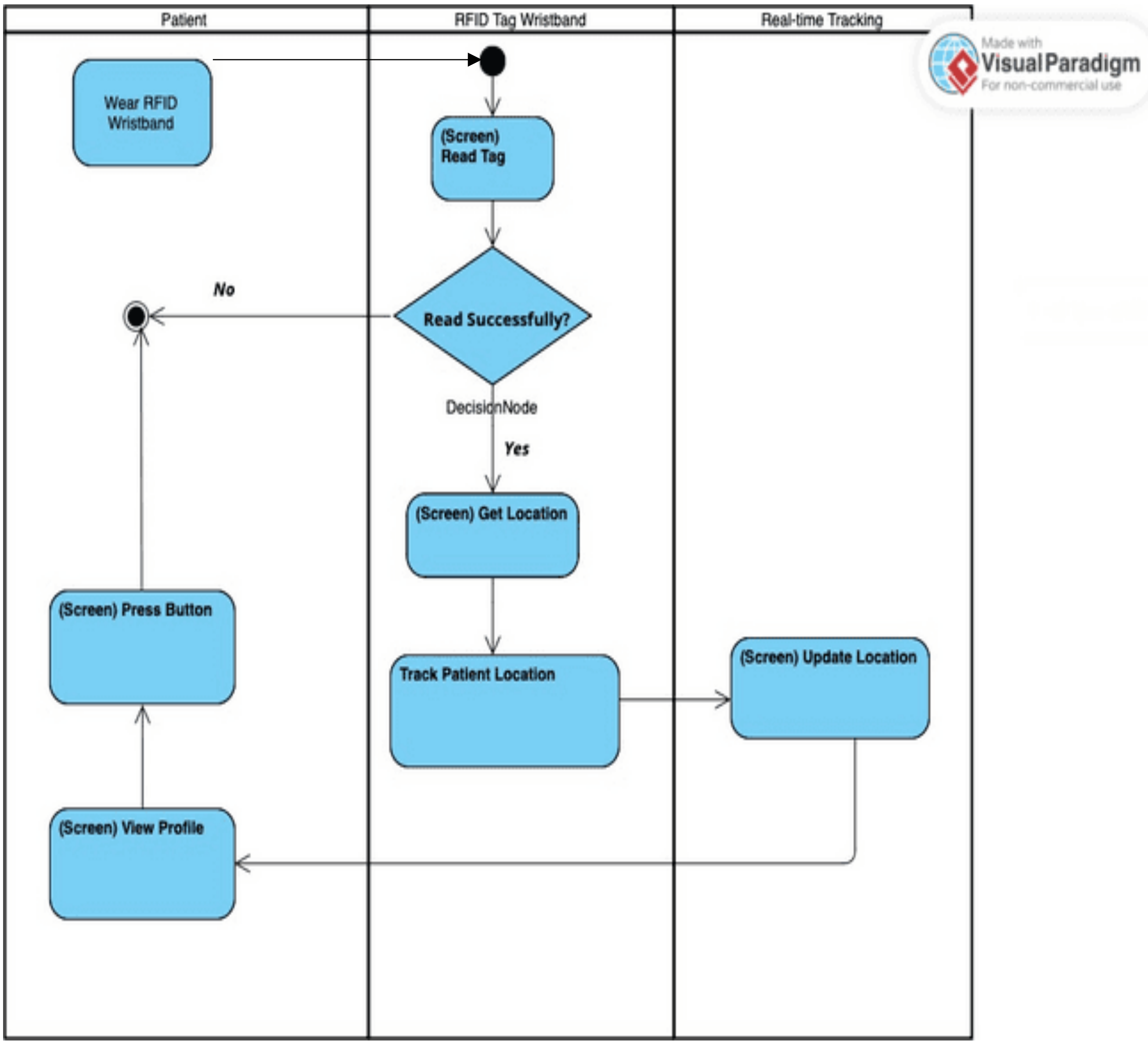


Figure 29
Activity Diagram
(Source: Developed by the Students)

→ *Documentation:*

This activity diagram illustrates the process of **tracking a patient's location using an RFID tag wristband**. It is divided into **three swimlanes** representing the roles of the **Patient**, **RFID Tag Wristband**, and **Real-time Tracking System**. Here is a step-by-step explanation:

- **Wear RFID Wristband:** The patient must first wear an RFID wristband (it is not an activity).
- **(Screen) Read Tag:** The activity diagram then starts by reading the RFID Tag.
- **Decision Node: Read Successfully?**
  - If **No**, the system terminates the tag reading process and the activity diagram ends.
  - If **Yes**, it proceeds to obtain the location.
- **(Screen) Get Location:** The system retrieves the physical location of patient through the RFID tag that he/she is wearing.
- **Track Patient Location:** The location is tracked and is prepared to be updated in the Real-time Tracking swimlane.
- **(Screen) Update Location:** The system updates the patient's current location on the tracking interface.
- **(Screen) View Profile:** The patient then can view his/her profile through "View Profile" (e.g., Name, ID, current location), assuming prior steps like tag reading and location tracking were successful.
- **(Screen) Press Button:** After viewing his/her profile, the patient may press a button to send an emergency alert when it is needed, and then the activity diagram ends.

Flow Summary:

1. Patient wears the RFID wristband.
2. The system reads the tag.
3. If the read is successful, it fetches and tracks the patient's location.
4. The location data is updated in the real-time tracking system.
5. The patient can then view their profile on a screen.
6. The patient can press button (SOS button).

Reflected Functional Requirement:

FR 1: Track Patient Location

Reflected Activities:

- Read Tag
- Get Location

• Track Patient Location • Update Location • View Profile • Press Button
Reflected Classes: • Patient • RFID Tag Wristband • Real-time Tracking

9.2 Ahmed Mustafa - 223269:

Activity-Diagram for Trigger Patient Emergency Alert Microservices & Documentatio

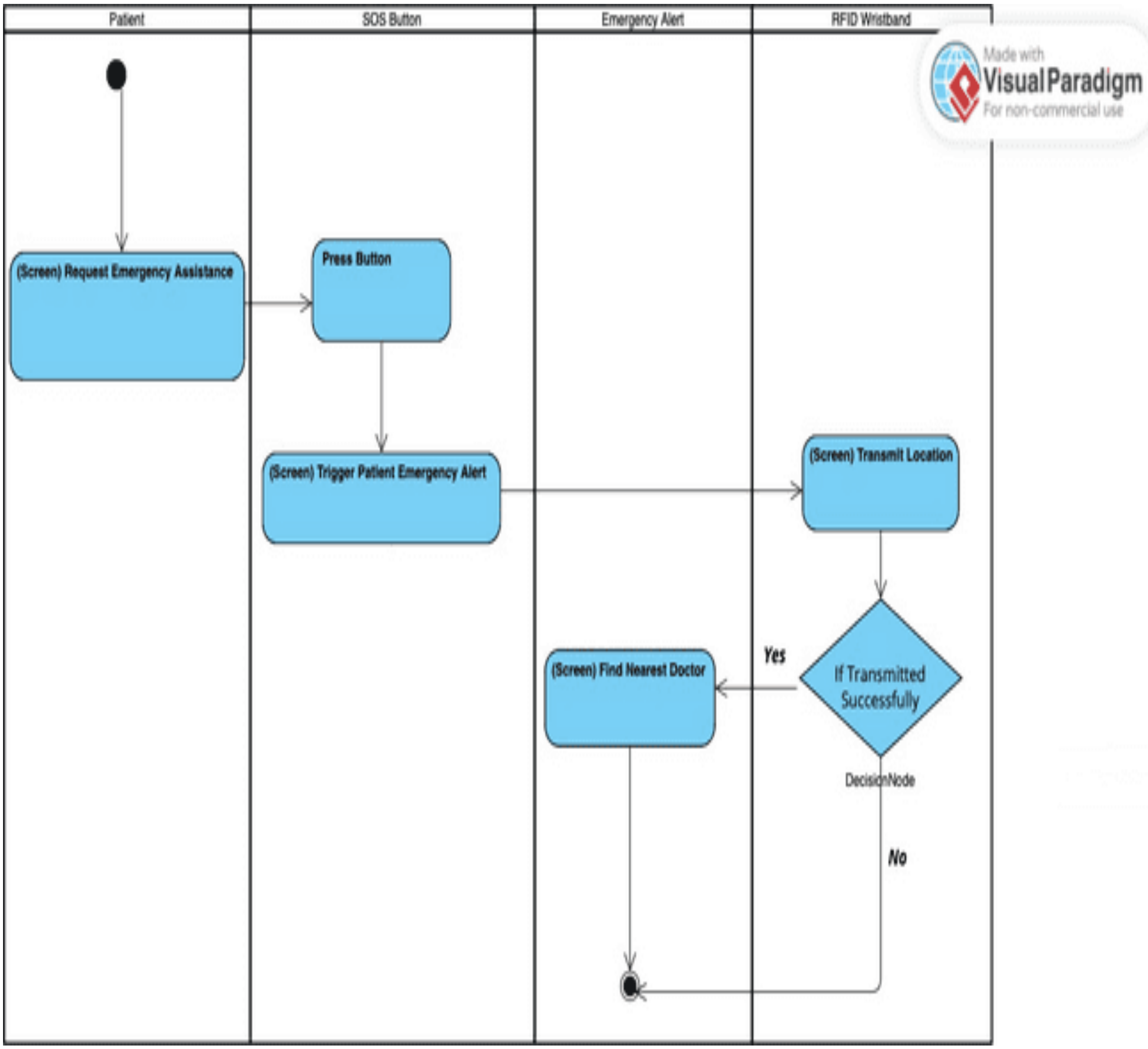


Figure 30
Activity Diagram
(Source: Developed by the Students)

→ *Documentation:*

This activity diagram models the process of a patient requesting emergency medical assistance using an SOS button integrated with an RFID wristband. The system is designed to alert the nearest doctor by transmitting the patient's location and giving it to the doctor. Here is a step-by-step explanation:

- **(Screen) Request Emergency Assistance:** The patient initiates a request for emergency help.
- **Press Button:** The system performs "Press Button" to start triggering the emergency alert that will be forwarded to the doctor.
- **(Screen) Trigger Patient Emergency Alert:** The button triggers an alert to initiate the emergency protocol.
- **(Screen) Transmit Location:** The RFID wristband attempts to transmit the patient's location.
- **Decision Node:** If Transmitted Successfully
  - If **No**, end the proces of triggering the alert, and the activity diagram ends.
  - If **Yes**, continue to "Find Nearest Doctor".
- **(Screen) Find Nearest Doctor:** Upon successful location transmission, the system proceeds to identify the nearest available doctor.

Flow Summary:

1. Patient Request Initiation.
2. SOS Button Activation.
3. Location Transmission via RFID Wristband.
4. Transmission Validation:
   - **If successful**, the system proceeds to find the nearest available doctor.
   - **If unsuccessful**, the process ends.
5. Finding Nearest Doctor.
6. The flow concludes once the nearest doctor has been located and alerted.

Reflected Functional Requirement:

FR 2: Trigger Patient Emergency Alert

Reflected Activities:

- Request Emergency Assistance
- Press Button
- Trigger Patient Emergency Alert

• Transmit Location • Find Nearest Doctor
Reflected Classes: • Patient • SOS Button • Emergency Alert • RFID Wristband

9.3 Merola Victor – 224329:

Activity-Diagram for Track Doctor Location Microservice & Documantation

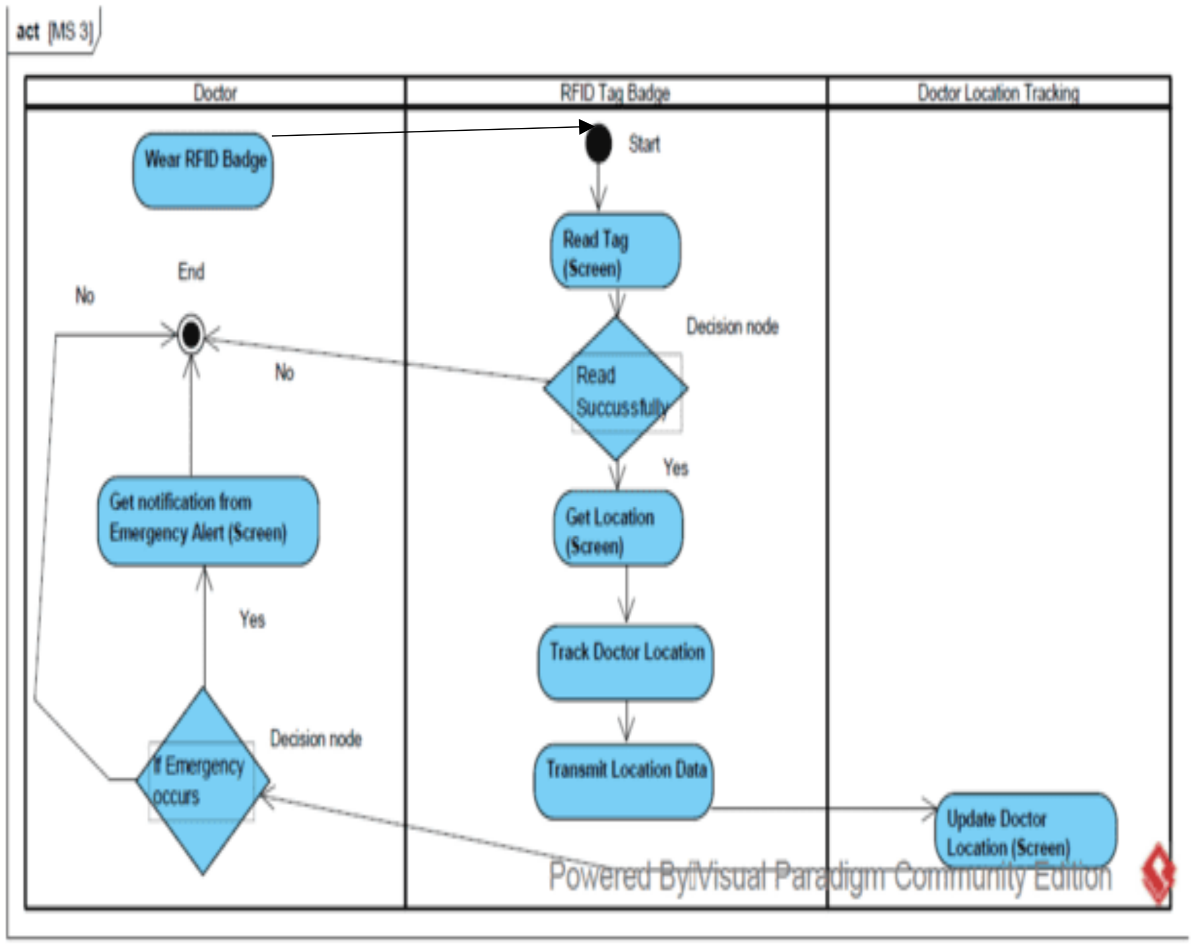


Figure 31
Activity Diagram
(Source: Developed by the Students)

→ *Documentation:*

This activity diagram will illustrate the workflow of the user session that involve the following operations: (Read Tag, Get Location, Track doctor Location, Transmit Location Data, Update Doctor Location and Get location from Emergency Alert) • The doctor will wear the RFID Badge. • The Activity diagram starts by reading the Tag through the RFID tag. • Then, there is a Decision node where the condition is read successfully if this condition is true then the process will continue if not then the process will end. • If the process continued, then the RFID will get Doctor's Location. • After that, the RFID Tag will track doctor location. As well as transmitting the data to the Doctor location Tracking. • Where the Doctor Location Tracking update Doctor's Location every second. • Finally, the doctor will get notification from emergency alert if an emergency occurs.
Reflected Functional Requirement: FR 3: Track Doctor location
Reflected Activities: • Read Tag • Get Location • Track Doctor Location • Transmit Location Data • Update Doctor Location • Get location from Emergency Alert
Reflected Classes: • Doctor • RFID Tag Badge • Doctor Location Tracking

10 Validation and Verification

10.1 The Validation Test:

10.1.1 Forward Traceability:

Stakeholder(s)	ID
RFID Tag Wristband	**RTW**
Patient	**P**
SOS Button	**S**
RFID Tag Badge	**RTB**

User ID	User Requirement	Forward Traceability
RTW	The patient wears a **RFID Tag Wristband** upon admission. This wristband automatically begins transmitting real-time location data as the patient moves through the hospital. Additionally, the wristband contains a unique ID linked to the patient's electronic health record (EHR), this integration enables the patient to view their Name, ID, and current location when pressing on “View Profile”. The RFID wristband remains active throughout the patient's stay, ensuring **continuous tracking** for safety, fall prevention, and emergency response purposes (SOS Alert).	**FR 1** *“Track Patient Location”*, **&** **FR 2** *“Trigger Patient Emergency Alert”*
P	When the patient is in a critical or emergency situation, they can **press the physical SOS button** embedded in their RFID Tag wristband. Upon pressing the button, an emergency alert is sent to the hospital's central tracking system. The system then **detects the patient’s current location** via the RFID infrastructure and immediately identifies the nearest doctor. Simultaneously, a **notification is triggered** on the doctors’ mobile	**FR 1** *“Track Patient Location”*, **&** **FR2** *“Trigger Patient Emergency Alert”*

	dashboards (web-based app) with the patient's current location (floor number and room number).	
S	The SOS button is embedded into the BLE Active RFID wristband worn by the patient. It is **tamperproof** and accessible to patients of varying physical abilities. Upon pressing the SOS button, the device **instantly transmits a high-priority emergency signal**, including the patient's real-time location. This signal is picked up by the nearest RFID reader, which then forwards it to the emergency alert microservice. The button is designed to avoid accidental presses by requiring a firm, 2-second press for activation, followed by a confirmation beep or LED signal to assure the patient that the alert was successfully sent.	**FR 2 "***Trigger Patient Emergency Alert"*
RTB	Each doctor is provided with an RFID-enabled smart ID badge, which they must wear at all times within the hospital. This badge emits a signal as every second, to allow the system to **track the doctor's real-time location** inside the hospital. When an emergency alert is triggered by a patient, the system uses the badge's location to **identify the nearest doctor**, minimizing response time. The doctor receives a real-time mobile/web notification with patient's exact location.	**FR 3** *"Track Doctor Location"*

