Preparation of FBMH and EFBWSN: A Firebase MAC Protocol and Enhanced WSN Design for Highways

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***Abstract*—Traffic on highways are on rapid growth from past few years; it is proposed to deploy enhanced firebase Wireless Sensor Network (EFBWSN) with appropriate Media Access Control (MAC) protocol that should be capable of handling energy conservation along with high rate of data delivery. Proposed firebase MAC protocol (FBMH) can conserve energy and also can tune its self according to traffic load and Fire situation. It focuses more on the data delivery and communication strategy. A design of enhanced WSN is also proposed for fire and smoke detection. In EFBWSN, sensor is integrated with microcontroller 8051, GSM-GPS module on which FBMH operates. WSN should be connected with some high speed backbone in order to propagate the information of the effected zone throughout the highway. FBMH mainly adopts Time Division Multiple Access (TDMA) and can dynamically adjusts the slot time depending upon the vehicles load and also allows contention in TDMA, sub-slots in fire situation to become more responsive and also manages two priority queues i.e. one for general information and other for fire incident. Implementation of proposed WSN design and FBMH will provide communication strategy among nodes and can enhance the road safety under disasters circumstances i.e. fire and smoke.**

***Index Terms*—Wireless sensor networks; fire base MAC protocol; MAC protocol for highway; energy conservation for WSN; FBMH; TDMA; Microcontroller.**

I. Introduction

In order to save lives on highways due to fire, it is required that highways should be deployed with a range of wireless sensors and actuators functioning as part of an overall highway management system. WSNs (Wireless Sensor Networks) which are easy to install and maintain consist of distributed sensors to monitor physical and environmental condition such as temperature, smoke, vibration and etc [1]. A wireless sensor network is a system of small wirelessly communicating nodes where each node is equipped with multiple components. Moreover, each node has a computation engine, communication and storage subsystems, a battery supply, sensors, and in some cases actuating devices. Furthermore, sensor network consist of radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery [2]. EFBWSN (see Fig. 1.) has a sensor node which is connected with microcontroller and attached with GSM-GPS module. It is assumed that each vehicle on highway is also equipped with GPS module as mentioned in Fig. 2. GPS tracker will track the car ids in its zone and cell numbers of vehicles will be recorded in the microcontroller's memory these numbers will be helpful in sending broadcast and unicast messages through GSM. Highway is divided in different zones and in case emergency happens information can be forwarded about the effected zone on high speed backbone to base station. Then base station will decide which zones should change its mode to firebase mode.

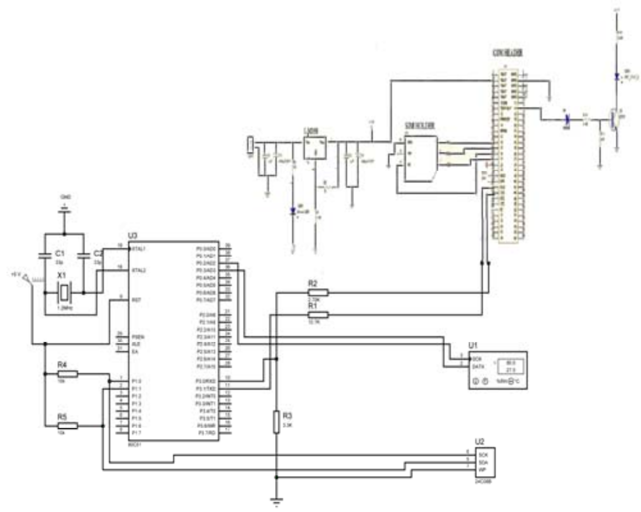

Fig. 1 Circuit diagram of EFBWSN

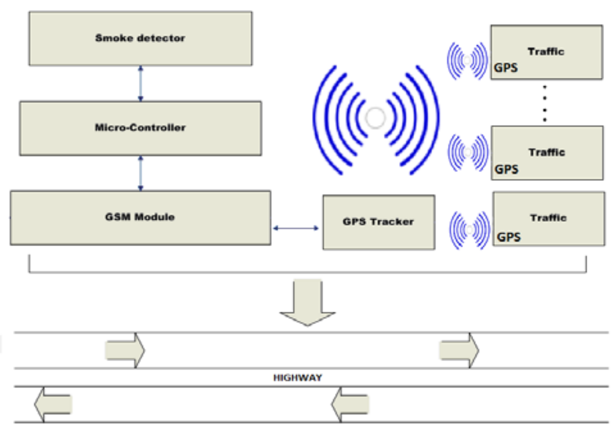

Fig. 2 Circuit diagram of EFBWSN.

