GEOGRAPHICAL LOCATION BASED HIERARCHICAL ROUTING STRATEGY FOR WIRELESS SENSOR NETWORKS

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***Abstract*-The overall performance and thus the achievable efficiency of wireless sensor networks (WSNs) rely on the type of protocols deployed to support particular application in hand. In WSN, network's lifetime depends upon the residual energy of individual nodes. In this paper; a brief survey comprises of various reported methodologies that make uses of geographical location attributes for routing in WSN is presented. To assist the routing algorithm on location aspect of the source and destination as well as other intermediate nodes; a location index is formulated based on binary encoded spatial frames. The merit of proposed spatial encoding scheme is its supportiveness on scalability aspects, so it can be easily tailored to accommodate hierarchy based network architectures. Further, the scheme incorporates an effective mechanism to select cluster heads for each cluster in such a way so as to avoid the localization of hot spot effects right from cluster level to network level.**

Key Words: Wireless sensor network, Hot spot effect, Residual Energy, spatial location

I.INTRODUCTION

A Wireless Sensor Network (WSN) contains hundreds or thousands of tiny sensor nodes. Out of these nodes; some of these are named as motes and they have the capability of limited processing in addition to communicate with each other or directly to an external base-station (BS)/sink node. Compared to other conventional networks, relatively higher densities of these sensors nodes facilitate job of sensing over relatively larger geographical regions with good degree of precision and accuracy. Figure 1 shows the sensor node architecture schematic in terms of its principal constituents. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer and position finding system). In this paper, it is assumed that sensor nodes are homogeneous in terms of their processing and communication capabilities, so in context to discussion sensor nodes and motes are used interchangeably. Figure 1 also highlights the communication architecture of a WSN. Usually, the sensors nodes are deployed scatteredly in the given monitoring area. Sensor nodes coordinate among themselves in a cooperative manner to produce high-quality information about the physical environment and/or sensing attributes. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s). A base-station may be stationary or mobile and is capable of connecting the sensor network to outside world using an existing communications infrastructure/Internet where, a user can have access to the reported data [1].

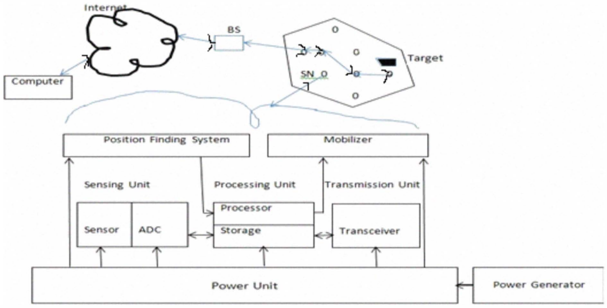

Figure 1: The System architecture of a Sensor Node

The age or lifetime of WSN mainly depends upon the two physical layer parameters: these are the channel state and the residual energy of sensors; however, these two measures are independent in nature. It indicates that life time maximizing protocols should exploit both the channel state information (CSI) and the residual energy information (REI) of individual sensors in a best possible manner. Listed below are important characteristics that affect the network lifetime.

Network Architecture: Network architecture specifies how sensors should report their data to the access points (APs). Based on network topology there are three types of network architecture (a) Flat Ad-hoc, (b) Hierarchical Ad-hoc, and (c) Sensor Network with Mobile Access (SENMA). In the flat ad hoc architecture, usually all sensor nodes are homogeneous and it contains large no of sensor nodes and one or multiple sink node(s) and these sensors relay each other's data via multiple hops to the APs. In hierarchical WSNs, based on sensing related attributes; sensor nodes can be homogeneous/heterogeneous/mixed in nature. Usually, hierarchical topology based network architectures deploy clustering mechanism, and comprises of simple sensor nodes, cluster heads and sink nodes(s) as its functional elements. In both of these architectures the sink node(s) can be stationary or mobile. A typical hierarchical sensor network architecture shown in Figure 2, it consists of a group of clusters (here cluster is smallest region that posses several sensor nodes and each cluster have one node as cluster head- CH) and overall coordinated activities among these CHs are administrated by master cluster head (MCH). The MCH receive instructions (queries) from the sink node and, in return, sends back associated cluster/sensors aggregate measures as response/reply to the sink. The MCH passes the queries received from sink to the affiliated cluster heads (CH). Every CH is responsible for a group of nodes within its cluster. Nodes communicate locally (i.e., within a cluster) with their counterparts. Nodes in a cluster cannot communicate with nodes that positioned in other clusters [2-4].In SENMA; sensors communicate directly with mobile APs that are moving around the sensing field.

