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A SIMPLE SCHEME FOR LOCATION AND DISTANCE ESTIMATION OF WIRELESS SENSOR NODES IN OUTDOOR ENVIRONMENTS

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Abstract- In this paper we suggest a simple, practical and cost effective localization scheme that can be used to manually deploy wireless sensors to form wireless sensor networks (WSNs). We test our scheme exclusively in outdoor environments using commercially available IRIS XM2110 sensor motes. The location discovery of sensor motes deployed in outdoor environments is obtained in accordance with geographical latitude and longitude. The distance between the deployed sensor motes is also computed using the Haversine formula. The proposed scheme is the outcome of experiments performed on data visualization and monitoring tool Mote View 2.0.F developed by Crossbow Technology™. The proposed scheme is easy to implement and requires less number of sensor motes as compared to other manual deployment based schemes. The visualization of location is validated on Google earth geographical information program.

Index terms: Google earth, IRIS XM2110, localization, Mote View 2.0.F, data visualization, WSNs.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consists of spatially distributed, fabricated autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, light, volatile organic compounds and many other phenomenon of interest over large sequential scales [1,2,3]. They have recently generated a lot of concern among research communities and have been identified as one of the most exceptional technology during the last few decades [4]. With advancements in the field of engineering and technology, sensor networks find more thriving grounds for a variety of applications pertaining to environment, defense, human health, industry and agriculture [5]. The above cited application domains require accurate knowledge about the deployment location of the sensors. Sensor network localization schemes are fundamentally essential for obtaining location information of sensor nodes and are an active area of research [6, 7, 8, 9, 10]. However, despite the attention these schemes have received, accurate localization is still a problem that remains unsolved in real deployments since majority of the proposed schemes have only been tested with simulation scenarios under ideal conditions. Therefore for reliable localization of sensor nodes in real environments a customized hardware-software solution is of course a better choice. In this paper we propose a simple, practical and cost effective scheme for location estimation of manually deployed sensor nodes. Experiments are performed using IRIS XM2110 motes supported by global positioning system (GPS). The visualization and monitoring of network is performed on Mote View2.0.F developed by Crossbow Technology™ [11]. The location information of deployed sensor nodes is obtained in terms of relative latitude and longitude. The values of latitude and longitude obtained are used to calculate the intermediate distance between the deployed IRIS XM21110 sensor motes using the Haversine formula for spherical earth [12]. The rest of the paper is as follows. In Section II we describe the important functional aspects of commercially available wireless sensor motes. Section III presents the review of various data visualization and monitoring tools for WSNs. The key features and technical aspects of Mote View2.0.F are discussed in Section IV. Section V briefly highlights the internal components and specifications of IRIS XM2110 sensor mote. The system model and experimental results are shown in Section VI. Finally, Section VI concludes this paper.

II.FUNCTIONAL ASPECTS OF WIRELESS SENSOR MOTES

WSNs are formed using commercially available sensor nodes called as motes in a variety of ways to address different priorities and make the appropriate technology trade-offs based on the necessities of the application. The self powered motes facilitate easy deployment and long network lifetime. These motes also support pervasive and fine-grained sensing and exhibit some universal features. This section summarizes the desired functional aspects of wireless sensor motes, selected from preferred literature [13].

(1) Low power consumption to support long-term operation, the power consumption of the radio link must be minimized so that motes are powered by compact and lightweight batteries.

(2) Scalability so that the quantity of motes are able to support future growth without causing much overhead.

(3) Responsiveness towards topology discovery and rediscovery especially for applications where motes are expected to be mobile.

(4) Adjustable range to emit low strength radio frequency signals at short distances for a number of times than to emit higher strength radio frequency signals at longer distances.

(5) Bi-directional communication with the gateway to enable transmission of signals according to the operating parameters.

(6) Reliability in critical applications especially in medical monitoring and defense.

(7) Small module form factor so that the motes fit inside a limited space and can be attached to other devices.

(8) Multi-Hop capability to send messages (peer-to-peer to a base station/gateway) within the defined range.

