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Emergency Mobile Navigation in Hazardous Environment using Wireless Sensor Network

Vaishnavi. S[1], Sneha Manikandan[2], Deepa. B.M[3]
[1,2,3,4] Department of Information Technology, Easwari Engineering College, Ramapuram , Chennai

Abstract: This paper presents a system to provide emergency navigation in hazardous environment using wireless sensor networks and android applications. This system is composed of large-scale deployment of Wireless Sensor Networks which includes Temperature and Gas sensor (WIRELESS SENSOR TECHNOLOGIES) which offers continuous environment monitoring. The incorporation of WSNs into emergency navigation systems aims at navigating people to safe exits by early and automatic detection of potential dangers. It's especially deployed in Gas stations to detect the oil/gas leakages, electrical accidents. The Users must have the emergency navigator application installed on their mobile phones. When emergencies happen, the sensor network explores the emergencies and the mobile users are notified through an SMS alert so that the users can be eventually guided to safe exits through ubiquitous interactions with sensors. It mainly focuses on finding the shortest/safest path for each person, while other sub-optimal (yet safe) paths are left unused throughout most of the evacuation process. Thus this system uses SHORTEST PATH ALGORITHM. Thus the system assists people in escaping from hazardous region quickly when an emergency occurs with guaranteed safety, while avoiding excessive congestions.

I. INTRODUCTION

A. Project Objective

The project aims at expanding navigation services at emergency situations in hazardous areas by providing alerts to the mobile user through wireless sensor networks. The project contributes in rendering necessary information regarding safe evacuation in emergency situations beforehand, especially in Gas stations.. It ensures to meet the standard emergency protocols that are to be followed such as providing the routes, exits, notifying the nearby fire station. The congested zones are identified and the crowd/work-men will be directed accordingly through the establishment of RMN technology and shortest path algorithm. A country like India needs emergency navigation services to provide the facilities to its users. The project fulfills these needs of the workers as well as consumers efficiently. It is beneficial to both citizens and the government, providing services to the citizens without any interference. It is also of immense importance to Gas station workers to escape from potential dangers like gas leakage, electrical accidents etc. Thus the project focuses on wireless infrastructure development that will contribute to the growth of digital economy.

B. Existing Approach

GPS, being a powerful tool, provides immense potential for an organization to improve its servicing of the workers and the consumers. However, this potential can be converted into results provided the hurdles like low quality manpower, absence of reward mechanism for the efficient are removed, and GPS tools and strategies are used appropriately. For example, lack of efficient and structured process and resistance to change them, lack of coordination among various departments, and improper monitoring methodology remain major challenges for the organization. A diversity of specifically designed solutions for emergency navigation with WSNs has been proposed. Earlier approaches [6], [8], [9], [10] rely on either exhaustive network-wide flooding or the availability of location information on each sensor/user. The follow-up studies [4], [11], [12], [13] release the requirement of location information, and begin to consider the impact of variations of dangerous areas, which greatly enhance their applicability to more practical scenarios. Most if not all of these location-free methods seek for a global topological structure embedded in the network as the public infrastructure, through which different users can be safely guided to the exit and avoid unnecessary overhead of individually path planning. However, these methods neglect the underlying congestion and detour problems [3], which are critical for a fast evacuation, as they mainly focus on finding the shortest/safest path for each person, while other sub-optimal (yet safe) paths are left unused throughout most of the evacuation process. CANS leverages the idea of level set method to track the evolution of the exit and the boundary of the hazardous area, so that people nearby the hazardous area achieve a mild congestion at the cost of a slight detour, while people distant from the danger avoid unnecessary detours. CANS also considers the situation in the event of emergency dynamics by incorporating a local yet simple status updating scheme.

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Our project puts forth the design and implementation of Sustainable navigation infrastructure that exploits the cutting-edge technologies of Wireless Sensor Networks and Road Map based Navigation approach for providing safe evacuation of the consumers at the verge of emergency. While there are other navigation systems which primarily focuses on congestion avoidance, navigating on a single route etc.