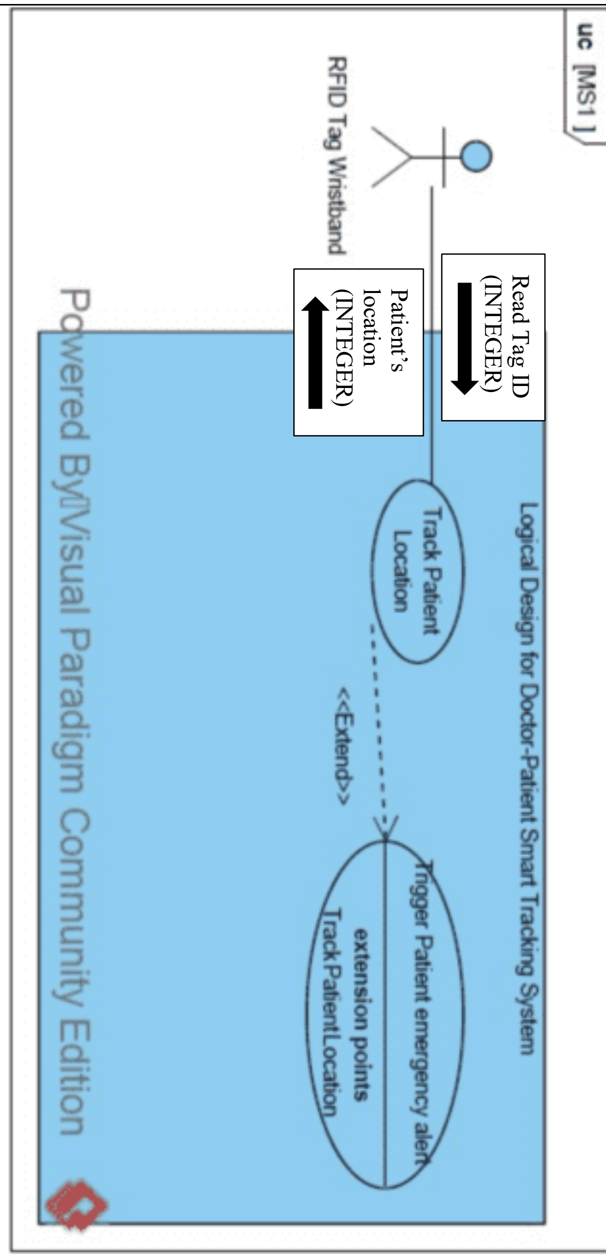
10.1.2 Backward Traceability:

ID	User Requirement	Backward Traceability
FR 1	The system will track the current location of patients to ensure that whenever the patient presses the SOS button, the doctor is immediately notified with the patient's exact location, using wearable smart RFID Tag Wristbands worn by patients (BLE Active RFID Wristband, SOS/Panic Button)	**RTW** *"RFID Tag Wristband"*, **&** **P** *"Patient"*
FR 2	The system will allow patients to manually trigger an emergency alert by pressing a physical emergency button called SOS Button embedded in the BLE Active RFID Wristband. Once pressed, the system will detect the patient's real time location using the hospital's RFID tracking infrastructure and will integrate with the hospital's alerting system to notify the nearest Doctor.	**P** *"Patient"*, **&** **S** *"SOS Button"*
FR 3	The system will track the current location of doctors Using RFID embedded in Doctor ID RFID badges, to update the doctor's location automatically. Where the alert emergency system notifies doctors of any potential patient emergency.	**RTB** *"RFID Tag Badge"*

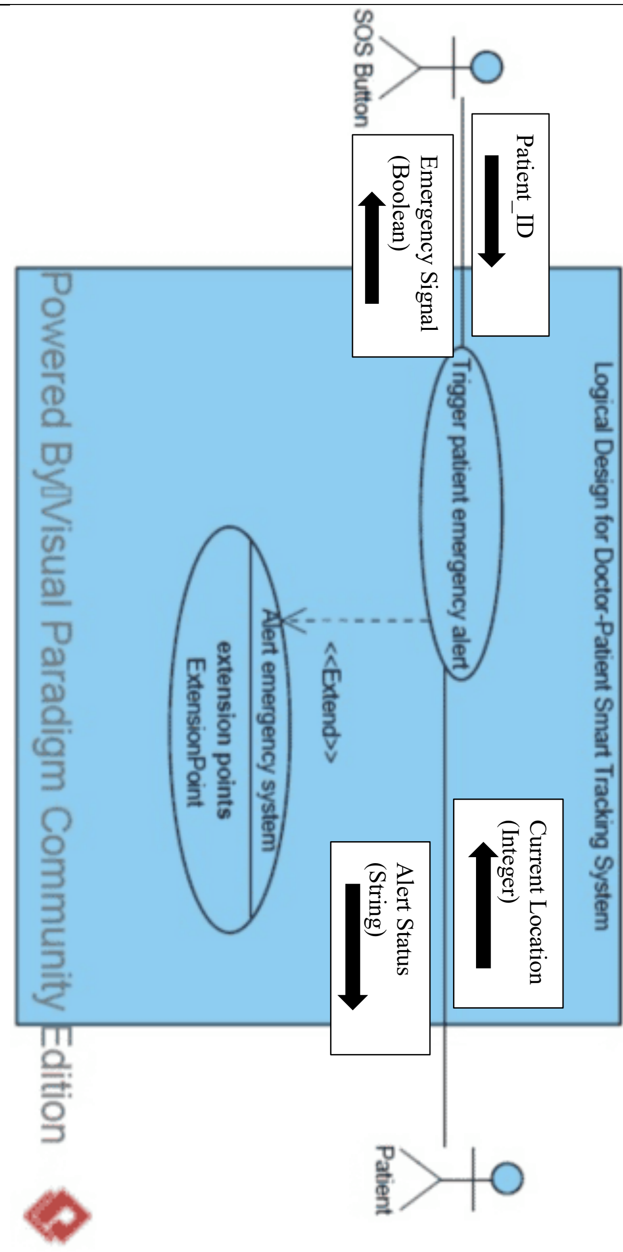
10.2 The Verification Test:

10.2.1 Traceability of the Problem with Functional Requirements with Use-Case Diagram:

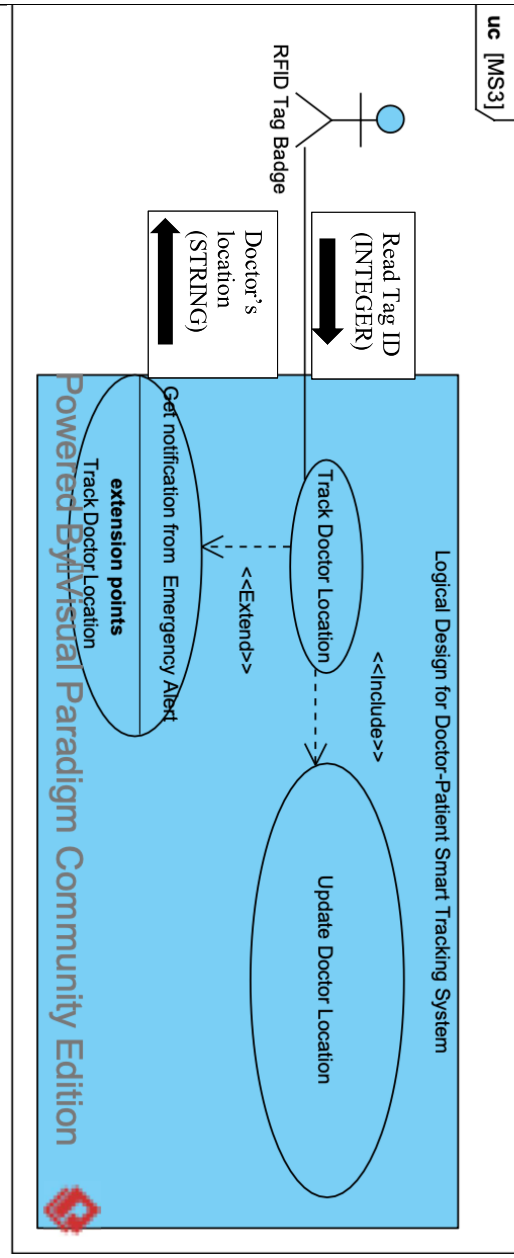
10.2.1.1 Fareeda Mohamed – 225163:

Problem	FR	Use-Case
Problem number 1: Lack of real-time location tracking. **Problem number 2:** Inability for patients to request immediate help.	**FR1:** Track Patient Location.	

10.2.1.2 Ahmed Mustafa - 223269:

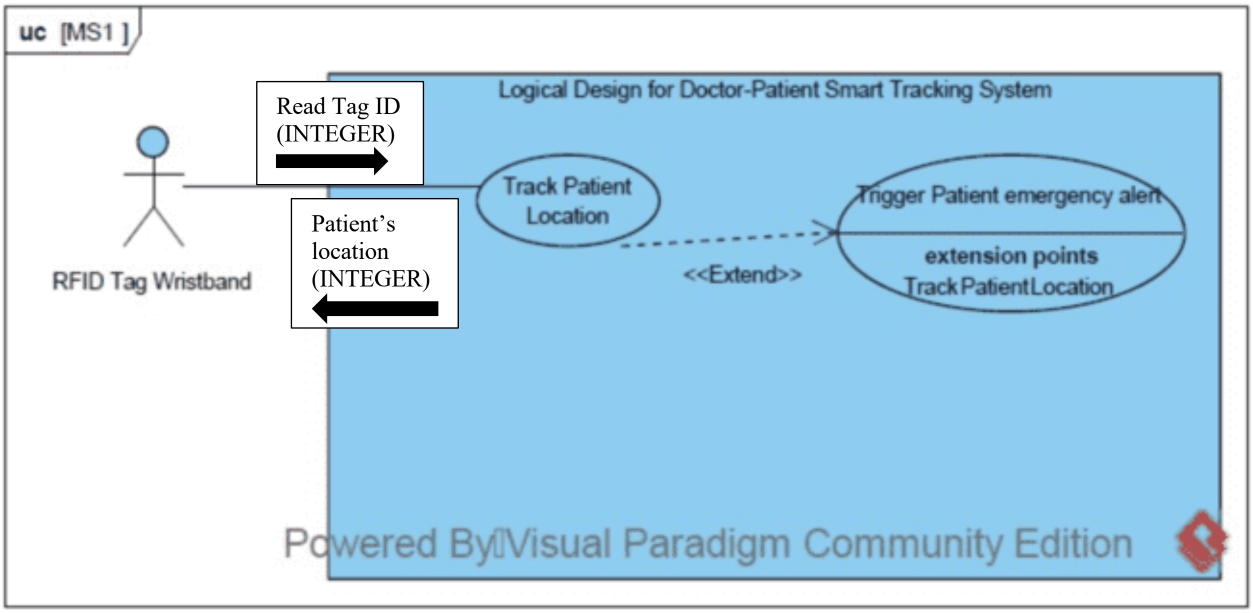
Problem	FR	Use-Case
Problem number 2: Inability for patients to request immediate help.	**FR2:** Trigger Patient Emergency Alert.	

10.2.1.3 Merola Victor - 224329:

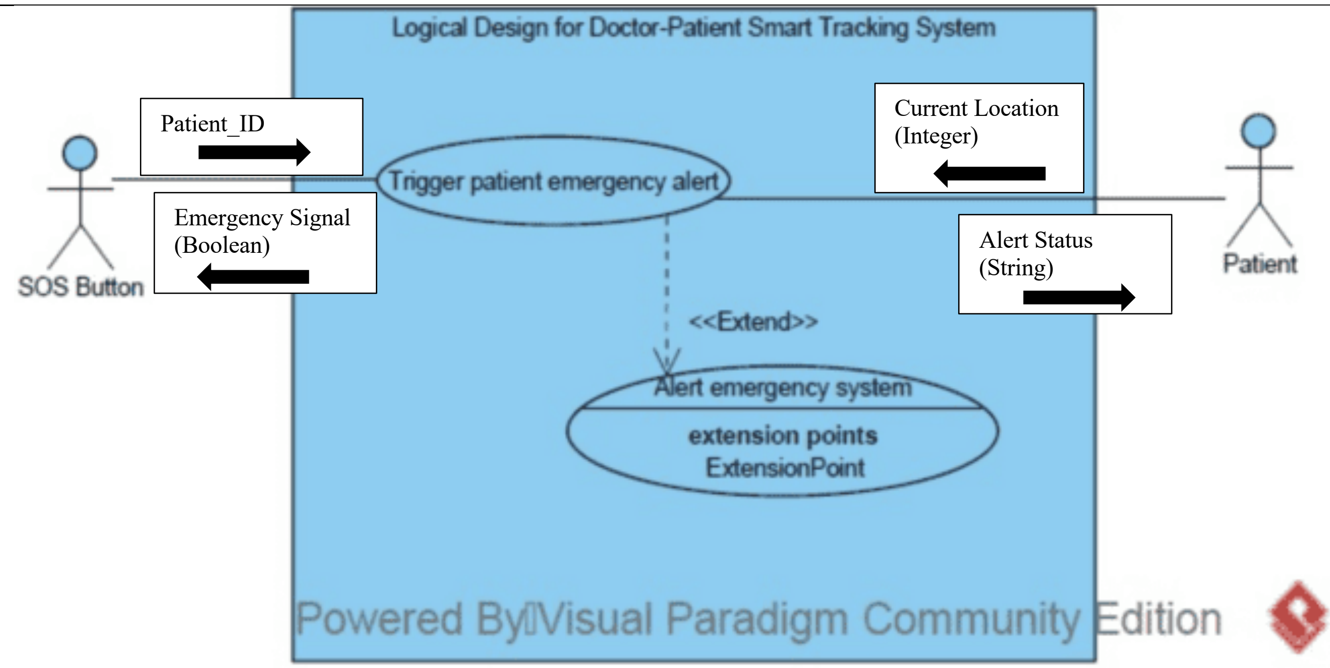
Problem	FR	Use-Case
Problem number 1: Lack of real-time location tracking. **Problem number 3:** Delayed doctor identification in emergencies.	**FR3:** Track Doctor location.	

10.2.2 Traceability of The Use Case Diagram with The Scope:

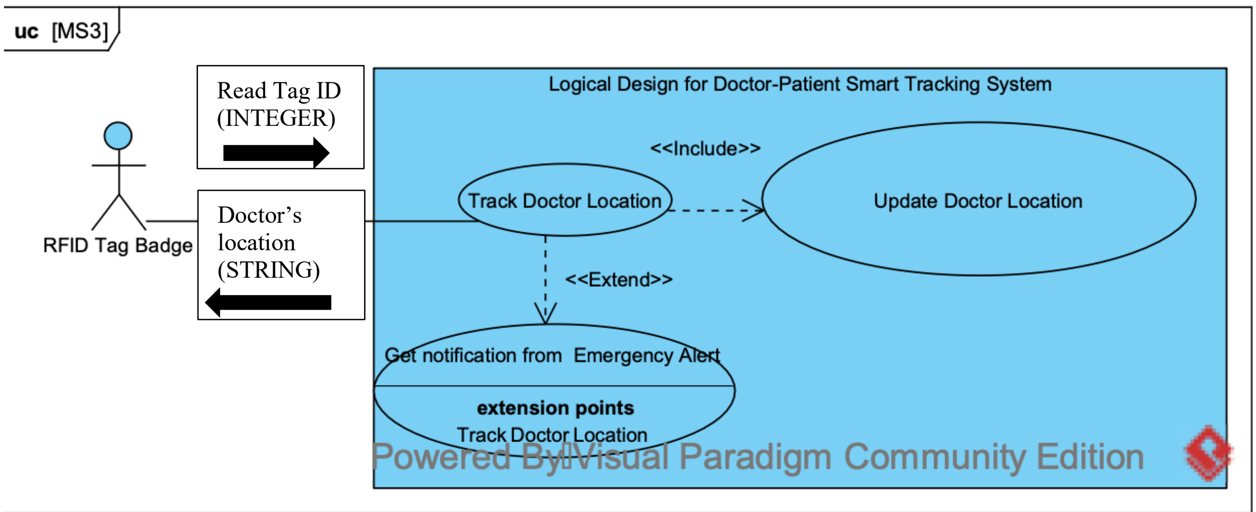
10.2.2.1 Fareeda Mohamed – 225163:

FR 1: Track Patient Location
The system will track the current location of patients to ensure that they are in designated areas within the hospital using wearable smart RFID Tag Wristbands worn by patients, and in case of emergencies the doctor can reach the patient through the "Track Patient Location".


10.2.2.2 Ahmed Mustafa - 223269:

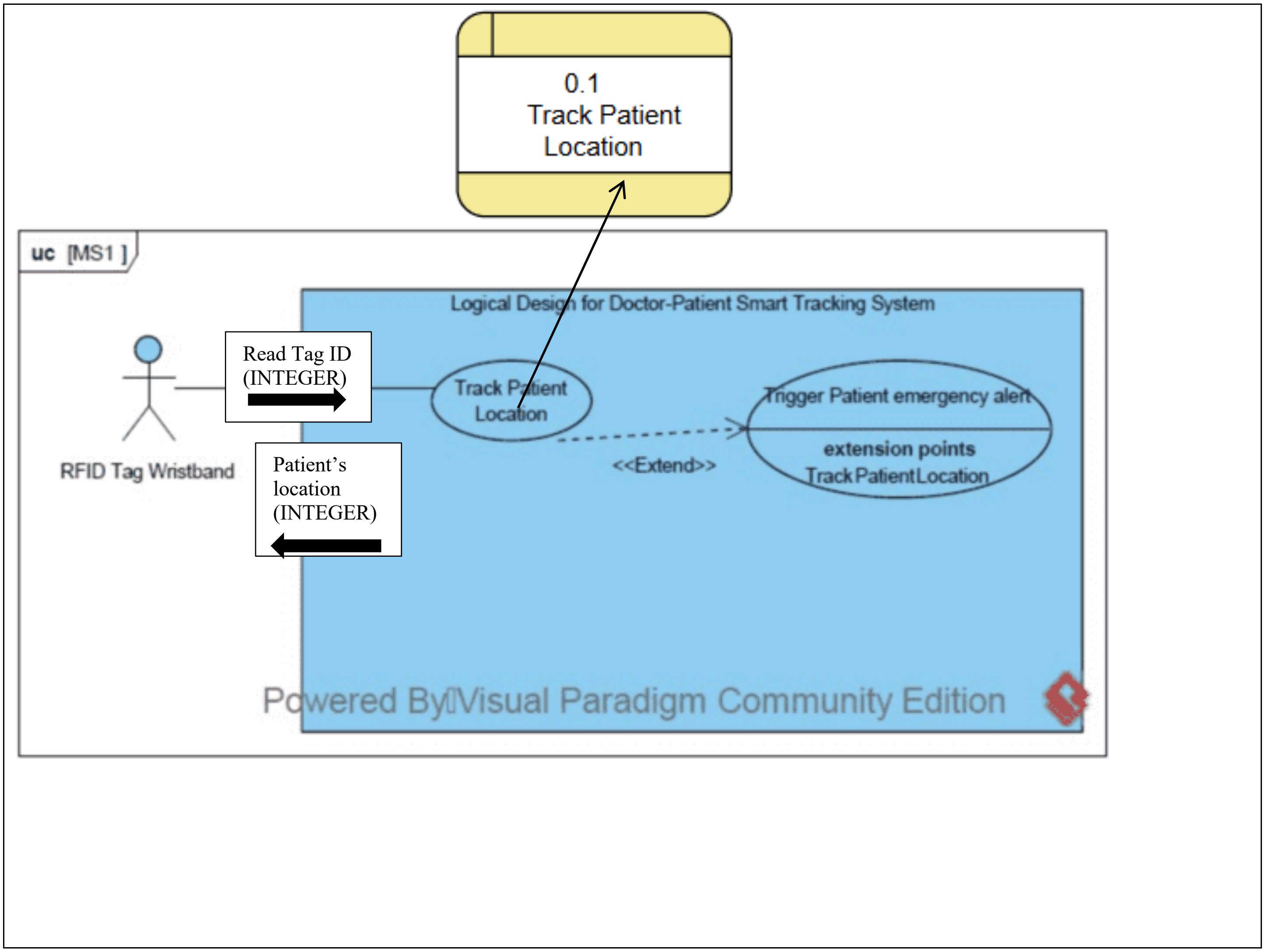
FR 2: Trigger patient emergency alert
The system will allow patients to manually trigger an emergency alert by pressing a physical emergency button. The emergency request will be transmitted through Sonitor tracking technology and RFID sensors embedded in patient wristbands. The system will integrate with the hospital's alerting system to notify the closest available medical personnel automatically.