(9) Self-Configurable to form a network without human intervention.

(10) Self-Healing and capable of addition and removal automatically without network reset.

(11) Dynamic to adaptively determine the routes under varying network conditions (e.g., link quality, hop-count and gradient).

III.REVIEW OF DATA VISUALZATION AND MONITORING TOOLS

First-rate data visualization and monitoring tool should execute in three standard ways. First, it needs to be receptive and shift the data rapidly. Second, it must offer a consequential assessment of the network status. Third, it must ensure data availability from the network to the end user in the most effectual and functional manner. In majority of sensor network applications, data monitoring and visualization is crucial since the data gathered from the network is usually saved in numerical form in a central base station. There are many programs that facilitate the viewing of large amount of collected data. These special programs for data monitoring are termed as visualization tools [14]. Visualization tools support different data types for visualizing the information over a flexible multi-layer. This section presents a brief description of visualization tools especially designed and developed for sensor network applications.

(1) Spy Glass [15] is used for sensor network debugging for visualizing the sensor network topology, the network state and the data sensed from the network. Spy Glass has a very flexible drawing and plug in architecture. The visualization framework consists mainly three major functional entities: The sensor network, the gateway nodes located in the sensor network and the visualization software.

(2) TinyViz [16] is an application specific software framework for user plug-in. It can be modified to suite specific simulation requirements. It is used for visualization of sensor readings, radio links and allows direct interaction with running simulations. The architecture allows addition of application specific visualization functionality and includes specialized drawing operations, subscription and reaction to events. It is tightly coupled to the TinyOS software, the TOSSIM simulator and the mica sensor network hardware.

(3) Surge Network Viewer [17] is Crossbow's product to visualize WSNs is based on a Java application. The Java application is inbuilt in the standard TinyOS tools distribution set up. It is a very useful tool for monitoring sensor network and analyzing the performance of mesh network.

(4) Mon Sense [18] provides modular applications with various extension points. It reuses various software libraries in order to reach an intended behavior. It displays the existing connections and routes as an undirected graph. Mon Sense is used for different goals like planning,

deployment and monitoring. The gathered data is easily understood by the end users and optionally this data can be published over the internet allowing access to the information without the need of any previous software installation.

(5) Octopus [19] is a visualization and control tool. Its main objective is to provide flexible access and control of deployed sensor networks.

(6) TOSGUI [20] project is composed of modular components that can be used to create a customized application. The component architecture is tightly connected with the TinyOS operating system and its hardware platform.

(7) MSR Sense [21] project is used for collection of data from sensor network, but the visualization is not performed in real time as the software is platform dependent.

(8) Trawler [22] is application from Mote IV and is well suited for monitoring small sized WSNs but, as the size increases the current network state becomes less apparent.

(9) Self-developed Sensor Network Analysis and Management Platform (SNAMP) [19] is a novel multi sniffer and multi-view visualization platform for WSNs. The data emitted by individual sensor nodes is collected by a multi-sniffer collation network and is passed to a flexible multi-view visualization mechanism. It indicates network topology, sensed data, hardware resource depletion, and other abnormalities in WSNs to allow developers to add application specific visualization functions.

(10) Mesh Netics [23] provides the network topology, sensed data and the signal quality between the nodes. It automatically generates network topology diagrams when nodes are detected and added to the system. These nodes are then regularly monitored and the sensed data is displayed in charts and tables on a PC screen. It features an XML-based framework for rapid customization of user interfaces to measure sensed parameters.

(11) Mica Graph Viewer (MGV) [24] provides 2D visualization and monitoring of WSNs.

(12) MARWIS [25] is management architecture for heterogeneous WSNs; it supports common management tasks such as visualization, monitoring, reconfiguration and reprogramming. It is preferred for a wireless mesh network to offer visualization, monitoring, reconfiguration and updating the program code

(13) Oscilloscope [26] is used as a tool to show the sensed data graphically on host screen and provides visualization of the nodes.

