Experimental WSN setup using XMesh networking protocol

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***Abstract*—In wireless sensor network (WSN), various tiny WSN nodes collect the data from their surrounding areas and send the same towards the base station(BS) using multi-hop wireless communication links. In order to conserve the limited battery energy available with the nodes, every data item is not sent to the BS. Instead, event related information is extracted from the data collected by these nodes and is stored. The information stored in WSN nodes or remote servers can be retrieved through querying by a user. This work provides an experimental WSN set up making use of XMesh networking protocol. The hardware details of two different WSN nodes have been provided along with the experimental results. Also, the XMesh protocol has been discussed.**

Keywords: WSN, topology, routing protocol, data aggregation

I. Introduction

In WSN applications, the nodes are deployed randomly on the field to track and monitor events in remote areas, which can be quite challenging [1],[2]. A WSN comprises of many resource constrained nodes and the nodes are battery operated without any human intervention. The replacement of batteries in the nodes after the deployment of a WSN can be quite difficult. While designing the WSN and its associated protocols, it needs to be ensured that these are energy efficient with less computational overheads. The nodes gather data related to physical phenomena from their surrounding areas. The RF module available in the node makes it *smart*. The gathered voltage values are digitized and the data is forwarded towards the base station (BS) using the RF transceivers of the nodes and multi-hop wireless communication links. The deployment of the nodes can be either structured or random and the topology can be flat or hierarchical. In hierarchical topology, the nodes are grouped into groups or clusters and the cluster heads are elected for each group. The data collected by the nodes is aggregated by the cluster head and the aggregated values are forwarded towards the BS. The data flow in the WSN is monitored near the BS and any authorised user can query the database and retrieve the data collected through the BS.

The nodes or motes used in this work have 8- bit ATmega128 micro-controller operating at 8 MHz. In the WSN, the nodes rely on XMesh [4] networking protocol. The mote layer as shown in Figure 1 is available with the tiny motes and the software component relies on nesC [5], a dialect of C++.

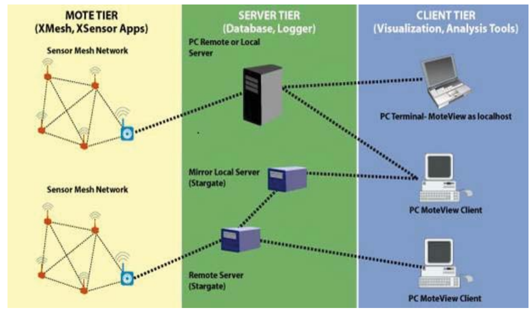

Fig. 1. Software framework of XMesh protocol [3]

This work provides the implementation results of a WSN using XMesh protocol. It is assumed that the nodes are deployed randomly in the network using Xmesh. This protocol supports dynamic changes in the network at any stage and thereby supporting the scalability of the WSN. The data analysis is carried out using the computer which is connected to the gateway device, MIB520, assisted by the XServe component. The Xserve has the requisite driver software. The Moteview and eKoView are client level applications supporting graphical user interface (GUI). The rest of the paper is organized as follows: Section II discusses the XMesh protocol and the three tiers in XMesh protocol, section III presents a WSN set up and gives the experimental analysis and section IV provides conclusions.

II. XMesh protocol

The XMesh is an ad-hoc, multi-hop networking protocol used in WSN's [6]. The XMesh is self-healable and self-sustainable protocol which supports dynamic changes in the network [7]. It uses mesh topology [8] in which the nodes can route the data and establish end-to-end connection efficiently. In order to discover various routing paths in the network, cost metric (CM) is used [9]. The link quality, which is calculated by a receiving node as $CM_{link-quality} = \frac{n_R}{n_E}$, where n_R is the number of messages received and n_E is the number of expected messages. The number of expected messages is computed from the serial number of the message from neighbouring node. The link quality parameter is updated periodically to discover bad links and the possible routes. The multi-hop routing guarantees end-to-end connectivity with reduced energy cost for the message transmission [10]. The selection of an an efficient route is performed with the *RouteSelect* interface and the route quality and route change interval are carried out using the *RouteControl* interface.