10.2.2.3 Merola Victor - 224329:

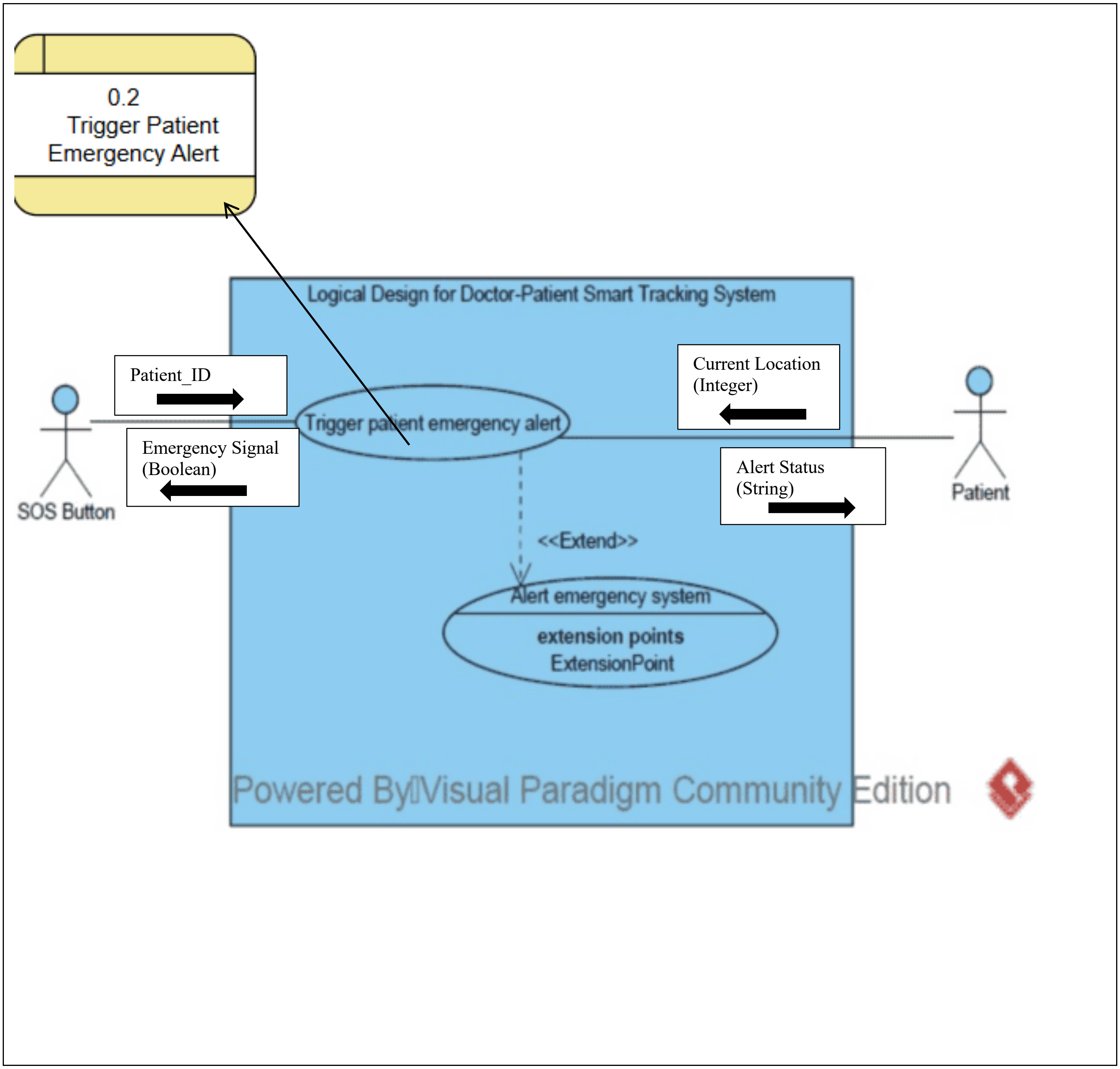
FR 3: Track Doctor location
The system will track the current location of doctors using staff ID RFID badges, to update the doctor's location automatically. Where the alert emergency system notifies doctors of any potential patient emergency, with the patient's location.


10.2.3 Traceability of the 0-level DFD with the use case:

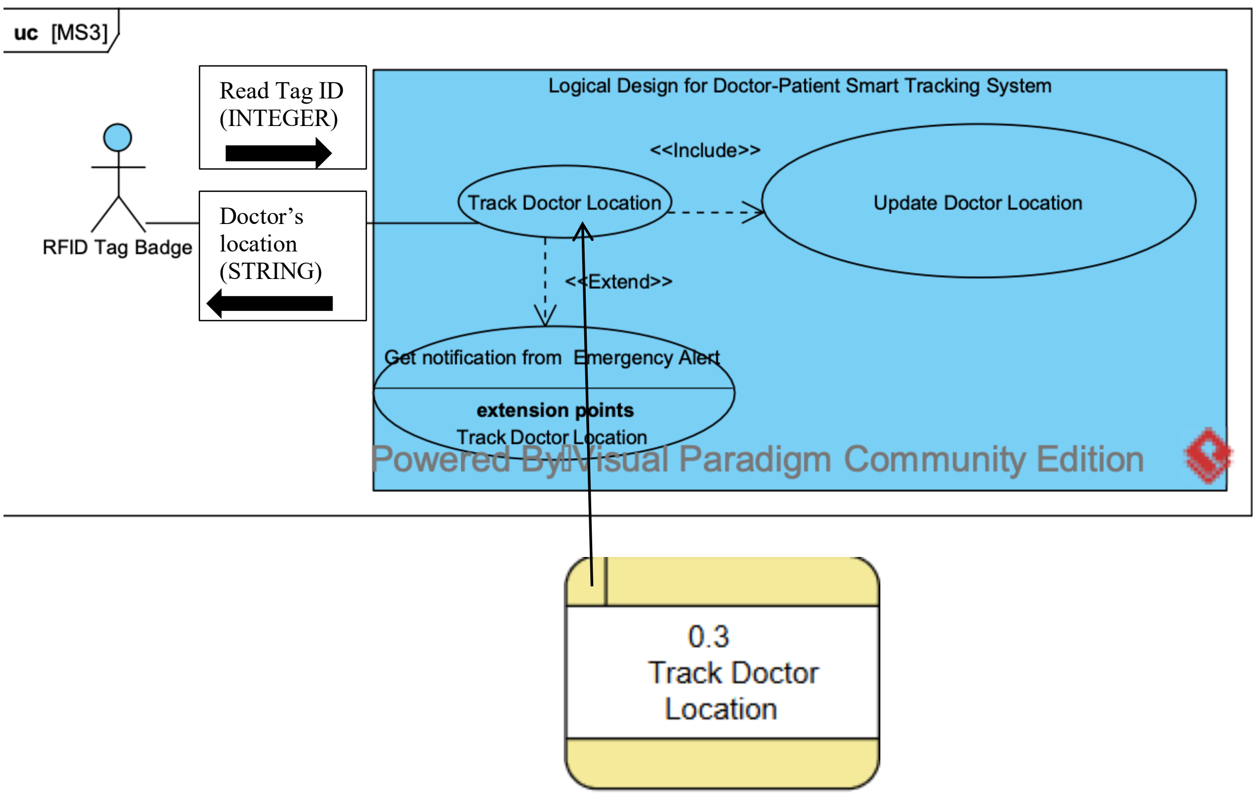
10.2.3.1 Fareeda Mohamed – 225163:



10.2.3.2 Ahmed Mustafa - 223269:

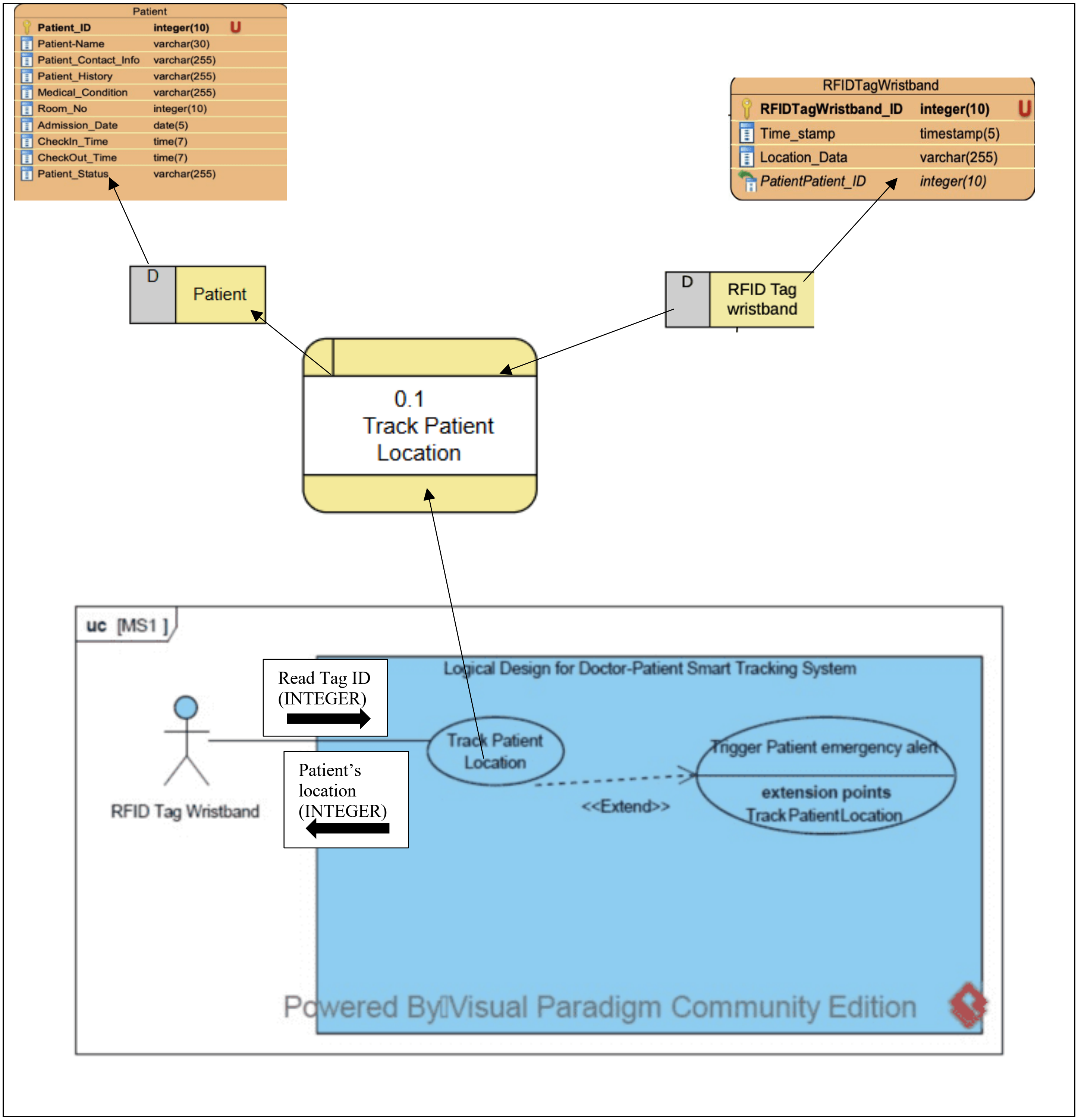


10.2.3.3 Merola Victor - 224329:

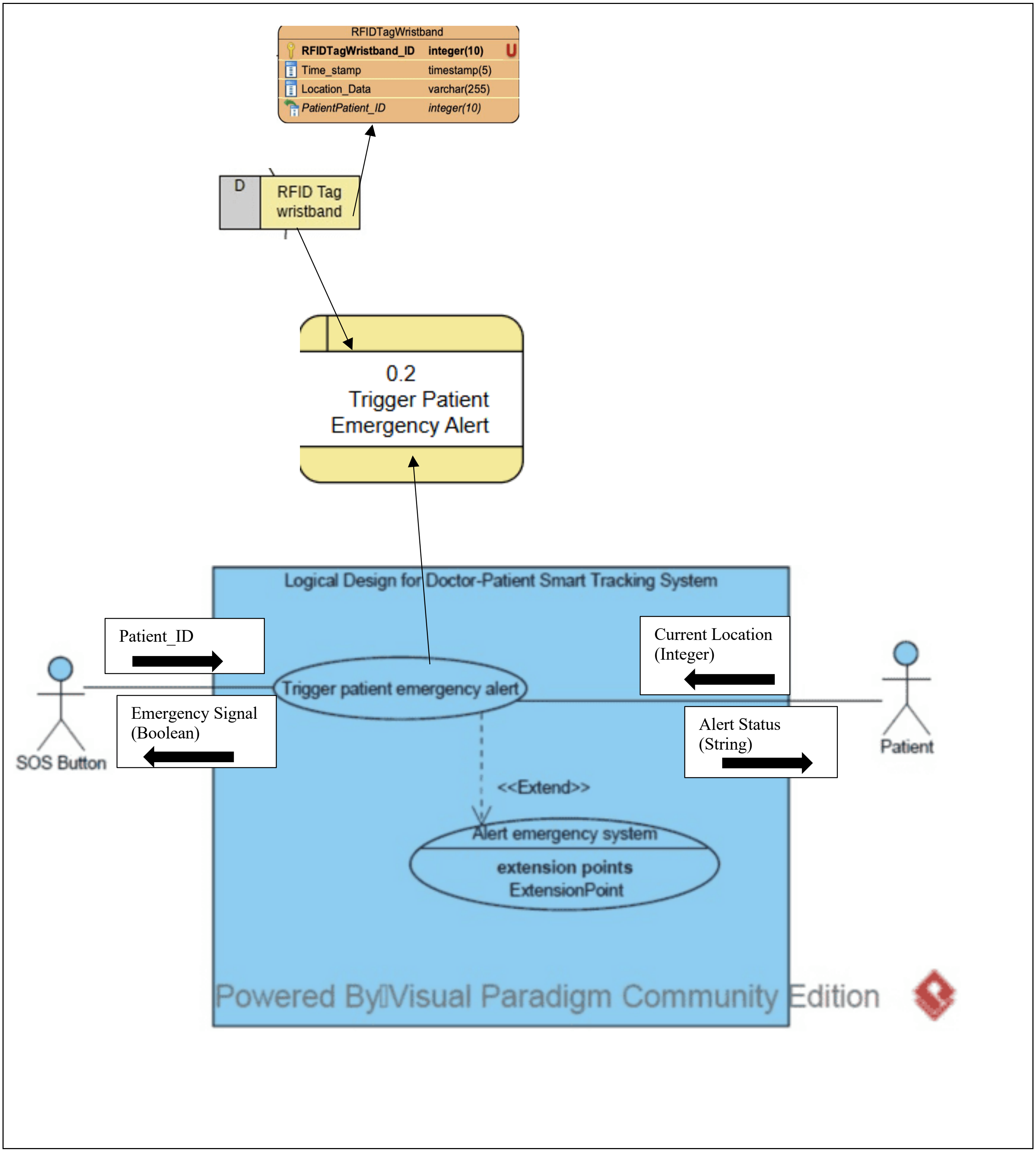


10.2.4 Traceability of the 0-level DFD and Use Case with the ERD:

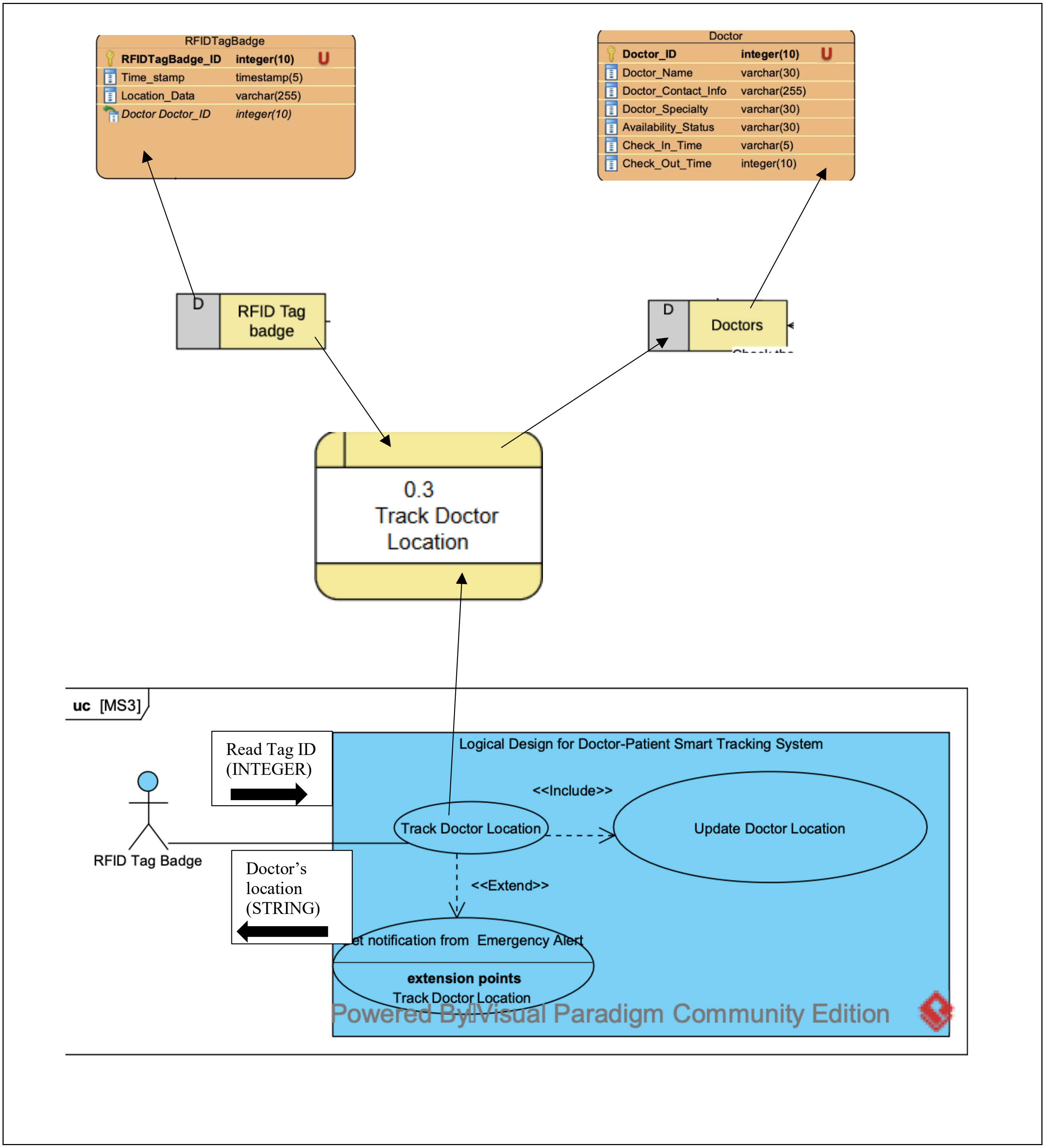
10.2.4.1 Fareeda Mohamed – 225163:



10.2.4.2 Ahmed Mustafa - 223269:

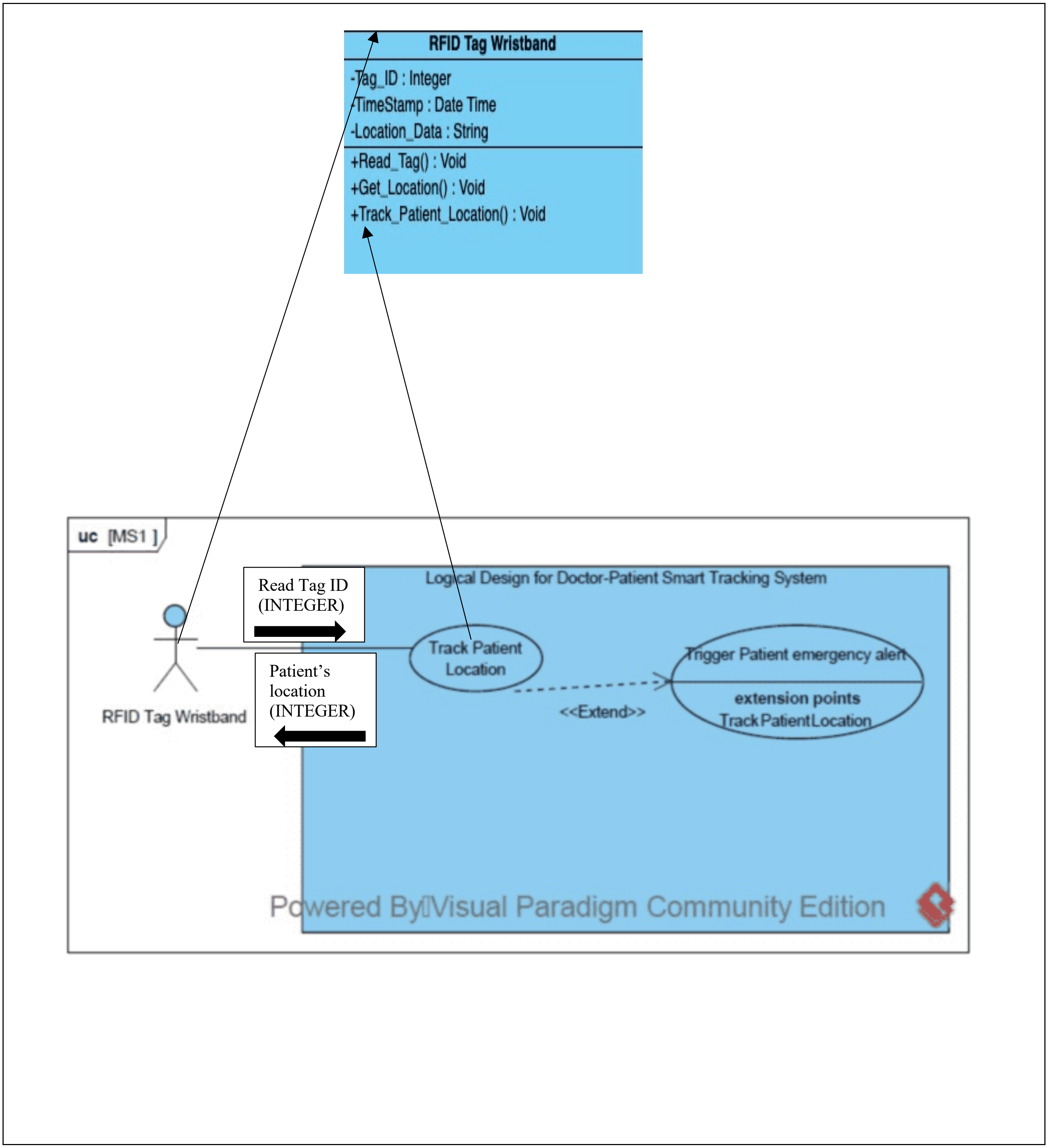


10.2.4.3 Merola Victor - 224329:

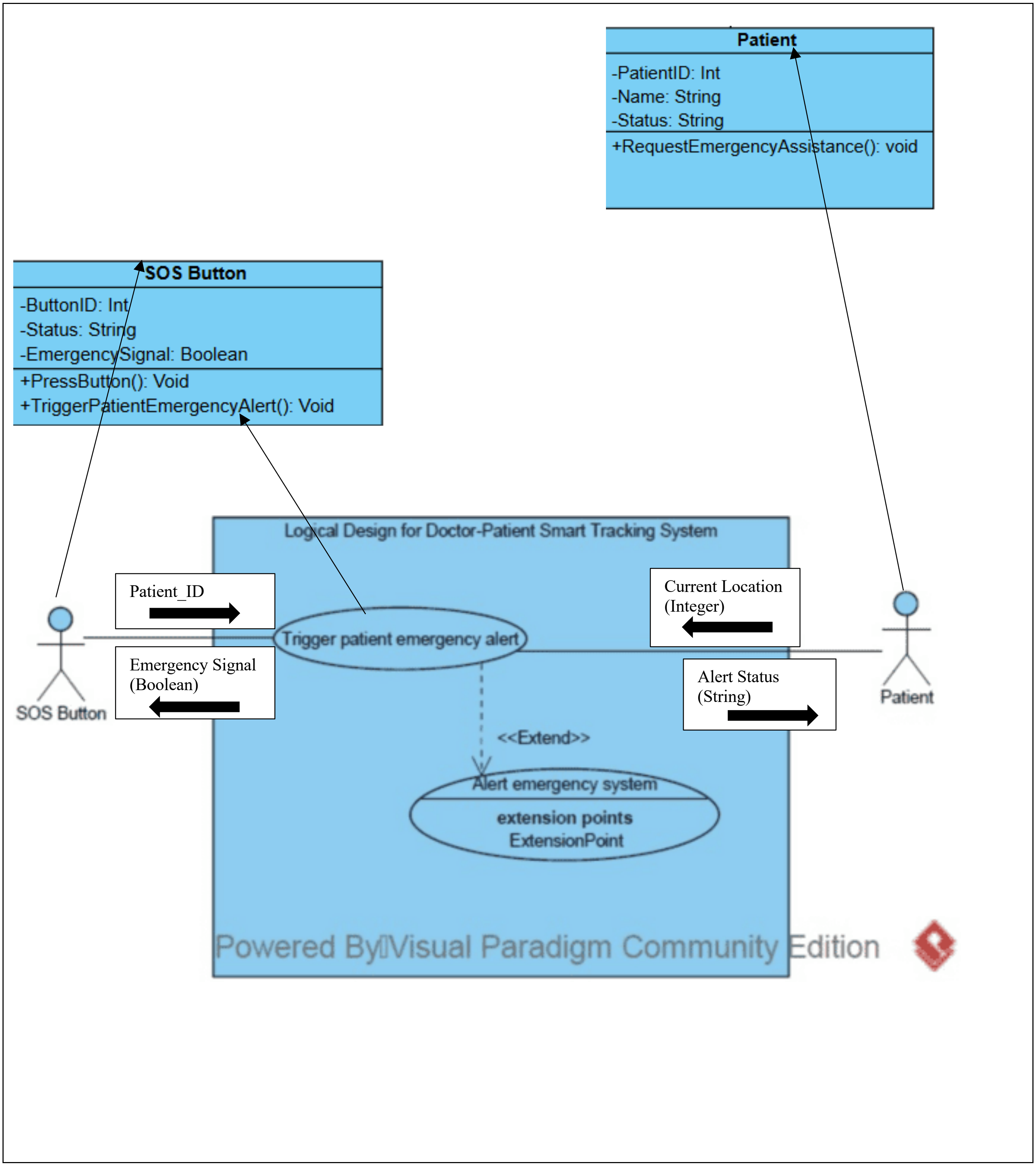


10.2.5 Traceability of the Class Diagram with the Use Case Diagram:

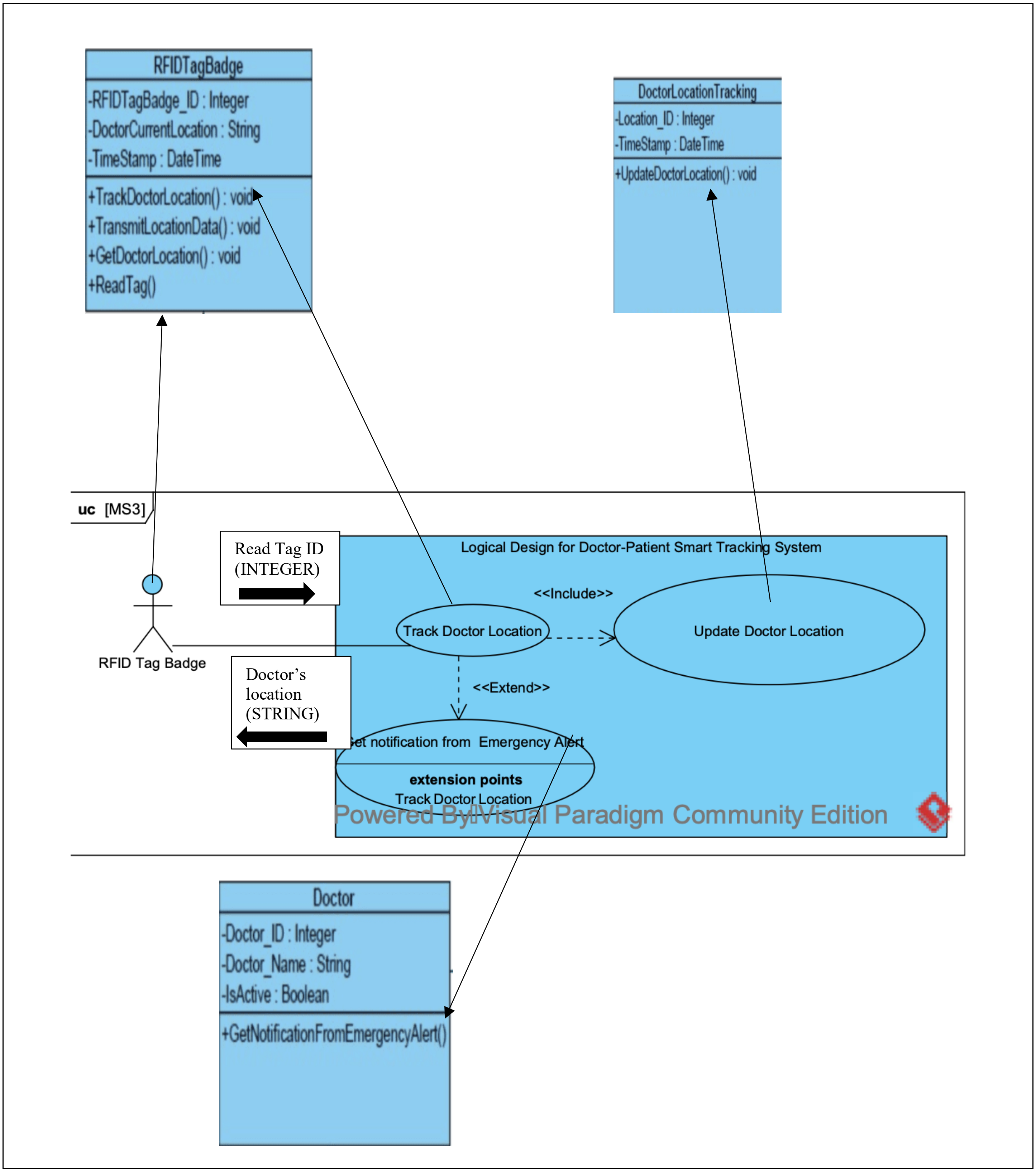
10.2.5.1 Fareeda Mohamed – 225163:



10.2.5.2 Ahmed Mustafa - 223269:

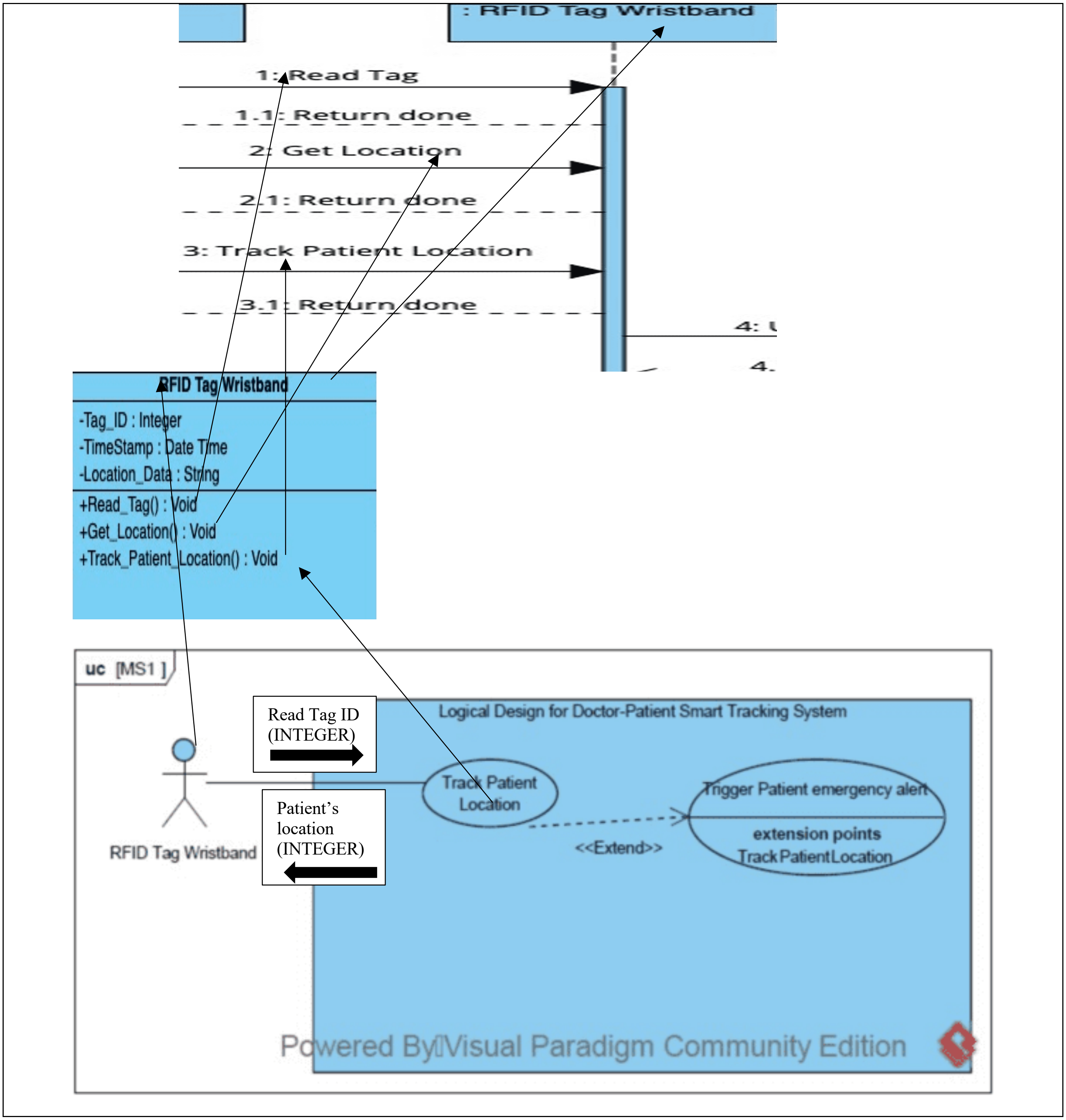


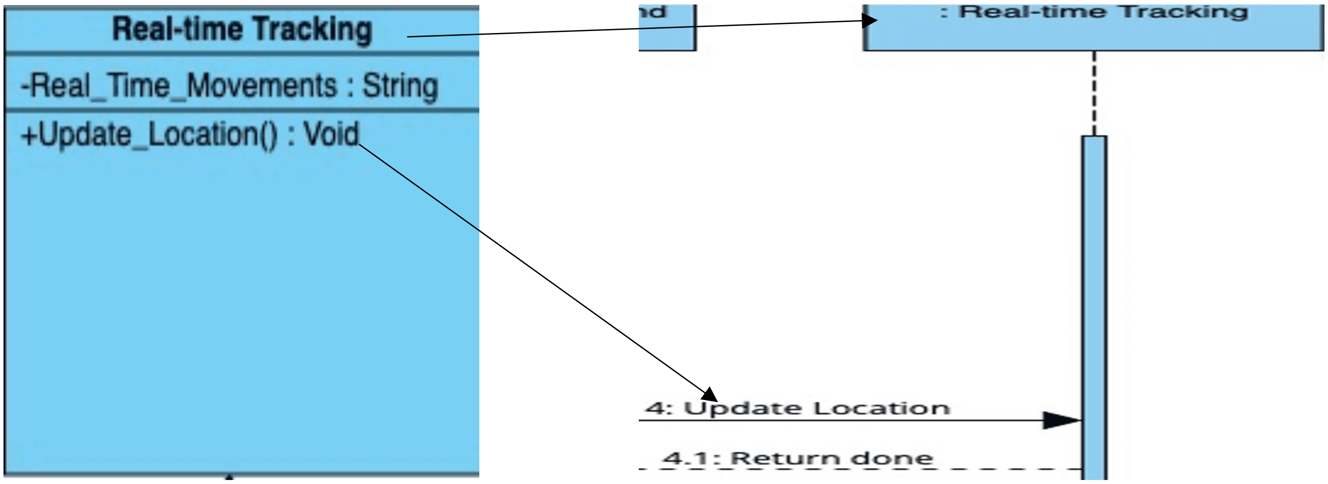
10.2.5.3 Merola Victor - 224329:

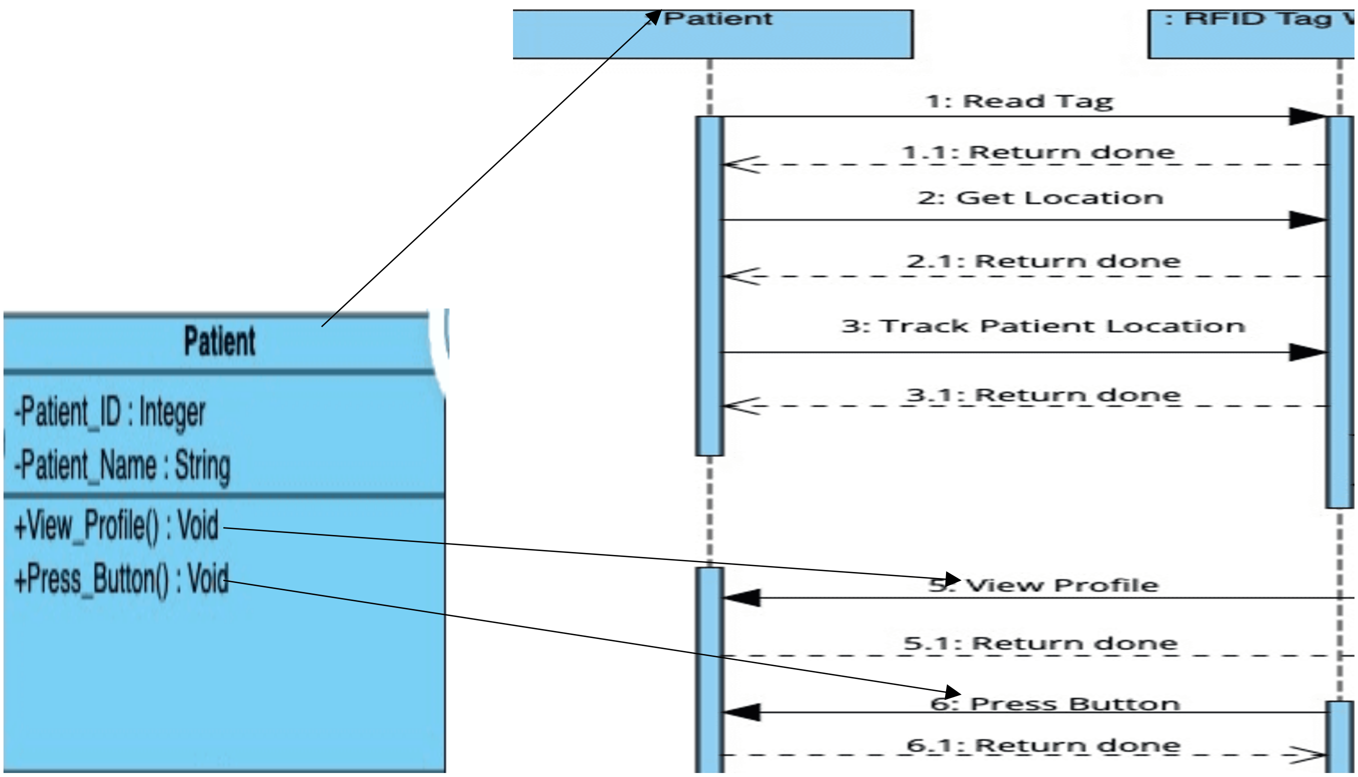


10.2.6 Traceability of the Sequence Diagram with the Class Diagram and the Use Case:

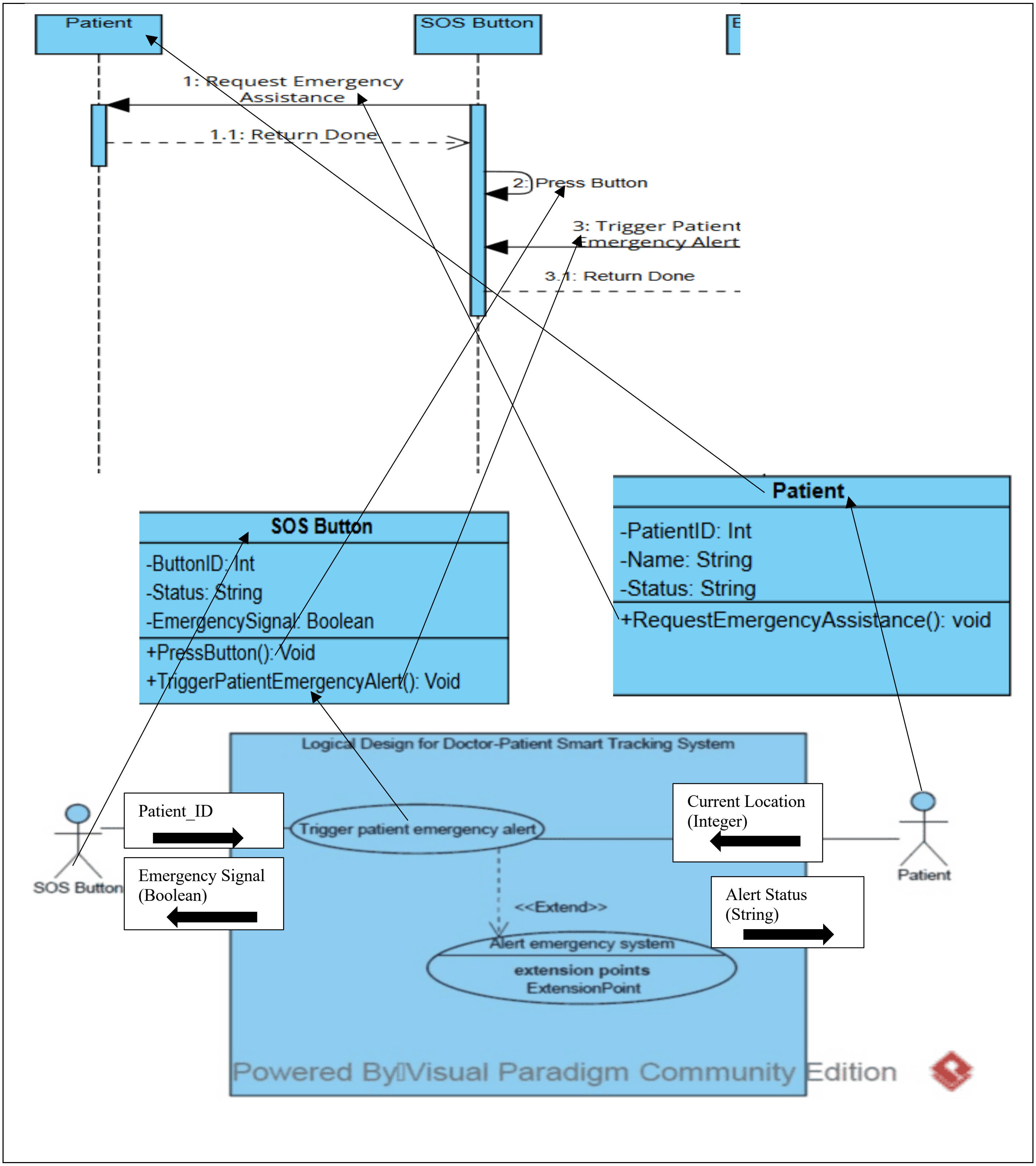
10.2.6.1 Fareeda Mohamed – 225163:

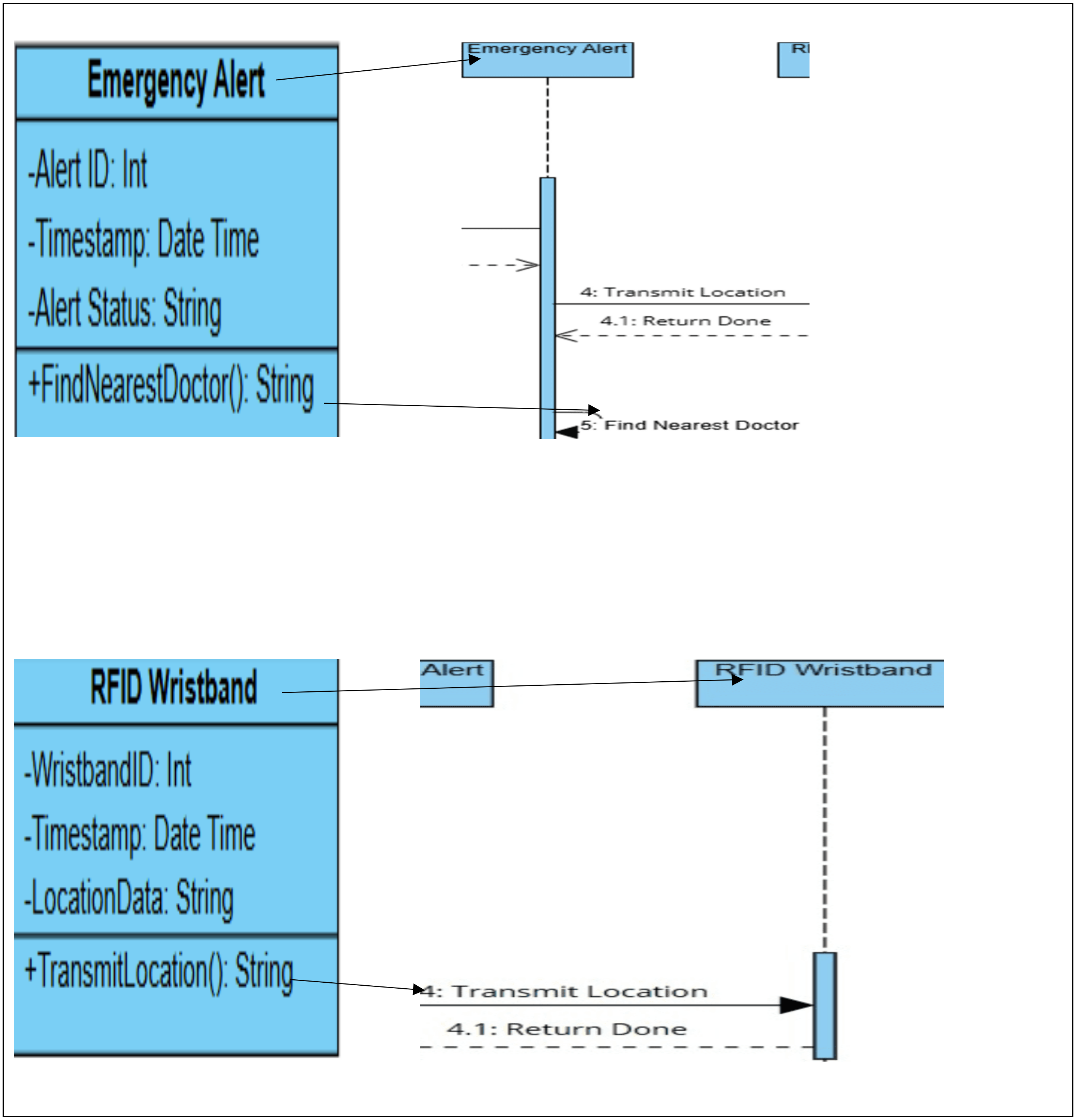



Real-time Tracking
-Real_Time_Movements : String
+Update_Location() : Void
: Real-time Tracking
4: Update Location
4.1: Return done

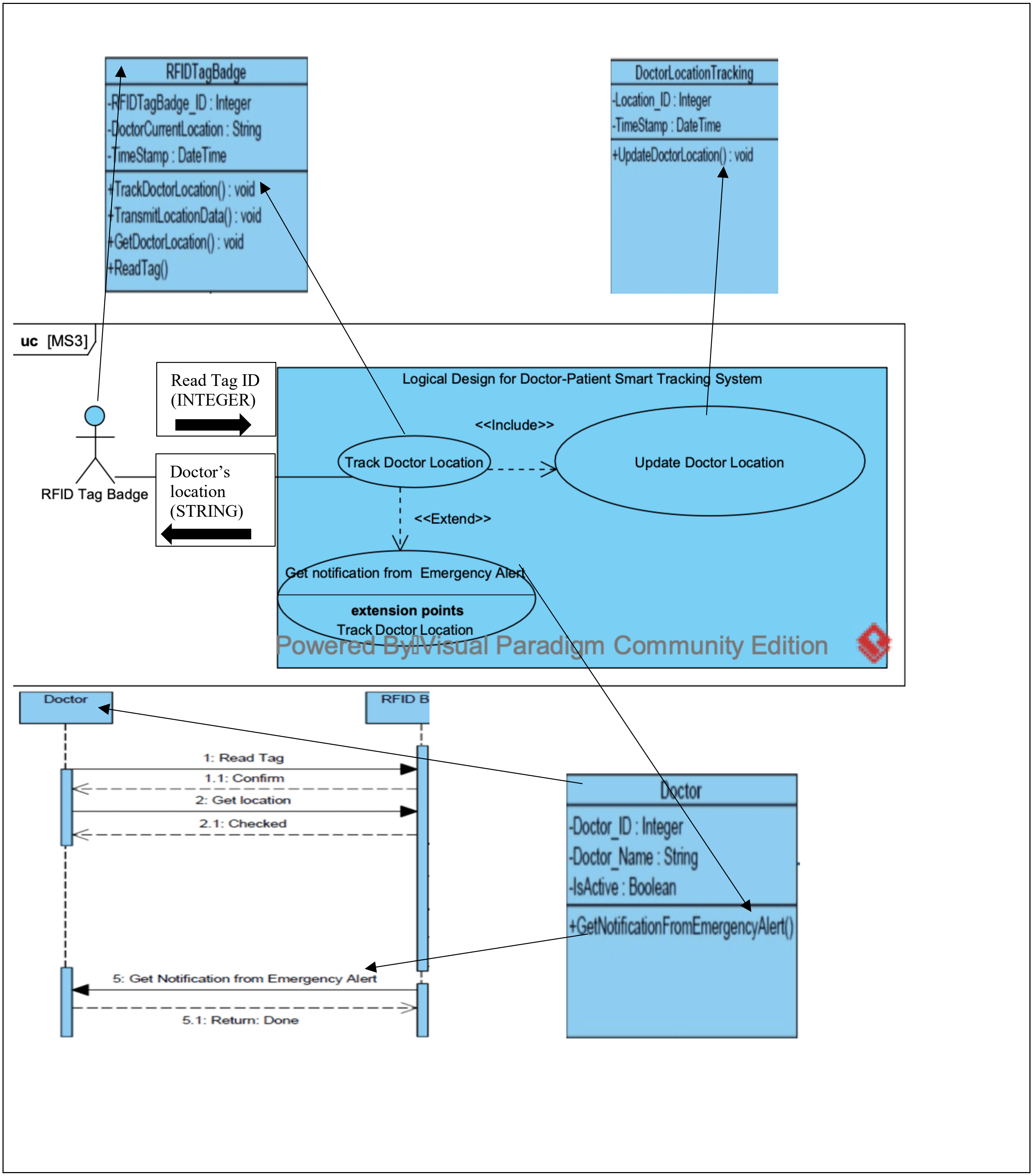

Patient
-Patient_ID : Integer
-Patient_Name : String
+View_Profile() : Void
+Press_Button() : Void
Patient
1: Read Tag
1.1: Return done
2: Get Location
2.1: Return done
3: Track Patient Location
3.1: Return done
5: View Profile
5.1: Return done
6: Press Button
6.1: Return done

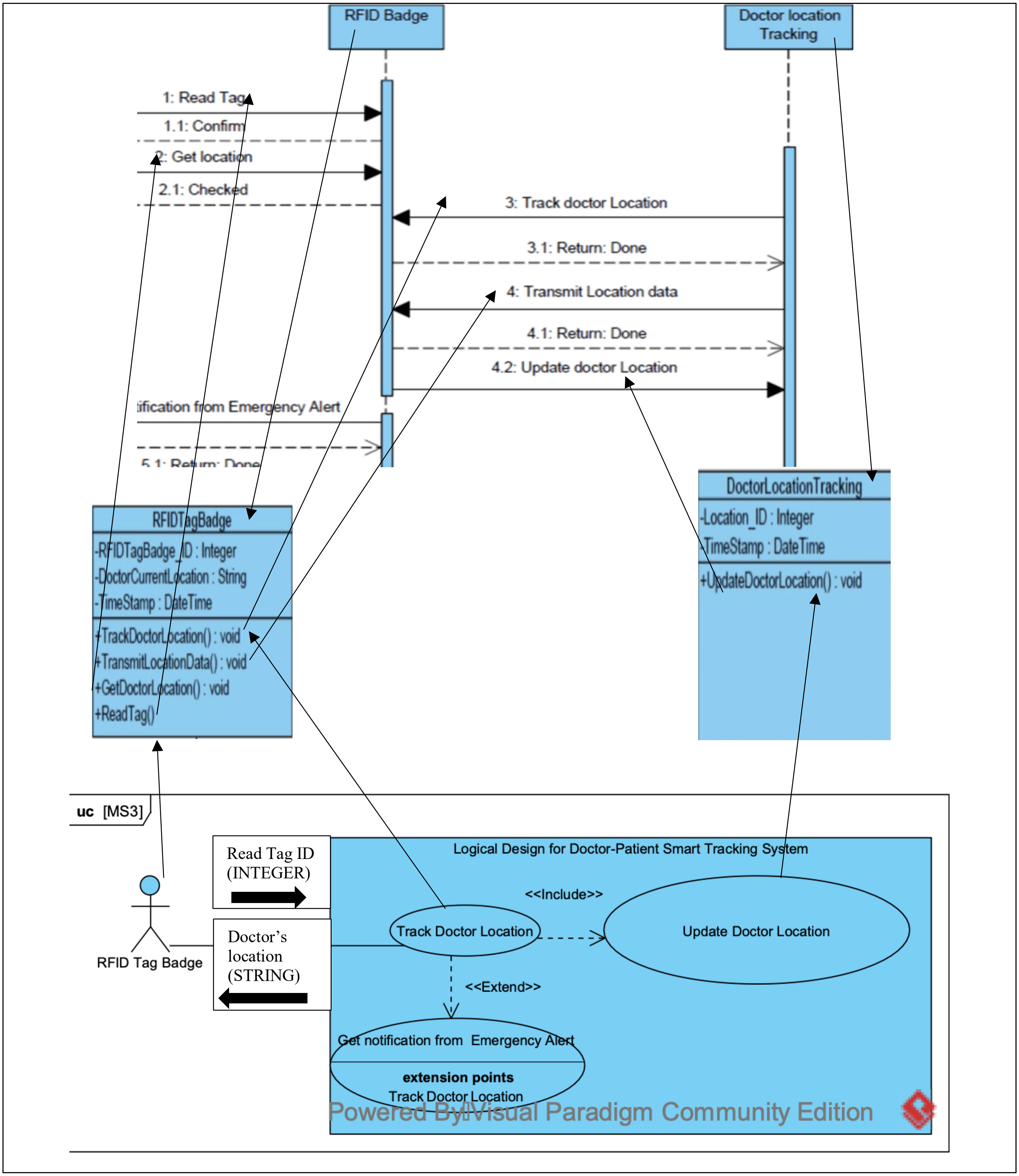
10.2.6.2 Ahmed Mustafa - 223269:




Emergency Alert
-Alert ID: Int
-Timestamp: Date Time
-Alert Status: String
+FindNearestDoctor(): String
Emergency Alert
4: Transmit Location
4.1: Return Done
5: Find Nearest Doctor
RFID Wristband
-WristbandID: Int
-Timestamp: Date Time
-LocationData: String
+TransmitLocation(): String
Alert
RFID Wristband
4: Transmit Location
4.1: Return Done