(14) GSN [27] is middleware software package to facilitate the viewing of large amount of data gathered form nodes and saved in the form of numerical data in a central base station.

(15) Wise Observer [28] visualizes and analyzes the data collected from wireless sensor network in a generic manner. It establishes a sensor network control interface and includes several facilities to treat the network data. It generates evolution charts, interpolation maps, data videos, and a compiled report. It also includes modules to add external data from other nodes that do not form the part of the network.

(16) Sense View [29] enables hierarchical visualization of physical locations. Visual maps are created by composing polygons and can be linked to a different view. The access to real time data is provided by directly subscribing to event nodes captured as links in the obtained map. The event nodes provide attribute and allows the end user to traverse through different views.

(17) Xbow Net [11] is a Crossbow developed visualization tool that corresponds to software driver called XServe and is installed on a gateway for the purpose of converting the sensed data into a stream over an internet service protocol.

IV. MOTE VIEW 2.0.F

The Mote View2.0.F is a product of Crossbow Technology™ designed to form an interface between an end user and the deployed wireless sensor mote network. It simplifies deployment, monitoring and is easy to connect to a database for graphically analyzing sensor readings [30]. The four main user interface sections are (a) Toolbar (b) Node List (c) Visualization Tabs (d) Server Messages. The software features topology and network statistics visualization for the logged data. The statistics function includes the end to end data packet flow and allows querying the sensor network for collected data in a database like manner. Users can ensure options to draw links between nodes and specify whether the gateway has a sensor on it for gradient visualization. The alert manager allows the end user to define alert condition based on data sensed from sensor motes; besides this it also supports conversion of various physical measurement units. It is compatible with various sensor and data acquisition boards like MICA2, MICA2DOT, and MICAz mote processor radio (MPR) platforms. The MPR platforms supported by Mote View

2.0.F are shown in Table 1. In addition, it can be used to monitor sensor integrated platforms such as the mote security detection system and mote environmental monitoring system.

Table 1: MPR platforms supported by Mote View

MPR	Model Number(s)	RF Frequency Band(s)
IRIS	XM2110	2400 MHz - 2483.5MHz
MICAz	MPR2400	2400 MHz - 2483.5MHz
MICA2	MPR400	868 MHz - 870 MHz
MICA2DOT	MPR510	868 MHz - 870 MHz 903 MHz - 928 MHz

Mote View 2.0.F offers a standard integrated platform for the development of smart devices for WSNs. It provides best network topology with low power profile and efficient bandwidth for various applications. The portfolio of wireless modules support a broad range of indoor and outdoor applications designed for low power operations at different radio frequencies, including 2.4 GHz option for interference, bandwidth and range. The data acquisition cards (e.g., MTS and MDA) mate directly to the wireless modules for sensing capabilities including temperature, pressure and motion and also support interfaces for external sensors with existing sensors in the wireless network. The Mote Interface Board (MIB 520) serves as gateway to connect the wireless sensor network directly to a personal computer (PC) through interfaces like universal serial bus, Ethernet and Wi-Fi. The wireless network landscape is shown in Figure 1 typically involve three distinct software tiers that are discussed next.

Mote Tier: It runs on the cloud of sensor nodes forming the network and provides the networking algorithms required to form a reliable communication backbone to connect all the nodes within the network. It comprises of embedded software that runs on the mote hardware and includes a tiny micro threaded operating system. The embedded software is written specifically in assembly language, C and nesC.

Server Tier: It is a facility to handle translation and buffering of data coming from the wireless network and acts as a bridge between the wireless motes and the internet clients. The server tier provides data logging, database storage, and services for forwarding sensor data coming from the gateway. Cross-platform portability is important in the server tier since the hardware may be a PC running Windows or a dedicated appliance running Linux. This portability requirement encourages the use of high-level languages such as Java and C++ within this server tier.

