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An Intelligent IoT-Based Architecture Towards Efficient Healthcare Facilities

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Abstract: This paper presents a comprehensive IoT-based architecture for healthcare facilities. The architecture proposes the use of IoT devices in ways that improve the efficiency of the healthcare facility and enhance the quality of care offered. The architecture spans the following areas: Lab tests administration, Patient Monitoring, Ambulance Services, and Meal quality. Four types of IoT devices are presented; one for each of the aforementioned areas. The system includes a central management system that connects the IoT devices and allows for integration with existing IT systems in the health facility. The paper presents the hardware design and the data model needed for each of these IoT devices. It also presents the use cases for these devices and how they can benefit patients as well as improve the efficiency of the healthcare facility.

Keywords: Internet of Things, IoT, Intelligent Systems, Healthcare Management System, Patient Monitoring

1. Introduction & Methodology

The use of Internet-of-Things (IoT) devices has been gaining lots of momentum in the past few years due to their reduced cost, and their ability to provide a constant stream of information in a data-driven world. The use of IoTs in the healthcare environment can be one of the best use cases for such devices, as it helps save lives, provide better healthcare quality, and reduce expenses.

Creating a complete architecture for a Healthcare Management System (HMS) is a complicated task that involves medical and financial aspects, customer preferences, and task scheduling. The medical aspects cover keeping track of the patient history, diagnosis of illnesses, laboratory tests, procedures, and treatment plans. Meanwhile, the financial side would cover: Payments for hospitals and health providers, insurance claims, as well as dealing with internal department payments and financials. As for the customer preferences aspect, it plays a crucial role in any HMS, for example allowing patients to select their physicians among a pool of available ones. Also allowing patients to select food items in meals that meet their dietary needs. Finally, one of the most important aspects of healthcare is timeliness. This task scheduling becomes a very involved task covering: scheduling appointments, lab tests, meals delivery, staff shifts, operations, and much more.
Thus it becomes apparent that proposing a complete architecture that details the aforementioned specifics is not feasible in the scope of the article. Instead, this article will focus on the parts of HMS where IoT devices can be used to:

- Reduce the time taken to deliver medical services or procedures.
- Reduce risks to patients by reducing the possibility of human error.
- Meet the personal preferences of patients.
- Enhance the quality of medical care by instating IoT supported quality control.

In this paper, a set of areas where IoT devices can be deployed is presented. For each of these areas, the proposed hardware design is discussed, then focus is shifted to what data will be collected and communicated to the Central Management System (CMS). Finally, to demonstrate the usefulness of these devices and how they integrate with the HMS, detailed use cases are presented that show how the proposed architecture can benefit the patients and the healthcare community. The areas of HMS that are proposed to use IoT-based devices are Laboratory Management, Patients Monitoring, Ambulance Services, and Meals Management.

In section 2 a review of related work is presented. Section 3 presents the overall system architecture. Meanwhile, Sections 4 through 7 describe the aforementioned four IoT devices with their detailed design, data, and use cases.

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Finally, section 8 presents the conclusion and how this work can be expanded.

2. Literature review

The use of IoT devices in the medical field has been expanding more and more in the past decade. This is probably because the healthcare industry is estimated to be more than 2 trillion US dollars by 2020 with an annual consumer market for remote/mobile monitoring devices estimated at 40 billion dollars globally [1]. This does not come as a surprise as the IoT technology has the potential to change the healthcare system to be more efficient.

In [1], [2], [3], [4], [5] the role and the challenges facing IoT in building smart e-healthcare services are discussed. In [1] the author focuses on the main applications that use IoT devices in the healthcare sector and attempts to understand the main characteristics of these applications and the patterns and protocols used in them. In [2] the author first discusses other IoT-based healthcare applications and identifies a set of challenges that need to be addressed to implement any IoT healthcare system, namely; security, privacy, and trust. Whereas in [3] the author attempts to understand how to optimize the use of IoT in the healthcare sector by comparing the existing IoT-based wearable solutions in healthcare and comparing the existing hardware, communication technologies, and cloud platforms to determine their suitability for healthcare applications. In [4] the author examined IoT applications in the medical field from a service-oriented and security perspective. The author demonstrated the need to move towards using IoT in the healthcare field, and that a service-oriented architecture simplifies the development of healthcare systems by supporting modular designs, program integration, and software reuse. Finally, the author discussed the need to have broader research on security in service-oriented architecture and IoT. A more recent study presented the major limitations in the current IoT systems; such as high power consumption, the availability of resources as well as security issues that arise from the use of many types of devices [5].

It is worth noting that an enormous segment of the current IoT research and applications is concerned with monitoring. Whether it is for in-patients, patients who just existed in the hospital but still need some form of care or even patients with chronic diseases or the elderly. In [6] an IoT remote patient monitoring system is introduced. The system offers faster and better medical intervention for patients in the hospital. The paper describes the implementation of the system that uses sensor nodes; where each node monitors one physiological signal. Each patient would be equipped with as many sensors as needed for the patient's case. A gateway will connect all the sensor nodes to the network and would gather the data from the nodes and provide it to the medical staff.

