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Tracking of Victim Persons using WSN

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Abstract: This paper describes a prototype of a wireless sensor network developed for tracking pilgrims in the Holy areas during Hajj (Pilgrimage). A delay tolerant network principle is used. Energy efficiency, robustness, and reliability are the key factors for the developed system. Every pilgrim will be given a mobile sensor unit that includes a GPS unit, a Microcontroller, antennas and a battery. A network of fixed master units is installed in the Holy area. Upon request or periodically, the sensor unit sends its UID number, latitude, longitude, and time. The close by master unit receives this information and passes it to a server that maps the latitude and longitude information on a Google map or any geographical information system. The developed system can be used to track specific pilgrims. Alternatively any pilgrim can request emergency help using the same system. The location of the person needing help will be identified on the map to make it easy for the help to reach in the most efficient way. The developed system works in coordination with an RFID identification system that was proposed earlier. The developed system was tested successfully during the recent pilgrim season.

Keywords: WSN, Pilgrims Tracking, Hajj season, Pilgrimage, GPS, RFID.

I. INTRODUTION

Hajj (Pilgrimage) is the most crowded gathering of Muslims on earth. It has unique characteristics with regard to the people who attend it (pilgrims), the place they meet in, and the kind of rituals they perform. These characteristics result in a set of challenges to the authorities in controlling the crowd, and identifying the personalities. What makes it even more challenging is that the whole crowd makes the same movements at the same times doing essentially the same thing. Muslims are obliged to perform Hajj once in their life time. Many of them love to perform it more than once. It is performed on specific days of the year (8th - 13th days of the 12th Hijri month) in designated boundaries around Makkah City in Saudi Arabia. The authorities for Hajj try their best to limit the crowd flooding to the area by assigning quotas for pilgrims from each country. Yet the number of pilgrims exceeds 2.5 million every year and is in the rise. Additional 4 million visitors who come to the Holy areas every year at other than Hajj times may benefit from the developed system as well. It is expected that the number of visitors will reach 10 million every year in the near future.While it is a great spiritual experience for all pilgrims, at the same time it poses great challenges of all sorts for the authorities responsible for facilitating the Hajj.

II. SYSTEM DESIGN AND WIRELESS SENSOR NETWORKS

During the past decade, there has been a lot of attention on Wireless Sensor Networks (WSN) from the research community. Monitoring and tracking has been sought as a prominent application among others. The sensor network for the proposed pilgrims tracking system uses a delay/disruption tolerant design. The number of mobile units to be monitored can be significantly large compared to the sensing units. Thus the WSN for this application has similarity to ZebraNet [7,8] designed for habitat monitoring.

It makes use of opportunistic, ad-hoc, and short-range wireless communications to disseminate data. Each pilgrim carries a matchbox sized unit that includes a GPS receiver and an IEEE802.16.4/ ZigBee radio to communicate with the fixed network of sensors. These fixed sensors have hardware and software to communicate with the mobile units carried by pilgrims to make queries and to receive location and UID information. Further, these fixed sensors can be made capable of communicating to each other so that to route the gathered data to the tracking and monitoring station via a gateway node. The gateway nodes communicate to base stations of a high data rate network such as High Speed Packet Access (HSPA) network. The server can receive the large volume of data via this high data rate network. Among the design criteria for the developed system are improving power efficiency and reducing latency. The mobile units are battery powered and therefore require power efficient hardware and software.

The processing in a mobile unit should be minimal. Similarly, the data volume to be communicated should be kept minimal. The algorithms and protocols should in effect minimize the duty cycle (percentage of time the mobile node is on). On the other hand, the fixed sensors can be powered from the power supply of street lighting for instance.

Nevertheless, their range of communication is limited due to regulations on emission and coexistence issues with other wireless networks in the area.

The location information of a pilgrim carrying the mobile unit along with the time stamp and UID information is transmitted to the nearest fixed sensors periodically, when the pilgrim requests emergency help or in response to a query originating from a monitoring station.

Periodic transmission of location information will facilitate continuous monitoring of a mobile unit and will reduce the time delay in locating the pilgrim in response to a query.

However, increased frequency of such transmission leads to increased power consumption and bandwidth occupancy. In addition to the periodic transmission of data, a mobile unit may respond to a query generated by the tracking station and the response is routed to the tracking station via the best path based on the routing criteria. Power efficiency of the mobile unit can be improved for instant by reducing the frequency of the periodic transmission of location information. As in a typical WSN, the developed system uses multi-hop communication to route information. Multi-hop communication yields reduced power consumption and scalability advantages. First, RF communication path loss has been a primary limitation for wireless networking where received power *Pr* decays with transmission range, *d*, as *Pr =k d-n* where *n* varies from 3 to 5 in typical indoor and outdoor environments [9]. However, in a dense sensor network, multi-hop architectures may permit *N* communication link hops between *N*+1 nodes. In the limit where communication system power dissipation (transceiver power) exceeds that of other systems within the premise of the sensor node, the introduction of *N* co-linear equal range hops between any node pair reduces power by a factor of *Nn*-1 in comparison with a single hop system. Multi-hop communication, therefore, provides an immediate advantage in capability for the low power devices.