The Xmesh protocol supports three different operating modes: high power(hp), low power (lp) and extended low power (elp). In both the hp and lp modes all multi-hop mesh networking features are enabled. In lp mode the latency is more as the peripherals are kept in *SLEEP* mode for most of the time in order to conserve energy. In addition, the LED's are turned off in low power mode.

The Xmesh protocol is initialized in all the motes and the gateway or BS. Various interfaces supported by the Xmesh are used and while developing application code in nesC for different types nodes. The broadcast messages are handled by *XCommand* interface and for different commands like *SETRATE, SLEEP,WAKEUP*, appropriate actions are taken.

A. Mote Tier

The motes, gateway and XMesh application code residing on the motes and the gateway fall under the mote tier. This work uses MTS400 and eS1100. MTS 400 as shown in Figure 2 supports accelerometer and its characteristics are given in Table-I.

Fig. 2. Sensor board

TABLE I
CHARACTERISTICS OF THE SENSOR BOARD- MTS400

Sensor type	Specification
Pressure	Accuracy: ± 3.5 Range: 300 to 110 mbar
Accelerometer	Range: $\pm 2G$ $(G = 9.81 m/s^2)$ Sensitivity: 167 mV/G
Light sensor	ON resistance (white light) $10K\Omega$ OFF Resistance $520K\Omega$
Temperature	Accuracy: $\pm 2^oC$ Range: -40^oC to 80^oC

1) Mote (IRIS): This work uses IRIS mote [11], with Atmel's AT1281 micro-controller and Atmel's AT86RF230 transceiver supported by IEEE 802.15.4 protocol and Zigbee compliant radio [12]. The RF module of the mote can be configured to make use of any of the frequency channels in the 2.405 GHz to 2.480 GHz frequency band having 16 channels. The range of the node can be altered by controlling transmission power from 3 dBm to -17.2 dBm. IRIS node is supported by 4 KB RAM and 128 KB flash memory to take care of the needs of WSN applications. The IRIS mote also contains external 512 KB flash memory to support On The Air Programming (OTAP).

2) ēKo node: The ēKo node, as shown in Figure 3, integrates an IRIS family processor/radio module, using a direct sequence spread spectrum radio (DSSS) supporting the 2.4 GHz global ISM band and IEEE 802.15.4 standard compliant. The ēKo base radio and nodes are factory configured to 2.475 GHz. This channel does not overlap with Wi-Fi band minimizing interference. The ADC is of 10-bit resolution. The following sensors are supported by the ēKo Pro series system: eS1100- soil moisture potential sensors, eS1110- soil water content sensors, eS1201- ambient temperature and humidity sensors, eS1301- leaf wetness sensors, eS1401- solar radiation sensors and eS2000- weather station sensor suite. The ēKo nodes are designed to accommodate almost any type of low power sensor and allow for future support of many sensors. The eS1100 sensor is used to measure variations in the soil moisture by connecting it to one of the ports in the ēKo node EN2100, and the characteristics of EN2100 are given in Table-II.

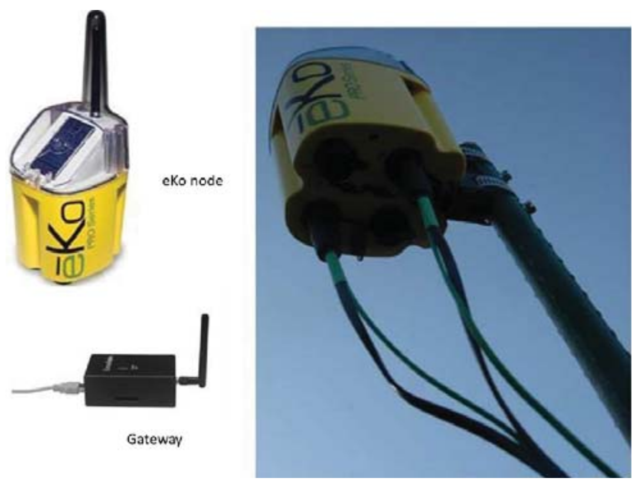

Fig. 3. ēKo node EN2100 and gateway

TABLE II
CHARACTERISTICS OF ĒKO NODE EN2100

Parameter	Value
Number of Sensor ports	4
Radio	2.405 to 2.480 GHz 16 channels DSSS, IEEE 802.15.4
Outdoor range	500ft to 1500ft LoS
Transmitter output	+3dBm
Receiver sensitivity	-101dBm
Water / Dust Resistance	IP66
Energy source	Self-contained 1.3"x 2.5" solar panel to recharge 3 AA low-leakage NiMH batteries