In order to implement FBMH efficiently we should have highway statistics in terms of traffic loads, segment lengths, exit points and etc. The most important is to have a count of average vehicles in all zones and also the count in case of heavy load. So in case of no fire, TDMA approach is proposed because of its energy saving characteristics and number of slots in TDMA equals to average count of vehicles

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in that zone [3]. FBMH will operate in either FBMH_NOFIRE_AL mode or in FBMH_NOFIRE_HL mode, former mode is applied in case of average vehicle load and latter mode will be adopted when load is high and there is need to shorten the TDMA slots dynamically depending upon load. In case of fire, again two modes will be used, one for average load and other for high load. The modes are FBMH_FIRE_AL and FBMH_FIRE_HL respectively. In fire situation two priority queues are maintained and FBMH_FIRE_AL allows contention in one of the sub-slots of TDMA while FBMH_FIRE_HL also maintains two queues but of same priority. Emergency slots are reserved in all modes which would be helpful in case of emergency to an individual car/node and two slots reserved for communication with adjacent EFBWSNs.

Under fire it is not necessary for all the nodes deployed on highway to change their mode because the fire could be at a distance from the specific particular node. When a particular WSN detects fire, it will immediately change its mode to FBMH_Fire_AL/FBMH_Fire_HL depending upon the traffic. It will then inform the base station and base station will decide which respective EFBWSNs will change their mode. While vehicle load decision is taken locally by EFBWSNs themselves with the help of adjacent EFBWSNs. In fire base situation communication is ensured at the expense of energy and in non-fire situation it focuses more on energy conservation.

The remainder of this paper is organized as follows. We review the related work on emergency adaptive routing protocols in section 2. We present the proposed fire base MAC for highways (FBMH) in section 3, with its implementation and design. Section 4 concludes the paper and presents our future work.

II. Related Work

The enhanced smoke detector system consists of smoke detector circuitry, PC (equipped with receiving device) connected with mobile network, in order to communicate with other mobile user. On detection of smoke, the smoke detector circuit will send data in digital form that will activate a relay which connected to it [6]. There are many protocols but they are not well suited for fire emergency situation [4]. In WSNs, Medium Access Control (MAC) plays an important role in a successful communication. Existing contention-based MAC protocols such as S-MAC [5], schedule-based MAC protocols, TRAMA [7] [9], traffic adaptive medium access point and the combination of both contention and schedule (hybrid) are not suitable for fire emergency. During this emergency situation, successful communication of the WSN depends on a reliable communication protocol to transport important messages. In emergency situation safety can be provided at the expense of energy conservation with high through put and low latency.

ER-MAC is proposed for the emergency response wireless sensor network, it is hybrid of TDMA and CSMA. It allows contention in its TDMA slots. Moreover it maintains two queues for handling packets of high and low priorities. The contention is proposed in time division slots to achieve high delivery against low latency. It also addresses the synchronization by adopting parent-child broadcast synchronization [3]. In simulations it is compared with Z-MAC and it is showed that it outperforms delivery ratio, low latency along with lesser energy consumption [3] [10]. MMAC is found similar to TRAMA but in those cases where nodes are mobile and high dynamics is involved it performs better than TRAMA and S-MAC. The main idea is to use mobility adaptive frame time which can tune it self in accordance with changes in mobility patterns which results in better performance in terms energy efficiency and packet delivery [8].

III. Implementation and Desgin

First, EFBWSNs deployed on a highway, network consists of number of smoke sensors. These sensors can measure the variables which show the fire occurrence and possibility of fire. These nodes calculate the humidity, temperature and density. Through these parameters, we also determine the rate of fire spread based on temperature increase.

Sensor node connected with microcontroller which is attached with GSM-GPS module. The information about vehicle is tracked by GPS tracker of that particular zone which includes the parameter like car id, cell number, type of vehicle, cars direction. These parameters will be saved on the micro-controller memory and whenever there is need to send message then GSM module will take those parameters from microcontroller.

A. *Circuit Diagram of WSN*

The Basic components used in the diagram are as follows:

- 80C51 microcontroller
- 24C08B Flash EEPROM(working as memory)
- Sensor
- SIM Holder
- GSM Header
- Crystal oscillator 1.2 MHz
- Transistors , capacitors, resistors etc

This is complete working module for Fire base Visibility sensor. GPS will locate vehicles if they are coming in / going out of the range and microcontroller will add or delete its contacts respectively. 24C08B/16 which is a 16Kb Flash EEPROM, its 5th and 6th pin is connected with 1st and 2nd pin of a microcontroller where 7th pin is connected with ground. Microcontroller pins 36th and 37th are connected with 2nd and 3rd pin of visibility sensor. It provides continues updates of the visible conditions. When visibility is poor or below a certain level, microcontroller will send text messages to all numbers that are present in its own memory and in flash through GPS-GSM module which is connected with 10th and 11th pin of the microcontroller. SIM holder contains a SIM card that is used to send text to all within the range. Crystal oscillator is attached on 18th and 19th pin of an 80C51 microcontroller. Other components i.e. resistors, capacitors, transistors and led's are used to support microcontroller. It uses only 5V dc battery source. See Fig. 1 for more details.

