Emergency Mobile Navigation in Hazardous Environment Using Wireless Sensor Network

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Abstract- *Emergency navigation is the process of providing safe and timely navigation for users under emergency. Increasing reliance on electronic navigation and communication systems has dramatically changed the perspective of emergency navigation. Of the various types of navigation, wireless sensor networks based navigation is of greater significance with social values. Leaving the scene of a disaster radically decreases the chance of rescue, and there is little excuse for failure to notify rescue authorities with worldwide communication. A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A Sensor is a device that responds and detects some type of input from both the physical or environmental conditions, such as pressure, heat, light, etc. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing. The sensor network connects to the internet, an enterprise WAN or LAN, or a specialized industrial network so that collected data can be transmitted to backend systems for analysis and used in applications. Emergency Navigation using WSN forms a core research area within engineering and computer science disciplines too.*

Keywords- Emergency Navigation, Sensor networks, Road Map navigation, Clustering.

I. INTRODUCTION

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. 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. 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., 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. These 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.

The remainder of this paper is organized as follows. We present the theoretical foundation in Section 2 and elaborate on our approach in Section 3, with further discussions in Section 4.

II. ARCHITECTURE DIAGRAM

Sensors[16] play a key role in collecting information to process the data gathered. They are used to measure parameters such as temperature, pressure, position, etc. Sensors are compact devices that are capable of sensing real time data and converting that accessed data into machine understandable codes. IoT relies on sensors for consistent, reliable and accurate data used in automation and intelligent integration of smart components. Flame detector, IR based fire sensors, gas leakage detector, alarm sensor for indicating alarm, light, temperature, and gas sensors can be deployed. Building monitoring can be done through the use of wireless sensors. The configuration of sensors plays a critical role in the system software and reliability of sensor network deployed in the building. Sensors are deployed based on the layout and floor planning of the building for efficient navigation in normal as well as abnormal emergency situation. This also depends on the peak usage of an area by users. Deployment is done keeping in mind all possible nearby exits for a particular segment/ floor in a building location. The exits will also have sensors for rescuing people in danger. Fig.1 depicts the system architecture of the proposed system.

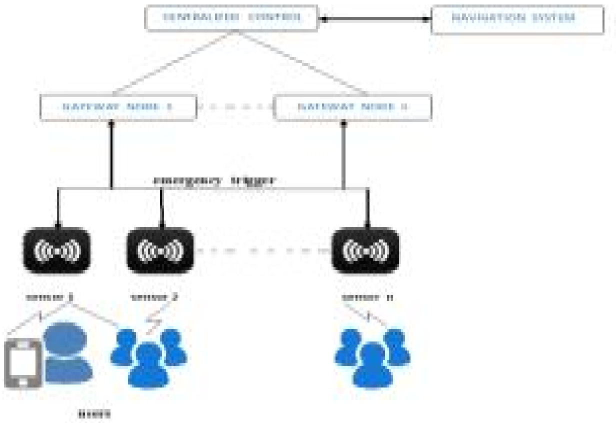


Figure 1. System Architecture of the Proposed System

The users equipped with mobile phones or PDA's interact with the sensors through Wi-Fi.GPS is inadequate for indoor location positioning. Wi-Fi is a technique used for location tracking with wireless access points(AP's). The centralized control/sever has the location details of the building (for path navigation and also mapping details to exit). On occurrence of hazardous accidents like fire or gas leakage, sensor value set

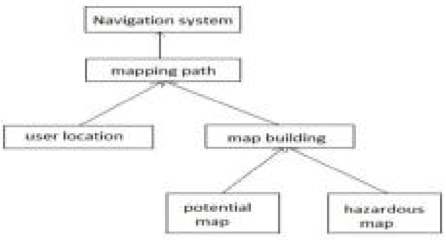


Figure 2. Navigation system diagram

goes beyond threshold and emergency is triggered. The source/initiator(sensor which detected danger) broadcasts the message which is directed to server control. The neighbouring sensors too pass the received information to the centralized system via gateway nodes. On reception of information, the server finds the source-id of the sensor belonging to danger zone and based on hop count, shortest path International Journal of Pure and Applied Mathematics Special Issue 492 computed is sent to the users in that location along with alert message for evacuation. The users in that zone are then directed to nearby safe exit.The steps involved in navigation system is depicted in Fig.2. The task is to build map and identify path based on user location. Then shortest and safest path is determined and users are navigated during occurrence of danger. The users in danger zone are routed safely to exit during emergency case (hazardous map). In normal scenario as well, users can get navigation to desired location (potential map). The sub systems of the emergency navigation system namely centralized control, network formation of user and sensor nodes and finally destination navigation are described in below sub sections. Centralized System The centralized system should have the prior knowledge about the environment. It contains details of the whole environment for the complete navigation of users by entering of the location details, registered user information and brief description about the block and exit. In our system, this task is maintained by the admin who manages the central control. The users are navigated by pre-processing the path for source to the destination based on request. Network formation A connection between user and sensor is to be created. Users are equipped with devices which can interact with sensors. Each sensor also covers neighbour nodes based on coverage and also the mobile nodes of user that come under the range of a sensor. Destination Navigation When emergency occurs, hop count received from sensor node is computed to determine the shortest path based on the mapping details stored in centralized system. In wireless network coding systems, user can exit in multiple paths. So user gets route information for navigating to desired location from his/her source location as well as a safe path to exit in case of danger. The emergency navigation system is split up into three segments. First, on detection of emergency by sensor, message has to be broadcasted and shortest path for evacuees is computed based on hop count. Secondly, all the broadcasted messages are directed to central system and danger zone is found. Thirdly, navigation to destination is done. 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.

