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Optimization of Clusterheads and Gateways for Energy Efficient Routing in WSNs

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Abstract-In wireless sensor networks, sensor nodes must report the sensing data to a central node, called the sink and this report always satisfies the report frequency required by the sink. This paper proposes a modified link aware clustering mechanism (MLCM) to support an energy efficient routing in WSNs. The main goal of the modified link aware clustering mechanism (MLCM) is to establish a persistent and reliable routing path by determining proper nodes to become clusterheads and gateways. In the MLCM, clusterhead and gateway candidates use the node status (e.g., residual energy), link condition (e.g., quality) and bandwidth (e.g., data rate) to determine a novel clustering metric, called the capable transmission count (CTX). It is defined as the number of transmissions that clusterhead and gateway candidates conduct. This metric can be determined by measuring the transmit power consumption, residual energy, link quality and bandwidth. The clusterhead or gateway candidate depends on a priority, derived from its capable transmission count (CTX) and to evaluate its qualification for clusterheads and gateways to construct clusters. The clusterhead or gateway candidate having the highest priority is elected as a clusterhead or a gateway, respectively. Simulation results confirm that the MLCM can achieve a high packet delivery ratio, extend the network lifetime, and reduce transmission latency.

Keywords- Capable transmission count, Energy efficient routing, Modified link aware clustering mechanism, Wireless sensor networks.

1 INTRODUCTION

A Wireless sensor networks (WSNs) is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or very close to it. The unique feature of sensor networks is the cooperative effort of sensor nodes. It is widely used in large number of applications including industrial sensing and diagnostics, infrastructure protection, battlefield awareness and context-aware computing. In WSNs, source nodes should transmit the sensing data to a central node, called the sink. One of the key challenges of WSNs is the efficient use of limited energy resources in battery operated sensor nodes. It's designed to perform a set of high level information processing tasks such as detection, tracking, communication and computation. Transmission of data takes more energy consumption in WSNs. Thus, it's a serious challenge to design an energy efficient routing scheme for reporting sensory data to achieve a high packet delivery ratio and extend the network life time.

1.1 CLUSTERING

Clustering is grouping of sensor nodes that are similar to one another within the same cluster and dissimilar to the nodes in other clusters. It supports route determination in WSNs. This approach groups all sensor nodes into multiple clusters.

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In a cluster, one node is elected as the clusterhead, which controls and manages the cluster. Multiple clusters can be connected via gateways. Clustering is effective in one-to-many, many-to-one, one-to-any and 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 clusterheads (CHs) and gateways (GWs).

A good clustering method will produce high quality clusters with high intra-class similarity and low inter-class similarity. The quality of a clustering result depends on both the similarity measure used by the method and its implementation. The quality of a clustering method is also measured by its ability to discover some or all of the hidden patterns.

1.2 ROUTING

Since a distributed network has multiple nodes and services many messages, and each node is a shared resource, many decisions must be made. There may be multiple paths from the source to the destination. Therefore, message routing is an important one. The main performance measures affected by the routing scheme are throughput (quantity of service) and average packet delay (quality of service). Routing schemes should also avoid both deadlock and livelock. Routing methods can be fixed (i.e. pre-planned), adaptive, centralized, distributed, broadcast, etc. Perhaps the simplest routing scheme is the token ring. Here, a simple topology and a straightforward fixed protocol result in very good reliability and precomputable QoS. A token passes continuously around a ring topology. When a node desires to transmit, it captures the token and attaches the message. As the token passes, the destination reads the header, and captures the message. In some schemes, it attaches a 'message received' signal to the token, which is then received by the original source node. Then, the token is released and can accept further messages. The token ring is a completely decentralized scheme that effectively uses Time division multiple access (TDMA). Though this scheme is very reliable, one can see that it results in a waste of network capacity. The token must pass once around the ring for each message. Therefore, there are various modifications of this scheme, including using several tokens, etc.