Client Tier: It controls the visualization software and graphical interface for managing the network. The client tier provides a graphical user interface (GUI) for managing and visualizing the server tier and the mote tier. It is typically designed to run well on an end-user platform of choice. (e.g. PC or a hand held personal digital assistant)

Mote View2.0.F has three representations: (a) instantaneous data points, (b) plots over a span of time, and (c) spatial maps at an instant time. These representations are implemented as (a) a spreadsheet view of most recent sensor readings from each node (b) a two dimensional chart with time span plot of a specific sensor over a selected set of nodes, and (c) a network topology map for overhead view of motes along with network links. These three visualizations are a small subset of the possible ways to view data provided by the network. Each of the three visualizations interacts with the lower layers. Mote view2.0.F provides a sound basis for addressing many challenges and is designed from the perspective of the end user in order to provide better administration of WSNs.

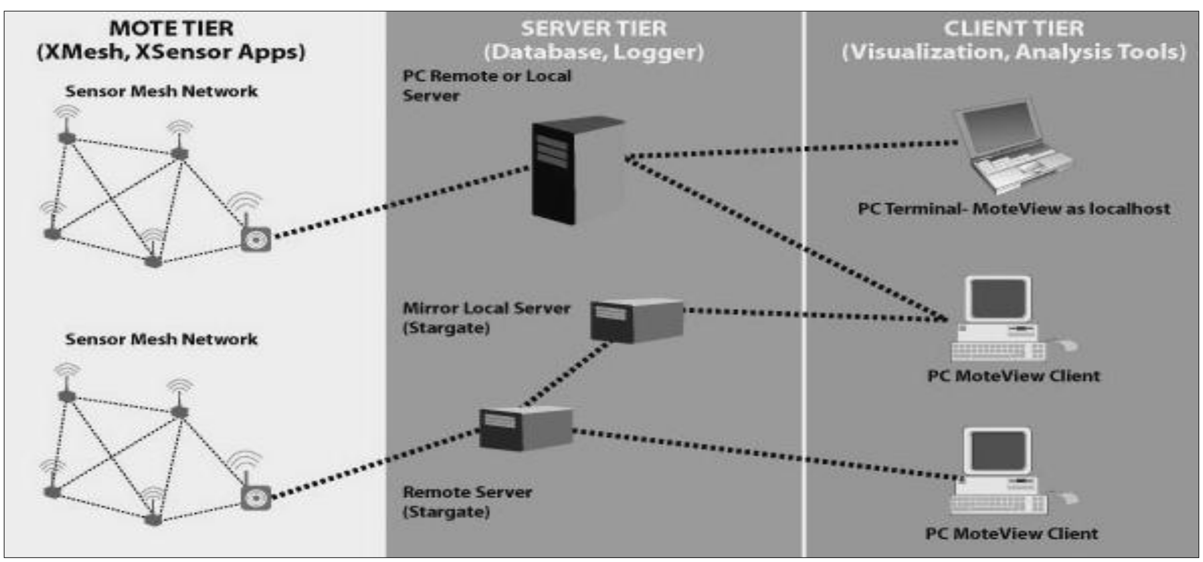

Figure 1. Tier architecture of Mote View 2.0.F

V. IRIS XM2110 MOTE

The IRIS XM2110 mote shown in Figure 2 is the latest generation of motes from Crossbow Technology^{TM}. It is considered as one of its type to sense and measure parameters such as temperature, humidity, pressure and light. The IRIS XM2110 operates on 3 Volts power supply and works well for star and distributed topology. The IRIS XM2110 has a band ranging from 2400 MHz to 2483.5 MHz and operates well in globally compatible industrial scientific and medical (ISM) band. It comprises of Atmel RF230 and AT Mega 1281 processing units along with an 8 bit microcontroller unit. It is also enhanced with IEEE 802.15.4 compliant RF transceiver and Zig-Bee radio frequency transceiver. These enhancements provide up to three times improved radio range and twice the program memory over previous generation of MICA motes. The application software and sensor board provide full compatibility with these motes to form a network for a specific application domain. Their outdoor line-of-sight ranges as far as 500 meters without amplification. The direct sequence spread spectrum radio is resistant to RF interference and provides inherent data security. The inbuilt processor, radio and the programmed sensor board can be easily interfaced with the gateway for maintaining data connectivity with the PC. The user can view the exact geographical region where these motes are deployed even from a remote location and organize the current information obtained from the specific geographic region in terms of its latitude and longitude.