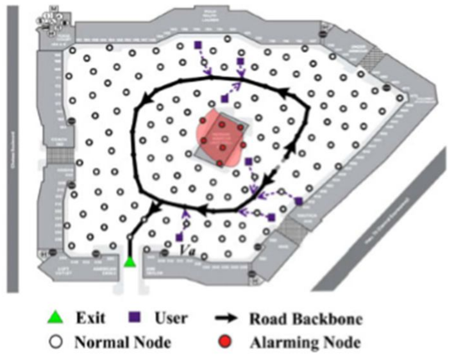

Fig.1.1 CANS detector

C. Proposed System

The proposed system focuses on finding the best possible route to the nearby exit, alternate paths (from which the optimal path can be chosen) and alert the nearby fire station regarding the type of emergency in order to facilitate the necessary actions to clear the area. The emergency situations are detected with the help of sensors that communicate with one another with the help of wireless sensor networks (WSN). A Mobile wireless sensor network is a set of physically distributed sensor nodes. Sensor node is a small wireless device with limited battery life, radio transmission range and storage size. A sensor node performs the task of collecting important data, processing the data, monitoring the environment, etc. This property of sensors i.e. mobility can be very efficiently used to improve the target coverage quality and network connectivity in randomly deployed mobile sensor networks [15]. These sensors will notify the server regarding the detected emergency which will immediately notify the users through an application. The user gets intimated through the form of vibration. When the user opens the application, a map that provides alternative paths to the nearby exit will be displayed. A Database (MySql5.0) is used in order to store the details of the path as well as the details about the user who have registered with the application. These paths are stored in the database such that, the same path when given again will be overridden. The information are stored and managed by the server. Some of the advantages of the proposed system are given below:

1) Alternative paths are provided to the user.
2) Congestion will be sensed beforehand and the paths will be provided accordingly.
3) Nearby fire station gets intimated regarding the emergency situation.

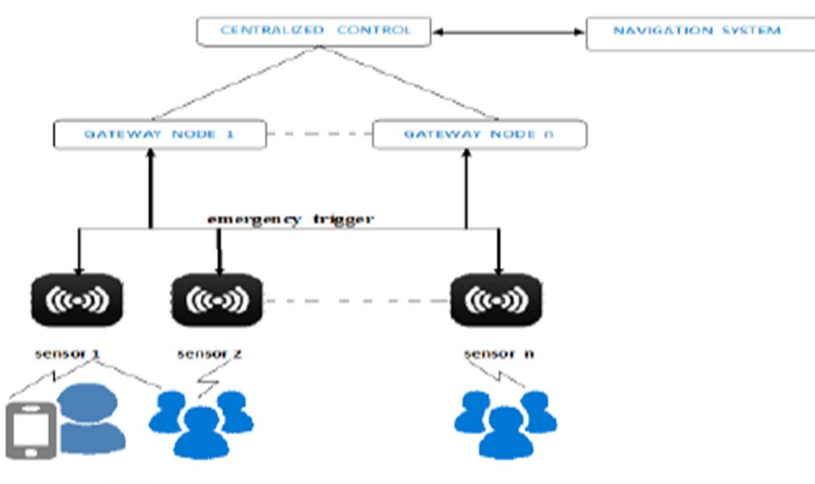

Fig.1.2 Proposed System Architecture

II. THEORETICAL FOUNDATION

When emergency situation like fire arises, after detection of danger, the information has to be broadcasted to the server control so that users can get navigation message to evacuate along with desired path. Also hop count maintained from each sensor helps in finding short path for users. In this section, we propose our design which emphasizes correctness in discovering escape paths even if users must pass hazardous areas. We divide the algorithm into two phases: RMN initialization and Navigation.

A. RMN Initialization Phase

In the initialization phase, we assign each sensor an altitude according to its hop distance to the nearest exit. We assign sensors near the exits smaller altitudes, and sensors farther from the exits higher altitudes. The escape paths are along sensors with higher altitudes to those with lower attitudes. When a sensor receives an initial packet, it increments the hop count by one and accepts this value as its initial altitude unless it has a smaller altitude. It then rebroadcasts the initial packet with the updated hop count. The initialization phase is complete when each sensor has an altitude. Exit sensors periodically restart the initialization phase to adjust for possible topology changes. In this process, each sensor keeps a neighbour table, in which each entry is of the format to track its neighbour's status.