B. *Client tier*

MEMSIC has provided Moteview and eKoview in order to visualize the data. The Moteview is supported using Windows platform and the eKoview is available in Ubuntu. Both of them connect all the three layers of XMesh protocol. After setting up the WSN, upon selecting the Topology tab in the Moteview interface shows all the nodes and the Gateway graphically indicating their positions and the status of the connectivity. The current status of the motes can be presented using Charts, Histogram, Scatter plot and Data tabs as provided in the interface. Other features like exporting data to spreadsheet, programming the mote, calibration of sensors are also supported. Similar features are also available in eKoview.

III. DATA COLLECTION FROM MOBILE SENSOR NODES

A. *WSN Monitoring in Moteview*

After configuring each node in the network and various connection options, Xserve is started and the current state of the network WSN is shown using the Moteview. All the connected nodes and the physical parameters sensed by them are monitored in Moteview. A sample topology of the network is shown in Figure 4 and it can be observed that the nodes in the network are listed on the left side and the current network topology status is shown on right side. Four IRIS motes with MTS400 sensor boards and the fifth node with gateway device MIB520 have been used.

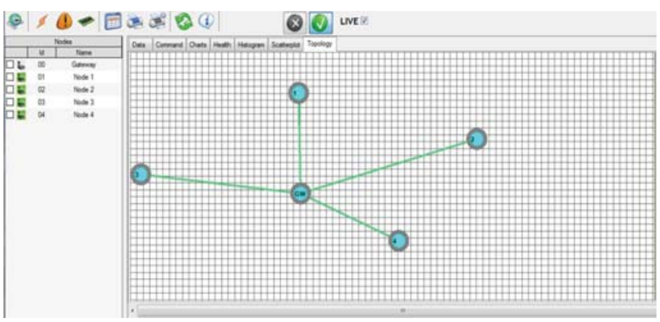

Fig. 4.

B. *Data Analysis in Moteview*

Moteview along with Xserve allows a user to analyse the data collected by the nodes. Experimental parameters are given in Table III.

Multi-hop routing: XMesh protocol supports multi-hop routing and conserves energy of the nodes and ensures reliable delivery of the data from each of the sensor nodes towards the gateway. To verify the multi-hop routing capability of XMesh protocol, initially the nodes are deployed nearer to the gateway and the resultant topology of the network is given in Figure 4. Now the node 4 is moved away from the gateway about 30 m. The resulting multi-hop topology of the network is shown in Figure 5. Node 3 has become the parent node for the node 4 now.

TABLE III
EXPERIMENTAL PARAMETERS

Number of mobile nodes	12
Sensor mote	IRIS
Sensor board	MTS400
Routing protocol	XMesh

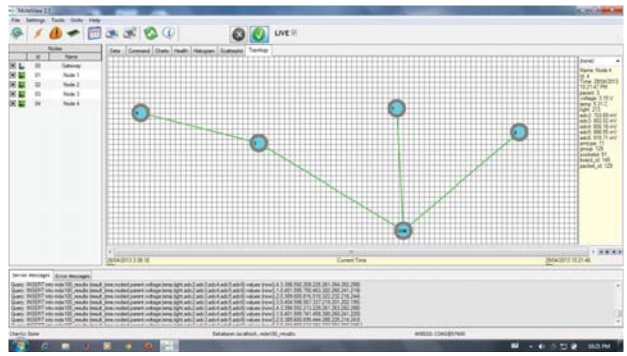

Fig. 5. Multi-hop routing in WSN (two hops)

