DISTRIBUTED WIRELESS MOBILE SENSOR NETWORK MODEL AND EFFICIENT ROUTING ADOPTED TO DYNAMIC CHANGE OF TOPOLOGY

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ABSTRACT

Integration of heterogeneous wireless networks poses challenges and limitations in building multiple interfaces and corresponding bridges/ gateways functionalities. Integration of heterogeneous wireless networks enables the information exchange across multiple wireless networks which are difficult now. We propose a wireless mobile sensor network in a distributed environment is a new architectural model that merges the advantages of wireless mesh networks, cellular networks, and wireless sensor networks and the data from Wireless Sensor Networks send to Internet through the Cellular Network. Integration of the sensor network which ride on cellular networks taking the advantages of GPS technology in collecting enormous data about environment like temperature, humidity, air pollution level etc. at low-cost. This rich, up-to-date, data collection helps researches to take dynamic decision and passing the same to the people instantaneously. In this paper we propose a scalable architecture DWMSN and analyze key research issues in routing adapted to mobility of both sink and node. A new method is proposed for an efficient protocol adopting the dynamic change of topology due to strong mobility. Further a prototype design is proposed for environmental monitoring and surveillance (EMS) applications under DWMSN architectural model.

Keywords: Wireless Mobile Sensor Networks, DWMSN, Environmental sensors, environmental monitoring system, EMS.

1. RELATED WORK

Recent advances in wireless sensor have led to many new protocols specifically designed for sensor networks where energy awareness is an essential consideration. Most of the attention however has been given to the routing protocols since they might differ depending on the applications and network architecture.[4,7] Sensor nodes are constrained in energy supply and bandwidth. Such constraints combined with a typical deployment of large number of sensor nodes have posed many challenges to the design and management of sensor networks. These challenges necessitate energy awareness at all layers of networking protocol stack. The issues related to physical and link layers are generally common for all kind of sensor applications, therefore the research on these areas has been focuses on energy aware MAC protocols.[3,10,11] At the network layers, the main aim is to find ways for energy efficient route setup and reliable relaying of data from the sensor nodes to the sink so that the life time of the network is maximized. The application of wireless sensor networks in a distributed environment [6] is to create awareness to the people about the environmental factors and providing reliable information and then enabling for intelligent decision making.

1.1 Wireless Sensor Network (WSN)

The flexibility, fault tolerance, high sensing, self organization, fidelity, low-cost and rapid deployment characteristics of sensor networks are ideal to many new and exciting applications areas such as military, environment monitoring, intelligent control, traffic management, medical treatment, manufacture industry and so on[8].The existing protocols for WSNs are built on the network architecture (ie) flat architecture such that all sensor nodes are homogeneous and send their data to a single sink node by multiple hops [9] Such a flat architecture is inapplicable to many real applications with large-scale, heterogeneous sensor nodes, the flat architectural model inherently has the following problems.

1. Unbalance energy consumption among modes.
2. Poor scalability and Poor robustness
3. Single point of failure causes total failure.

Owing to above limitations of traditional architecture of WSNs, Distributed wireless mobile sensor networks-DWMSNs is designed to improve scalability, reliability and throughput of sensor network and to support mobility of both sink and nodes. The characteristics of routing in sensor network that makes it different from that of traditional communication and wireless ad_hoc network. To deal with the specific characteristics of sensor nodes along with the application and topology, many routing mechanisms have been proposed. [1,4] Almost all of them can be classified as data centric, hierarchical or location based although there are few distinct based on network flow or QoS awareness.

1.2 Wireless Mesh Network (WMN)

WMN is a kind of new wireless network architecture paid more and more attention recently. [2,12] WMNs is a self organized, self configured and decentralized wireless network. There are two kinds of nodes in WMN: 1. Mesh router. 2. Mobile client. Mesh routers with powerful capacities and lower mobility are automatically setup and maintain wireless connection forming the backbone of WMNs. One of the most significant characteristics of WMNs is that it provides interconnections among all networked nodes, where each node can send and receive data directly to each other. WMNs are able to automatically discover topology change and self adaptively modify routing for more efficient data transmission. Moreover WMNs are teach to achieve load balance by routing parts of data to gateway nodes with lower load. The proposed issue of network integration of wireless sensor networks with WMNs(fig.1.) highlighted and connected to internet through the gateway .