The research in [7] proposes an IoT platform for human services that will function as a self-management model for chronic diseases. The system has sensors that monitor the patient's needed vitals related to his disease. The sensors will send quantified information to a REST API and the last piece of the system; the mobile application will pass the data to a specialist to analyze the vitals and the medical status. In addition to this, the medical data is stored in the patient's cell phone and the doctor's facility information server that will be indicated by the client.

Another form of monitoring was proposed by [8] , the author proposes a smart hospital system for tracking patients, personnel, and biomedical devices within the hospital. The system combined radio frequency identification (RFID) along with wireless sensor network technology. It takes advantage of the low-cost low power of RFID and the fact that it can operate within the reader coverage of a maximum of 25 meters. This is combined with the larger coverage that wireless sensor network offers, patients would have host tags that sense their vitals and transmit them to several nodes that are deployed in the hospital. The nodes would send the data to the IoT Smart Gateway, and then the data would be processed in the cloud where it is stored in an online database that the medical staff can access through an application or a web interface. In case of critical events, the host node would go into a high-power consumption - high coverage range mode and send an alert to the monitoring application to inform the medical staff.

In some cases, systems were proposed to not only monitor but control the patient's state, such as [9] where the authors proposed an IoT-based P2P medical support system. They have implemented a smart box device with many functions that allow the system to monitor the patients' situation and control the patients' surroundings through a body sensor, chair or bed vibrator control, light control, smell control, sound control, and remote-control socket. The system has been tested and it successfully detected the patient's situation in three different scenarios and acted properly.

Paper [10] discusses remote elderly monitoring from a user-centered perspective to discover the elderly care requirements in an IoT-based system. The author analyzed existing IoT elderly monitoring systems and categorized them into 5 categories: health monitoring, nutrition monitoring, safety monitoring, localization and navigation, and finally social network. The author discussed different applications in each category and investigated their advantages and shortcomings considering the elderly requirements. [11] discussed a different approach for remote elderly monitoring, where the author gathered data from IoT devices from senior homes over 1 year, then used indoor density-based clustering analysis of location tracking to analyze the residents' movements. Using this type of monitoring instead of wearable devices helps to ensure that the data collected is as ecologically valid as possible due to its passive nature. The authors of [12] presents a summary of elderly people monitoring applications using IoT frameworks. The paper also discusses aspects of patients' data security and integrity. Specialized case monitoring is discussed in [13], [14], [15], [16], [17]. In [13], [14] authors propose to develop a system for people with special needs. Paper [13] presents an algorithm that uses cameras with the non-overlapping field of views along with sensors to detect the presence of a person and identify him. Afterward, the system will analyze the data and provide reports and alerts to the caregiving staff. Meanwhile, in [14] the author proposes an architecture that consists of wearable sensors that can be used to closely monitor changes in a patient's vital signs. The collected data will be uploaded to the cloud for further analysis. The data is constantly uploaded via an application that provides real-time feedback for the caregiver.

Paper [15] proposes a mobile application for monitoring patients who suffer from dementia, autism, and Alzheimer's. The main objective was to detect dangerous activities or dangerous zones that the patients should not be in as designated by the caregiver. This is done through various sensors used in geofencing and activity recognition including tri-axial accelerometers, gyroscope, GPS, and others. The application processes the input from these sensors and uses danger detection algorithms to alert the caregiver in case of danger.

In [16], not only the author discussed monitoring but also the diagnosis of Parkinson's disease. The author proposed an approach to use IoT to create an automatic remote procedure for tremor register and postural instability assessment, the system will take the data collected from wearable sensors, and analyze it to produce reports on the patient's case and alerts if necessary. The analyzed data then is checked by an intelligent clinical decision support system to give the diagnosis and treatment. Using IoT in the diagnosis stage will eliminate the possible errors caused by the subjective nature of the tests used for diagnosis. A sleep quality monitoring system was proposed and designed using off the shelve component [17]. The system achieved an accuracy of 95% when compared with manual data. The author of [18] focused on remote patient monitoring by proposing a 7-layers architecture for developing an IoT-based healthcare platform. The platform connects the patient's home, his family's home, the ambulance service, and the hospital. This allows for monitoring the patients and alerting the family and medical staff in case of an emergency. The paper discussed the data management for patients, medical staff, and the alerts needed.

Authors in [19] identified new data processing platforms that can be used in processing electronic health records to help determine the appropriate processing platform that can support real-time processing for these records. After describing and comparing a large variety of proposals the author went to discuss key points in healthcare record processing -such as deployment, robustness, and security- and how they should be present in the various proposals discussed. An ontology-based system was proposed to facilitate the interoperability and interconnectivity of IoT devices in the medical field [20]. While the proposed methodology is very generic, the current paper outlines some use cases and devices that have not been discussed.