To test robustness of the XMesh protocol, 11 nodes and a gateway (GW) are deployed in a 30m radius area initially and Figure 6 shows the topology of the initial set up. A parent node, node 7 is turned off to study the robustness of the Xmesh proocol against node failures. The child nodes connected to the node 7 look for alternate parent nodes based on the link quality parameter. It can be noticed from Figure 7 that only the node 7 is disconnected from the rest of the network. The modified topology of the network is depicted in Figure 7. Then, another parent node, node 2 has also been turned off. This time other nodes in the network are affected. Figure 8 shows the modified topology of the network. However, the time required for the topology changes in the network involve delays and depend on the operating mode. This may lead to certain amount data loss.

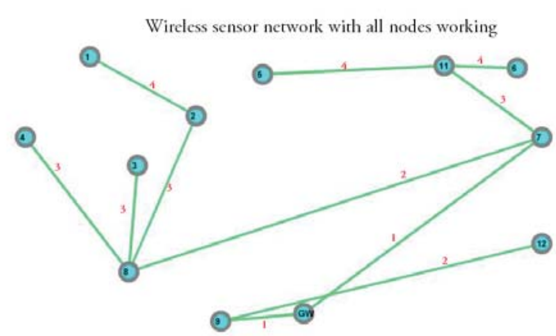

Fig. 6. Multi-hop topology

C. *Temporal analysis in Moteview and eKoview*

The data collected by a node supported by MTS400 sensor board is shown in figures 9 and 10. The raw data collected by

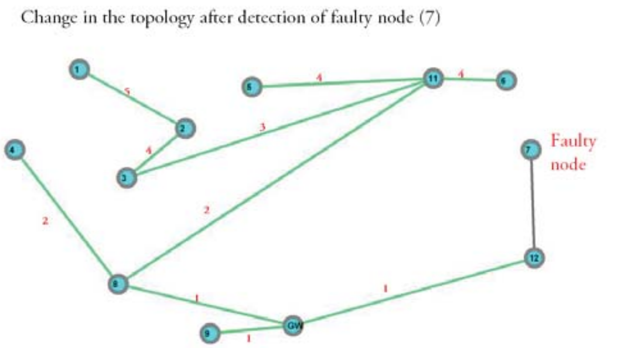

Fig. 7. Multi-hop topology with one faulty node

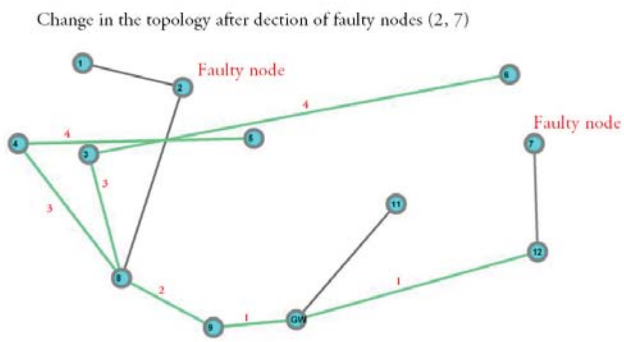

Fig. 8. Multi-hop topology update with two faulty nodes

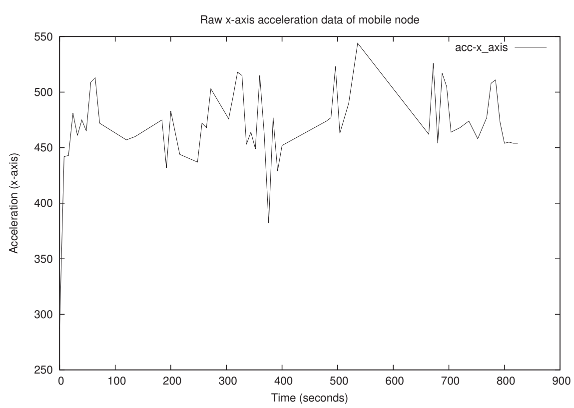

Fig. 9. Accelerometer raw data (x-axis)