Figure 2. IRIS XM2110 sensor mote

VI. SYSTEM MODEL AND EXPERIMENTAL RESULTS

The system model of the experimental set up is shown in Figure 3. The IRIS XM2110 motes with sensing modalities are deployed in outdoor environments to monitor environmental parameters. These motes are enclosed in castings and are preprogrammed with unique node identification (ID) assigned as Node 22 and Node 24. The PC interfaced to the gateway

(MIB520) facilitates network coordination and serves as a centre for information display. For live data display the data acquisition module is linked with front panel control to select gateway to start network operation. The gateway is programmed using Crossbow's driver functions to open gateway port, start data streaming, detect node ID and collect raw message packets with date and time stamp. As soon as the nodes are detected, their ID is displayed. The raw message packet information retrieved as sensor readings is converted into engineering units. The message packet holds the information related to node ID, voltage value, date and time and is displayed on table indicator. The location finder module consists of GPS device for scanning packet information to display the coordinates (latitude and longitude) for dynamically linking it to a web enabled application for finding geographical location on the earth map. When IRIS XM2110 motes are powered on, they transmit the specific administered values of latitude and longitude to the gateway. The obtained values of latitude and longitude of the point are shown in Table 2. The geographic location represented by latitude and longitude are the respective angular measures from the equator to north or south, and prime meridian to east or west.

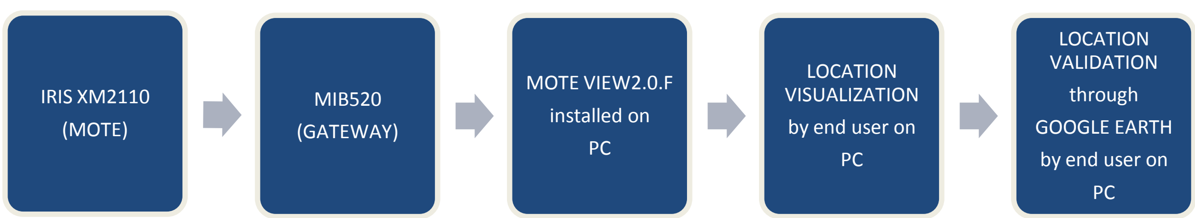

Figure 3. System model of the experimental set up

Table 2: Relative values of latitude and longitude

Node ID	Latitude	Longitude
22	28°29'2217" N	79°49'4267" E
24	28°29'2210" N	79°49'4257" E

The specific geographic location of the site where the motes were manually deployed was validated on Google earth information program [31] with the obtained values of latitude and longitude. The Google earth image of the site where the IRIS XM2110 motes were deployed is shown in Figure 4. The image obtained on Google earth map provides a perfect match between the deployment location of motes and their relative latitudes and longitudes. The localization errors due to the limitations of GPS device and irregular deployments are not considered in this experiment. The distance between the two motes was calculated using the Haversine formula for spherical earth. The Haversine formula suits well for numerical computations at smaller distances and offers accurate results for measurement of distance between the deployed motes. The distance; d, between the deployed motes was calculated as 0.3458 Kilometers according to equation (1) and equation (2).

$$d = R \times C \tag{1}$$

$$d = a\cos\,[\sin(lat_1).\sin(lat_2) + \cos(lat_1).\cos(lat_2).\cos(long_2 - long_1)].R \tag{2}$$

In equation (1) and equation (2), R is the mean radius of earth and its value is 6371 Kilometers. The value of C is calculated according to equation (3).

$$C = 2\,a\tan2\,[\sqrt{a}, \sqrt{(1-a)}] \tag{3}$$

The value of angle a, obtained from equation (4), is considered in radians to pass to trigonometric functions.

$$a = \sin^2(\Delta\, latitude/2) + \cos(latitude_1).\cos(latitude_2).\sin^2(\Delta\, longitude/2) \tag{4}$$