1.3 Network Integration

By deploying some super mesh nodes as gateway node with capacities to transmit data in a long-distance way and self-organize reliably, DWMSN merges the advantages of WMN mesh networks and WSN. It provides the capacities to interconnect multiple homogeneous and heterogeneous sensor networks, and to improve scalability, robustness and data throughput of sensor networks and support the mobility of nodes (both sink and node) there by adaptive to dynamically changing environment and topology.

2 PROBLEM DEFINITION And ISSUES

Routing is highly related to network architecture. Also for DWMSN there has not yet a well defined architectural model with scalability, robustness. Also, there is a lack of efficient routing protocols for DWMSN considering multiple mobile sink nodes adapting to mobility. This paper addresses the above challenging issues focusing on these parts:

1). The proposed protocols supports mobility adoption for dynamically changing topology due to strong mobility of nodes and needs synchronization of nodes.
2.) Efficient routing protocols adopting mobility and aiming at maximizing the lifetime of the sensor networks.
3.) Design of a prototype to WSN architectural model for environmental monitoring

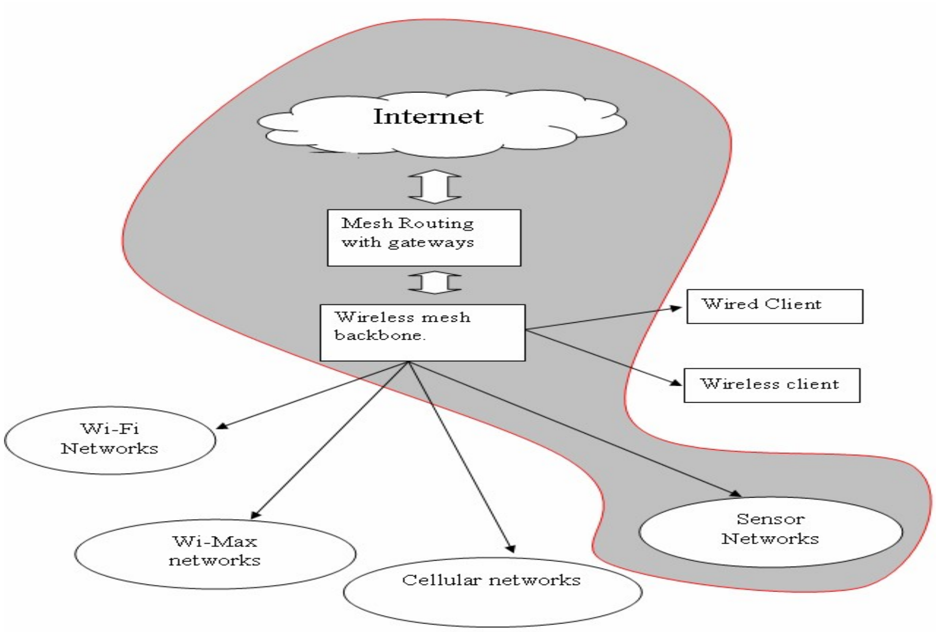

Fig1 . Integration of WSN, WMN and Internet.

3. PROPOSED ARCHITECTURE

DWMSN – supports mobility of sensor nodes and each sensor networks includes more than one Wireless Gateway Nodes (sink). This model can easily connect multiple homogeneous (or) heterogeneous sensor networks. The Gateways and routers deployed in different sensor networks automatically interconnect to form a mesh network while are connected with internet through power full base station. The Advantages of WMNs are applied to mobile sensor network and a new architecture is proposed DWMSN as shown in Fig 2.