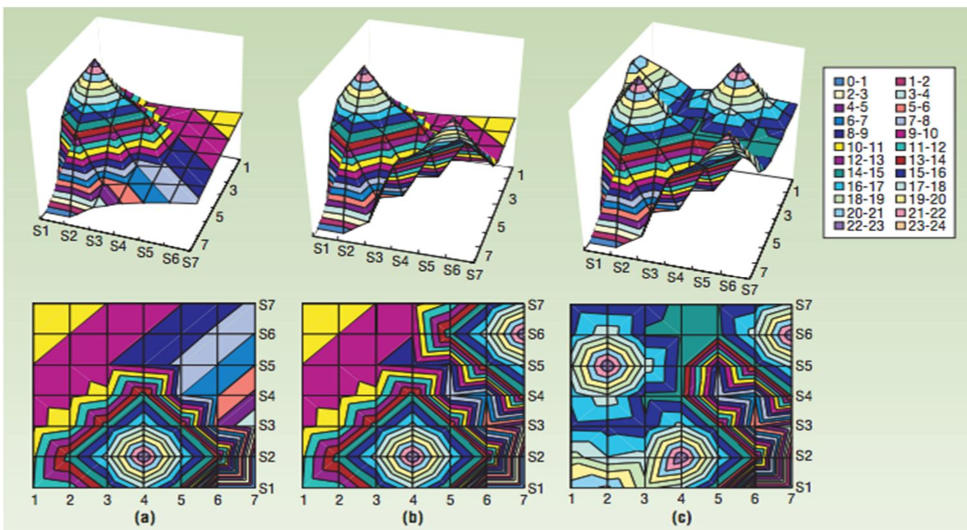

Figure 2.1 Examples of altitude changes when emergency events occur in (a) coordinates (S2, 4), (b) coordinates (S6, 7), and (c) coordinates (S5, 2).

B. Navigation Phase

The navigation phase begins when the system detects an emergency event. The goal is for each sensor to choose the neighbor with the smallest altitude as its escape direction.

We use the following notations:

a) D is a constant such that any sensor whose distance to any emergency location is less than or equal to D is considered within a hazardous region. We use hop count to calculate the distance.

b) Aemg is a large constant that the algorithm assigns to a sensor that detects an emergency event. • Ai is sensor i's altitude. • Ii is the altitude of sensor i obtained in the initialization phase.

c) ei,j is the hop count from an emergency sensor i to a sensor j.

d) An EMG packet is the emergency notification packet.

It has five fields: event sequence number, ID of the sensor finding the emergency event, sender's ID, sender's altitude, and hop count from the sender to the emergency sensor.

Assume a sensor x detects an emergency. It sets its altitude to Aemg and immediately broadcasts an EMG(seq, x, x, Aemg, 0) packet, which is flooded in the network.

The following steps summarize the system's actions when a sensor y receives from a sensor w an EMG(seq, x, w, Aw, h) packet originating from x.

1) Step 1. Sensor y determines whether the packet describes a new emergency by checking the tuple (seq, x). If it is, y records the event and sets ex,y to h + 1. Otherwise, y checks if h + 1 < ex,y. If so, y changes ex,y to h + 1. Next, y records w's altitude (Aw) in its neighbour table. If w = x and x is an exit sensor, y clears the flag is_exit in the table entry for x to avoid guiding users into this emergency location.

2) Step 2.If y changed ex,y in step 1 and ex,y ≤ D, y considers itself to be within the hazardous region formed by sensor x and recalculates its altitude as: The algorithm increases the altitude of a sensor inside a hazardous region by an amount inversely proportionate to the square of its distance to the emergency location. We include the value Iy to reflect y's distance to its nearest exit. The maximum function accounts for the possibility that y is located within multiple hazardous regions and thus might receive EMG packets from several sources. In this case, y's new altitude should reflect its distance to the nearest emergency location.
3) Step 3. Unless it's an exit sensor, y then determines whether it has a local minimum altitude. If y is a local minimum (that is, its altitude is less than that of its neighbours), it adjusts its altitude as: where Ny is the set of all of y's neighbours, STA() is the standard deviation of the sensor altitudes in Ny, and δ is a small constant. Using a standard deviation lets the system respond to emergency situations quickly. When Ny's altitudes vary significantly, y is likely near a hazardous region and should increase its altitude quickly to avoid becoming a local minimum again. A fixed constant δ guarantees convergence. Developers should carefully choose its value because a large δ could easily guide sensors to cross hazardous regions. On the other hand, although it could help sensors find safer paths, a small δ can cost too many message exchanges. The reciprocal of |Ny| reflects the number of possible choices that a sensor has for selecting escape directions. A sensor with fewer neighbours will increase its altitude more quickly to avoid becoming a local minimum. These elements will speed up the algorithm's convergence time. Each sensor must keep returning to this step to check whether it has become a local minimum.
4) Step 4. Finally, y broadcasts an EMG(seq, x, y, Ay, ex,y) packet if either of the following conditions is true:

The emergency packet is new.

e) The sensor changed Ay or ex,y in the previous steps. Step 3 uses the partial-reversal concept to adjust local minimum nodes' altitudes.

