COMP8230
MINING UNSTRUCTURED DATA
(SESSION 1, 2025)

ASSESSMENT TASK 1

Report on IoT Technologies to Further Optimise Emergency Medical Support

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Table of Contents

List of Figures

1. Executive Summary

This report proposes an IoT-based solution to improve emergency healthcare workflows, focusing on faster response, efficient communication, and better resource management. It introduces three core components: the **Smart Ambulance**, the **Smart Wearable Paramedic Device**, and the **Medical Resource Management System**.

Together, these technologies enable real-time data sharing, AI-assisted reporting, and streamlined hospital coordination, ultimately aiming to enhance patient outcomes during critical emergencies. A network overview and diagrams are proposed to depict system functionality, and our future goal is to evaluate the models based on response time, communication, and survival rate improvements.

2. Problem Background

2.1 Introduction to Healthcare

The Internet of Things (IoT) is defined at the most fundamental level as a network of devices interacting with each other via machine-to-machine communications, enabling the collection and exchange of data. [1] Within healthcare, IoT technologies facilitate automation and data gathering at unprecedented scales, providing continuous streams of information that can inform and improve clinical decision-making. [2]

From a healthcare perspective, IoT devices include any devices that can collect health-related data — computing devices, mobile phones, smart bands and wearables, digital medications, and even implantable surgical devices — and connect these data points to the internet. [3] This ecosystem allows healthcare providers to remotely monitor patient health, track medical performance, and respond more effectively in emergencies.

A key IoT-driven benefit in healthcare is the continuous monitoring of patients in real time, including those at home. This capability not only enables timely intervention and improved patient outcomes but also powers large-scale data analytics in areas such as disease trend analysis, resource management, and predictive care. [4][5] As the demand for more efficient and reactive healthcare grows, IoT stands out as a crucial enabler of advanced services like telemedicine, remote diagnosis, and emergency response optimisation.

2.2 What Type of IoT Data and Why It Matters

To enhance patient care, healthcare providers need diverse types of IoT data, both structured and unstructured. For instance:

- Vital Signs & Sensor Data: Continuous streams of vital signs (e.g., heart rate, blood pressure, and pulse oximetry) inform doctors in near real-time, reducing care delays.
- Environmental & Contextual Data: Ambient conditions (e.g., weather, temperature, road congestion) influence emergency routes and resource allocation.
- Equipment & Infrastructure Data: Monitoring medical devices, hospital capacities, and supply inventories ensures efficient resource deployment.
- Clinician/Paramedic Voice Logs & Notes: Paramedics often provide unstructured, voice-based status updates. Mining these voice logs can reveal insights that complement structured patient data.

Such wide varieties of data are pivotal not just for routine care but also for urgent, life-critical services, improving operational efficiency and enabling data-driven decision-making when minutes matter.

2.3 Data Sources

Given the broad spectrum of healthcare needs, data must be gathered from various sources and continuously monitored. Key sources for this paper include:

- **IoT-Based Sensors:**
  - CCTV, mmWave scanners, wearable sensors (e.g., heart rate), and on-device sensors for medical equipment.
  - Paramedic-facing devices, such as a wearable smartphone that captures real-time voice reports and visualises collected data.
- **Historical Hospital Data:**
  - Current and projected hospital capacity, staffing (HR) availability, and patient records.
  - Electronic Health Records (EHR) for patient histories and ongoing care requirements.
- **Open Data:**
  - Environmental and traffic data (weather, road congestion) to optimise ambulance routing.
  - Up-to-date medical literature or relevant studies to support clinical decision-making.

3. Motivating Scenario

An illustrative use case is **emergency healthcare**, where immediate responsiveness saves lives. With IoT devices monitoring patients at home, alerts can be sent directly to healthcare professionals when critical thresholds are met (e.g., dangerously low blood pressure, falling detection). Paramedics are then dispatched to the patient's location, equipped with **Smart Wearable Paramedic Devices** that integrate real-time vitals and contextual information.

Because time is critical in emergencies, reducing communication delays is paramount. Paramedics must rapidly transmit updated patient vitals, voice notes, and contextual data to hospital physicians. Meanwhile, physicians rely on unstructured IoT data (e.g., streaming video, voice logs, or dynamically updated hospital capacity metrics) to make well-informed decisions about the best treatment plan and most appropriate facility. Even en route to the hospital, paramedics are required to take notes of the patient, and the data will be shared with the transported hospital. By mining these unstructured data sources -potentially enriched with AI-driven analytics -clinicians gain clearer, faster insights that can significantly improve patient outcomes.