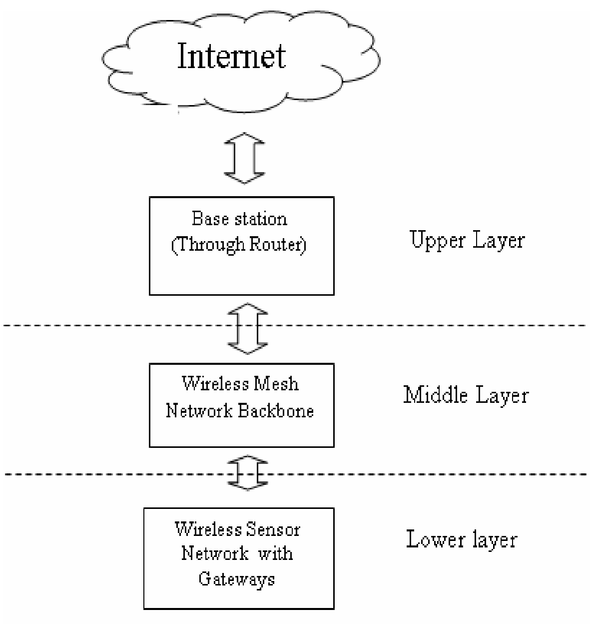

Fig 2. Proposed layered Architectural model

There are three logical layers.

1. Lower layer – wireless sensor networks for monitoring and reporting objects: information (eg. Temperature, humidity)
2. Middle layer – wireless mesh network for transmitting sensed data in long distance and reliable way.
3. Upper layer – Internet for users to remotely access sensed data.

State of the art DWMSN often has some of the following characteristics.

1. They are self-forming. As nodes are powered on, they automatically enter the network.
2. They are self-healing. As a node leaves the network the remaining nodes automatically re-routed their signals around the out-of-network. Node to ensure a more reliable communication path.
3. They support multihop routing. This means that data from a node can jump through multiple nodes before delivering its information to a host gateway (or) controller that may be monitoring the network.
4. They support mobility of both sink and node there by adapting the dynamic change of topology.

4. EFFICIENT ROUTING PROTOCOL FOR WMSN

Most of the routing protocols [4] for sensor networks require location information for sensor network. The location information needed in order to calculate the distance between two nodes since there is no addressing scheme for sensors networks like IP addresses and they are spatially deployed on a region location information can be utilized in routing data in an energy efficient way. [13,14] For example of the region to be sensed is known using location of sensors, the query can be diffused only to that particular region which will eliminate the number of transmission significantly.

In traditional architecture of sensor networks with a single sink, sensor nodes around the sink (Fig. 3.a) inevitably drain their energy ahead of other nodes because of more heavy data forwarding, whether using flat, hierarchical or other routing.

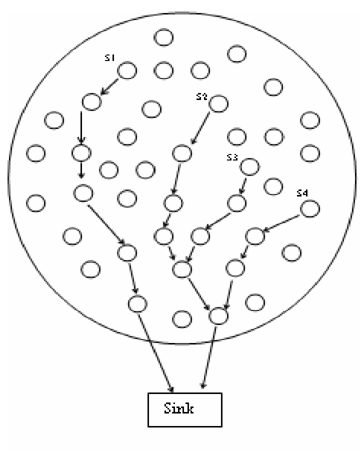

Fig.3 Routing in sensor network with one sink

The issues taken in this paper for routing protocols is the consideration of nodes mobility. Almost all the current protocols assume that the sensor nodes and the sink are stationary. However, there might be situation such as battle environment where the sink and the sensors need to be mobile. In such case, the frequent update of the position of the command node and the sensor nodes and the propagation of that information safely through the wireless network may excessively drain the energy of nodes. New routing algorithms are needed in order to handle the overhead of mobility and dynamic changes of topology in such changing and unsafe environment. We propose a new routing protocol which supports mobility adoption

Another issue of routing protocols includes the integration of sensor networks with wired network (eg) internet. Most of the applications in security and environmental monitoring require the data collected from sensor nodes to be transmitted to a server so that further analysis can be done. On the other hand the request from the user should be made to the sink through internet. Since the routing requirement of each environment is different we have to consider the mobility of node and sink so the location changed and need to interface between wired networks to sensor networks.[11]

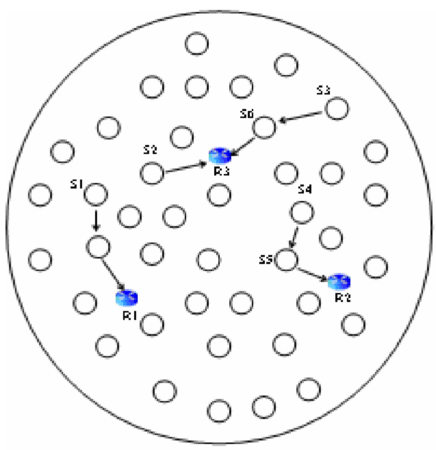

Fig. 4.a Routing in sensor network with multiple gateways.