Our design doesn't adopt the full-reversal approach because it could easily guide users to pass through a hazardous region unnecessarily. Using partial reversal can help guide users around a hazardous region. If users are inside a hazardous region when an emergency occurs, a nearby exit sensor can guide the users either to this exit or to exits in non-hazardous regions. Our algorithm uses a hybrid approach. Sensors inside hazardous regions can choose an exit sensor that is also in a hazardous region if the exit sensor is within one hop from them. However, sensors in non-hazardous regions will never choose an exit inside a hazardous region unless the sensor is surrounded by hazardous regions or the safe areas offer no proper exits. In this case, sensors continue increasing their altitudes until they reach a level higher than the sensors in hazardous regions. So, the escape rules for any sensor are as follows:

f) If y is in a hazardous region and it detects an exit sensor in Ny that is also in a hazardous region, y chooses this exit sensor.

g) In all other cases, y directs users to its neighbouring sensor with the lowest altitude.

As long as at least one exit sensor isn't located in an emergency location, our protocol can find an escape path for each nonexit sensor in a finite number of steps. Disregarding exit sensors, only sensors that are local minimums have no escape paths. Because δ is a nonzero constant, our protocol is convergent because it has a progress property in the sense that the number of sensors with no escape paths will decrease. The value of Aemg will affect the navigation results. If the value is too small, altitudes at the boundaries of hazardous regions can be smaller than some sensors' initial altitudes. To avoid this problem, assuming that the sensor's maximum altitude in the initialization phase is MAXini, Aemg's value should be at least larger than MAXini × (D + 1)2.

Navigation examples Figure 1a shows a hazardous region that isn't closed (that is, an exit path exists around the region). In this scenario, sensors A, B, and C can temporarily become a local minimum. Suppose sensor D has already found an escape path. Sensors A, B, and C will eventually find their escape paths via D. In Figure 1b, sensors A, B, and C are surrounded by a hazardous region. In this scenario, the three sensors should raise their altitudes to a level higher than the altitude of at least one sensor in the hazardous region. Assume sensor D has the smallest altitude in the hazardous region. With a proper δ, our algorithm will likely guide users to an exit via D. Figure 1c is similar to the case in Figure 1b except that sensors A, B, and C are all inside the hazardous region, and thus have similar escape paths. In Figure 1d, an exit sensor is in the hazardous region. Sensors A, B, C, and D, which are the exit sensor's direct neighbours, will guide users to that exit. Sensors that aren't the exit sensor's direct neighbours will guide users out of the hazardous region via the shortest paths first, and then to other exits outside of the hazardous region unless no such exits exist. Figure 2 shows how altitude changes occur in a 7 × 7 grid network with D = 2. Three emergency events occur in coordinates (S2, 4), (S6, 7), and (S5, 2), in that order. An exit is located in (S1, 7). Both the side and top views show altitude changes, in decibels (dB). Navigation paths are from sensors with higher altitudes to sensors with lower altitudes.

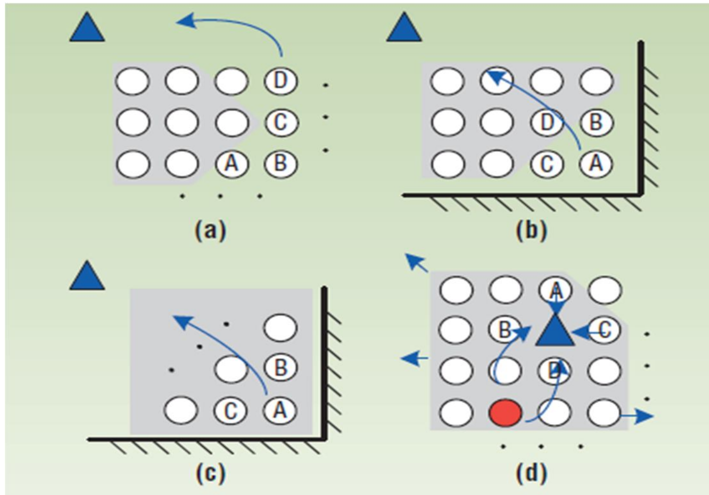

Fig 2.2 Navigation examples.

