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An Efficient Cluster head Selection Strategy for Multicasting and Geocasting

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Abstract: The wireless sensor network wsn consist of a group of sensor nodes. These sensor nodes must send the sensing data to the sink node and the frequency at which these messages are send is known as the reporting frequency. Multicasting and geocasting are two communication types in wsn. Muticasting involves the sending of a message from node to multiple nodes in one single transmission. Theese nodes will be identified by the multicast group address. Geocasting is a type of multicasting in which message are transmitted to the nodes located in a particular geographical region by a single node located in any other geographical location. Multicasting has many commerce applications and geocasting is very important in the case of an environmental calamities. So it's highly essential that a strong communication mechanism exists in these fields. A link aware clustering mechanism LCM efficiently chooses the cluster head and thus provides a secure and uninterruptable communication.LCM considers both the link condition and node status and uses predicted transmission count PTX and expected transmission count ETX to acess the cluster head. This paper proposes the use of LCM in muticasting and geocasting environments.

Key Words: Clustering, link aware, routing, node status, wireless sensor network, PTX, ETX

I. INTRODUCTION

A WSN consists of a group of spatially distributed sensor nodes which are interconnected without wires. Each of the distributed sensor nodes typically consist of one or more sensing elements, a data processing unit, communication components and a power source which is usually a battery. The sensed data is collected, processed and then routed to the desired end user through a designated sink point, referred as base station. WSNs are originally motivated for the use in military applications, such as border monitoring. The wireless sensor network (WSN) has recently become a promising network architecture and is widely used in many applications, including environmental monitoring, object detection, event tracking, and security surveillance In general, WSNs consist of large numbers of tiny autonomous wireless devices, called sensor nodes, which perform multiple functions such as sensing, computing, and communication.

Multicasting is an efficient method of supporting group communication. It allows transmission and routing of packets to multiple destinations using fewer network resources. Wide spread and the devolvement of wsn had made that the multiple data transmission procedure to gain more important in this field. Applications of wireless multicast support group-oriented mobile commerce, military command and control, distance education, and intelligent transportation systems.

Many new m-commerce applications, including mobile auctions, will also gain significant benefit if group communication among mobile users is supported by wireless networks. Such applications require continued connectivity, and reliable wireless multicast.

Geocast allows a node to send messages to all nodes within a given geographic region without the sender node having any knowledge about which nodes are present in that region. The destination nodes may be located outside the radio transmission range of the source node. Thus the geocast message may need to be forwarded by intermediate nodes to the destination region. Using geocast, a user can instruct all nodes in an region where fire is spreading to report temperature readings at a faster rate.

Energy usage is an important issue in the design of WSNs which typically depends on portable energy sources like batteries for power .WSNs is large scale networks of small embedded devices, each with sensing, computation and communication capabilities. They have been widely discussed in recent years. These sensors nodes are small devices with limited power, processing and computation resources. Smart sensors are power constrained devices that have one or more sensors, memory unit, processor, power supply and actuator. In WSNs, sensor nodes have constrained in term of processing power, communication bandwidth, and storage space which required very efficient resource utilization [17]. In WSNs the sensor nodes are often grouped into individual disjoint sets called a cluster, clustering is used in WSNs, as it provides network scalability, resource sharing and efficient use of constrained resources that gives network topology stability and energy saving attributes. Clustering schemes offer reduced communication overheads, and efficient resource allocations thus decreasing the overall energy consumption and reducing the interferences among sensor nodes.