As the growth of IoT applications has resulted in tremendous amounts of data, many researchers have discussed the methods to handle big data generated by IoT devices. In [21], the author started by dividing the IoT applications into three main layers and identified the challenges in each layer related to IoT and cloud services. Then the author discussed big data processing in IoT applications starting from pre-processing, data storage, and various proposals to the analysis of big data. Finally, two tools for managing IoT data were discussed. While in [22], the author proposed an approach for multi-cloud storage for mobile devices after reviewing three existing systems and evaluating them based on battery consumption, CPU usage, and data usage. The proposed system was able to overcome the limitations of the existing three. A more recent study investigated the doctors' intentions to use IoT healthcare devices in Iraq during COVID-19 pandemic [23]. The study finds that external factors such as privacy and cost significantly impacted doctors' behavioral intention to use IoT devices during the COVID-19 pandemic.

It can be seen that previous research has either focused on a specific target group, like the elderly, or a specific application like vitals monitoring. In this paper, a comprehensive architecture that is not bound by specific target groups nor an application is being presented.

3. System Architecture

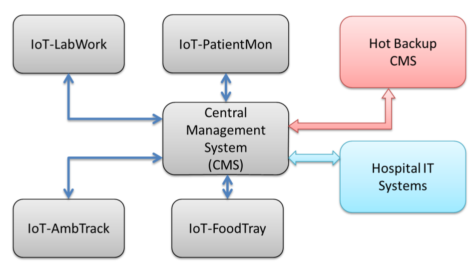

Figure 1. Architecture of an IoT-Based Healthcare Management System

The core component of the proposed architecture is a Central Management System (CMS). The CMS will be responsible for communicating with a large number of instances of the four IoT devices mentioned earlier. The main motivation for using the CMS is to provide continuous tracking on the devices that are distributed inside and outside the health care facility. The CMS will also be responsible for interfacing with the rest of the hospital IT systems, as shown in Figure 1. With this setup, the CMS will shield the hospital systems from having to deal with a large number of message exchanges with the wide range of IoT devices, and only provide high-level needed information to the hospital system. The function of the CMS is so critical, such that there needs to be a hot backup replica of the system. The replica should take over immediately in case the main system fails.

The multiple IoT-based systems will be used inside and outside the hospital and will communicate with the CMS over Internet connections. The system needs to be able to locate the IoT devices inside and outside the hospital premise. Finding the location outside the hospital can be done via GPS modules. However, inside the hospital, an Indoor Positioning System (IPS) is needed. The details of the IPS are not discussed in this paper, but it can be implemented by using a hybrid of WiFi-based IPS and an RFID tag locator.

4. Laboratory Management - IoT-LabWork

Laboratory tests constitute a major task to manage inside any health care facility as multiple parties and stages are involved. First, doctors order lab work, nurses head to rooms to take samples. Next, samples are sent to the lab, labs perform the needed testing and finally, results are communicated back to the medical staff. The fact that this is done very often increases the chances of mistakes and delays.

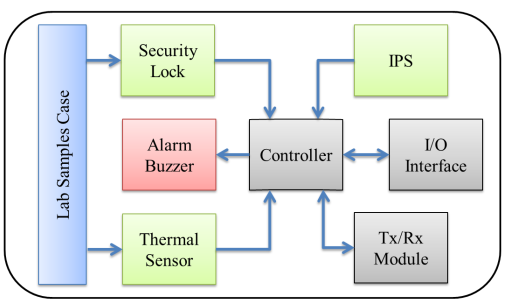

Figure 2. High-Level Hardware Design of IoT-LabWork

A. Hardware Design

An IoT-based device is proposed to organize and track the laboratory work in the hospital, let's call it IoT-LabWork. Each set of samples taken would be stored in an IoT-LabWork device. Figure 2 shows the proposed hardware of the device. The device will contain: A case to hold the samples, a security lock, an IPS module, a temperature sensor, an alarm, I/O interfacing devices, a communication module, and finally a controller. Once started an IoT-LabWork device can query from the CMS the samples needed based on the patient ID.

B. Data Model

This section discusses the data model for the data collected by the IoT-LabWork device. Figure 3 demonstrates the relationships organized by these data entities. While some of the data is being stored momentarily on the device, eventually all data need to be maintained on the CMS for further analysis and performance enhancement.

When the doctor requests a sample a new sample profile is created and connected to both the doctor's profile who requested the sample and the patient's profile. Upon requesting a sample, the doctor will set its priority and test ID, the priority will denote the urgency of the test, and the test ID will connect the sample to a test's profile which will determine the type of test that will be performed, the validity time and temperature of the sample. It will also determine the equipment needed to perform the test. Once the sample is taken the IoT-LabWork will store the sample date time and will connect the sample's profile to the profile of the nurse who took the sample. Each sample would be associated with an IoT-ID which will refer to the Device where the sample will be stored before the test. A start test date-time will be stored when the test starts, and when the test finishes a result date-time will be stored, the test results then will be delivered to their destination whether it was the nursing staff, the doctor, or the emergency room staff depending on the doctor's notes given when requesting the sample.