(a) If an exit path around a hazardous region exists, sensors guide the user toward the exit sensor. (b) When sensors are surrounded by a hazardous region, they raise their altitudes to a level higher than the altitude of at least one sensor in the hazardous region. (c) Sensors that are inside a hazardous region follow similar escape paths. (d) If an exit sensor is in the hazardous region Zn, the algorithm guides users also in the hazardous region to that sensor.

C. User Identification

The network formation module depicts how network is formed by user and sensor nodes. It is International Journal of Pure and Applied Mathematics Special Issue 495 represented in the form of simulation where in random nodes are created. User nodes are generated along with neighbour nodes. This is shown in Fig.2.3, where N8743 and N9693 are neighbour nodes of N3229. Further N9893 node is a neighbour to both N8743 and N9671.

Fig 2.3 User Identifier simulation

Many user nodes form network in the same fashion. Fig.2.4 displays fire accident in its panel due to the occurrence of danger in the area where those users belong.

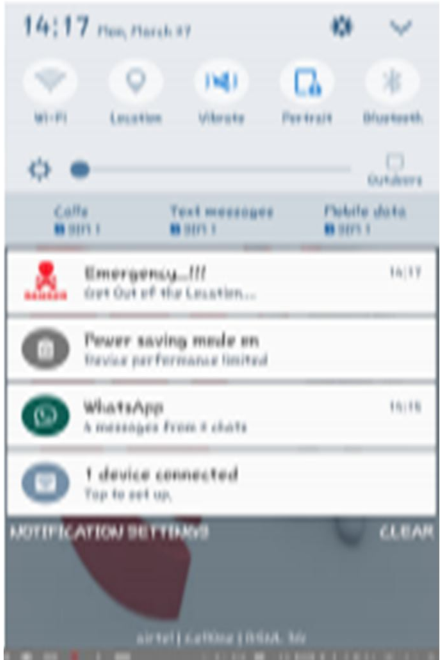

Fig 2.4 Emergency Notification

When sensor detects an emergency, users receive notification carrying alert message and mobile vibration accompanied with an alarm. This communication occurs with the help of a Bluetooth medium.

III. ALGORITHMS APPLIED

When emergency situation like fire arises, after detection of danger, the information has to be broadcast to the server control so that users can get navigation message to evacuate along with desired path. Also hop count maintained from each sensor helps in finding short path for users. The danger message passing algorithms are explained below:

A. RMN Clustering Algorithm

The algorithms from 1 to 3 represent the ways of grouping the mobile nodes along the latitude and longitudes of the building map. From the output, each mobile node is assigned to nearest neighbouring clusters. This further employs the application of shortest path algorithm to find exits.

Algorithm 1. RMN CLUSTERING

Input : E_i: I € k exit clusters, n number of pints in RMN graph,
e-number of exits
Output : Cluster Size k number of clusters K, Cluster C_i
1: K= e
2: k=N/K
3: for each cluster € K
4: for each point P € (k-1)s+1 to ks
C=P
Decrement k
5: return C,K,k

Algorithm 2 . NEAREST CENTROID NOMINATION

Input : Centroids of C{$G_1, G_2, \ldots G_K$}, E_{i-} exits
Output : G_i nearest to E_i: i € k
1: for each centroid G € k
2: for each exit E € K
4: for each distance d between G & E,d=distance(G,E)
5: min=min(d)
6: for i €(1,k)
7: if(d_i==min)
8: G_i belongs to E_i
9: exit

Algorithm 3. POINT-CENTROID NOMINATION

Input : Points{$P_1, P_2, \ldots, P_n$}, E_i exits
Output : P_i nearest to G_i: i € k, minimum distance between point and centroid D
1: for each P(x,y)€ C
2: for each G,E € K
4: for each distance D between G & E D=distance(P,G)
5: min_point=min(D)
6: for i €(1,k)
7: if(D_i==min)
8: P_i belongs to G_i
9: exit

B. Message communication Algorithm

When sensor detects an emergency, users receive notification carrying alert message and mobile vibration accompanied with an alarm. This communication occurs with the help of a Bluetooth medium.