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In a cluster, one node is elected as the cluster head, which controls and manages the cluster. Multiple clusters can be connected via gateways. Because clustering is effective in one-to-many, many-to-one, one-to-any, or one-to-all communications, it can assist in delivering packets and improving the routing performance. The main challenge of clustering is to select proper nodes to act as cluster heads and gateways. Researchers have proposed many cluster head election approaches for constructing clusters [3], [8], [10], [11]. Each node in these approaches locally exchanges messages with the nodes in its communication range to determine whether it should become a cluster head. This concept of these approaches is known as active clustering. In addition to active approaches, Kwon and Gerla [12] have proposed a clustering technique, called passive clustering, to construct clusters in a passive manner. In the passive clustering technique, each node in a cluster has an external cluster state, and the cluster head and gateway nodes are major participants in packet delivery. When a node receives a data packet, it depends on its current state and the state of the sender of the packet to determine whether it must change its current state. Each node piggybacks its state onto the transmitted packet, and thus a node can realize the cluster states of all its neighbors. The passive clustering technique can effectively decrease the number of explicit control packets to constantly maintain cluster information, and thereby reduce communication overhead. If there are many cluster head candidates, most of the existing clustering approaches use a random strategy to determine cluster heads. However, this strategy is likely to determine improper cluster heads. Note that cluster heads generally consume more battery power than other nodes in cluster-based routing protocols. If the cluster head exhausts its battery power, the routing path may be destroyed. This threatens persistent transmission, thereby reducing the packet delivery ratio. However, if the cluster head is associated with a poor quality link, it generates additional retransmissions, which leads to unnecessary energy consumption.

By using the idea of the passive clustering technique a link aware clustering mechanism was devolved in which the cluster head is elected by considering both the node status and the link condition. This technique defiantly overcomes the random strategy of the cluster head election. They use two metrics called predicted transmission count and the expected transmission count to acess the Cluster head.PTX is the no of transmissions that the cluster head or the gateway candidates conduct and the cluster head is elected by the priority based PTX evaluation. The candidate having the greatest priority is elected as the cluster head.ETX is defined as the inverse of the product of the forward and the reverse delivery ratios. Simulation results of LCM have proven that it outperforms any other passive clustering mechanism.

This paper proposes the use of LCM in multicasting and geocasting environments. Multicasting is a more efficient method of supporting group communication than unicasting or broadcasting, as it allows transmission and routing of packets to multiple destinations using fewer network resources. Geocasting allows a sensor node to send messages to all nodes in a given geographical region without the sender node having any knowledge about which nodes are present in that region.

II. PROPOSED ALGORITHM

This section describes the concept of clustering metrics and presents the original passive clustering technique and LCM in multicasting and geocasting

A. Passive Clustering (PC) Technique

A majority of previous work has focused on active clustering techniques, but now a technique called passive clustering (PC) technique for construction of a cluster structure has been devoloped. By using on-going data packets instead of extra explicit control packets, the PC can reduce the control overhead during constructing and maintaining clusters. The PC technique uses five external states to represent a node's role in a cluster, and each node possesses an external state. The external states include initial (IN), ordinary (OD), cluster head (CH), gateway (GW), and distributed gateway (D_GW). The PC technique also introduces two internal states, cluster head ready (CH_R) and gateway ready (GW_R), to represent the tentative role of a node. When a node in the external state receives data packets, it may change its current state. A node in the internal state must enter the external state when it sends out a data packet. For the lack of space, the rules of state transition in the PC technique can be obtained in [12].

The candidates are elected by two mechanisms in PC technique. They are First declaration wins mechanism and the gateway selection heuristic mechanism. In the former the candidate which is first claiming will become the CH node. The latter use the concept that there should be a minimal number of GW nodes for the proper working of the cluster.

B. Some Assumptions Made For The Paper

To implement LCM in multicasting and geocasting communication types we are creating a random sensor network. Then we are dividing the network into four regions to implement the four geographical locations. The nodes in each location is then identified. Let V is the set of nodes and $E \subseteq V \times V$ is the set of links between two neighbouring nodes.

Let $eij \in E$ denote the link between two nodes, si and sj.Let Si_{nbr} the set of si's neighbouring node The cluster identifier of node si is $ID(i)$.The reporting frequency is indicated by N_{req} Let qij and ρi denote the predicted transmission count of eij and the priority of candidate si, respectively.[1]

C. Link-Aware Clustering Mechanism

This section first presents the predicted transmission count and the procedure of priority calculation in the proposed LCM, followed by an example of LCM operation.

