iMED-Tour: An IoT-based Privacy-assured framework for Medical Services in Smart Tourism

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***Abstract*—Tourism is one of the key revenue generators in communities worldwide. In the present day, traveling has become a lot easier with all the information available through the Internet. However, there are still challenges in identifying the right medical resources while traveling to a new city for the first time. In this research we propose a privacy-assured framework that can help in identifying the medical services for a tourist. Through this research we have developed a cost-effective tour wearable, We-Tour, that can notify the user if they need to visit a hospital service in case of emergency and provide suggestions for the preferred medical services. The proposed framework was evaluated for its latency with regards to the wearable's performance and ability to find shortest path. The We-Tour wearable had an overall latency in the order of few milliseconds and the shortest path algorithm implemented in CupCarbon had a latency of 10 seconds.**

***Index terms*—** Internet of Things (IoT), Smart Healthcare, Smart city, Smart Tourism, Tourist wearable

I. INTRODUCTION

With evolution of affordable travel packages, any enthusiast traveler can reach all corners of the world and explore the beauty of our planet. Tourism is one of the key factors for the socio-economic development of the cities in today's world. As much as joy and excitement tourists might have in exploring a city or a country for the first time, it makes them anxious to learn more about the facilities, services, activities and dining options available in the destination. In today's connected world, most of this information can be available on the Internet. Figure 1 shows the thematic figure of the proposed iMed-Tour framework with we-Tour wearable and iMed-Tour mobile application.

Fig. 1. Thematic Picture of IoT-based iMed-Tour framework which contains We-Tour wearable and mobile application

The official tourism websites and various platforms focus more on advertising their fun activities, whereas there is little to no information on the local medical services. First-time Travellers rely on resources such as blogs or vlogs on the internet, which might have information from tourists who had visited the city recently. This makes families and older couples to remain apprehensive in planning travel. The major concerns facing tourism are lack of trust in services that may be provided; insecurity of the tourists due to a different language is spoken; lack of Government support; and unavailability of real-time help centers when required [1]. Additionally, investments of private sectors in tourism have reduced the interoperability of most of the services provided by the respective Government agencies and private sectors.

The Internet of Things helps in connecting many devices together where each device is recognizable in the network. In a cyber-physical world, many applications that require real-time and virtual objects are deployed. Some of the applications include surveillance [2], agriculture, healthcare [3], security, vehicular technologies and so on in Smart cities [4] . Architectures and elements used to deploy a wireless network can be easily merged with sensors to form an IoT network [5]. Significant investments have been made by public and private agencies towards improving communications between various platforms and providers in the smart city framework [6].

To address the concern of lack of medical services of the destinations, and to improve the trust factor of tourists, we propose an IoT-based framework, iMED-Tour, which can help tourists to reach their required medical services as needed.

Through this research, we propose a We-Tour wearable, which can help tourists to stay informed of their health throughout their trip and find medical services in travel destinations depending upon their existing preconditions. The organization of this paper is as follows: The novel contributions of this paper are described in Section II. A broader perspective of the proposed iMed-Tour platform in smart cities is presented in III. A brief Some literature on existing research work on modeling tourist platforms is discussed in Section IV. An overview of the system-level modeling of the iMed-Tour framework along with the wearable and privacy concerns are given in V. The implementation of the designed blocks along with simulation results and the corresponding limitations are discussed in VI. Discussion on further advancements of the proposed research is given in VII.

II. Novel Contribution

The iMed-Tour framework aims in monitoring the we-tour wearable user's health information, alert the user as and when required and find the medical services as per the user's need. To achieve this, the proposed framework is designed with following contributions:

- A novel IoT-based framework to reach medical services for tourists is proposed.
- A privacy-assured tourist wearable, We-Tour, has been designed.
- An algorithm to identify the nearest medical service in an environment has been proposed.
- The proposed privacy-assured we-tour wearable has been validated using a single-board computer and off-the-shelf components.

III. iMED-Tour as a Smart City Medical Tour Plan: A Broad Perspective

The we-tour wearable is envisioned as a consumer electronic product that can be bought by tourists as they travel. While setting up the we-Tour wearable, the user can input their pre-medical conditions which need to be known to a physician during the moment of hour, through a user interface, iMed-Tour App. The we-tour wearable will be worn by the traveler throughout the trip to monitor the temperature and heart rate values to address any kind of emergency. Figure 2 shows an overview of the proposed iMed-Tour framework. In this IoT-based framework, multiple We-Tour wearables are connected through internet. This information is stored in the IoT cloud, which contains 2 main computing blocks: node clustering unit and a database with nearest medical devices. The Node Clustering Unit (NCU) helps in grouping the nodes together based on their location information obtained from the user's mobile phone. Once the nodes are clustered, the nearest available service is recommended to them based on their priorities. This recommendation is provided to the user theough the iMED-Tour mobile application.