For instance, if a hospital is near full capacity, real-time data analytics can route the ambulance to a facility better equipped to handle the specific emergency. Such immediate insights play a pivotal role in ensuring that the patient receives optimal care without unnecessary delays.

Once the patient arrives, IoT devices (e.g., wearable monitors, video footage) and **generative AI** can streamline the creation or updating of electronic medical records, making essential patient information instantly accessible across different hospital departments. This seamless handover—from ambulance transport to hospital admission—exemplifies the **feasibility** and **key value** of IoT data mining: speeding up clinical workflows, reducing human error, and enhancing the overall quality of care.

4. Problem Statement

Despite advancements in continuous patient monitoring (CPM) through IoT, physically dispatching paramedics remains a necessity for emergency assessment and stabilisation. In these scenarios, **every minute counts**, and any **delay** in communication or hospital capacity can negatively impact the patient's survival.

Key Factors Affecting Survival Rate:

- **Ambulance Response Time:** Shorter response times often lead to improved survival outcomes. This has achieved significant improvement for those monitored.
- **Pre-Hospital Care Quality:** Critical interventions provided by paramedics before hospital arrival.
- **Hospital Resources:** Real-time data of advanced facilities or specialised care can further improve outcomes.

While CPM has significantly contributed to faster ambulance response, challenges still remain from the moment an ambulance is dispatched to the patient's arrival at the hospital. These include delays in relaying patient vitals, unstructured voice data, and hospital capacity updates—all of which are critical for triage decisions.

Accordingly, this paper focuses on further optimising that workflow by introducing three key IoT-driven applications—Smart Ambulance, Smart Wearable Paramedic Device, and Medical Resource Management System—to address communication, real-time analytics, and resource allocation gaps.

To tackle these challenges in an emergency, we propose an integrated IoT-driven framework comprising:

- **Smart Ambulance:**
  - Equipped with sensors and high-speed communications to continuously relay patient vitals and location data to hospital teams.
- **Smart Wearable Paramedic Device:**
  - Provides paramedics with real-time recommendations based on patient status, historical data.
  - Equipped with speech-to-text and generative AI to summarise the voice report (e.g., cutting obsolete information to precisely report what's most important based on accumulated data).
- **Medical Resource Management System:**
  - Utilises IoT data and predictive analytics to update hospital staff on incoming patients' condition with the generated report, optimise capacity, and allocate resources effectively.

This holistic solution ensures that emergency response is not only quick but also data-driven, enabling physicians to make immediate and informed decisions en route.

To note, this research focuses on the emergency care pipeline from paramedic dispatch to patient handover at the hospital. Prototyping and testing are limited to IoT applications within emergency healthcare settings, with particular emphasis on data exchange, analytics, and clinical decision support during critical, time-sensitive scenarios.

The effectiveness of the proposed IoT technologies will be evaluated using the following metrics:

- Measure improvements in response time and communication efficiency.
- Assess hospital resource utilisation—including bed capacity, staff availability, and specialised equipment—enabled by real-time IoT data.
- Investigate the impact of integrated IoT workflows on patient outcomes, particularly survival rates in critical emergencies.

5. Approach

This research adopts an applied and exploratory approach, combining simulation-based prototyping with a review of existing IoT applications in healthcare. The goal is to evaluate how proposed IoT systems can together enhance emergency response workflows, focusing on real-time communication, data processing, and hospital coordination.

5.1 Smart Ambulance

The Smart Ambulance is designed to enable real-time data collection and transmission, including vital signs such as heart rate and respiration. Equipped with IoT sensors, cameras, and 5G connectivity, the ambulance captures patient data and sends it to hospital physicians instantly. Physicians can make more data-driven decisions with real-time data, paramedics' reports, and predictive analysis using Python.