Algorithm 4 .SENSOR MESSAGE PASSING

Input : Si be a sensor node deployed in building
Si ϵ S, where S is the set of all sensor nodes
St be segments in a floor
CS be centralized system
Nt be neighbour table having list of sensor nodes
Output : Message communication between S_i and N_t
1: for every Si ϵ S
{
2: If val[Si] > threshold
{
3: set Aemg = val[Si];
4: hop_count=0; // initially
5: broadcast
6: message(source_id,destination_id,Aemg,hop_count)

```
        }
7:      if
8:      message(source_id,destination_id,Aemg,hop_count)
9       :received
        {
10:     unpack packet;
11:     hop_count = hop_count +1;
        }
        }
```

C. Shortest Path Navigation Algorithm

This algorithm is based upon the observation that a path linking any two vertices u and v may have zero or more intermediate vertices. The algorithm begins by disallowing all intermediate vertices.The algorithm proceeds by allowing an additional intermediate vertex at each step. For each introduction of a new intermediate vertex x, the shortest path between any pair of vertices u and v, $x,u,v \in V$, is the minimum of the previous best estimate of $\delta(u,v)$, or the combination of the paths from $u \rightarrow x$ and $x \rightarrow v$.

$$\delta(u,v) \leftarrow \min(\delta(u,v), \delta(u,x)+\delta(x,v))$$

Algorithm 5 .SHORTEST PATH DISCOVERY

```
Input :   n number of nodes
          D optimal weight between nodes
          d neighbour distance
Output : Shortest path to exit

1:    n ← rows [W]
2:    D(0) ← W
3:    for k ← 1 to n
4:      for i ← 1 to n
5:        for j ← 1 to n
6             dij (k) ← MIN ( dij (k-1) , dik (k-1) + dkj (k-1) )
7:    return D(n)
```

Thus the algorithms provide safe evacuation of the users from crowded areas giving good performance ratios.

IV. FUTURE SCOPE OF THE PROJECT

The Emergency navigation services deployed through WSNs aids the inherent requirements of Real-time monitoring and quick response for emergency. Evacuees with mobile devices can follow personalized navigation paths with distributed decisions that mitigate congestion.

Emerging technologies for heterogeneous network integration emphasize compliance with standards that open an opportunity to integrate WSNs with other networks. However, current technologies still rely on gateway nodes to transfer data.

Since opportunistic networking is at the confluence of *ad hoc* networking and disruption tolerant networks, this recent technology requires a more seamless networking environment to allow intermittent communications between any pair of devices at any time and place. Since emerging sensing devices are equipped with multiple types of wireless interfaces (for example, a smartphone has 3G, wifi and Bluetooth interfaces), a device may belong to multiple types of networks at the same time. Network virtualization for devices will then choose the best communication network for conveying data seamlessly based on urgency, available bandwidth and communication cost. On the other hand, instead of node-centric networks, knowledgecentric network designs are needed to advance towards distributed intelligence. Thus, knowledge-driven solutions will steer collaboration between several networks to integrate knowledge extracted from diverse data sources. Regarding security, emerging technologies can offer secure communications between devices only when they have the same sensing signature. This approach facilitates automatic authentication between devices and secure pairing of devices in physical proximity. Thus the above mentioned analysis can also lead to further research on WSNs and Navigation services and for emergencies. We feel that there is an opportunity for more work in these directions. We aim at establishing a relation between a healthy environment and healthy body. Our project will be providing real-time readings using various sensors and prepare an appropriate database of the environment of the project for months. We aim at making our project and easy to use, compiling it into a permanent portable setup. We will be developing an system which will provide real time values from the sensor and in case of any sudden change of the values, the concerned authorities would be notified and alarmed.

V. CONCLUSION

Emergency Mobile Navigation in Hazardous Environment using wireless sensor networks assist the users to evacuate the hazardous region with guaranteed safety. There will not be any unnecessary detours around the building in order to find an exit. The area which is congested will be sensed in advance such that the paths will be displayed accordingly. There is no denying the fact that Congestion –Adaptive and Small Stretch Emergency Navigation is one of the best candidates to provide navigation at the time of emergency but does not take into account the different hazards level of emergency and different capabilities of exits. This project focuses on overcoming this drawback. It not only offers better path at the time of emergency but also provides alternative path from which the best one can be chosen. Another major advantage is that nearby fire station would be notified regarding the emergency. The message will be sent from a user who is in the coverage area through the SOAP protocol. Not only developed nations are cashing on the advantages of emergency navigation systems, but countries with minimal knowledge on the latest technology are going for it because of its ease of use, the always available routes in order to navigate from a hazardous area quickly and in a safer way. The Emergency Navigation system along with its corresponding applications and other standardization initiatives are coming up very fast and this technology is soon going to be a pervasive phenomenon in the Hazard prevention and control area. This project can act as one of the facilitators in making India meet its long term goals of Digital India and Smart Cities. The pioneers of this technology are already taking interest in the Indian market and India should reciprocate their interest by coming up with a facilitating framework for this new technology.