IV. Related Prior Research

Significance of smart tourism and their current challenges are detailed in [1]. In [7], methods to improve the mobility and improve the interoperability of tourism platform in smart cities is discussed. A machine learning approach to propose smart tourism destinations is proposed in [8]. An interactive Augmented Reality framework to assist the tourists are presented in [9]. A smartphone GUI-based smart city framework for Dubai has been designed in [10]. Similarly, a big-data perspective on smart tourism specific to Sanya city is discussed in [11]. Smart city planning in case of emergencies such as natural disasters [12], soil erosion [13], oil spills [14], small pox attacks [15], fire simulation model [16] are discussed in respective literatures. For pathfinding and smart city planning, algorithms and models based on fuzzy-logic [17], A* algorithm [18], and a PSO-based packaging algorithm [19], have been explored. In smart healthcare frameworks, pervasive monitoring systems have been proposed for smart families [20], diet-monitoring [21], women's health [22], respiratory-monitoring system [23] and so on.

V. System level modeling iMED-Tour

A. Proposed We-Tour wearable in iMED-Tour framework

The functionalities of the proposed We-Tour wearable is to monitor the body temperature, and heart rate continuously and help the tourist to identify nearest medical service as and when needed. The We-Tour wearable was designed with a vision to be a medical wrist- band which can connect the user in real-time to the present local environment. As this wrist-band will be connected with a mobile phone in real-time, a GPS module wasn't included in the wearable design. The we-tour wearable will contain an Emergency user-input which will be used by the user to indicate if they would need a medical service immediately.
In addition to detecting the nearest medical services, the role of the wearable is to identify if the temperature and heart rate sensor values are above or below the threshold. To achieve this, the users are asked to input some basic information such as their pre-medical conditions, height, weight, ideal BMI, in order to calculate the safe range of these vital signals.

B. Algorithm for iMED-Tour Plan

The steps involved in algorithm design for iMED-Tour plan is detailed in 1. These steps can be broadly grouped into 3 steps: Pre-execution, at the time of emergency, and post-execution. In the pre-execution phase the priorities of the user are determined based on user input during the iMED-Tour mobile application. This includes determining the priorities of medical services requested by the user i.e. if the user is experiencing a backache before the travel, the user will prefer to know the nearest Orthopaedics or Chiropractors in an around the travel destination. In addition to obtaining this information, the user's non-health data such as insurance, pre-medical conditions, and payment options

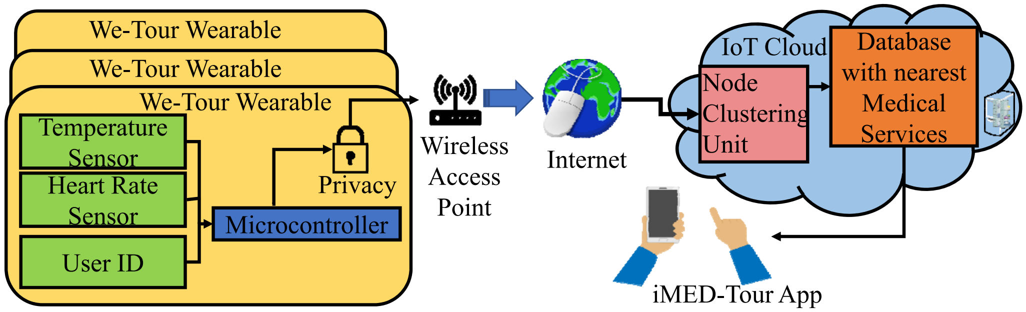


Fig. 2. An Overview of the proposed IoT-based iMed-Tour framework

are obtained. The time of emergency is determined when the user presses the emergency button for a longer time in the We-Tour wearable. Immediately, the user's current location is determined using the user's mobile phone and their temperature and heart rate values are noted. Based on the user's priority, the nearest medical service, which has been recommended by most of the users are suggested to the user. Once the user decides the medical service, the destination node is determined. The distance between the source and destination is determined using the path-finding algorithm, A* algorithm.

Algorithm 1 Algorithm for iMED-Tour framework

1: *Pre-Execution*:
Obtain the priority of medical services during iMED-Tour app installation
2: Based on user's input and previous recommendations, prepare a list of highly-recommended medical services
3: Obtain the non-health data such as insurance, medical conditions, payment options (optional)
4: *Upon Emergency button press*:
Determine Patient's current location as source node.
5: Determine the type of medical service
6: Locate the Destination node based on the location and preferred medical service
7: Find the shortest path from source node to the destination using A* algorithm.
8: *Post-execution*:
Request User's status: *Recovered or Still in recovery*
9: Request User's recommendation on the medical service through the mobile application
10: Update the "Database of Medical Service" in the IoT Cloud
11: Remind the user about payments/ follow-up/ paper-work, once recovery is reported.