B. *FBMH Working*

Now according to design each EFBWSN are equipped with microcontroller, sensors, GSM-GPS module. Fig. 2

explains communication block diagram of FBWSN and vehicles. FBMH will work in one of four modes that were discussed earlier in this paper. Intention is provide energy conservation when there is no fire and in case of fire the goal is to accommodate nodes as more information will be exchanged among vehicles and WSNs. Nodes sensing the thermal data will detect the fire location and track the rate of fire spreading. This information will be sent to base station using high speed backbone; decided FBWSN will then broadcast fire message to all nodes/vehicles in their respective zones. At this point FBMH will tune itself to operate in FBMH_FIRE_AL or FBMH_FIRE_HL depending upon the traffic load. Otherwise it will continue to perform working in FBMH_NOFIRE_AL or FBMH_NOFIRE_HL. So load switching mode will be a local decision rather than centralized as it is in the case of fire.

1) FBMH in no fire situation

Firebase WSN will work in a periodic manner in order to conserve the energy consumed. When the vehicle enters in its vicinity, it will perform active scanning then tries to establish registration with WSN and share the parameters like car id, type of vehicle, vehicle direction and etc. If FBWSN is active it will record those parameters otherwise when it returns to active state then it will record. In case if it's in sleep mode it will wait for awakening of the node. As the ranges of fire base sensor is very short, so it might be possible under normal situation node may pass to that zones without having registrations. But sleep time is adjusted in a way that vehicle must register after three to four zones.

Different strategies will be adopted for WSN nodes which are deployed at exit points. WSN nodes at exit points will have lesser time in sleeping mode i.e. sleep time is reduced to a factor that a vehicle must be registered in that zone.

For average vehicular load, TDMA is purposed and upon registration of vehicles with FBWSN each slot will be dedicated to a single node/vehicle. Now FBMH will work in FBMH_NOFIRE_AL and reason for choosing TDMA is its energy conservation approach. Node can go to sleep mode after registration and wake up according to assigned slot [3]. Two slots are reserved for emergency and two slots are reserve for communication among adjacent FBWSNs in each zone. The slots which are reserved for emergency will perform their tasks by using carrier sensing method. The emergencies are divided in two classes; one is 'emergency for an individual' and 'emergency for all'. In case of 'emergency for an individual' the base station will provide appropriate resources. On the other hand 'emergency for all' is considered as the fire situation and will be discussed later. Out of the two reserved slot, one slot will be dedicated for communication until emergency situation is resolved for that particular node. Furthermore, if the vehicular load increases than average load then each slot will be further divided dynamically depending upon the traffic load [3]. Now it will adopt FBMH_NOFIRE_HL mode for heavy load and in this mode each slot will be of small duration as compare to previous mode. Emergency slots will be doubled in this case as these slots also gets shorten but the communication strategy will remain the same.

2) FBMH in fire situation

The objective of FBMH is to provide services at the expense of energy because saving lives are more important than energy conservation of WSN and nodes. Now in this case when WSN detects fire it immediately switches its mode to FBMH_FIRE_AL (average load) and informs the base station. Upon confirmation base station will broadcast the message to all other WSNs and also decides which WSNs operate in fire mode. By doing so, overall energy of FBWSN can be conserved because there is no need for those WSNs to switch their mode to firebase which are at far distance or at different directions. FBWSNs which are ordered to switch their mode will broadcast the fire message with in their respective zones. In this situation two queues will be maintained one is of high priority and other one is low priority [3]. High priority is responsible for incident communication among WSN and vehicles. On the other hand low priority queue will be used for exchanging general information.

Furthermore, sizes of the slots will be reduced in order to process information more quickly. In fire situation broadcasts from WSN will be frequent so this will be of very high priority. Whenever there is need of sending broadcast message, all the traffic will cease. Similarly, it might be possible that nodes also need to communicate with WSN more frequently. Each slot is assigned to each node using TDMA and further divided into two sub-slots. The first sub-slot of each slot will perform contention using carrier sensing but not allowed to transmit data (low priority queue used for data transmission), while the second sub-slot will continue its operation for TDMA. Only those nodes will contend for this slot that cannot wait to communicate in there respective slot and want to share information of much more importance.

Few slots are also reserve in low priority queue, for this kind of situation the contender winner of high priority queue will be assigned first available slot of low priority queue for data transmission. For the exchange of general information remaining slots in low priority queue will be used through carrier sensing mechanism.

If load is more than average, then FBMH will work in FBMH_FIRE_HL and non reserve slots will be tuned to perform the same task as high priority queue. In this case both the queues will be of same priority. Contender winner of these sub slots of low priory queue will also use reserve slots of low priority queue for data transmission.

IV. Conclusion

In future, deploying FBWSN on highways for detecting fire would be beneficial for saving lives. In this paper we presented firebase MAC protocol FMBH for fire emergency along with FBWSNs design for highways with flexibility to adapt to traffic and environmental conditions. Our design posses the capability of achieving high packet delivery, lower latency by using TDMA, it consumes less energy and in fire situation carrier sensing mechanism is merged with TDMA. Moreover, four different modes are considered under FBMH protocol which is capable of handling less or high vehicular loads in an efficient manner. FBMH also addresses the emergencies to individuals and demonstrate the communication strategy for this as well. Furthermore, two slots are reserved for rapid sharing of information among adjacent FBWSNs.

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