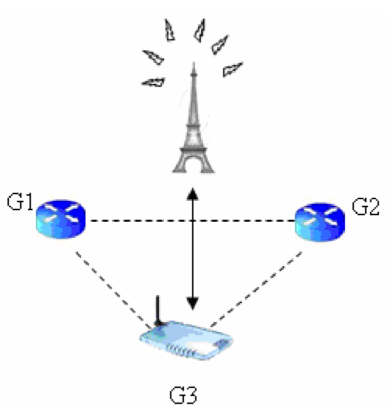

Fig. 4.b. Multiple gateways/Router connected to base station.

Deploying multiple gateways in a sensor network (Fig. 4.a) aims at overcoming this problem, as well as improving network performance and lengthening network lifetime. [10] The multiple routers deployed in different sensor networks automatically interconnect to form a mesh network while are connected with internet through power full base station. (Fig.4.b).

5. MOBILITY ADAPTION

Consider a multi hop wireless sensor network with homogeneous sensor nodes and gateways.

Ni (a) – (i – hop neighbors of a node where i = 1,2,3,….)

PPi (a,b) –> Probability that a € N(b)

The network topology could change due to a) Node join b) Node failures c) Concurrent node join / failure d) Physical mobility of individual nodes e) Physical mobility of gateways/sink. Nodes may fail due to hardware failure or energy drained more than one nodes may concurrently fail or join the network. Such failures are more difficult to handle by the MAC protocol then individual nodes. The physical mobility of sensor nodes and gateways called strong mobility where as the usual change in topology due to node failure by hardware or battery consumption is called weak mobility.

Node join:

a in Ni (b) – In mobility or join transaction where a € Ni (b) after transaction not before.

Node Failure:

a out Ni (b) _ Out mobility or failure transaction where a € Ni (b) before transaction not after.

The factor effecting the probability P. Pi (a,b) when initially a € Ni (b)s node failure and also effects a Out Ni (b) in mobile network model (MNM). Hence the node join can occur if a) new nodes deployed b) nodes wakeup often a long time c) nodes recover from failure also node join can occur for the reason of a in Ni (b) d) nodes physically moves e) gateways physically moves.

Fi –> Complete frame i under consideration
t – frame time.

INi (a) _ Nodes expected to join N2(a) in Fi

Out (a) _ Nodes expected to depart n2(a) in Fi

In MNM(Mobile Network Model), we assume the nodes to be static during Fi. The mobility behavior of N2 (a) in Fi is predicted during Fi-1. If a node b is expected to leave N2(a) during Fi then b € N2(a) from the STAET of Fi. Similarly a node is expected to join N2(a) during Fi then b € N2(a) from START of Fi. In other words (INi (a) Union OUT i (a)) € N2(a) from the start of Fi.

Mobility adoption algorithm uses location information to predict the mobility behavior of sensor nodes. Localization and mobility estimation along with mobility state prediction is a well studied problem [15,16]. We identified the following issues with the adoptive algorithm to support strong mobility:

1. Broadcast of future mobility state information of current sensor node to all other nodes for

a) Fixing the N/W topology at that time

b) Needed to calculate new time frame for collision free access (predefined or random)

2. Need synchronization of nodes due to independent computation of time frame at nodes that may different for each node.

To address these issues we deploy the Mesh Gate Ways in WSN as cluster head and will also aggregate the data and act as a router to send the data to internet via the base station. We model the gateways as G = {(Gi, (Xj, Yi))}: 1<=i<=n, (Xj, Yi) represents any point located in the sensor network}, where n is the number of gateways. In our model sensor node Si (1<=i<m) keep on static or moving while gateway(s) Gj (1<=j<=n) discretely move(s) with in the range of its sensor network. and the number of gate ways selected is 5% which is reasonable number.