This algorithm finds the shortest distance between nodes (source to destination) [24] and is an extension of Dijkstra's algorithm. The A* algorithm takes into account three main values during execution: total weight ($f(n)$), cost of the path from the start node to n ($g(n)$), and the heuristic value, or the cheapest path to the destination ($h(n)$). The heuristic distance, for the purposes of the algorithm implementation, can be thought of as the euclidean distance between n on the plane to the destination on the same plane. The total weight value $f(n)$ is sum of $g(n)$ and $h(n)$ as given in the following equation:

$$f(n) = g(n) + h(n) \tag{1}$$

The process repeats itself, as the current node is passed onto the next optimized node continuously until it reaches the destination node. Then, from the destination node, the program backtracks and finds all of the nodes linking the optimized path to the start node (the nodes in the closed list), determining the shortest or cheapest path. This cheapest path offers the fastest travel time from the start node to the destination, assuming the data transfer speed is the same across all possible paths. From the patient's residence to the medical facility, the path proposed by the A* algorithm will allow for the shortest time. Once the user has reached the destination, the proposed algorithm shifts to the Post-execution phase. In this phase, the system waits until the user reports their recovery status i.e., recovered or still in recovery. Once the user updates the status as "recovered", the user's recommendation on the provided medical service is recorded for future reference and recommendations to other users. Additionally a reminder to complete the paper-work such as insurance filing, follow-ups and payments are recorded and updated in the IoT cloud.

C. Privacy module in the iMED-Tour framework

Since the we-Tour wearable and iMED-Tour application will connect to the local wi-fi and rely on the internet service provider to connect to the IoT cloud, it can be assumed that the data is being sent through non-trusted data aggregator. In this case, it is important to evaluate the application of local differential privacy for ensuring the privacy of the data that is transmitted and received through this network. In our proposed framework, this is implemented by recording the we-tour wearable information as histograms along with the user-ID and timestamp, when the data is transmitted to the cloud from the wearable. A secret number is assigned for each user ID, and the number related to each ID is revealed using two-factor authentication, such that even if the data is being viewed by unauthorized person, the User ID is not revealed.

VI. IMPLEMENTATION AND VALIDATION OF IMED-TOUR

A proof-of-concept prototype of the proposed research was implemented using off-the shelf components and open source tools such as CupCarbon which are available for smart city planning.

A. Prototype of We-Tour Wearable

We-Tour wearable was designed using DHT11 temperature sensor, MAX20102 Heart rate sensor and a wifi-enabled Arduino Nano ESP32. The components involved in the design of the proposed we-tour wearable is given in Figure 3.

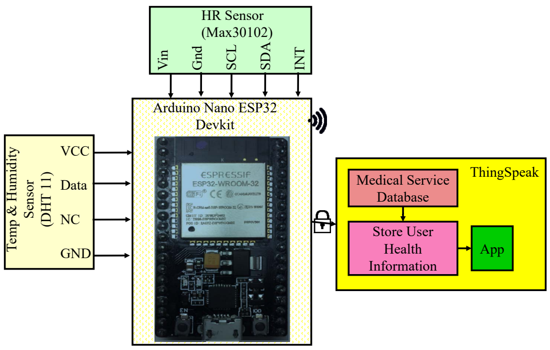
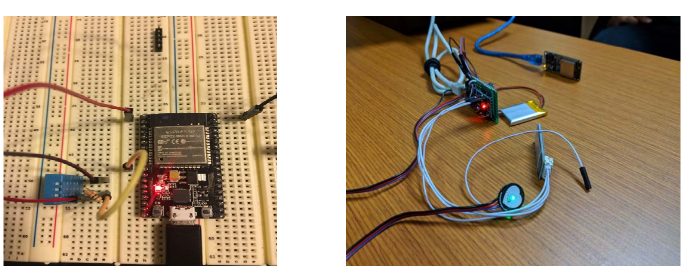


Fig. 3. Components available in We-Tour wearable

The proposed we-tour wearable was able to determine the threshold for temperature and heart rate sensor and throw an alert as and when required. Figure 4 (a) shows a temperature sensor (DHT11) connected to Arduino Nano ESP32. The temperature values obtained from this sensor was stored in a locally published web-server in a Raspberry-Pi. The We-Tour wearable will remain connected to the mobile phone through the Bluetooth module and if wi-fi services are available, then it connects to the nearest wi-fi services. To demonstrate its capability to connect to the nearest local environment, the wearable was connected to different types of base stations. The prototype was first connected to a Bluetooth-enabled base as shown in Figure 4 (b), and it was evaluated with wi-fi enabled Raspberry-Pi in the nearest surrounding. The overall latency in both these type of connections was in the orders of few milliseconds (700-900) ms.