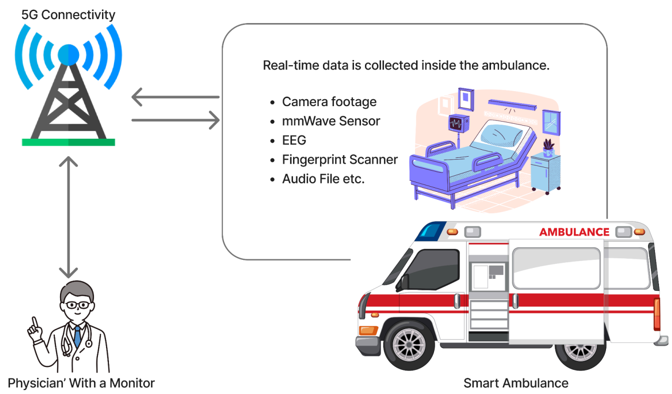

Figure 1: Smart Ambulance

5.2 Smart Paramedic Wearable Device (SPWD)

The SPWD is worn on the paramedic's arm to reduce interference during emergency procedures. It accepts voice input, converts it to text using speech-to-text APIs (e.g., Google Speech API), and generates a summarised report with the help of generative AI (e.g., GPT-based models). These summaries combine spoken input with real-time sensor data, mirroring real-life reporting tasks. The device also includes a fingerprint matching system to retrieve a patient's medical history, enhancing decision-making speed at the exact location of the patient. Training data consisted of anonymised EMR examples and paramedic case reports, enabling the system to extract relevant features for emergency contexts.

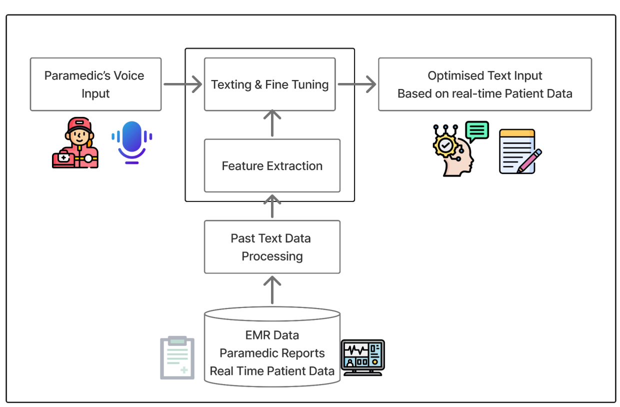

Figure 2: Smart Paramedic Device

5.3 Medical Resource Management System

MRMS is a platform that collects data from ambulances, wearable devices, hospital databases, cameras, and many open sources such as medical papers. It updates the emergency department with estimated arrival times and incoming patient information, optimising triage and bed allocation. Real-time updates are visualised, while predictive analytics are powered by simple rule-based models to simulate priority scoring and resource suggestions. However, the scoring system may not be necessary until its accuracy is assured as doctors are responsible for the decision. Simple analytics might suffice.

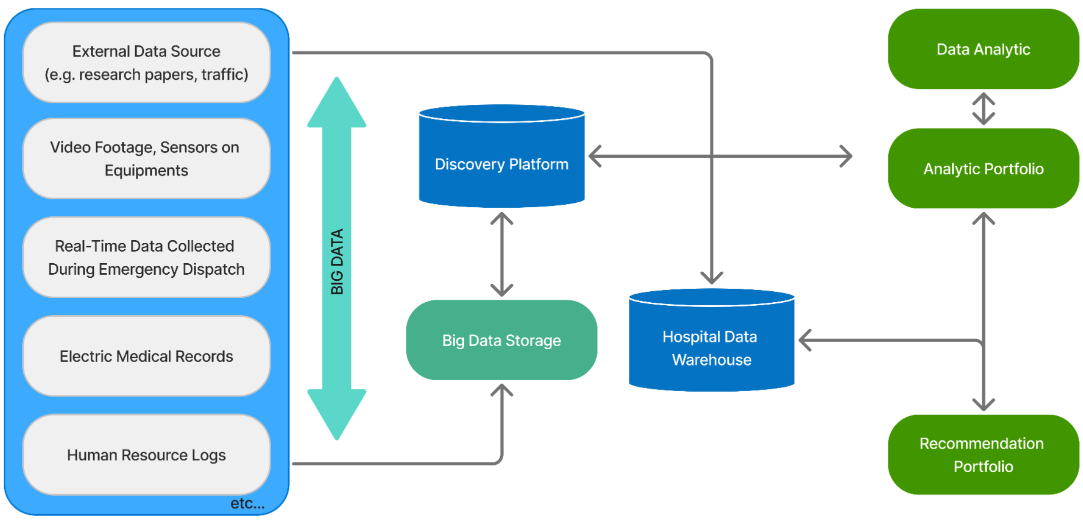

Figure 3: Hospital Resource Management System

5.4 Network Overview

This section provides an overview of the network, illustrating how the proposed applications are interconnected and how healthcare professionals use them to improve patient outcomes during emergencies. The Medical Resource Management System (MRMS) serves as a central hub, capturing a wide range of data to ensure seamless patient transport and post-care processes. For example, it can automatically transfer patient data to the existing Electronic Medical Records (EMR) system and update the emergency department with the patient's estimated arrival time. Generative AI can further optimise post-emergency care. In many cases, emergency departments maintain separate EMR systems, and physicians are required to manually document details that structured data alone cannot capture, such as the patient's visible reactions or observational health assessments. This creates an opportunity for AI to assist by generating or completing these unstructured records, enhancing both efficiency and accuracy in documentation.