C. Use Cases

In this section, we examine the different usage scenarios where the hospital can leverage its services by using IoT devices. typically, the Normal operation use case is presented first, then alternate use cases are presented

1) **Normal Operation:** Upon taking the sample from the patient, the system will register the date and time that the sample was taken. While the sample is being delivered to the lab, the IPS will register the current location of the device. Upon the arrival of the IoT to the lab, the sample is checked into the lab. Once the testing is started, the system will register the time that the sample was tested. This information would be stored in the CMS database and will be available for the medical staff and/or the patient, based on previously defined parameters.
2) **Sample Validity:** Each test has a predefined period that it needs to be performed within. Also, medical samples need to be maintained within a certain temperature range, otherwise, they are rendered invalid. The IoT with the help of the CMS keeps track of the sampling time and temperature. The nurse taking the samples can set the device once the sample has been taken successfully from the patient. In cases the sample has got delayed while being delivered from the patient room to the lab, the IoT-LabWork device would invalidate the sample on the CMS, set a Red light on the IoT device, and send an alert to the lab technician and the physician requesting the test. It also can perform the same if the temperature of the apparatus exceeded the allowed temperature range for the respective sample. Tracking sample invalidation is a key performance indicator (KPI) for the quality of tests in the lab.
3) **Sample Location Tracking:** The IoT-LabWork is equipped with an Internal Positioning System (IPS)

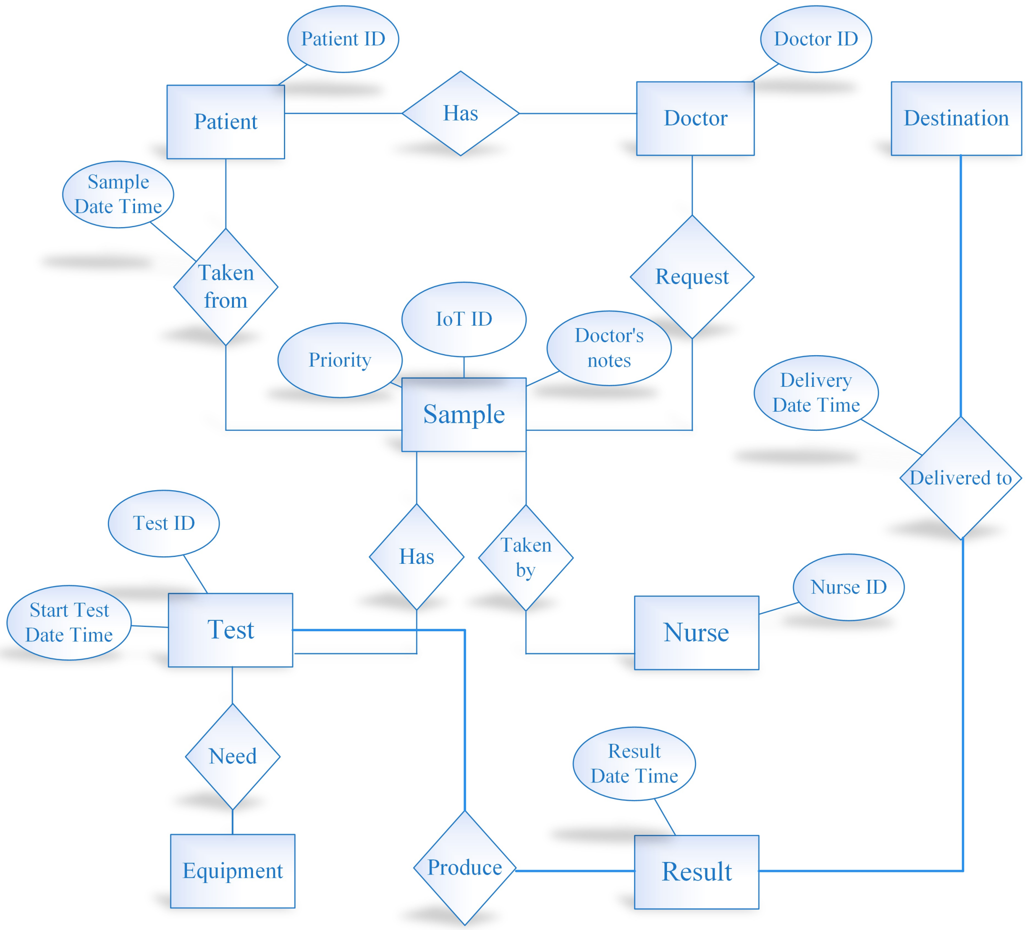

Figure 3. Data Model for the IoT-LabWork Device

that allows locating the unit in the perimeter of the hospital in case it gets lost. In cases where the sample unit is missing the CMS can issue a request to the IoT-LabWork to send the last location recorded. This would easily allow locating misplaced samples within the perimeter of the hospital.

4) **Equipment Usage Scheduling:** Different tests need different equipment to take and test the sample. By associating the tests with the equipment needed to complete them, the CMS can schedule the use of equipment efficiently. It also can notify nurses and Lab technicians when certain equipment becomes available.
5) **Quality of Service:** The IoT device can be programmed to ask the patient - if he/she is in reasonable condition- to rate the quality of care they received from the nurse during taking samples. The data can be collected and analyzed to provide feedback to medical staff.

5. Patient Monitoring - IoT-PatientMon

The next IoT device is the Patient's Vitals and condition monitoring. The advantage of the proposed IoT-PatientMon device stems from having it aware of the current patient history and medications. Thus, the device monitors the patient vitals in light of what medications he/she is currently taking and what are the recent medical procedures he was subjected to.