We introduce the gateway moves discretely and will be in one location for a fixed time duration called round 'r' and during that time any one gate way acts as aggregate node. The responsibility of aggregate node is scheduled among the gate ways and the selection is based on the LEACH mechanism. This proposed method can lead to node energy consumption balance and extend overall network lifetime without performance degradation. To increase the network life time the proposed algorithm uses a probability function while considering use of node residual energy for selection of gateways to aggregate the data along with cluster head.

$$T(n) = \frac{P_t}{(1-P_t)*(r*\mathrm{mod}(\frac{1}{P_t}))} * \frac{E_{res}}{E_{init}} * L(n), \qquad \text{if } n \in G$$

$$T(n) = 0, \qquad \text{otherwise} \qquad (1)$$

and

$$L(n) = \mathrm{Min}\left(\frac{L(G_j)}{\sum_{j=1}^{n} L(G_j)}\right) \qquad (2)$$

Where 'Pt' is the desired percentage of cluster head and aggregator , 'r' is the current round number, 'G' is the set of gate way that have not been act as aggregator in the last '1/Pt' rounds. Er is the current energy and Em is the initial energy of the gate way. The round 'r' is defined as r = k * t where t= is the frame time and k>1 an integer variable. L(Gj) is the load of current gateway and L(n) is the minimum load percentage of gateways. T(n) is the thresh hold value computed using the equation (1) for the selection of gateway to act as aggregate node and router. Also when the gateway moves to new location, it only notifies its new location to all nodes. This approach reduces the delay and save energy of nodes and when nodes are moved, the nodes will broadcast its location, next mobility state information along with data.

A round consist of three phases: 1) a configuration phase 2) data aggregation phase 3) setup phase. The first stage is for configuring the head and router gateway and the second stage is data transfer along with predicted mobility state information to the gateway and the last stage is computation of residual energy and load of gateways needed for next computation of T(n).

The algorithm work as follows:

1. In configuration phase
   - Each gateway generates a random probability (p) at beginning of a new round and computes threshold value T(n) with the use of equation(1). If r = 1 (The first round), let Emax of all nodes and load be 1.
   - In case of P<Pt the gateway selected act as aggregate node and router.
   - The selected gateway broadcasts an advertised message over neighbor nodes and gateways.
   - The neighbor nodes collect advertised messages during a given time interval and then send a "Join_Req" message to the nearest gateway.
   - The each gateway receives the "Join_Req" messages and builds the group member list and TDMA
   - At the a start of frame Fi every node computes next mobility state information (a, Fi+1) and is send to gateway header.
   - The gateway broadcast the next mobility state information to all its member nodes and save the message for data transfer.

2. In the data aggregation phase
   - Each member node sends data, predicted state information and residual energy to the head by given TDMA schedule.
   - Each gateway sends the current load to the router to compute the load balance.

- Head maintains the residual energy information of member node and router maintains load information of gateways.

3. In setup phase
   - Before last frame of a round completes the head sends router the maximum residual energy value of nodes belongs to its own group.
   - Router collects all maximum residual energy values from heads, finds the maximum residual energy values (Emax) of the network, and sends E max back to group head.
   - The header/ gateway broadcast Emax over group nodes.
   - Each node save the value of Emax for the next computation of T(n) and the gateway save the L(Gi) for the next computation of L(n) in turn calculate T(n).
   - At the end of current round the SYN signal is broadcast to all nodes in the group for synchronization and current round is terminated.

6. ENVIRONMENTAL MONITORING SYSTEM: DWMSN-EMS

The Environment sensing is usually done using a few reading stations spread around cities. The data like temperature, humidity, air pollution, wind speed etc are measured form various locations at reasonable cost and send to concerned office for compilation at fixed time interval. We proposed a new idea that makes the integration of sensor networks, cellular networks and mesh networks enables information exchange across the multiple networks. It can be used along with Software tools that can be developed for users in cellular networking environment to collect the data about the environmental factors [5,12]. Such information are collected from various mobile users from different location and are forward to servers. DWMSN transmit the sensed data in long distance and reliable way to the centralized severs and internet through powerful base stations.