10.2.6.3 Merola Victor - 224329:



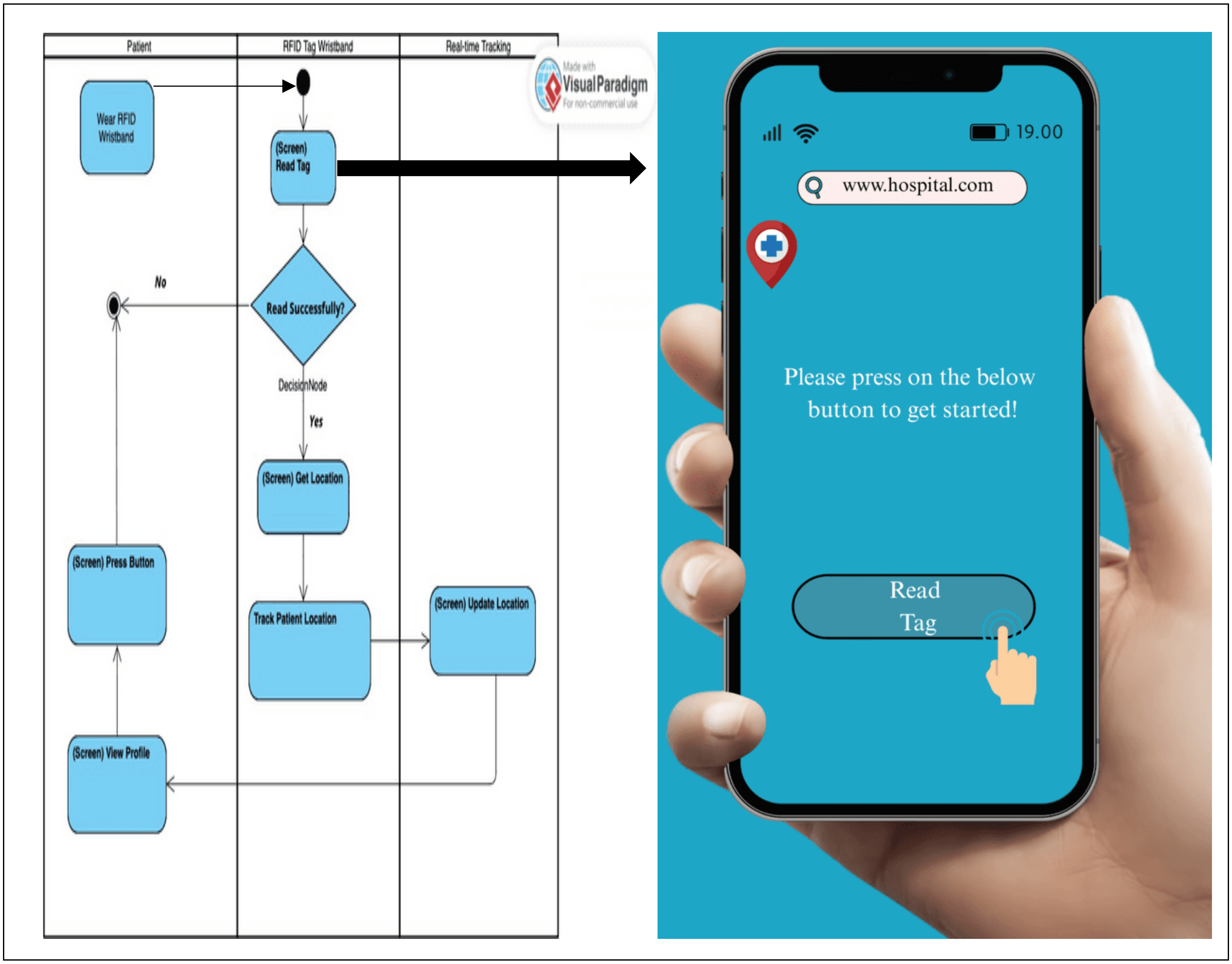

RFID Badge
Doctor location Tracking
1: Read Tag
1.1: Confirm
2: Get location
2.1: Checked
3: Track doctor Location
3.1: Return: Done
4: Transmit Location data
4.1: Return: Done
4.2: Update doctor Location
tification from Emergency Alert
5.1: Return: Done
RFIDTagBadge
-RFIDTagBadge_ID : Integer
-DoctorCurrentLocation : String
-TimeStamp : DateTime
+TrackDoctorLocation() : void
+TransmitLocationData() : void
+GetDoctorLocation() : void
+ReadTag()
DoctorLocationTracking
-Location_ID : Integer
-TimeStamp : DateTime
+UpdateDoctorLocation() : void
uc [MS3]
Read Tag ID (INTEGER)
Doctor's location (STRING)
RFID Tag Badge
Logical Design for Doctor-Patient Smart Tracking System
<<Include>>
Track Doctor Location
Update Doctor Location
<<Extend>>
Get notification from Emergency Alert
extension points
Track Doctor Location
Powered By Visual Paradigm Community Edition

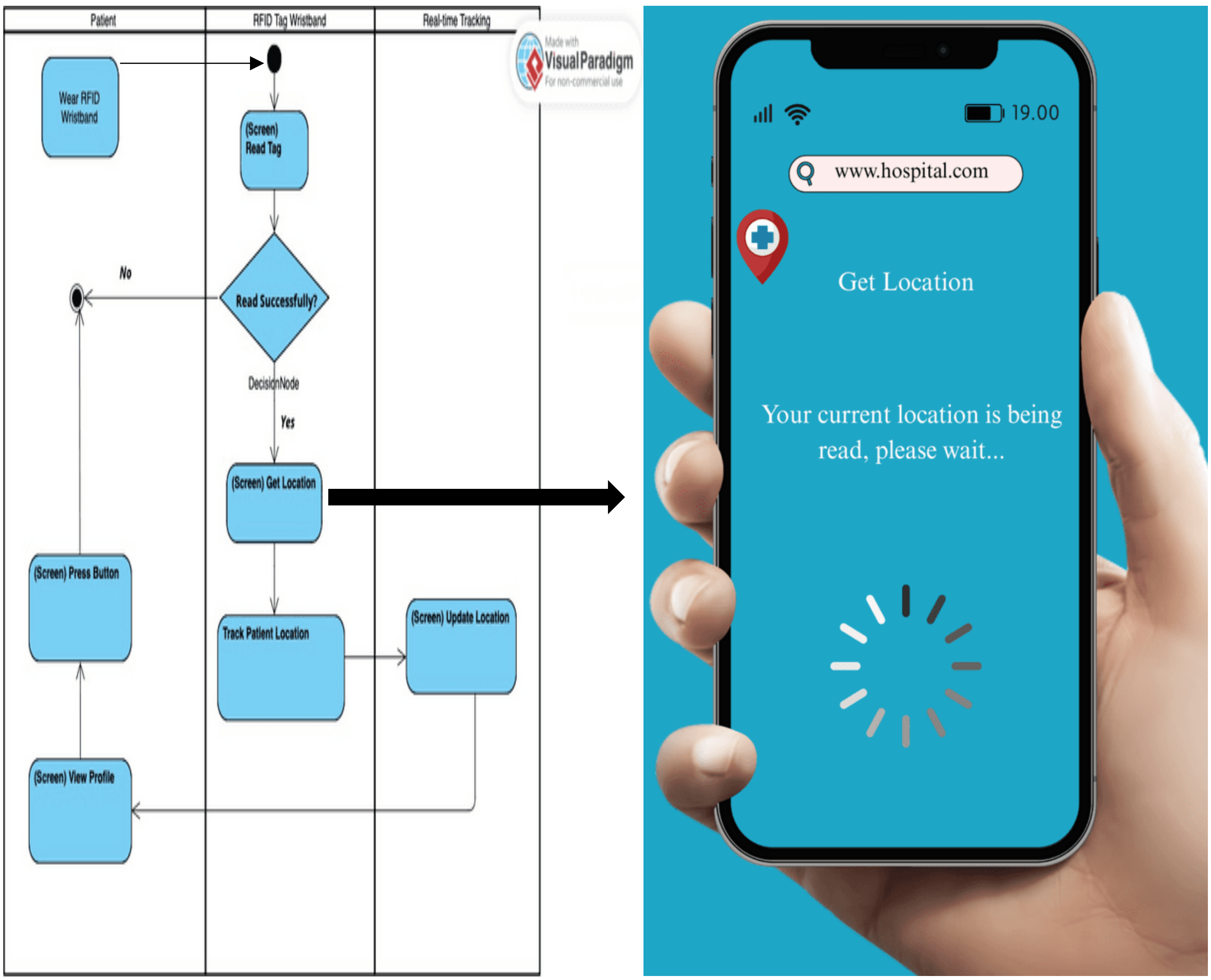
11 Screens Format Design with Reference to Activity Diagram

11.1 Life Prototype:

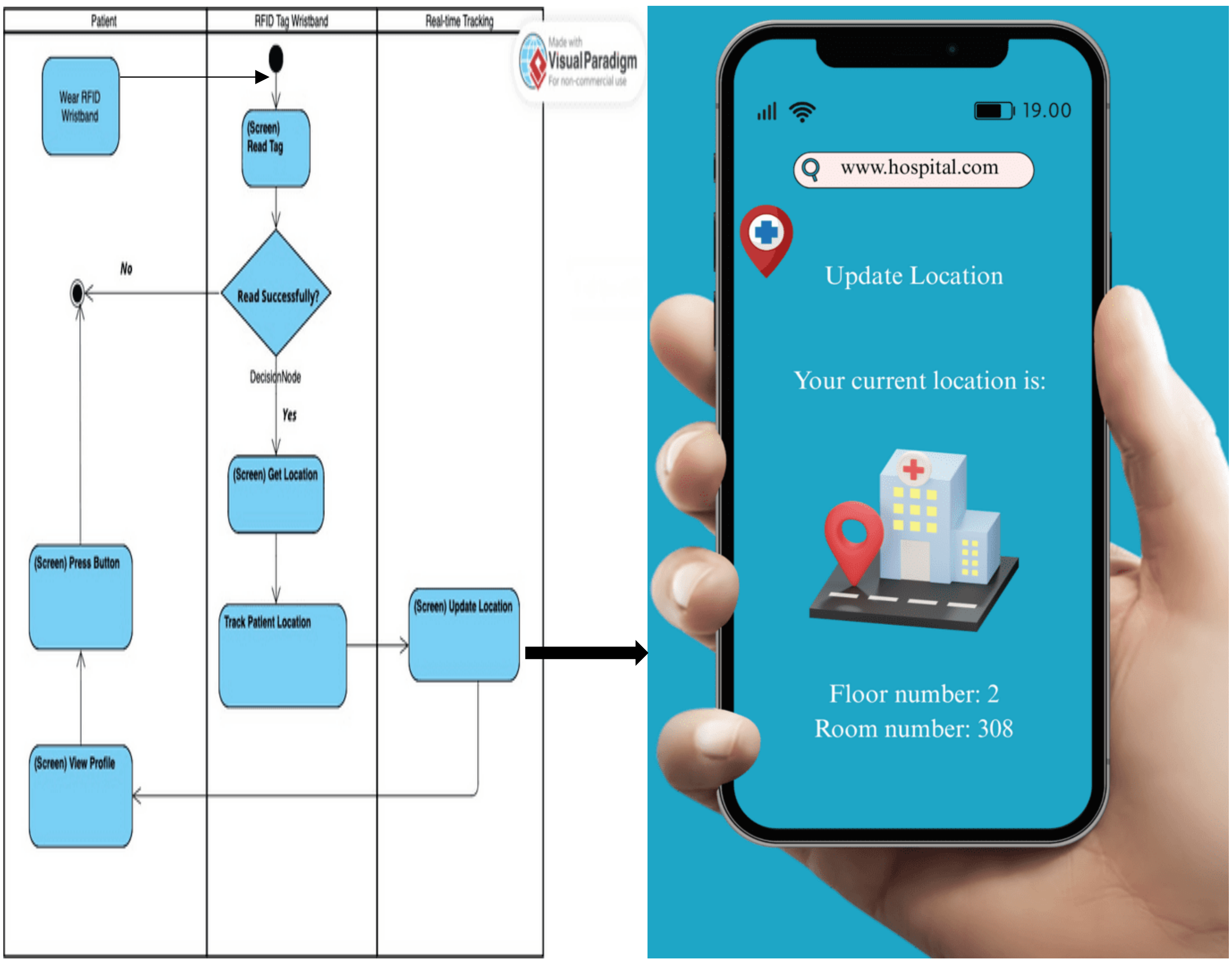
11.1.1 Fareeda Mohamed – 225163:

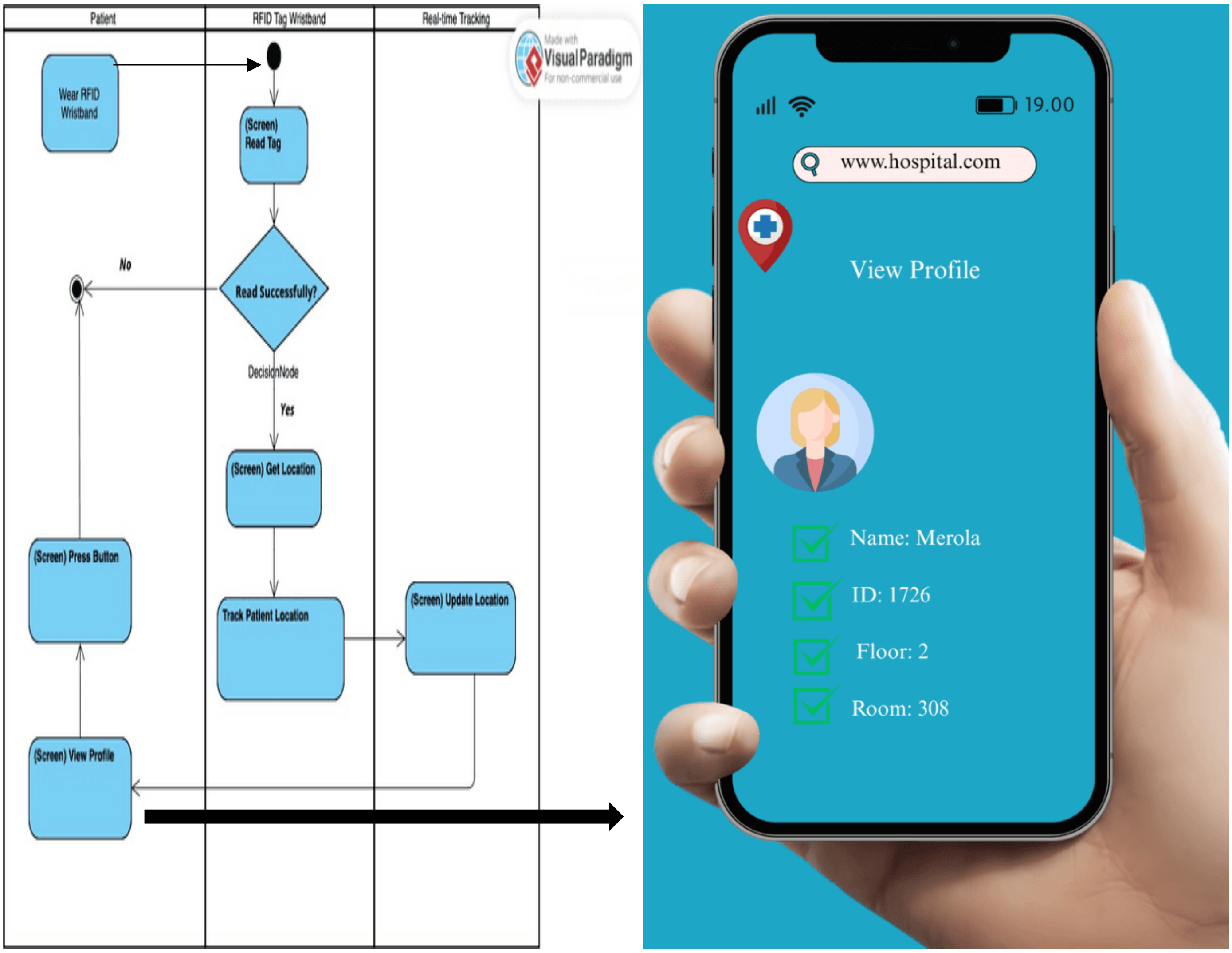
Screen Dialogs for Track Patient Location Microservice in relation with the Activity-Diagram

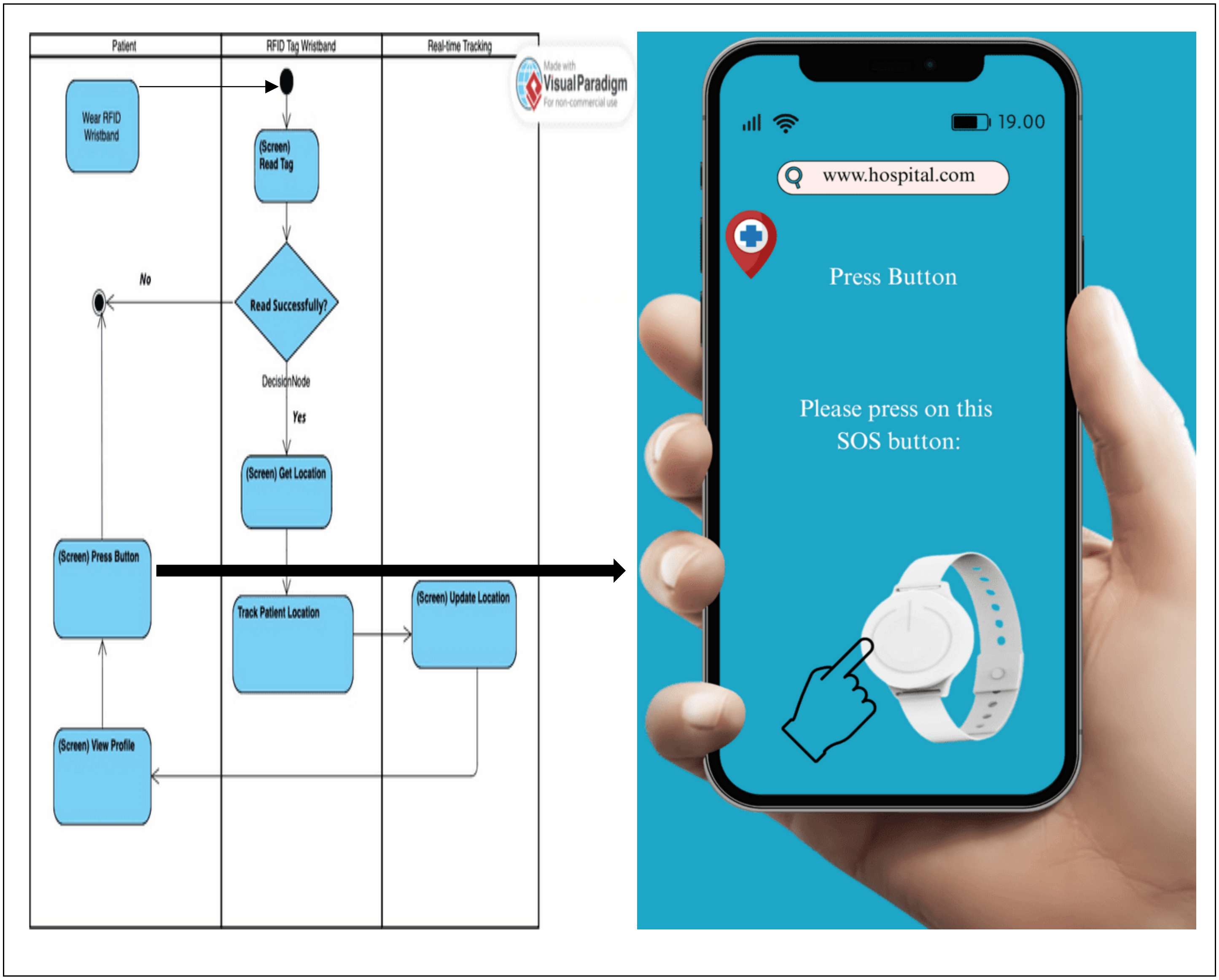




Patient
RFID Tag Wristband
Real-time Tracking
Made with Visual Paradigm
For non-commercial use
Wear RFID Wristband
(Screen) Read Tag
No
Read Successfully?
DecisionNode
Yes
(Screen) Get Location
(Screen) Press Button
Track Patient Location
(Screen) Update Location
(Screen) View Profile
19.00
www.hospital.com
Get Location
Your current location is being read, please wait...