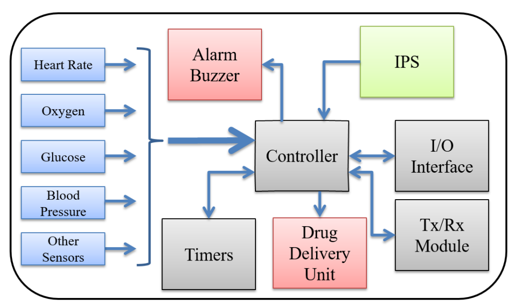

Figure 4. High-Level Hardware Design of IoT-PatientMon

A. *Hardware Design*

The IoT-PatientMon device can be equipped with a larger range of biomedical sensors, such as Glucose level, heart rate, oxygen level, and blood pressure. The controller, shown in Figure 4, interfaces with these sensors to read their values at configurable intervals. The controller can configure multiple timer triggers that will invoke reading different sensors at different times. The unit is also equipped with an IPS that allows locating the device in the hospital and a Tx/Rx module that allows the device to communicate with the CMS. The IoT-PatientMon has an Alarm/ Buzzer that allows the device to sound an alarm when some of the vital signs are outside the acceptable range. It also encompasses a drug delivery unit that can control how much and how often drugs can be given to patients.

B. Data Model

Figure 5 demonstrates how the IoT-PatientMon is connected to the patient's medical history and current medications through the patient's profile. For each vital that is being monitored, there is a record of the frequency that the vital is measured in, a safe range of results where there is a dynamic minimum and a maximum critical value, the values take into consideration the patient's medical history and current medication.

Whenever a vital value exceeds the permissible range an alert will be generated. Alerts could have different severity levels, mild ones that could require the nurse to check on the patient, and severe ones that might require the CPR team to immediately come to resuscitate the patient. Each alert has a type, that is the type of action the alert would invoke, whether it is an alarm or a call, etc. In addition, the alert is associated with the person that the alarm should notify, that could be the ER doctor, the nursing staff, the CPR team, etc. The system holds records of the alert history for every patient.

For the patients' medication, the system will keep track of both the prescription history and current medication the patient is taking. The prescription history will hold a record for each prescription the patient had, including the start and end date and time of the prescription, the medication name, the frequency, dosage, and duration of the treatment.

The medication history will also include any medical procedures the patient was subject to. The record will specify the treatment, the date-time, the response of the patient to treatment, and the location of where it was administered.

C. Use Cases

1) **Intelligent Patient Monitoring:** The use of IoT-based monitoring allows for more intelligent monitoring. Vital signs are typically monitored to be with a fixed static upper and lower bound. With the use of IoT-based monitoring and since the devices have access to the patient profile, the limits can be a function of the patient-specific condition, the time of day, and the function of the medicines that he/she has taken recently. For example, if the patient has taken a medicine that is expected to raise his/her blood pressure then the limits are adjusted accordingly. Also, the system can do more complex decisions on where to alert or not as data from multiple sensors are fused. Thus, eliminating the false alarms that could arise temporarily due to a sensor glitch.
2) **Remote Monitoring & Immediate Notification:** Vital signs and allowing healthcare professionals to monitor changes in real-time from mobile devices. The system will give healthcare professionals remote access to the patient's vitals and sensor data via mobile devices. This data will be available immediately for inspection and tracking by healthcare professionals once they are taken. Doctors can alter the frequency of certain measurements or even request an on-the-spot immediate measurement from the IoT device.
   During monitoring, if abnormalities are present a severity level gets associated with that measurement. Based on the severity level, different stake-holder could be notified of this abnormality, shown in Figure 6. For example, lower severity levels could mean notifying the nursing staff to check on the patient, higher ones could notify the resident doctor or the patient's doctor insuring that the patient would be provided with the best care immediately. In more extreme cases of a heart stop, the resuscitation team can be called automatically, saving crucial minutes in the lives of patients.
3) **Optimal Drug Delivery:** One of the most important parts of the treatment is how to sustain the right dosage of medicine in the patient body. With the use of constant monitoring along with the drug delivery control module, the system can deliver the perfect dosage of the medicine to the patient.

6. Ambulance Services - AmbTrack

The next area to use IoTs is inside ambulances. Ambulances are a very critical part of saving the lives of patients. Every second saved in the process of transporting the patient to the hospital could be crucial in saving his/her life.

A. Hardware Design

The Ambulance IoT Device will consist of similar modules to those used in the patient vitals IoT. This is mainly because the ambulance will be connected to equipment measuring the vitals of the patient. However, the critical module change here is that instead of the IPS, we would need a GPS module instead to locate the ambulance outside the premises of the hospital, as shown in Figure 7.