A. Node Configurations

All nodes in the fixed WSN are made equivalent to keep the deployment, configuration and reconfiguration process simple. Configuration is performed such that some of the nodes will function only as end nodes receiving queries from the network, collecting data from the mobile nodes in the vicinity, and sending the data to nearby sensors. Some nodes function as routers in addition to performing the functions of end nodes. Yet a few strategically placed nodes function also as gateways sending volumes of data to base stations connected to public communication networks. Figure 1 shows a typical scenario where the mobile units and fixed sensors of different configurations communicating to each other.In the scenario we consider, the mobile units are highly dense in a limited geographic region. Therefore the sensor network may comprise of units mounted on nearby infrastructure such as lamp posts in the Holy areas. When dense sensing is employed, each patch of sensors only has to deal with a few mobile units carried by the pilgrims in a limited spatial region. Signal processing is greatly simplified because the sensors are close to the source, so that the Signal to Noise Ratio (SNR) is high. To simplify the complexity, the mobile units use flooding protocol thus a group of closest fixed sensors all receive the same data. These data are stored and routed through the best multi-hop route to the tracking and monitoring station. In this scenario, the query generation can grow tremendously, thus a tree based routing is suitable.

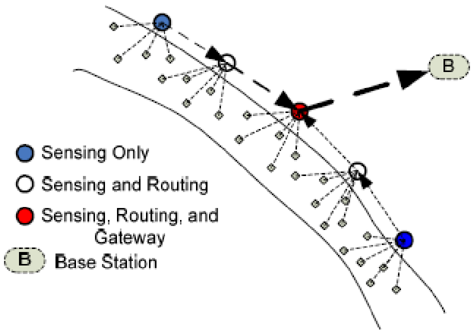

Figure 1: Sensor configurations and data routing.

B. Monitoring and Tracking

In the simplest scenario, all the queries on the location of an object will be sent by a single monitoring station. One interesting aspect of this is to design the optimal routing protocol to send the query for a particular object. Along with other criteria, this protocol will make use of any past knowledge on the location of the person being queried. Also the protocol includes parallel routing of multiple queries so that to minimize the latency resulting from multiple queries.

This process is enabled by the fact that it is possible to initiate multiple parallel routes in a sensor network of sufficiently large number of nodes.

C. Implementation of algorithms and protocols

The WSN incorporates algorithms operating at multiple layers namely Physical (PHY), Medium Access Control (MAC), network, and application layers, and includes elements to achieve necessary security for data, and to retain location information. The history of location information will be useful for future computations with increased energy efficiency and reduced computational load. Moreover, previous location information minimizes latency in responding to future queries. Among the candidate techniques to achieve energy efficiency and security is joint data compression and encryption technique. The benchmark standard for the current implementation is IEEE 802.15.4/ZigBee protocol suite for low bit rate communications.

Carrier-Sense Multiple Access (CSMA) protocol can be modified to provide low-duty-cycle operation. By sensing and detecting whether there is activity on the channel, a node may sleep and periodically awake and sample the channel. If a node detects incoming energy on the channel, it stays awake to receive the packet. Because the transmitter might repeatedly send a packet, the receiver must be awake during at least one transmission of the packet - a scheme commonly called Low-Power Listening (LPL) inspired by ALOHA with preamble sampling. The node's duty cycle using LPL depends on the number of its neighbors, as well as the application and sensor sampling rate. As the number of neighbors or sampling rate increases, the traffic in any given cell increases, causing the node to be awake more often. Since the transmission length must match the channel-sampling frequency, each transmission is more expensive than in the case of traditional CSMA systems. Thus the optimization of the network performance takes into consideration the effects of parameters such as sampling frequency and the number of neighbors to communicate by each node. It is essential to mention here that while the choice of low data rate WSN for the data collection leads to a cost and energy efficient design, the already in place commercial wireless networks namely 3G and beyond may greatly facilitates in time deployment of a the proposed tracking and monitoring system. Such networks fulfill the requirement of an interface between the end application and the WSN built for the tracking and monitoring purpose.

III PROOF OF CONCEPT

The developed system was tested on the Holy sites. A master unit and three mobile units were used. The three units were carried by three pilgrims whose movement was restricted to a 50 meter radius from the master unit. The master unit was moved throughout the Holy area to simulate a fixed network spread throughout the area. The mobile units sent their location information periodically to the master unit who sent this information to the server. Figure 2 shows the tracking of the movements of one pilgrim throughout a route that is usually used by pilgrims during Hajj season. It is interesting to see how the system was able to record the exact locations of the pilgrim.

Figure 2. Tracking of Pilgrims in the Holy area

III. CONCLUSION

This paper described a developed system for tracking and monitoring pilgrims during Hajj in the Holy area. The system consists of mobile units carried by pilgrims and a wireless sensor network fixed in the region. The WSN communicates to a server, the location information of the pilgrims periodically based on pre-set parameters. The mobile units transmit UID and location information to nearby master units. Such data are processed and routed to a server by the WSN using energy efficient algorithms and protocols. The communications between mobile units and the WSN take place using IEEE802.15.4/Zigbee protocol suite. The high volume date from the WSN is transmitted to the server via a high data rate network via the WSN gateway nodes. The developed system provides an option for the pilgrims to request help in case of emergency. The location information is mapped onto a Google map or any geographical information system for ease of localization and efficiency in providing needed help. A proof of concept experiment was implemented in the Holy area right after the past pilgrimage season. The experiment showed the viability of the proposed system for tracking pilgrims. In the next pilgrimage season the proposed system will be applied on a large sample of pilgrims, particularly to observe the operation of such system in large crowd and heavy use of the communication network.

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