Patient
RFID Tag Wristband
Real-time Tracking
Made with Visual Paradigm For non-commercial use
Wear RFID Wristband
(Screen) Read Tag
No
Read Successfully?
DecisionNode
Yes
(Screen) Get Location
(Screen) Press Button
Track Patient Location
(Screen) Update Location
(Screen) View Profile
19.00
www.hospital.com
Update Location
Your current location is:
Floor number: 2
Room number: 308

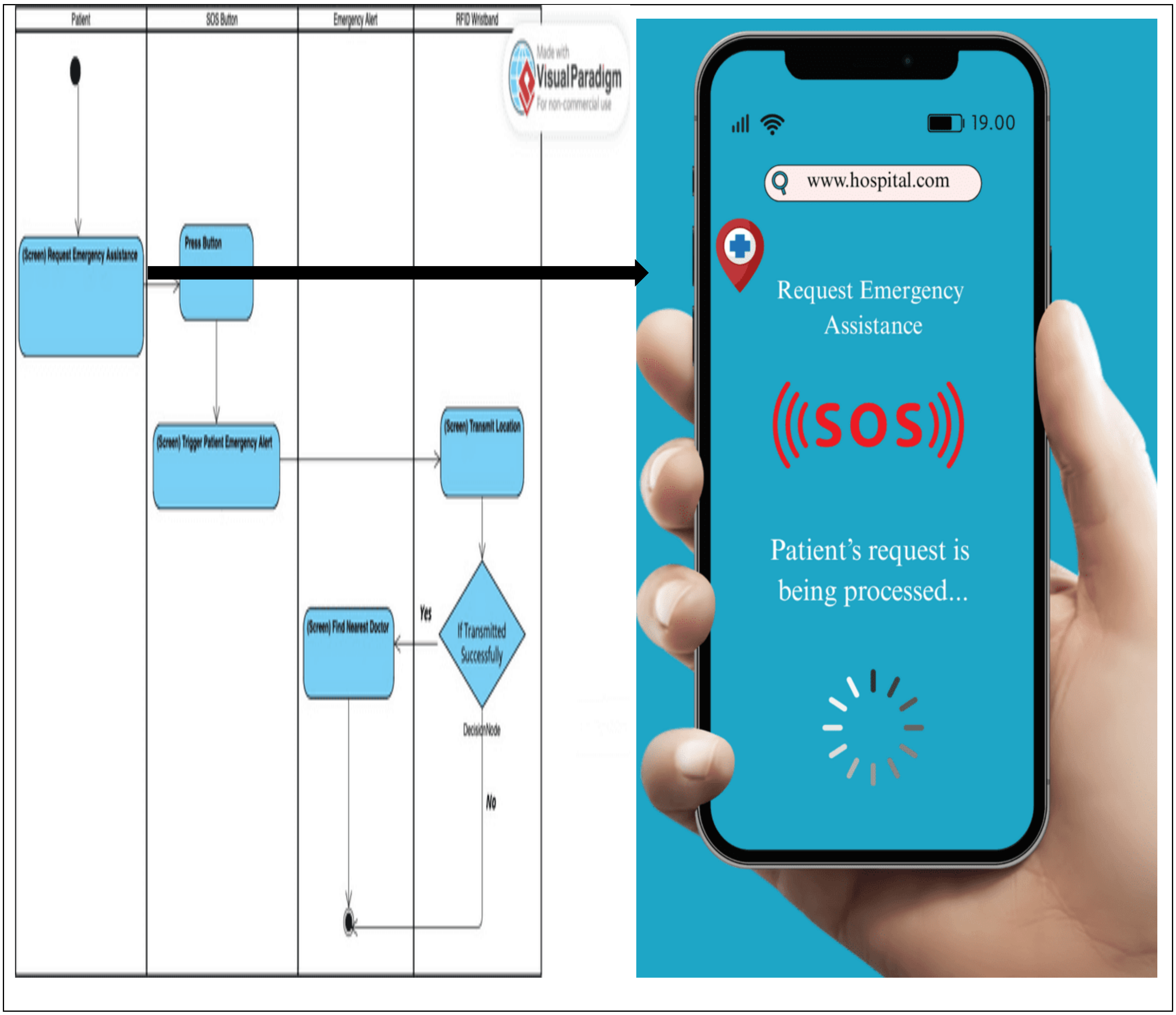

Patient
RFID Tag Wristband
Real-time Tracking
Made with Visual Paradigm For non-commercial use
Wear RFID Wristband
(Screen) Read Tag
No
Read Successfully?
DecisionNode
Yes
(Screen) Get Location
(Screen) Press Button
Track Patient Location
(Screen) Update Location
(Screen) View Profile
19.00
www.hospital.com
View Profile
Name: Merola
ID: 1726
Floor: 2
Room: 308

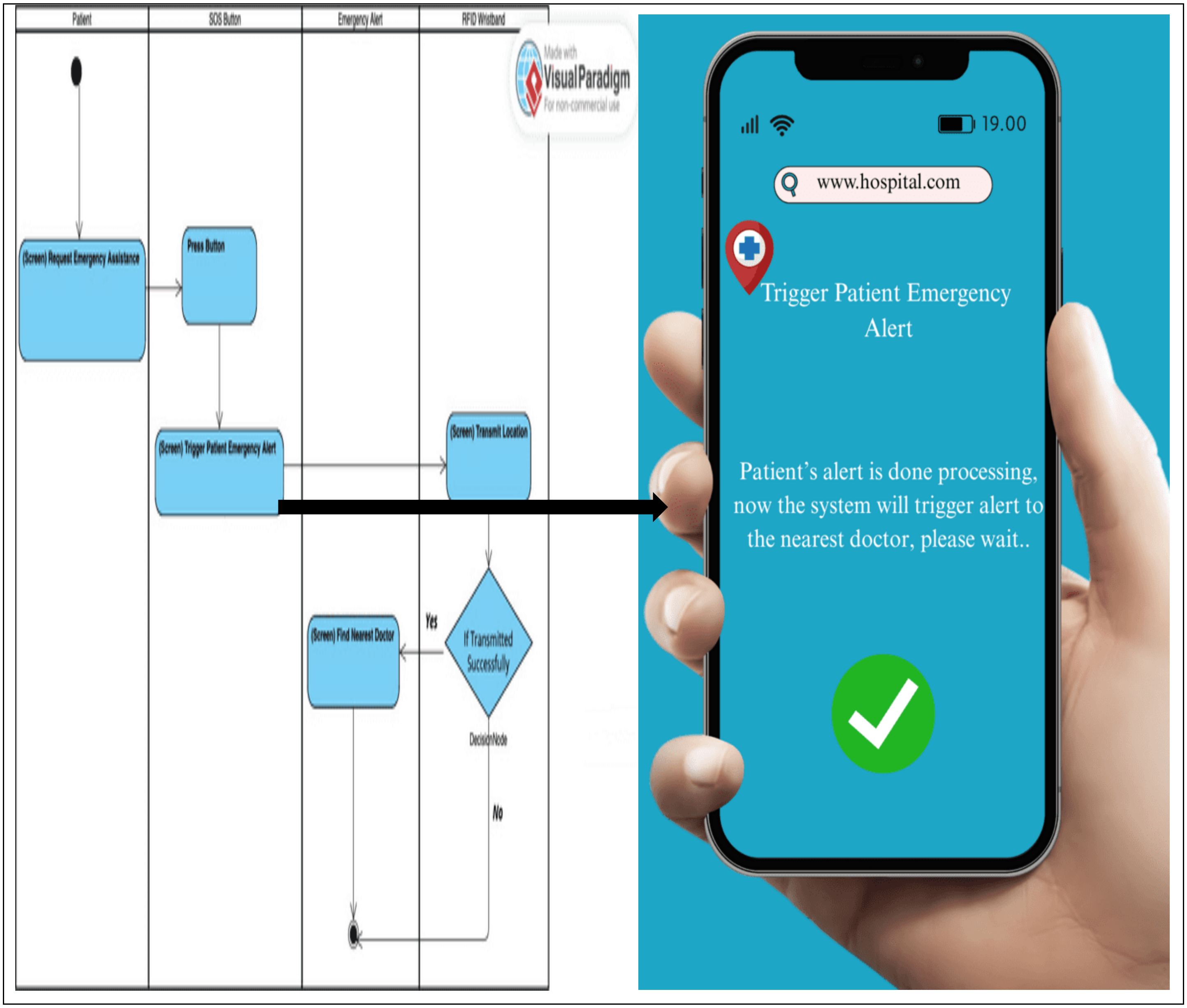


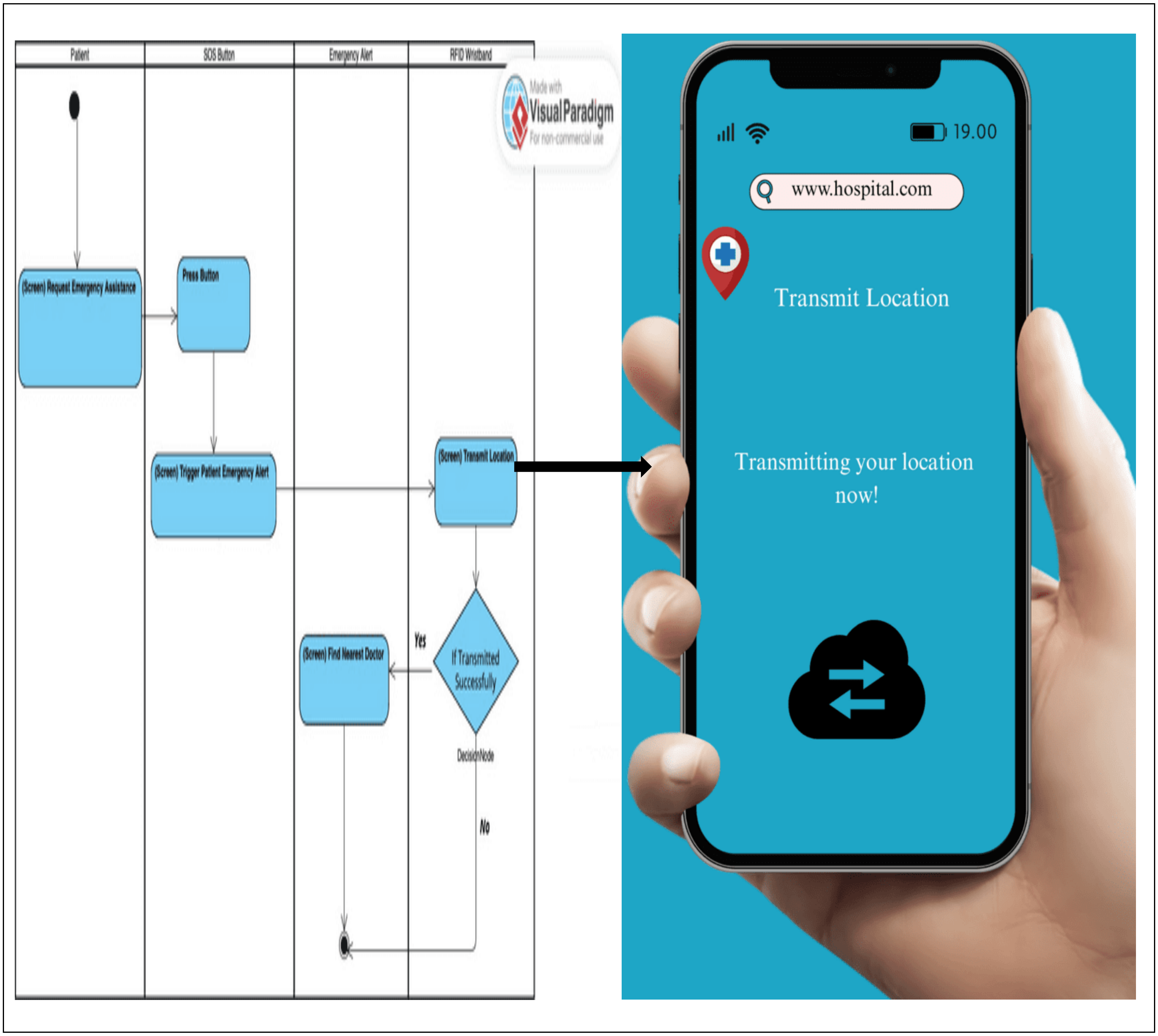
→ ***Note***: In our Life Screens Dialog, we have chosen a simple and user-friendly interface so that it can be easily used by anyone (e.g., patients and doctors).

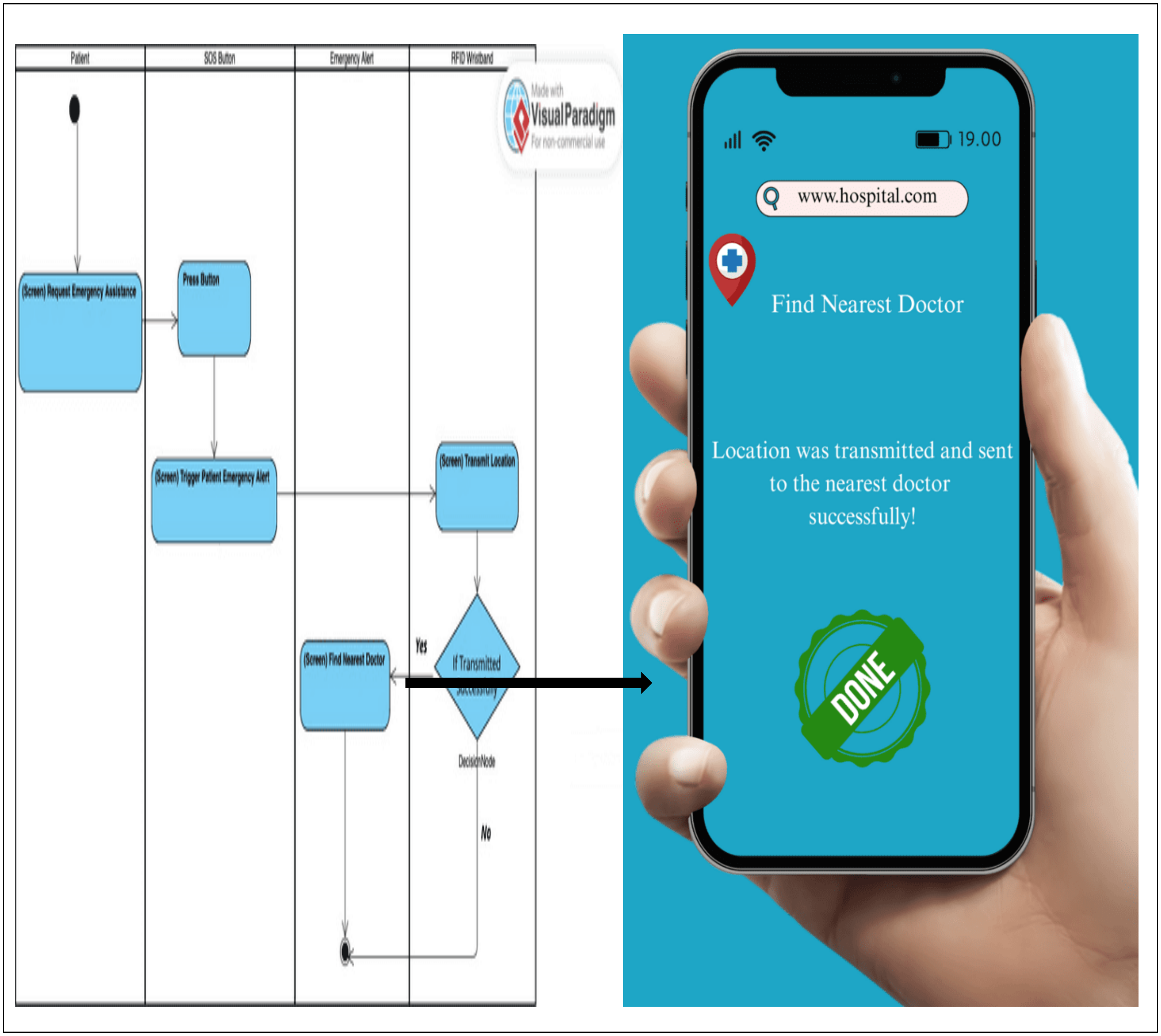
11.1.2 Ahmed Mustafa – 223269:

Screen Dialogs for Trigger Emergency Alert Microservices in relation with the Activity-Diagram



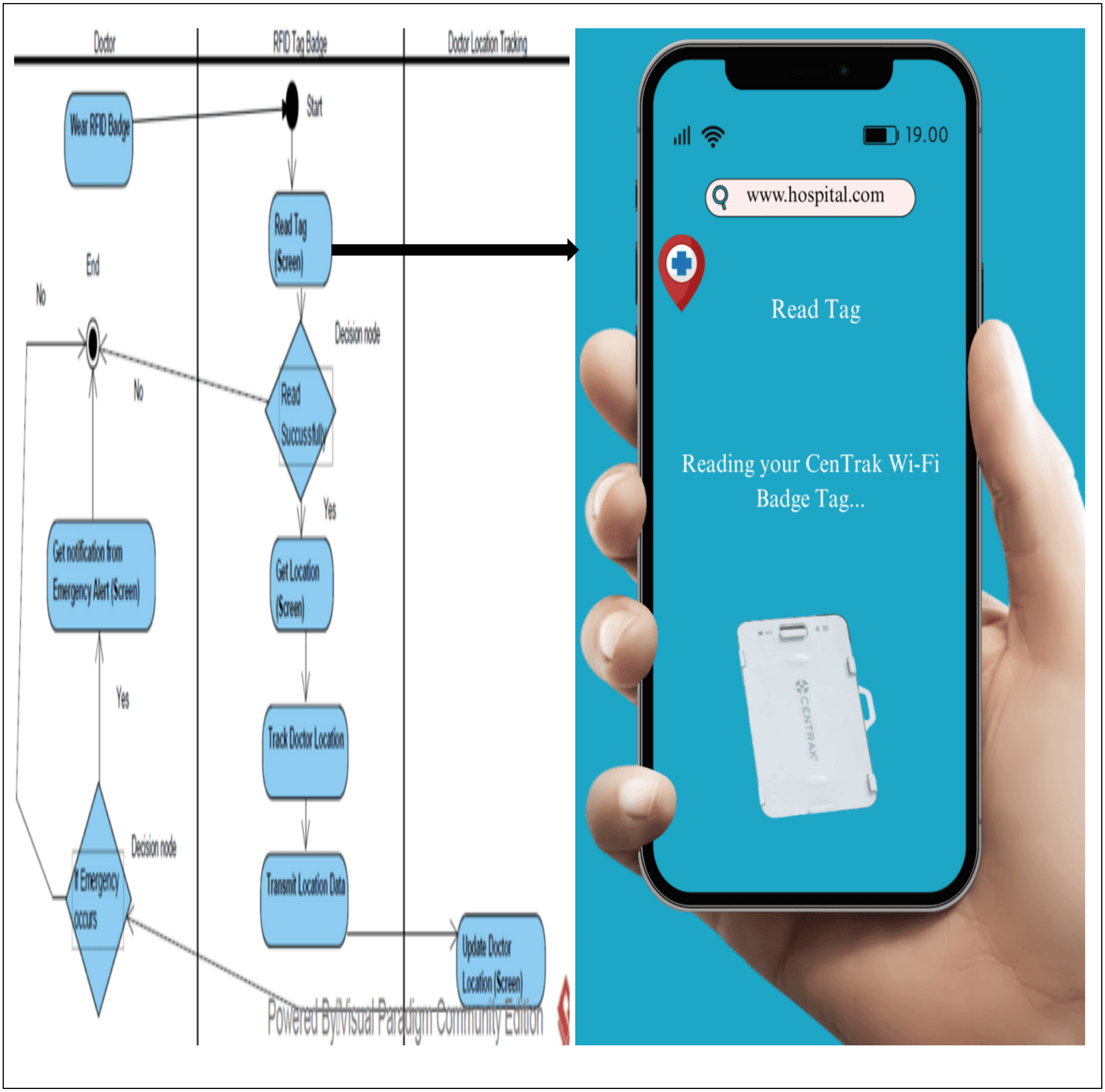

Patient
SOS Button
Emergency Alert
RFID Wristband
Made with
VisualParadigm
For non-commercial use
(Screen) Request Emergency Assistance
Press Button
(Screen) Trigger Patient Emergency Alert
(Screen) Transmit Location
If Transmitted Successfully
Yes
(Screen) Find Nearest Doctor
DecisionNode
No
19.00
www.hospital.com
Trigger Patient Emergency Alert
Patient's alert is done processing, now the system will trigger alert to the nearest doctor, please wait..