Data Collection Initiation: According to the applications, data collections in a WSN can be initiated by the internal clock of sensors, the event of interest, or the demand of the end-user. In clock-driven WSNs, sensors collect and transmit data at predetermined time intervals. In event-driven or demand-driven WSNs, data collections are triggered by an event of interest or in eventuality of getting a request from the APs.

Channel and Energy Consumption Model: The energy consumption models characterize the sources of energy consumption in the network. According to the rate of energy expenditure, energy consumption is classified into two general categories, (i) the continuous energy consumption and (ii) the reporting energy consumption. The continuous energy consumption is the minimum energy needed to sustain the network during its lifetime without indulging in data collection activities. It includes, for example, battery leakage and sensor sleeping energy. The reporting energy consumption is the additional energy consumed in data collections. It depends on the rate of data collection as well as the channel model, the network architecture and type of protocols deployed. It includes the energy consumed in transmission, reception, and possibly channels acquisition [5].

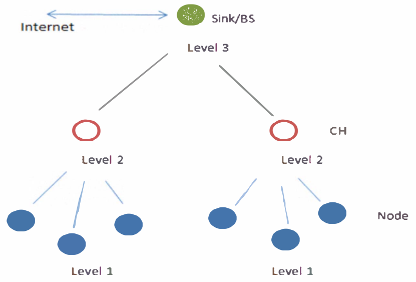

Figure 2. Hierarchical Sensor Network Architecture

In this paper, an attempt is made to consolidate reported works that streamline geographical location attributes for routing in WSN. Usually, the routing schemes are formulated to address specific purposes and depending upon a particular application the elements of WSN, namely MCH, CH and motes may be stationary or mobile. It has been observed that geographical location based localization of nodes are more effective methods as it consumes less energy to convey requisite measures from many sensor nodes to a sink. When it comes to storing the measured or conveyed data; different storage policies are used and reported. In general, these storage policies can be classified into three types: local storage, external, and data centric storage. Considering the dependency of transmission or communication overhead and the associated energy consumption that a node is supposed to handle, it can be concluded that a node with high communication overhead will consume more energy and thus have less energy reserve and vice versa. These specific sensors are and likely to be inactive or will die in near future. So as to avoid this situation for relatively fair coverage, and thereby refraining islanding of some local measures, the issue which is popularly termed as "hot spot" in WSN literature should be properly addressed. In this paper, a scheme is proposed to overcome "hot spot" effect with low overhead. The rest of the paper is organized as follows: Related work based on the geographical location based routing protocols are described in section 2; proposed scheme is described in section 3, while section 4 concludes the paper.

II. RELATED WORK

Gergely V. Zaruba et. al, proposed a new hybrid virtual backbone and geographical location area based ad hoc routing (LABAR) protocol. In LABAR, nodes enabled with global positioning system (GPS) equipment are referred as G-nodes; G-nodes are interconnected into a virtual backbone structure to enable efficient exchange of information for the mapping of IP addresses to locations.

Thus, LABAR is a combination of proactive and reactive protocols, since a virtual backbone structure is used to disseminate and update location information between G nodes (in a proactive manner), while user packets are relayed using directional routing towards the direction zone (or area) of the destination[6].

Zeeshn I-lameed Mir et al, proposed algorithm integrates a Zone based Location Service (ZLS) and restricted directional flooding. The restricted directional flooding is used as the packet forwarding strategy. In order to provide each nodes position to the other network nodes, a distributed location service has to be used in Zone-based Location Service. node's location update zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as the location update zone radius. They assume each node is required to know its own physical location i.e., its precise geographic Coordinates, which may be obtained using the Global Positioning System (GPS) [7].

Huifeng Hou et al, proposed minimum energy consumption (MEC) routing algorithm for WSN, global location based decentralised minimum energy consumption routing (GLB-DMECR). Comparing with other present algorithms, GLB-DMECR has three obvious features: First, GLB-DMECR adopts a novel mechanism to realize MEC routing. GLB-DMECR uses the ideal MEC path to guide a practical routing procedure to minimize the practical E2E energy consumption. Second, GLB-DMECR is a decentralized and localized routing algorithm [8].