This kind of enormous information collection about the environment is not possible in the traditional way. Also the information are immediately forwarded to centralized server and processed and enhance the decision making based on these data are quick, reliable and dynamic. This application brings tremendous benefits to customer. These kinds of functions cannot be accomplished by any other existing networks. The self forming, self healing and battery operable attributes of DWMSN make it ideal for environmental monitoring applications in a wide range of facilities.

The proposed idea/concept is to study using sensors that sample the air and send data to a person's cell phone via a Bluetooth link and to central server. By using GPS signals, we can have real-time traffic monitoring, pollution monitoring and weather conditions in particular locations. We propose to interface various environment sensors into cell phones. Everyday cell phone users will measure environmental data like temperature, wind speed, humidity, and air pollution levels and transmits them to local servers/gateways. This would give researchers thousands of mobile sensors gathering rich sets of local data at almost no cost. Thus combining GPS with sensed data will be making the people as "Digital object people".

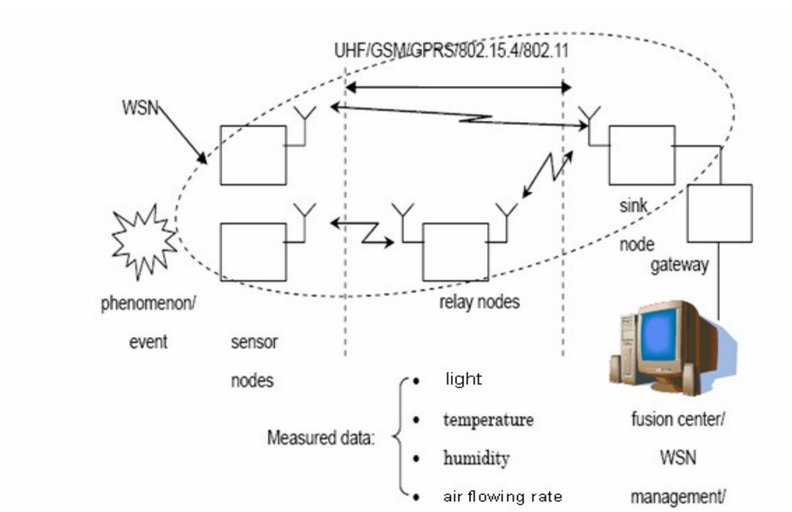

fig.6. EMS Prototype

6.1 DWMSN – EMS Prototype

The processing steps involved in the proposed EMS using DWMSN architecture are given below.

- In first section the input signal is transduced and signal conditioned.
- The acquired samples are preprocessed (ie) averaging the measurements and the results are sent through serial interfaces to the embedded systems that performs the final processing and transmission of data and final storage at local server.
- The required data (ie) Output is published on demand through one or more interface connected to the system.

The benefits of using DWMSN in this type of application include:

1. Easy installation.
2. Scalable and cost-effective.
3. Flexibility.

7. CONCLUSION AND FUTURE ENHANCEMENT:

In future ubiquitous environment the individual tiny wireless sensors may be mobile in nature. We developed an algorithm and it will adopt the mobility of sink and node and will maintain the dynamic change of topology in wireless sensor networks without degrading the performance in terms energy efficient, delay and data transmission. The deployment of mesh gateways in sensor networks makes it possible the integration of multiple heterogeneous networks which enables the information exchange across multiple networks.

We proposed a new idea that makes the integration of sensors with mobile or cell phone and wireless mesh network to collect the environmental data and transmit the data along with location information to the local servers. The DWMSN is an unique application that transmit the sensed data in long distance and reliable way to the centralized severs and internet through powerful base stations. we proposed a design of prototype model for the above application.

Further, we propose the implementation of EMS for distributed measurement system published through Web Service as our next future enhancement. The output of the EMS is available in the Web for the user and then this system offers great possibility in terms of fast and easy access to measured data, of integration of large complex Web Sensor Networks, of realization, of flexible custom applications and of service reusability.

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