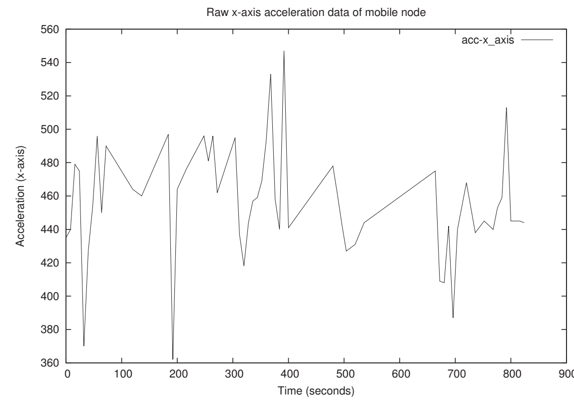

Fig. 10. Accelerometer raw data (y-axis)

the sensor node is calibrated in terms of acceleration due to gravity (g). The magnitude and the angle of the acceleration data is calculated to analyse the motion of the mobile node. Temporal analysis of the data can be carried out in eKoview by selecting *Charts* tab. The historical data for the past hour/day/week/month can be analysed. Also, both Moteview and eKoview allow to view graphs of more than one sensed parameter and nodes in a single window. Figure 11 shows various ēKo nodes present in the network and the sensor nodes connected to each ēKo node. Any ēKo node can be selected and one of its sensor ports can be chosen to monitor the live data collected using eKoview interface. The voltages of both the solar panel and battery energy sources are also provided. The ēKo nodes can run up to 3 months without any sunlight. Figure 12 shows a chart for soil moisture for one day. The ēKo nodes are factory configured to send sensor data once every 15 minutes. A sample is selected to identify the soil moisture value for the sample as shown in Figure 12.

IV. Conclusion

This work has considered both Moteview and eKoView GUI's and the XMesh networking protocol. The characteristics of two different WSN hardware platforms have been provided. The experimental results using both the platforms have also been presented. The XMesh has proven to be a reliable and robust protocol for WSN applications where scalability and robust connectivity in a WSN are very important.

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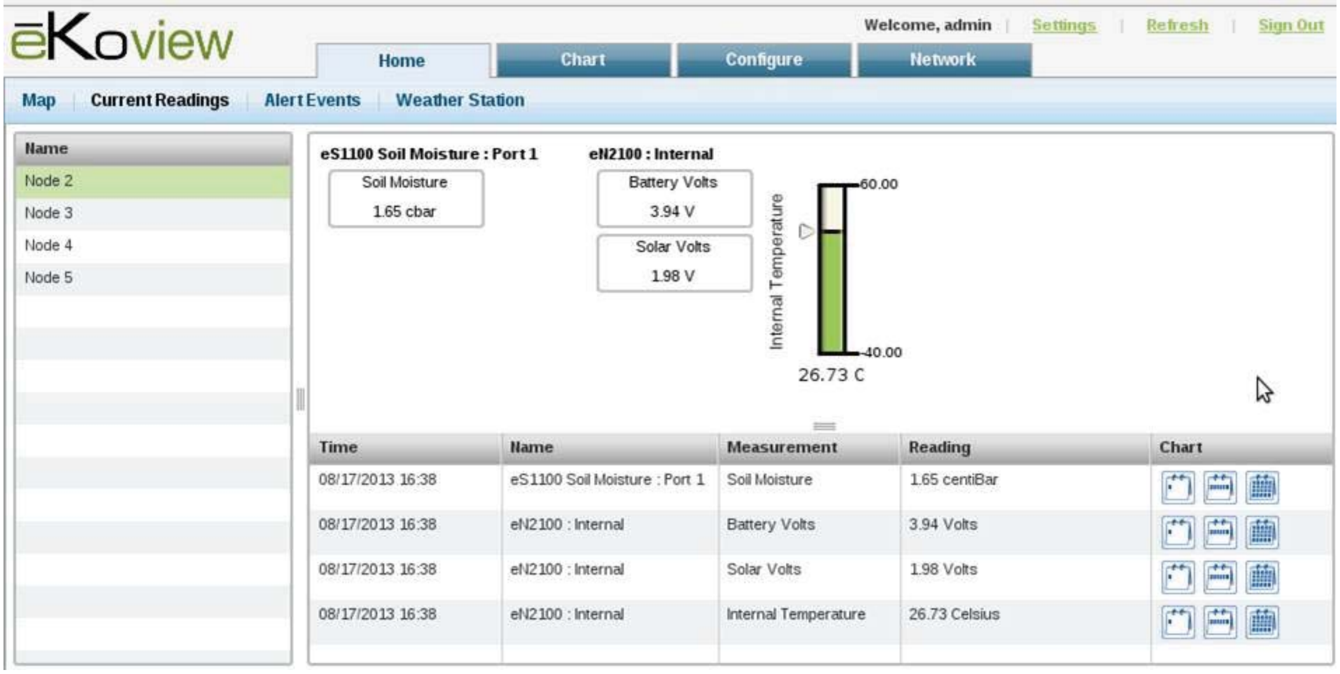