Haidong Yuan et al, proposed wireless sensor actor networks (WSAN), sensors acquire information such as temperature, humidity, noise levels and light from the surroundings, while actors take decisions based on the acquirements and performing relevant actions. According to the four steps paradigm of sensing relaying- decision-acting, a novel three-level coordination model for WSANs is proposed. In this model, sensors are stationary and location-aware, whereas actors may change their locations dynamically. They focus on three aspects of coordination model:

Sensor-sensor coordination
Sensor-actor coordination
Actor-actor coordination [9].

Lei Zhang et al proposed a grouping scheme whereby nodes partition themselves into groups such that nodes that fall within a given group are relatively close to one another in terms of geographical information. Our grouping approach differs from the previous solutions by using grouping CHs scheme for cluster-based routing and results in terms of reducing energy consumption, improving scalability, and prolongs the lifetime of WSN [10].

S. Voliotis et al, proposed the life time and throughput of the network, the achieved delay and the security level. they relies on the combination of location based routing protocols, which offer efficient scalability support, with trust information in order to perform trusted path selection. Once the trust value has been quantified (based on one of the numerous trust models), different options regarding the use of the trust information during route selection [11].

QIAN Hong-yan et al proposed a low-energy adaptive clustering hierarchy protocol based on specific location (LEACH-L). LEACH-L is presented to solve the problems of LEACH and similar clustering algorithms. It is based on node's location with following main features:

1) Uniform clustering: The monitor region is divided into dynamic squares with border r. Nodes in same square make up of a cluster. It makes the cluster uniform while the cluster of LEACH is uneven. "Dynamic" means that the centres of each square moves in different rounds.

2) Reasonable cluster-head selecting: It forms cluster before selecting CHs, which is in contrast with LEACH and other clustering algorithms. So CH is chosen near the cluster centre and considering its residual energy instead of randomly distributed.

3) Having relay nodes: CH may transmit data to relay node firstly, then to BS, so the energy needed total is reduced and the lifetime of the network is prolonged. Relay nodes come from the temporary cluster-heads (TCH) not belonging to any cluster [12].

Ying-Hong Wang et al proposed An Efficient Mechanism for Mobile Target Tracking in Grid-based Wireless Sensor Networks" fully utilizes the power of sensor node; through the decisions which sensor node should be wake up to track target. Under the premise of acceptable tracking error, we hope to be able to wake up the sensor node only when it needs to work in WSNs. The focus of this paper is to design a method in tracking target which can be applied in grid-based [13].

Hamdi Idjmayyel et al described Vehicular ad hoc networks (VANETs);which are known to have no fixed infrastructure; however they rely on the mobile nodes to disseminate the information throughout the network. In this these two parameters are important:

1) High mobility of nodes which leads to frequent network partitioning

2) Rapid change in link topology due to the fast movement of vehicles and

3) Variable network reliability as the network may fail in unpredictable ways [14].

III.PROPOSED METHOD

In this approach; entire service is divided into four zones and indexed as (I, II, III & IV), further these zones are subdivided into subzones, subzones are subdivided into regions, regions are subdivided into sub-regions, sub-regions are subdivided into grids and are shown in Figure 3-5.for initial simulation study, the sink is assumed stationary. In a hierarchical manner, these grids are further decomposed into smallest size of infinitesimal area and are known as cells shown in figure 6. Proposed methodology adopted includes formation of binary coded frame for location identification based on indexing. In query based protocol every query is passes through the initially selected local aggregators (LAs), As time passes; consistent uses pattern of these LAs and simple nodes might leads to a situation, where these LAs as well as the sensor nodes attains pre specified lowest possible energy level (threshold) and it leads to a phenomenon "HOT SPOT". For life time maximization of entire network selection of LAs (from the set of nodes) should be done in such a way that likelihood of the HOT SPOT effect can be prolonged till the occurrence of horizon time (maximum expected life time)