Predicted Transmission Count

Although random selection is an effortless strategy to determine CH and GW nodes, it is not an efficient

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approach because of its disregard of node status and link condition. Moreover, using only a single factor cannot expose the influence of other factors on routing performance. The LCM considers node status and link condition, and proposes a novel metric, called the predicted transmission count (PTX), to acess the suitability of CH or GW candidates. The PTX represents the capability of a candidate for persistent transmission to a specific neighbouring node. This study considers the transmit power, residual energy, and link quality to derive the PTX of CH or GW candidate. A large PTX value indicates a high likelihood of becoming a CH or GW node. Because the channel condition of wireless links varies with time, the link reliability often depends on the channel condition. If a node is associated with an unreliable link, data delivery is likely to fail, thereby leading to packet retransmissions.. Previous research usually uses the expected transmission count, called ETX, to acess the level of link quality [15], [16]. The LCM also uses the ETX to measure the expected bi-directional transmission count of a link. Let *ETXij* be the ETX of link *eij*, and therefore *ET Xij* can be defined as

$$ETXij = 1/p^{f}_{ij}.p^{r}_{ij} \quad (2)$$

Wherep^{f}_{ij} and p^{r}_{ij}denote the forward and reverse delivery ratios from node *si* to node *sj*, respectively. The forward delivery ratio is the measured probability that indicates that a data packet successfully arrives at the recipient. The reverse delivery ratio is the probability that indicates that the acknowledgment (ACK) packet is successfully received. Each node in the LCM periodically broadcasts a message to obtain the distance, forward delivery ratio, and reverse delivery ratio of its neighbors, thereby making it possible to determine the ETX. When node *si*, receives report messages form *sj*, it can use Eq. (3) to derive the PTX, *qij* [1]

$$qij = \frac{E_{i}^{res}}{ET Xij \cdot E^{tx}(k, dij)} \quad (3)$$

where E_{i}^{res} is the residual energy of *si*, *dij* is the distance between *si* and *sj*,and $E^{tx}(k, dij)$ is the energy consumption for *si* to transmit a *k*-bit message over a distance *dij*. Without the loss of generality, this study considers the first order model for the radio hardware energy dissipation [17]. In this model, transmitters dissipate energy to run the radio electronics and the power amplifier. Let $E^{tx}_{elec}(k)$ and$E^{tx}_{amp}(k,d_{ij}^{n})$ denote the energy consumption of the radio electronics and the power amplifier, respectively, to transmit a *k*-bit message over a distance *dij*. $E^{tx}(k, dij)$ can be derived from[1]

$$E^{tx}(k,dij)=E^{tx}_{elec}(k)+E^{tx}_{amp}(k,^{n}) \quad (4)$$

The first order model uses both the free space and multipath fading channel models [18]. If the distance between the transmitter and the receiver is less than a pre-defined threshold, denoted as *d*0, the free space model is adopted; otherwise, the multipath model is adopted. Let *E*elec indicate the electronics energy , which is related to the digital coding, modulation, and filtering techniques. $E^{tx}(k, dij)$ in Eq. (4) can be written as

$$E^{tx}(k, dij) = \begin{cases} k \cdot E\text{elec} + k \cdot \varepsilon\text{fs} \cdot d^{2}_{ij}\, dij < d0 \\ k\, E\text{elec} + k\, \varepsilon\text{mp}\, d^{4}_{ij},\ d_{ij} \geq d0 \end{cases} \quad (5)$$

where $\varepsilon\text{fs}\cdot d_{ij}^{2}$ or $\varepsilon\text{mp}\cdot d_{ij}^{4}$ is the amplifier energy, which is related to the distance between the transmitter and the receiver and the acceptable bit error rate.[1]

Priority Calculation

The LCM acesss the suitability of CH or GW candidates to determine proper participants to forward data packets. A CH candidate (CH_R node) or a GW candidate (GW_R node), *si* , performs the following steps to determine its priority.

Step 1: Calculate the PTX of each neighbouring.

Step 2: Divide $\mathbf{S}_{i}^{nbr}$ into two subsets, **S***sat*(*i*) and **S'***sat*(*i*),where the PTXs of all elements in **S***sat*(*i*) are greater than or equal to *Nreq* , and the PTXs of all elements in **S'***sat*(*i*) are smaller than *Nreq* .