Fig. 11. Live Data

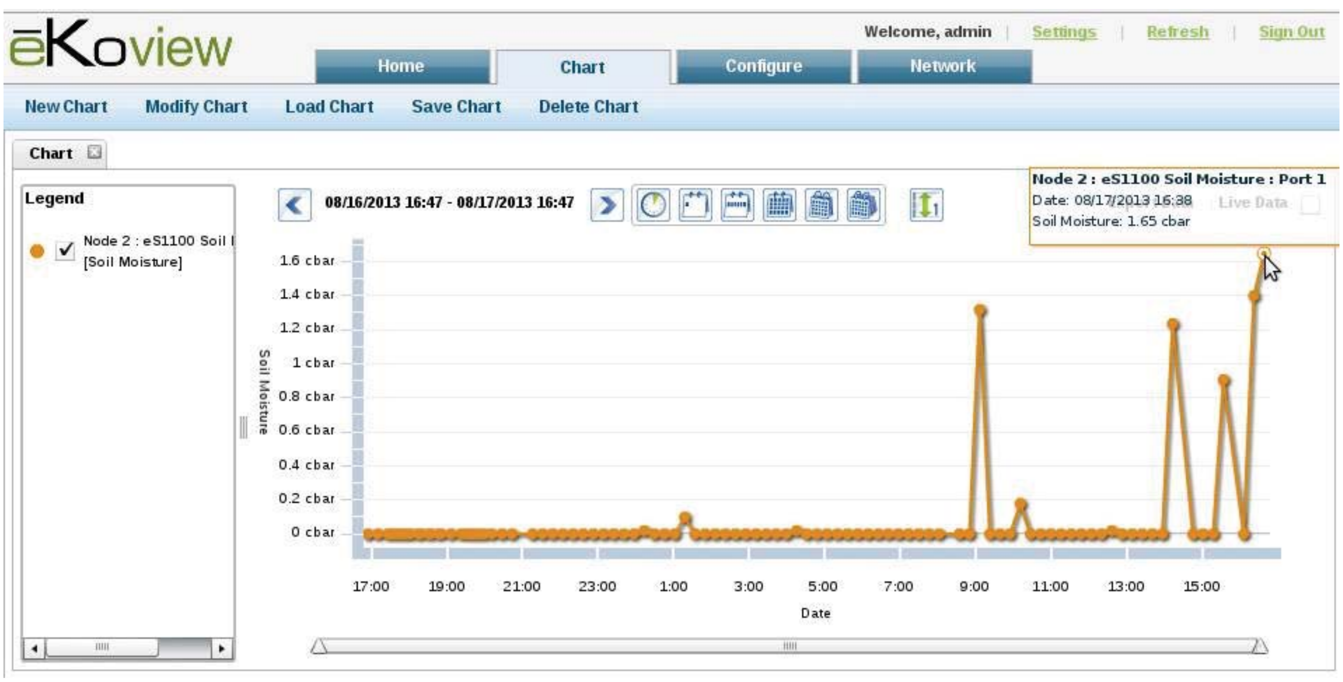

Fig. 12. Variation in soil moisture