(a) (b)

Fig. 4. Proof-of-concept for We-Tour wearable, (a) Temperature and Humidity Sensor connected to WiFi-enabled microcontoller and (b) Temperature and Heart rate sensor connected to the Bluetooth module

B. Validation of iMed-Tour framework

1) Optimized Path finding: The proposed iMED-Tour algorithm to determine the shortest path using A* algorithm is modeled in CupCarbon [25]. CupCarbon is a wireless sensor network design and simulation tool that offers simulating environments for smart cities [26].A prototype of the smart response plan based on the A* algorithm, implemented in CupCarbon is shown in Figure 5. The nodes are the sensors or edge devices that connect to the internet which help in collecting the data at the top level. In real-time implementation, these nodes can also be the hub devices under which multiple such sensors can be present in the hierarchy. Table I shows the evaluation of each node at a given instance. When the A* algorithm is implemented, node S35 is considered as the start node and node S36 is considered as the destination node. The shortest path from the start node to destination node is evaluated. At each instance, the open (fringe) node and the unevaluated nodes are tabulated to understand the algorithm. It can be seen that the shortest path from the start to destination node is determined with the minimal amount of nodes in between them.
The particular A* algorithm iteration was able to find the shortest path in a total of 10 seconds. This iteration was based on simulation parameters set to 1 second for an arrow and simulation speed at 1000 milliseconds.

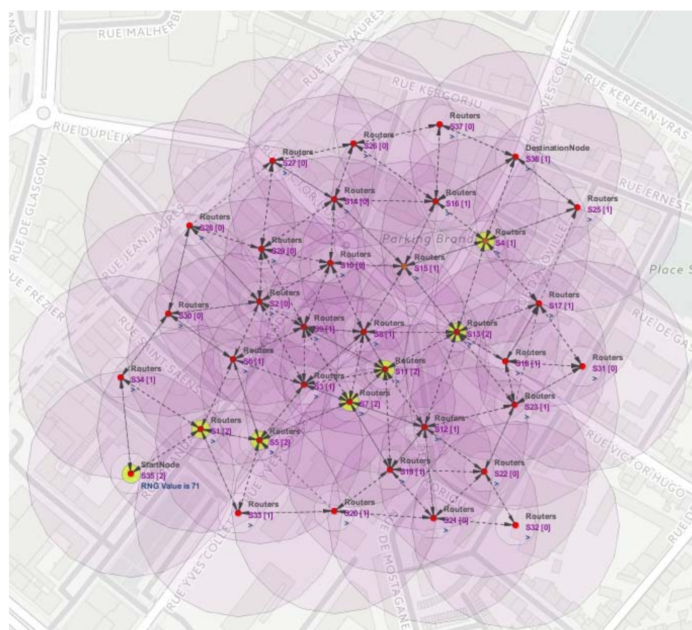


Fig. 5. A* algorithm modeled in CupCarbon

VII. CONCLUSIONS AND FUTURE RESEARCH

The proposed iMED-Tour framework aims in providing information regarding medical services available to the user in their travel destination. The proposed framework was evaluated using a custom-built, we-tour wearable, which

TABLE I
A CHART REPRESENTING THE CLOSED LIST, OPEN LIST AND UNEVALUATED NODES FOR THE CUPCARBON IMPLEMENTATION.

Closed list nodes (MY=2)	Fringe (Open) list nodes (MY = 1)	Unevaluated nodes (MY=0)
S35 (Start node)	S34	S28
S1	S33	S29
S5	S6	S30
S7	S9	S2
S11	S3	S27
S13	S20	S26
S4	S19	S10
S36 (Destination)	S8, S12, S23, S18, S15, S17, S16, S25	S14, S37, S21, S32, S22, S31

constantly monitors the user's health information and helps them remain connected to the iMED-Tour framework by transmitting the information in a privacy-assured method to the iMED-Tour application. The evaluation of the A* algorithm showed that the shortest path based on user priorities was determined in 10 seconds and the overall latency of the We-Tour wearable was in the order of few milliseconds. Currently, the user information was obtained in a user-interface (web-page). Future research includes deploying the proposed algorithm as a mobile application and evaluating the overall performance. Additionally, a machine learning model is to be deployed for storing user's preferred medical services and recommendations.

VIII. ACKNOWLEGMENT

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