Step 3: If **S***sat*(*i*) =∅,set ρ*i* as the PTX of the node, which has the minimum PTX in **S***sat*(*i*); otherwise, set ρ*i* as the PTX of the node, which has the maximum PTX in **S'***sat*(*i*). According to the definition of the PTX, a candidate derives a large PTX value if it connects to nodes with a higher quality or supports more transmission counts. The proposed LCM determines the candidates satisfying the report quality by putting them into **S***sat*(*i*).If **S***sat*(*i*) =∅, the LCM considers the minimum PTX of all PTXs as the priority of *si* .This is because the link corresponding to the minimum PTX can adequately support the report quality. If none of the links are able to satisfy the report quality (i.e., **S***sat*(*i*) =∅), this study selects the link that can support as many message reports as possible. Thus, the LCM considers the maximum PTX of all PTXs in **S***sat*(*i*) as the priority of *si* . To ensure that the high priority node becomes the CH or GW node, the LCM uses a random backoff approach to defer the transmission of data packets. Let T_{i}^{w} be the waiting period of candidate node *si* . Then, T_{i}^{w} can be obtained as

$$T_{i}^{w} = t_{slot}\Theta \cdot (1/\rho i) \quad (6)$$

where t_{slot} is the time slot unit, and Θ(*x*) rounds the value of *x* to the nearest integer less than or equal to *x*.[1]

Cluster State Transition

Fig. 1 shows the cluster state transition diagram. When an IN node receives messages from either a CH node or a GW node, it changes its cluster identifier as that of the sender, because this IN node and the sender belong to the same cluster. If the sender is a CH node, the IN node then transits its state to GW_R. Otherwise, the IN node then transits its state to CH_R if the sender is a GW node. Meanwhile, the IN node calculate its priority and determine its ultimate state. If the node becomes a CH or GW node, it then forwards the received message.[1]

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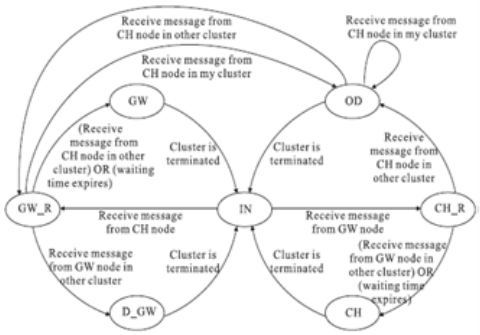

Fig 1 Cluster State Transition Daigram

Working of LCM

To explain the LCM operation we are considering that at first all the nodes are in the initial condition. Then we select a particular node and will find out its neighbouring nodes. Thus they form a cluster .when the source sends out the message; the nodes receiving these messages will now calculate their PTX values and will undergo those priority calculation steps. the having the greatest priority will now become the cluster head. Once the cluster head has been found out the messages will be transmitted to its neighbouring nodes by the CH. Now the nodes receiving messages from the cluster head will become the GW_R candidate and will undergo the same priority calculation to find out the GW node.

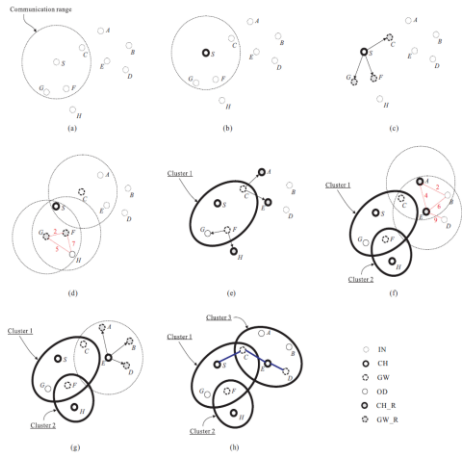

Fig 2 LCM Operation

Fig. 2. Example of the cluster construction of the proposed LCM. Suppose that *Nreq* = 5. Nodes *S* and *D* indicate the source node and the sink, respectively.The red line indicates the link between two nodes, and the red number indicates the PTX of the nearby red link. (a) All nodes are in the IN state. (b) Node*S* becomes a CH node because it has no CH neighbor. (c) When receiving packets from node *S*, nodes *C*, *F*, and *G* become GW_R nodes and contend for becoming a GW node. (d) Nodes *C* and *F* become GW nodes. (e) Nodes *A* and *E* become CH_R nodes because receiving message form node *C* (GWnode). When receiving message from node *F*, node *H* become a CH_R node and node *G* becomes an OD node. (f) Node *H* becomes a CH node. (g) Node*E* becomes a CH node because its priority is higher than node *A*'s priority. (h) Nodes *A* and *B* become OD nodes, and node *D* becomes a GW node[1].