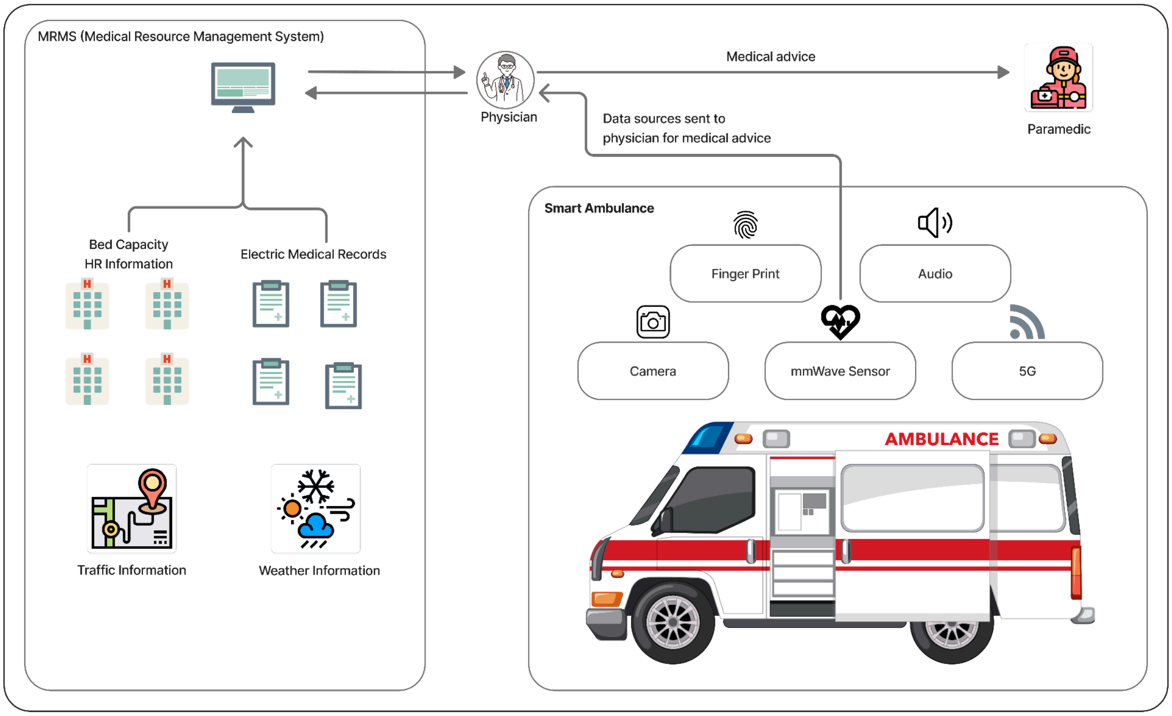

Figure 4: Network Overview

6. Prototype

Data analysis involved combining structured (e.g., sensor) and unstructured (e.g., voice) inputs to generate prioritised, summarised records. Generative AI was evaluated on its ability to produce accurate summaries based on the emergency scenarios. Basic metrics such as latency (response time), data accuracy, and patient outcome can be used to assess system performance.

Prototyping and simulation were chosen due to ethical and logistical constraints in accessing real emergency medical data. Using publicly available datasets and generating synthetic data allowed for safe, controlled testing. AI and IoT tools were selected for their proven applications in real-time systems and their relevance to healthcare automation.

7. Conclusion

This paper presents a proposed framework that leverages IoT and AI technologies to enhance emergency healthcare delivery. The integrated system, comprising Smart Ambulance, Smart Wearable Paramedic Device, and Medical Resource Management System, aims to optimise the critical workflow from paramedic dispatch to hospital admission. By enabling real-time data transmission, AI-assisted reporting, and predictive hospital resource management, the proposed applications are expected to improve response times, reduce communication delays, and ultimately enhance patient outcomes in emergency scenarios.

Future Scope:
Further development could involve integration with national healthcare databases, more advanced natural language processing (NLP) for medical reports, and deployment in real-world testing environments. Additional features such as facial recognition for patient identification, blockchain for secure data transfer could be explored to improve robustness and scalability. Continuous data collection and AI training will enhance system accuracy over time, making the solution smarter and more adaptive with increased usage.

8. Reference

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