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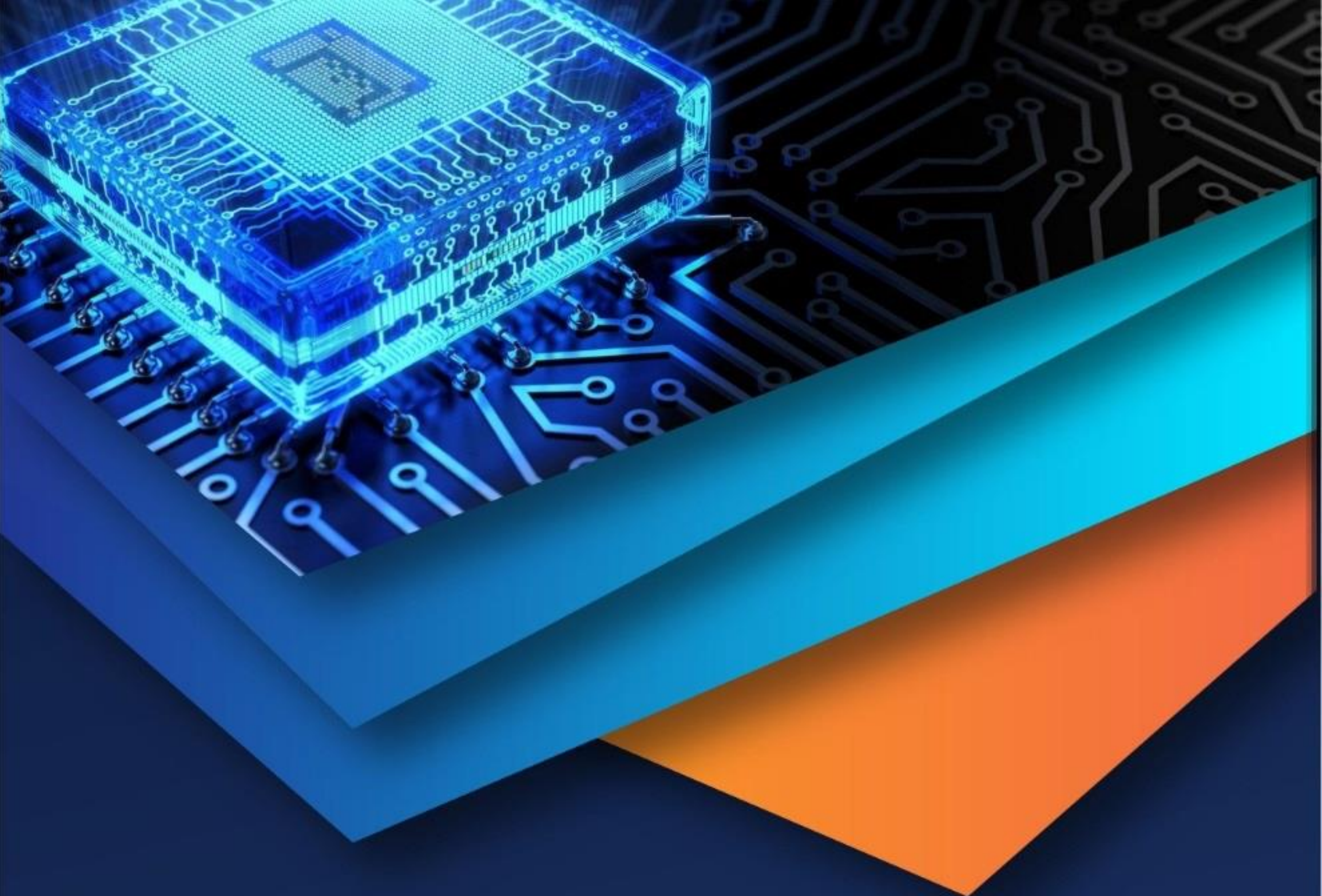

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