B. Data Model

Figure 8 describes how the IoT-AmbTrack device would collect and organize the data transfer between the ambulance and the hospital. The ambulance constantly logs its current location. Once an emergency call is placed, an incident profile is created. The profile will include the data about the incident such as the reporting time and location of the incident, the expected and actual date-time

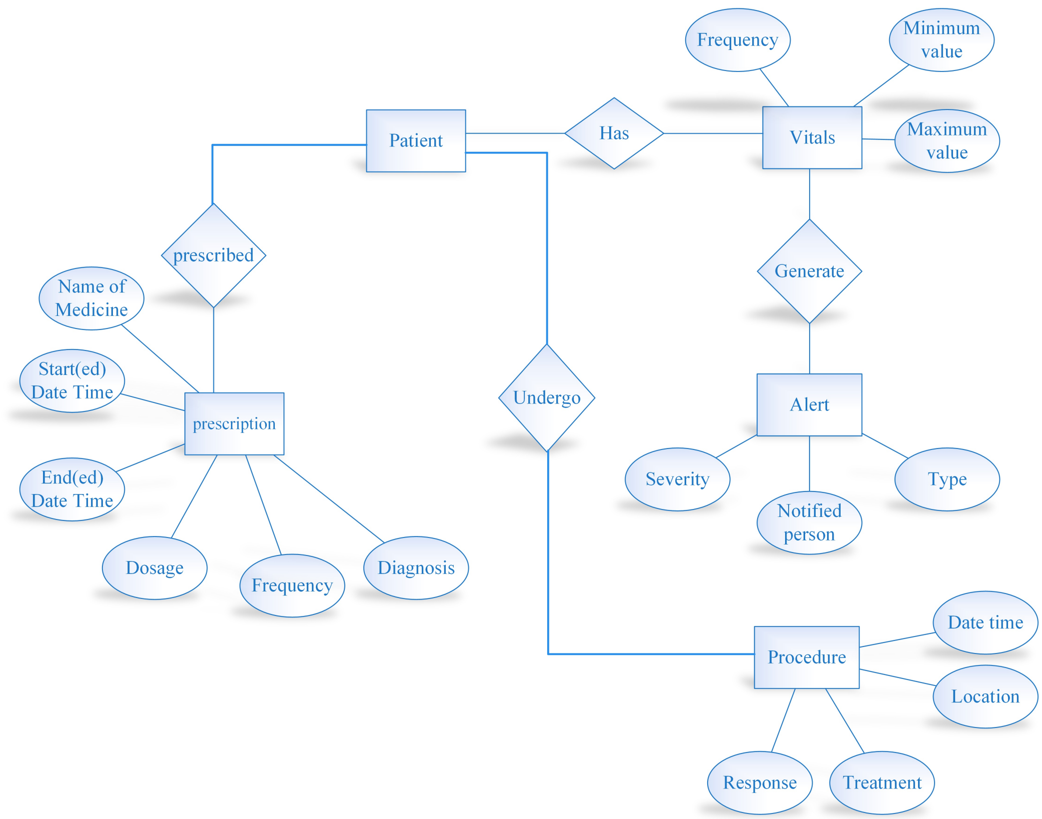

Figure 5. Data Model for the IoT-PatientMon Device

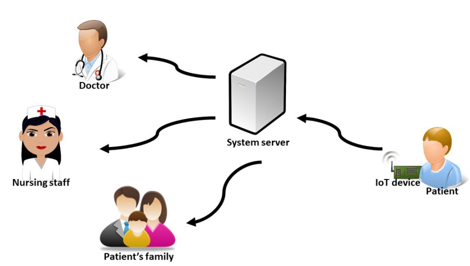

Figure 6. Alert action types

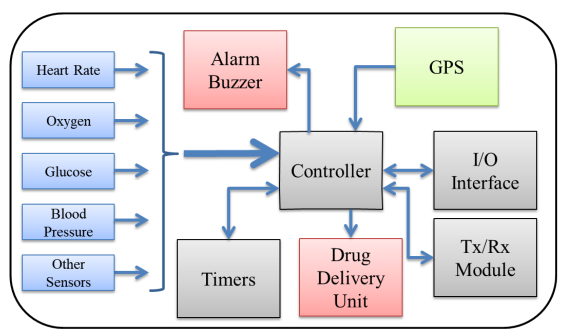

Figure 7. High-Level Hardware Design of IoT-AmbTrack

of the ambulance's arrival to the incident's location. It also includes the expected and actual arrival time to the hospital. And -if needed- it will include the hospital to which the patient will be transferred. The IoT-AmbTrack will constantly modify the incident and patient profile to update the necessary information such as the medical history and the initial diagnosis. The incidents profile will be used later to obtain feedback and analyze the efficiency of the emergency system.