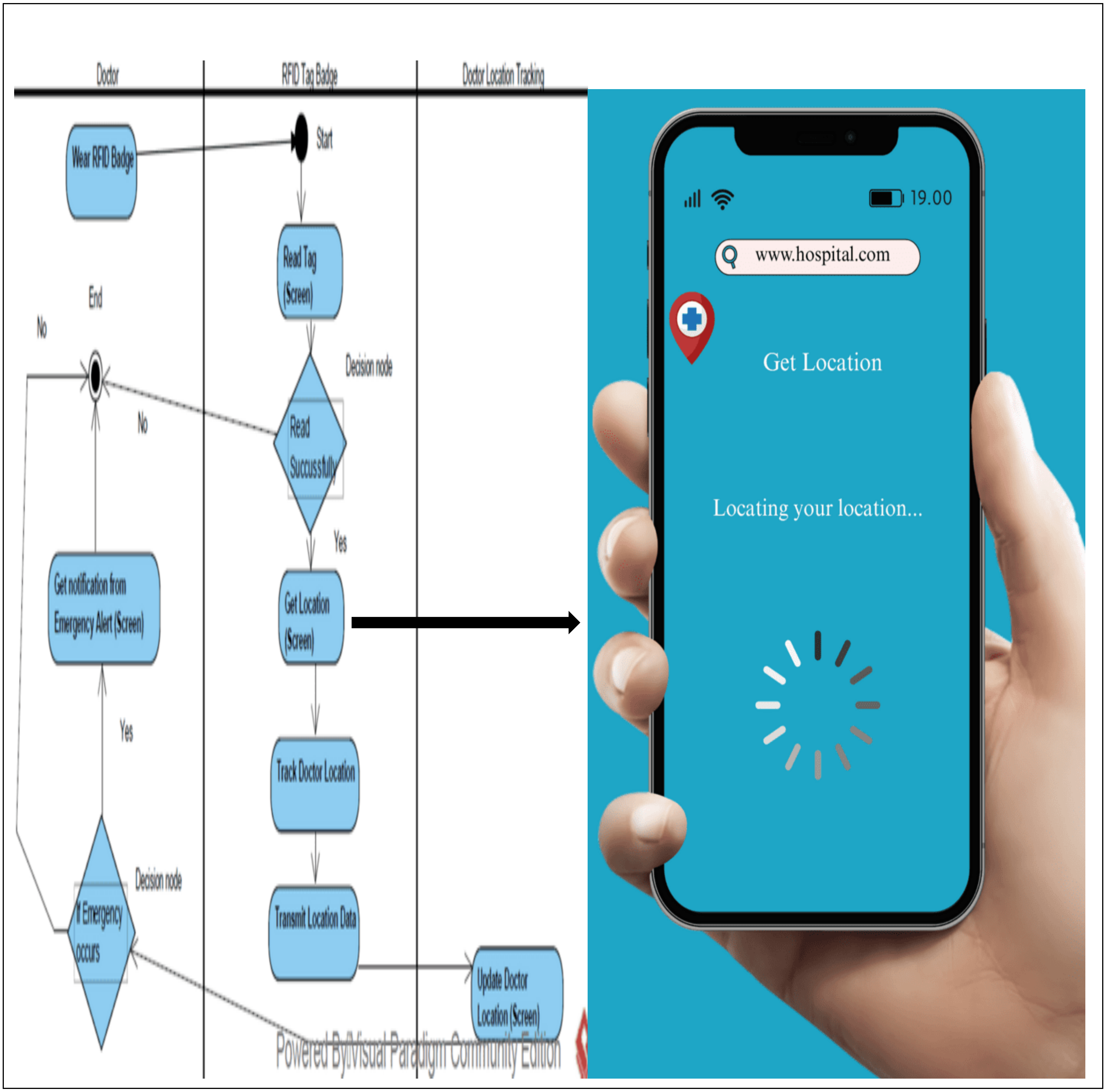

Patient
SOS Button
Emergency Alert
RFID Wristband
Made with
Visual Paradigm
For non-commercial use
(Screen) Request Emergency Assistance
Press Button
(Screen) Trigger Patient Emergency Alert
(Screen) Transmit Location
If Transmitted Successfully
Yes
(Screen) Find Nearest Doctor
DecisionNode
No
19.00
www.hospital.com
Transmit Location
Transmitting your location now!

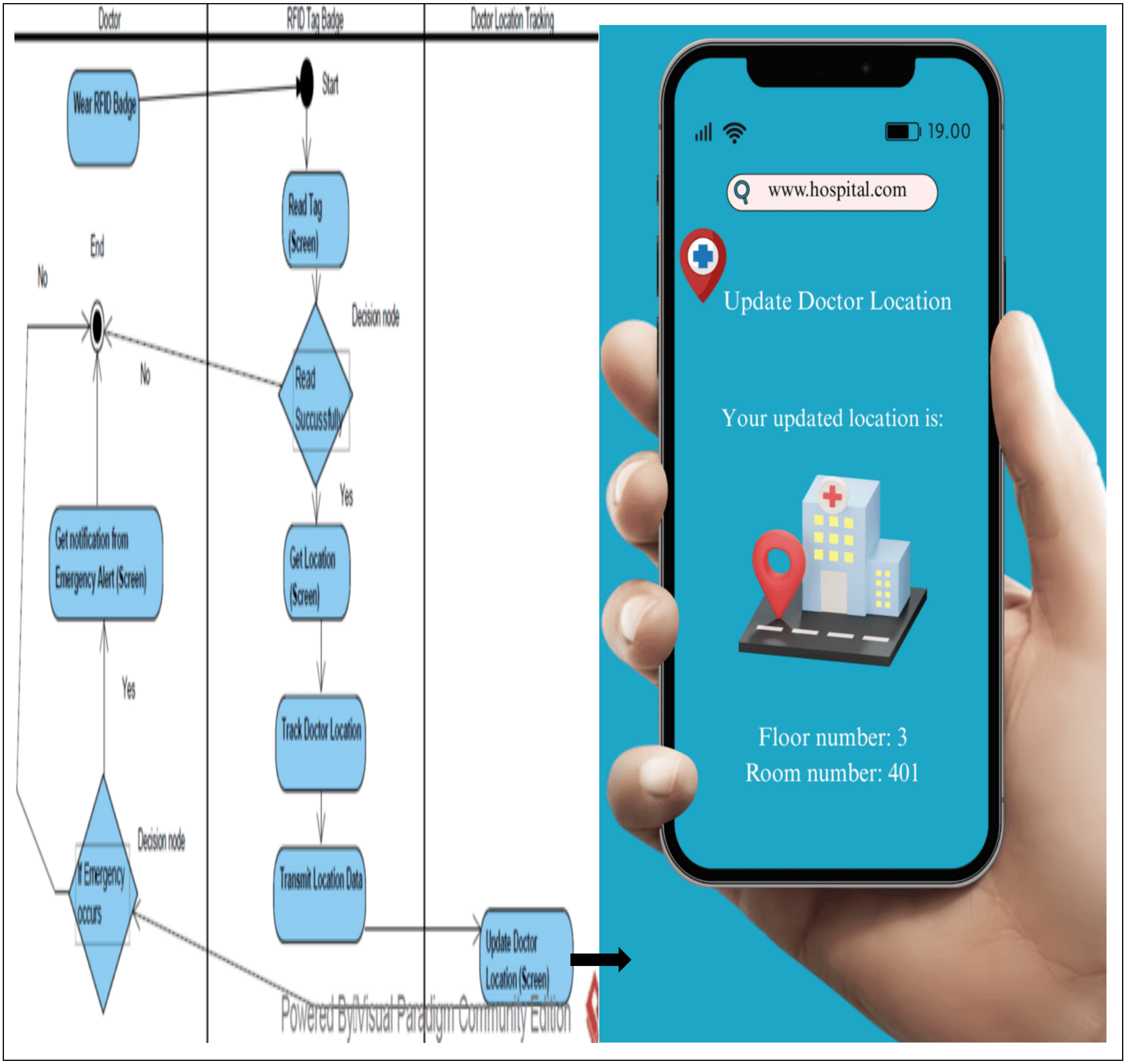

Patient
SOS Button
Emergency Alert
RFID Wristband
Made with
Visual Paradigm
For non-commercial use
(Screen) Request Emergency Assistance
Press Button
(Screen) Trigger Patient Emergency Alert
(Screen) Transmit Location
If Transmitted
Yes
(Screen) Find Nearest Doctor
DecisionNode
No
19.00
www.hospital.com
Find Nearest Doctor
Location was transmitted and sent to the nearest doctor successfully!
DONE

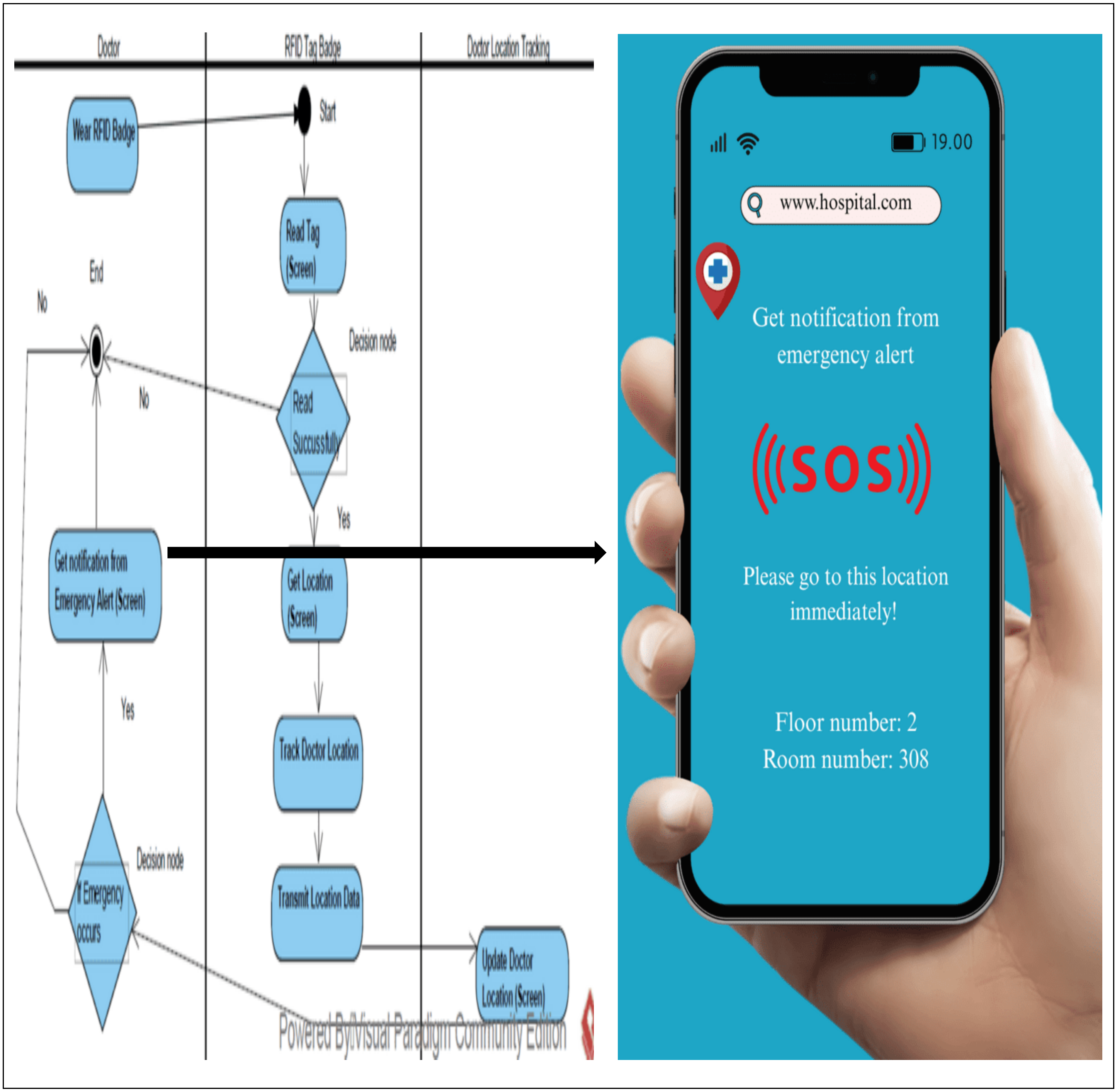
11.1.3 Merola Victor – 224329:

Screen Dialogs for Track Doctor Location Microservice in relation with the Activity-Diagram




Doctor
RFID Tag Badge
Doctor Location Tracking
Wear RFID Badge
Start
Read Tag (Screen)
End
No
Decision node
Read Succussfully
No
Yes
Get notification from Emergency Alert (Screen)
Get Location (Screen)
Yes
Track Doctor Location
Decision node
If Emergency occurs
Transmit Location Data
Update Doctor Location (Screen)
Powered By Visual Paradigm Community Edition
19.00
www.hospital.com
Get Location
Locating your location...


Doctor
RFID Tag Badge
Doctor Location Tracking
Wear RFID Badge
Start
Read Tag (Screen)
End
No
Decision node
Read Successfully
No
Yes
Get Location (Screen)
Get notification from Emergency Alert (Screen)
Track Doctor Location
Yes
Decision node
If Emergency occurs
Transmit Location Data
Update Doctor Location (Screen)
Powered By Visual Paradigm Community Edition
19.00
www.hospital.com
Update Doctor Location
Your updated location is:
Floor number: 3
Room number: 401



Doctor
RFID Tag Badge
Doctor Location Tracking
Wear RFID Badge
Start
Read Tag (Screen)
End
No
Decision node
No
Read Successfully
Yes
Get notification from Emergency Alert (Screen)
Get Location (Screen)
Yes
Track Doctor Location
Decision node
If Emergency occurs
Transmit Location Data
Update Doctor Location (Screen)
Powered By Visual Paradigm Community Edition
19.00
www.hospital.com
Get notification from emergency alert
((SOS))
Please go to this location immediately!
Floor number: 2
Room number: 308

12 Future Development Work

The Doctor-Patient Smart Tracking System offers a strong foundation for improving healthcare. Future advancements will further elevate its capabilities:

- **Deeper EHR/HIS Integration with Automated Data Sync:**
  - **Enhancement:** Implement real-time, bidirectional integration with EHR/HIS for automated updates of patient statuses, appointments, and medical notes using location and alert data.
  - **Benefit:** Offers comprehensive, up-to-the-minute patient overviews for informed medical decisions and streamlined workflows.
- **Predictive Analytics for Proactive Patient Safety:**
  - **Enhancement:** Utilize machine learning to analyze historical data (location, alerts, demographics) to identify abnormal behaviors or potential risks (e.g., wandering) and generate predictive alerts.
  - **Benefit:** Enables proactive patient monitoring, significantly enhancing safety and allowing timely interventions.
- **AI-Powered Patient Flow and Resource Optimization:**
  - **Enhancement:** Employ AI to analyze real-time patient movement and doctor availability, optimizing patient flow, predicting wait times, and allocating nearest resources (e.g., wheelchairs).
  - **Benefit:** Reduces patient wait times, improves resource use, and enhances hospital operational efficiency.
- **Enhanced Mobile Application for Patient/Family Engagement:**
  - **Enhancement:** Develop a sophisticated mobile app for patients/families, featuring secure, consent-based general location tracking, appointment reminders, educational materials, and direct communication with care teams.
  - **Benefit:** Empowers patients/families with transparency, control, improved communication, and reduced anxiety.
- **Expansion to Asset Tracking for Medical Equipment:**
  - **Enhancement:** Extend RFID infrastructure to track valuable medical equipment (e.g., pumps, ventilators) within the hospital.

  - **Benefit:** Optimizes asset utilization, reduces operational costs, and ensures critical equipment availability.
- **Integration with IoT Wearables for Comprehensive Health Monitoring:**
  - **Enhancement:** Integrate with IoT wearables for vital sign monitoring (e.g., heart rate, SpO2), providing a holistic view of patient's physiological state alongside location.
  - **Benefit:** Enables continuous health monitoring, early detection of deteriorating conditions, and immediate medical response.

This roadmap aims to transform the system into an intelligent, integrated, and vital tool for modern healthcare, improving patient outcomes and operational excellence.

We thank **Prof. Adel Ghanam** for his invaluable guidance, support, and mentorship, which shaped this project and its future potential.

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