For example, at some intermediate time if each grid consists of m nodes; out which k nodes have already attains threshold limit one out of (m-k) nodes can be deputed as LA in a particular grid at future times. In figure 3; sub-region of service is chosen which have proximity with sink node, in depicted area of figure 4, let initially cell indexed as 10 arbitrary chosen as LA.also let this cell (i^{th}=10) x and y coordinates are represented by x_i & y_i respectively. Then in immediate future time to estimate the centroid of highest energy from the set i=1, 2….16; cell 10^{th} is exempted.so

$$(x_i, y_i)\ \forall i, \text{except } i = 10$$

After serving as LA for some time; an inevitable energy norms is

Residual Energy $(RE)_{10} \ll RE\,i$,i=1-16 except i=10

After some stipulated time; mapping is done from the set of 15 remaining cells so as to verify following inequality relation.

$$(RE)_{III} > (RE)_{II} > (RE)_{I}$$

Assume that initially cell no. 10^{th} is communicating to the sink; so set of LA (6, 7, 10, and 11) in that 10th will be first out element. Let us assume x and y represents the coordinate of i^{th} LA.

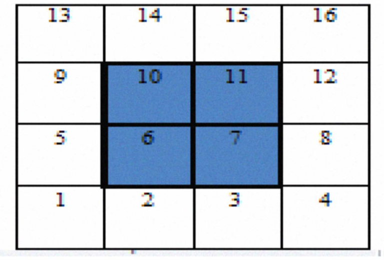

Figure: 3

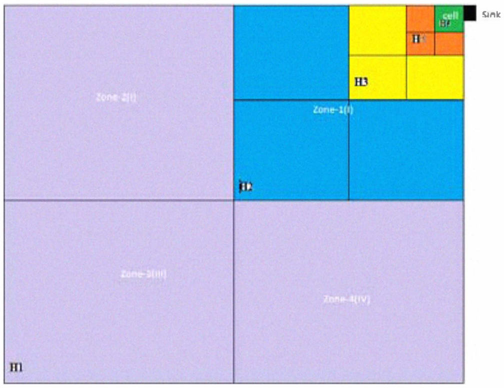

Figure 4: Coordinate Scheme of area

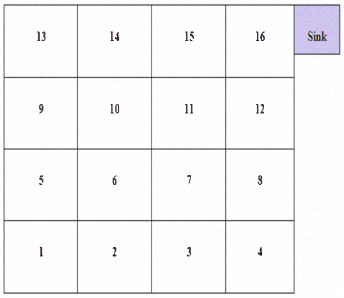

Figure 5: Coordinate Scheme of Grid

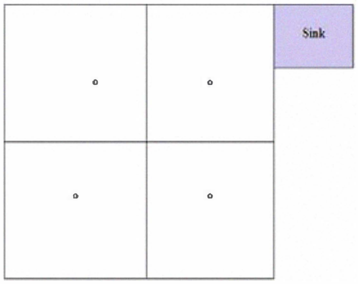

Figure 6: Coordinate Scheme of Cell.

Heuristic mechanism for setting threshold levels and weight factors to Sensor Nodes (SN's): As time passes, to get a reasonably good approximation of HOT SPOT the clarification of weight elements is further increased to five different classes from initially chosen three class. If measurement or estimate on residual energy (RE) is defined on min-max interval $[0.4\text{-}0.65]_{RE.}$ Mapping from actual residual energy (ARE) status to weight factors on total N no. of SN's and estimation leads to following threshold settings:

(a) Prime set $(RE)_P \geq 0.90$
(b) Secondary set $0.8 \leq (RE)_S < 0.9$ and so on.
To assign the weight factors to remaining participating 15 nodes (M=15) we proposed, following expression to estimate (map) weight factors of kth on per unit basis as

$$<RE>_K = \frac{1}{M}\sum_{i=1}^{M} RE_i$$

Other strategy may deploy normalization of individual weights by maximal of participating node set. In a random simulation run, assign weights are as below

$$\omega_{III} = 0.95 \text{ for } (11,12,15,16)$$
$$\omega_{II} = 0.9 \text{ for } (3,4,7,8,9,13,14)$$
$$\omega_{I} = 0.8 \text{ for } (1,2,5,6)$$