C. Use Cases

1) **Normal Operation:** Once an incident is reported, an ambulance is dispatched to the reported location. The device will be able to estimate the arrival time of the ambulance, the IoT-AmbTrack will be sending the Location of the ambulance in real-time to the hospital. Once paramedics are on-site, they can use the device to report the initial diagnosis, query the patient profile and any previous clinical conditions of the patient. Based on the initial diagnostics, a destination hospital will be communicated to the

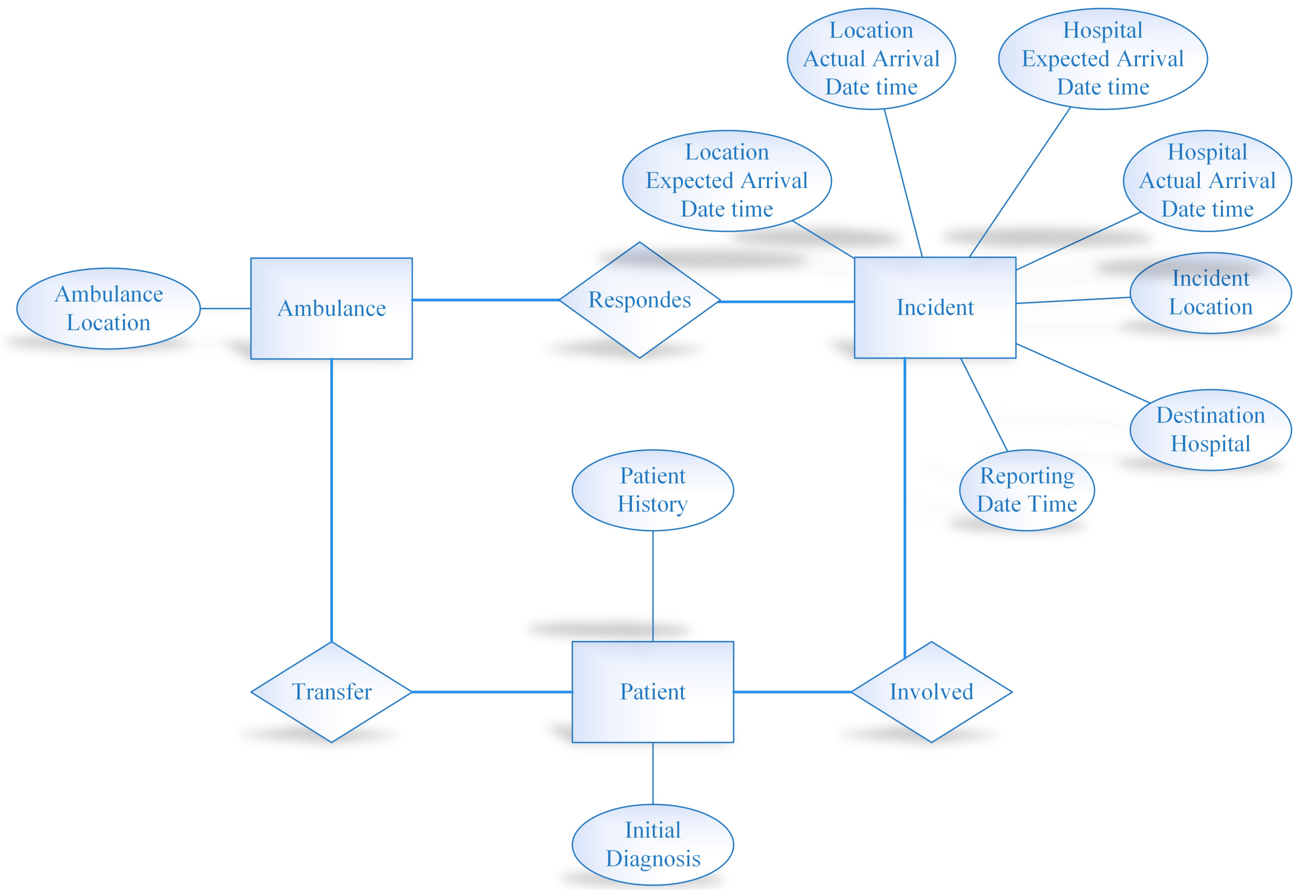

Figure 8. Data Model for the IoT-AmbTrack Device

device. The device will be able to communicate the vitals and the condition of the patient to the destination hospital.

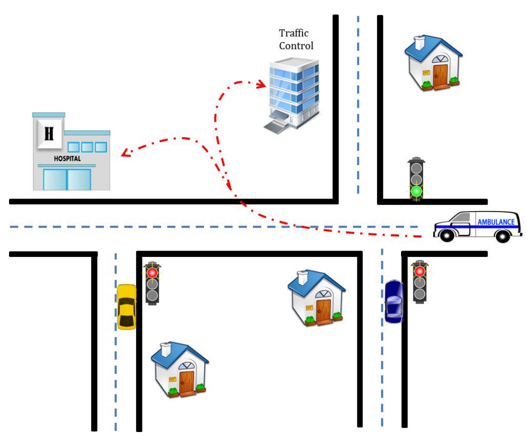

Figure 9. IoT-AmbTrack interaction with Hospital CMS and Smart City Traffic Control

2) **Integration with Smart City Traffic System:** : In a smart city the location of the Ambulance can be communicated to the city traffic system. The traffic system can figure out which traffic lights to turn on/off to speed up the arrival of the ambulance to the destination hospital, shown in Figure 9.

3) **Ambulance Tracking for Timely Service:** When an ambulance is called an incident profile is immediately created, an expected arrival date time to the incident location is estimated based on the incident's location, the current traffic conditions. The ambulance will be connected to a GPS which will enable tracking its location and get the actual arrival time to the incident location. The difference between the expected and the actual arrival time would then be analyzed to obtain a clear indication of the ambulance aptitude and provide more accurate estimates in the future.