The difference between latitude and longitude, Δ is obtained from equation (5) and equation (6) respectively.

$$\Delta\, latitude = latitude_2 - latitude_1 \tag{5}$$

$$\Delta\, longitude = longitude_2 - longitude_1 \tag{6}$$

This formula does not take into account the non spherical (ellipsoidal) shape of the Earth. It tends to overestimate trans-polar distances and underestimate trans equatorial distances. The radius of the earth (6373 kilometers) is optimized for locations around 39 degrees from the equator (roughly the latitude of Washington, DC, USA).

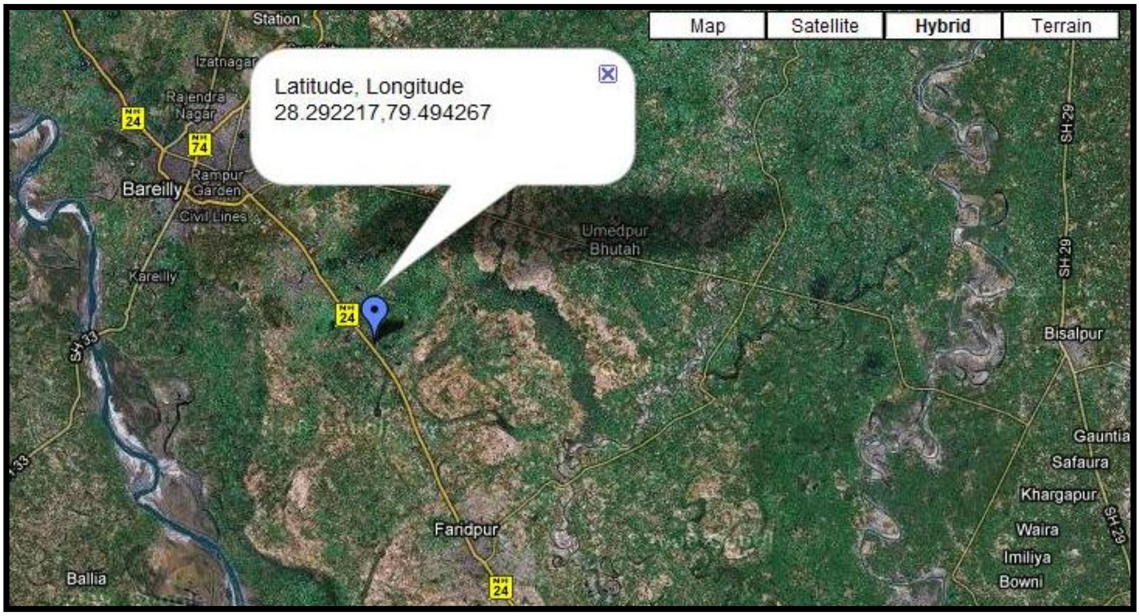

Figure 4. Google earth image of the location

In this experiment we did not assumed any specific routing or protocol therefore the transmission from motes to the gateway takes any possible path. The deployed motes have open access to the outdoor environment and allow uninterrupted data transmission to the gateway equipped with a GPS device connected with the PC. The results show a real time estimation of latitude and longitude of the point where the IRIS XM2110 motes were deployed. The exact deployment location is finally validated on Google earth geographical information program.

VII. CONCLUSIONS AND FUTURE WORK

In this paper we implemented a localization scheme for WSNs using IRIS XM2110 motes in scenarios where manual deployment is possible. The results show that the deployed motes estimate the relative values of latitude and longitude. The distance between the deployed motes was calculated using the Haversine formula. This represents an improvement over our previous work demonstrating more precise and feasible deployment of motes in outdoor environments. The proposed scheme is consistent as the motes run in a low power mode and communicate wirelessly with the gateway connected to the PC. The IRIS XM2110 motes provide critical benefits of complete coverage and reliability. In future we plan to improve this location estimation scheme by considering the deployment rate and altitude for self-localization of WSNs.

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