III. THEORETICAL FOUNDATION

In this section we propose Our design emphasizes correctness in discovering escape paths even if users must pass hazardous areas. We divide the algorithm into two phases: RMN initialization and navigation.

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 neighbor table, in which each entry is of the format to track its neighbors' status.

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: • 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. • 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. • ei,j is the hop count from an emergency sensor i to a sensor j. • 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. 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. 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. 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. 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. • 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. 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: • 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. • 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 3 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.

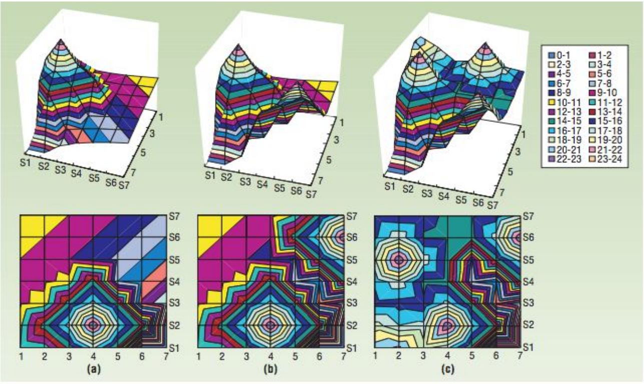


Figure 3. Examples of altitude changes when emergency events occur in (a) coordinates (S2, 4), (b) coordinates (S6, 7), and (c) coordinates (S5, 2).

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.4, where N8743 and N9671 are neighbour nodes. Further N9893 node is a neighbour to both N8743 and N9671.

Figure 4: User Identification

Many user nodes form network in the same fashion. Similarly, sensor nodes are created along with neighbour sensor nodes.

Emergency...!!!
Get Out of the Location...

Power saving mode on

WhatsApp

1 device connected
Tap to set up

Figure 5: 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.

IV. ALGORITHMS

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:

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

```
K= e
k=N/K
  for each cluster € K
    for each point P € (k-1)s+1 to ks
          C=P
          Decrement k
return C,K,k
```

Algorithm 2 .NEAREST CENTROID NOMINATION

Input : Centroids of C{G_1,G_2,…G_K}, E_i. exits

Output :G_i nearest to E_i:i € k

```
for each centroid G € k
  for each exit E € K
    for each distance d between G & E
     d=distance(G,E)
   min=min(d)
    for i €(1,k)
      if($d_i$==min)
              $G_i$ belongs to $E_i$
exit
```

Algorithm 3.POINT-CENTROID NOMINATION

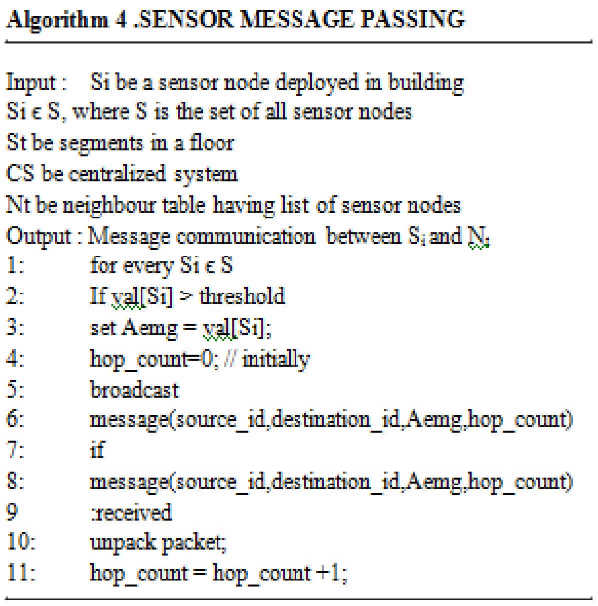
Input : Points{P_1,P_2,….,P_n}, E_i exits

Output : P_i nearest to G_i:i € k, minimum distance between point and centroid D

```
for each P(x,y)€ C
  for each G,E € K
    for each distance D between G & E
     D=distance(P,G)
   min_point=min(D)
    for i €(1,k)
      if($D_i$==min)
              $P_i$ belongs to $G_i$
exit
```

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.



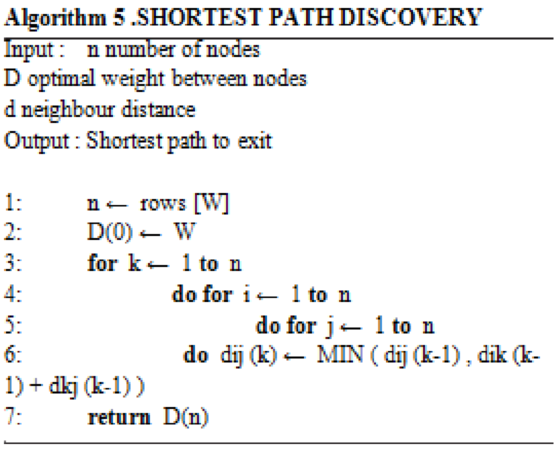
Algorithm 4 .SENSOR MESSAGE PASSING

```
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 $N_i$
          for every Si ϵ S
          If val[Si] > threshold
          set Aemg = val[Si];
          hop_count=0; // initially
          broadcast
          message(source_id,destination_id,Aemg,hop_count)
          if
          message(source_id,destination_id,Aemg,hop_count)
          :received
          unpack packet;
          hop_count = hop_count +1;
```

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→x and x→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

          n ← rows [W]
          D(0) ← W
          for k ← 1 to n
                    do for i ← 1 to n
                              do for j ← 1 to n
                                   do dij (k) ← MIN ( dij (k-1) , dik (k-1) + dkj (k-1) )
          return D(n)
```

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

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 Navigationis 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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