D. LCM in Multicasting and Geocasting feilds

Previous studies shows that LCM provides an reliable and energy efficient routing path to wsns. Multicasting and Geocasting are two types of communication used in wireless field. Applications of wireless multicast support group oriented mobile commerce military command and control distance education, and intelligent transportation systems .Many new m-commerce application including mobile auctions will also gain significant benefit if group communication among mobile users is supported by wireless networks. Such application requires continued connectivity. Secure and reliable wireless multicast. Multicast communications has been supported for at least the past years in the Internet environment for fixed users using wired links. In such environments, a host joins a multicast group by informing a local multicast router that in turn contacts other multicast routers; a multicast tree is thus created through a multicast routing protocol. The multicast router periodically sends queries to determine whether any of the hosts in its coverage is still a member of the multicast group[4]

Geocast messages should be reliably delivered to the destination region in the presence of unreliable wireless links, a typical characteristic of practical sensor network deployments. The protocol should minimize the number of radio transmissions and avoid control traffic to save energy, which is a scarce resource in sensor networks. The protocol should be robust against a wide range of network densities. Geocast allows a node to send messages to all nodes within a given geographic region without the sender node having any knowledge about which nodes are present in that region. The destination nodes may be located outside the radio transmission range of the source node. Thus the geocast message may need to be forwarded by intermediate nodes to the destination region.[16]

Thus it reqires that an energy efficient and reliable routing path is highly required for these two communication types. Implementing LCM to find out the cluster head and thereby providing a reliable routing path will save the energy required for the data transmissions.LCM use predicted transmission count PTX and expected transmission count ETX to find out the node energy and link quality respectively. The node with highest PTX will be selected as the cluster head and gateway respectively.

III. RESULTS AND DISCUSSIONS

At first a random sensor network is created. Then the network is divided into four regions to implement four geographical locations. The nodes in each region is identified. Later first quadrant is considered and a node is selected.

Clustering is done on the basis of this node. Now when a source node communicates with this cluster the nodes which receives the message will undergo the LCM steps and will calculate the efficient node as the CH. Communication within the quadrant represent the multicasting and from one quadrant to another represent the geocasting.

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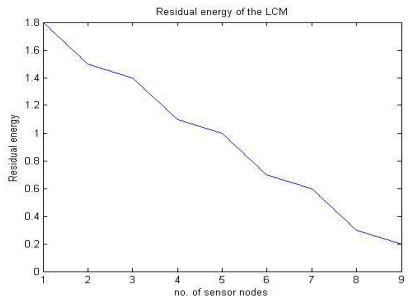

Fig 7 Residual Energy

Also residual energy and the message delivery ratios of the nodes are plotted and we can find that the node elected by the LCM as CH is having the highest message delivery ratio and residual energy.The below two Figs shows the Residual energy and Message delivery characteristics for a group of nine nodes in which a cluster if five node is formed. The first node is the cluster head and we can see its having the highest values

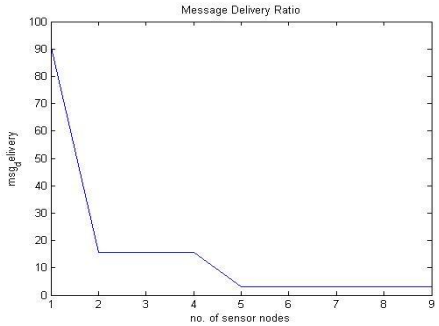

Fig 8 Message Delivery Ratio

IV. CONCLUSION

Thus in this paper we have implemented a multicast and geocast sensor network with an efficient cluster head selection strategy. Multicast and the geocast are the fields where we require a strong and secure communication. Any defect in the communication path can seriously affect the system. LCM considers both the node status and the link condition and uses PTX and ETX to acess the CH.The elected CH will be having high energy and will be able to control the message transmissions in the Cluster effectively. Also the applications of the multicast and the geocast network can be boosted by the usage of LCM CH election method.

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