So obtained weight factors participates in the probable location of centroid for grid under considerations; the x, y coordinates for centroid are estimated using following expression

$$C_k(x,y) = \frac{1}{15}\sum_{\substack{i=1\\ i\neq 10\\ j=I}}^{16,III} \omega_j (x_i, y_i) \tag{1}$$

k is the iteration count after deputing one node randomly as grid head.
Equation (1) can be re-written for the individual x & y components as below

$$x_{C_K} = \frac{1}{15}\left\{\begin{bmatrix} 0.8x_1 + 0.8x_2 + 0.8x_5 + 0.8x_6 + 0.9x_3 + \\ 0.9x_4 + 0.9x_7 + 0.9x_8 + 0.9x_9 + 0.9x_{13} + \\ 0.9x_{14} + 0.95x_{11} + \\ 0.95x_{12} + 0.95x_{15} + 0.95x_{16} \end{bmatrix}\right\}$$

$$y_{C_K} = \frac{1}{15}\left\{\begin{bmatrix} 0.8y_1 + 0.8y_2 + 0.8y_5 + 0.8y_6 + 0.9y_3 + \ldots\ldots \\ +0.9y_{14} + 0.95y_{11} + \ldots\ldots + 0.95y_{16} \end{bmatrix}\right\} \tag{2}$$

Further, on estimating the centroid's coordinates; it is used to estimate the relative distance of all prosperous coordinates (except node no. 10) that can be assigned the responsibility of grid head. Then on using following expression; the distance of all participating 15 nodes are estimated with reference to previously estimated centroid as:

$$d_{iC_K} = \sqrt{(x_C - x_i)^2 + (y_C - y_i)^2} \tag{3}$$

$$(x_i, y_i)\ \forall\, \text{i} = 1\text{-}16, \text{i} \neq 10$$

Where x_i, y_i are x and y coordinates of nodes(i=1,2….16,i≠10) and k is the update (iteration) count for some finite time interval;In every successive time slots (iteration index) depending upon the participating nodes,M,using equation(1-2) relative distance of recent centroid is estimated and arrange this distance profile is a set and pick the smallest distance (closest node to centroid) as possible grid head.
Thus, following set theory notation results in furnishing information about the shortest path

$$\bigcup_{\substack{i=1\\ i\neq 10}}^{16} d_{i_{c_k}}$$

Location indexing of grids using binary coded: Based on geographical area (GA) to be served, its dimensions along x and y axes is resolved into smaller units (grids) of suitable and sizable dimension using n_x and n_y bits for x and y segment of GA respectively. GA geometry may be of square/rectangular shape. For the present case study square shape GA is considered.

Frame structure for Square Shape GA: For this geometrical aspect, uniform resolution along x and y axes results in $\text{n}_\text{X} = \text{n}_\text{Y}$, i.e., the same number of bits are required to transform the x and y distance measures into binary encoded frame, and in reported work, here after is referred as Binary Location Index (BLI). In BLI with uniform resolution either n_x or n_y can be treated as Most Significant Bits Segment (MSBS) or Least Significant Bits Segment (LSBS) and vice-versa. Thus, let us select n_x as LSBS then corresponding BLI is presented in Fig. 7.

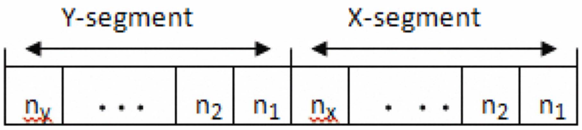

Figure 7. BLI for square

The exact location, EL, in terms of mapped x and y coordinates a cell can be decoded from the BLI as:

$$EL= (BL)_x+ (BL)_y \tag{4}$$

Where, $(BL)_x=n_x 2^{n_x-1}+\ldots\ldots\ldots+n_2 2^1+n_1 2^0$ (5)

$$(BL)_y=n_y 2^{n_y-1}+\ldots\ldots\ldots+n_2 2^1+n_1 2^0 \tag{6}$$

IV. CONCLUSIONS

In this work, an attempt has been made to analyze geographical location based hierarchical routing algorithms. As the network life time depends upon the energy of individual nodes; to utilize this scare resource more proficiently, the routing algorithm is amended in such a way that it highly depends upon locational information. Further, to impart locational aspects in an algorithm in much simpler way, a Binary Location Index (BLI) is formulated based on binary encoded spatial frames for all the participating network nodes. It is concluded that properly framed heuristics which utilizes residual energy level of sensor nodes and binary location index may infer avoidance of the hot spot effect till network attains its set/targeted span of lifetime.

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