4) **Ambulance Tracking to Enhance Readiness at the Hospital:** Once the ambulance reaches the incident location, the initial diagnosis of the patient's condition, along with his vitals are transmitted to the hospital. This information along with an accurate estimated arrival time to the hospital, allows hospital staff to be well prepared for the specific condition of the patient once he/she arrives.

7. Meals Management

The last IoT device is an IoT device attached to a food tray. In hospitals, what patients eat is as important as their medication. This device can be used to monitor the quality of the food as well as collect feedback on how well patients are eating.

A. Hardware Design

The hardware of the IoT-FoodTray Device will be similar to that of the IoT-LabWork, with the exception that instead of the sample compartment, it will have a container for the meal. The security lock will be activated once the meal is prepared, this is to ensure it is not opened till it arrived at the patient. The Device will also include a simple interface so that patient(s) and hospital staff can use it.

B. Data Model

Figure 10 describes how the IoT-FoodTray device would be used to collect the data associated with meals being delivered to patients. The Kitchen prepares the meals. The meal preparation time and the IoT-Device ID (Tray ID) used to deliver this meal will be stored. Each meal consists of multiple food items, each of which has its ingredients, nutritional value, and type. Once ready meals are delivered to patients, who provide feedback to the kitchen related to the quality of the food and whether it matched the patient taste. The staff and nurses who collect the meal will also be able to provide feedback on whether patient completed their meals or not. When meals are delivered, delivery time is recorded, this can also be used to guarantee the quality and the freshness of the food being delivered.

C. Use Cases

1) **Enhanced Patient Treatment:** This is achieved by two means: the first is by keeping a record of each ingredient the patient has consumed in his meals. The second is by having the staff who collect meals enter whether the patient has completed his/her meal or not. By keeping track of what the patient has consumed, and whether he/she has completed the meal or not, healthcare professionals would be able to better assess the wellbeing of the patient.
2) **Better Meals Quality:** The quality of the food being fed to the patient will be monitored and improved via the following mechanisms:
   a) Monitoring temperature of the food being delivered to patients.
   b) Monitoring how much time it took to be delivered.
   c) Allowing the patient to enter their feedback on the food being delivered to them directly on the IoT-FoodTray.
   d) Allow patients to enter their preference on what they would like to eat directly on the IoT-FoodTray.

   All this data would be analyzed to ensure that each patient would get the meals he prefers in the future with the best possible quality.

8. Conclusion

In this paper, we have presented a complete architectural proposal for the use of IoT devices in hospitals and healthcare facilities. The proposal is based on deploying four types of IoT devices that can work with a central Management system to deliver high-quality healthcare to patients. These four devices can work seamlessly with any existing IT system, should be able to increase the efficiency of the healthcare facility. The next phase of this work would be implementing a prototype of these devices and test them in a real environment.

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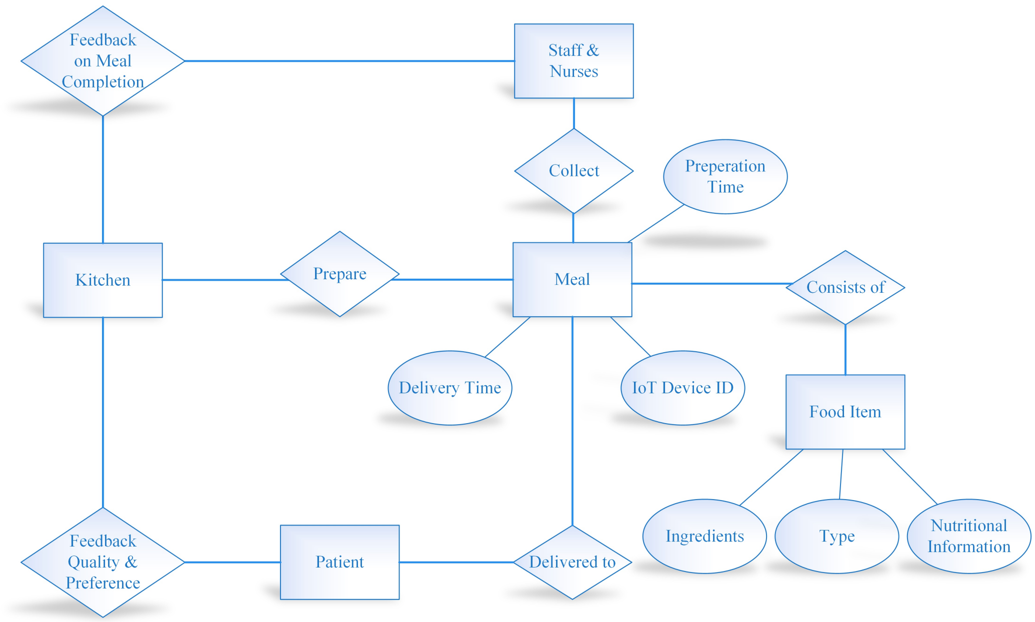

Figure 10. Data Model for the IoT-FoodTray Device

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