Energy Efficient Routing

It considers a network of static (e.g. immobile) energy constrained sensors that are deployed over a flat region with each node knowing its own location. Assume that all nodes in the network are assigned with a unique ID and all nodes are participating in the network and forward the given data. Additionally, these sensor nodes have limited processing power, storage and energy, while the sink nodes have powerful resources to perform any tasks or communicate with the sensor nodes. To allow an increase in the network lifetime additional mechanisms are done in routing protocols to verify other parameters beyond the hop count that accept a more intelligent route establishment. The energy efficient routing algorithm is used for making a decision on which neighbor a sensor node should forward the data message to. A node is selected to forward the data based on its residual energy level, signal strength and bandwidth. Ideally, the greater the energy in the node and farther the node from the previous one, is the more likely to be selected as the next hop. The nodes which are not selected in this process will move to the sleep state in order to conserve power. The communication is assumed to be bidirectional and symmetric. The protocol replies with a complete route from the source node to the sink quickly, and prepares many route paths to balance the energy of each node. It also enables intermediate nodes to aggregate all the received packets during a short period time and transmit only one aggregated packet to the following node.

Cluster Based Routing Schemes

The lifetime of a sensor network can be defined as the duration from the deployment of the network to the time when the first or the last sensor runs out of energy. This cluster based routing scheme lets sensors vote for their neighbors to elect suitable clusterheads. It utilizes hybrid protocol that combines the cluster architecture with multi-hop routing for the reduction of the transmission energy.

This scheme lets a node wanting to transmit the data to a destination find one or multiple intermediate nodes. Assume that all nodes in the network are assigned with a unique ID and all nodes are participating in the network and forward the given data. The data packets from the source node are processes among the intermediate nodes until it reaches the destination. In this method, after clusters have been organized, the clusterheads can form a multi-hop routing backbone. For the communication within a cluster, every member node forwards the data to the clusterhead directly. The clusterhead forwards the aggregated data to another clusterhead via gateway.

2 RELATED WORK

In this section we discuss about some existing works related to this clustering based energy efficient routing scheme in WSNs.

In [1] Sheng-Shih wang and Ze-Ping Chen proposed a link aware clustering mechanism to determine an efficient routing path. It uses a method named as predicted transmission count to calculate the highest priority for clusterheads and gateways. It achieves good message delivery rate. Even though it's an effortless method because it does not take bandwidth parameter in clustering and it results in bad routing performance.

In [2] Sang H. Kang and Thin Nguyen proposed the distributed low energy adaptive clustering hierarchy(LEACH) - based clusterhead selection algorithm in which nodes are self-selected to become clusterheads with different probabilities depending on their distances to the base station. The circular-cluster assumption might not be sufficiently accurate to model many real-world scenarios. A single-hop sensor network is not appropriate due to the limited power of a sensor to transmit signals over a long distance.

In [3] Dali Wei, Yichao Jin, Serdar Vural, Klaus Moessner and Rahim Tafazolli proposed a distributed clustering algorithm, energy-efficient clustering (EC), that determines suitable cluster size based on hop distance to the sink. EC is suitable for any data collection protocol that focuses on energy conservation. EC effectively controls cluster sizes, which allows an approximately uniform use of the overall energy resources of a WSN. It is still based on single-hop transmissions to the sink from the clusterheads and is not scalable to large-scale networks. The analysis of energy

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consumption in control overhead caused by route discovery and cluster formation is not fully covered.

In [4] Kyounghwa Lee, Joohyun Lee, Hyeopgeon Lee and Yongtae Shin proposed the density and distance based cluster head selection (DDCHS) algorithm. This algorithm divides cluster area into several perpendicular diameters. It selects clusterheads based on their number of neighbors and distance based. DDCHS algorithm improves the performance of clustering. Sensor networks consist of large number of small, relatively inexpensive and low-power sensors that are connected to the wireless network.

In [5] Eric Rozner, Jayesh Seshadri, Yogita Ashok Mehta and Lili Qui proposed a simple opportunistic adaptive routing protocol (SOAR) to support multiple simultaneous flows in wireless mesh networks. Opportunistic routing can effectively combine multiple weak links into a strong link. The SOAR can significantly outperform traditional routing and a seminal opportunistic routing protocol. Routing protocol design is critical to the performance and reliability of wireless mesh networks. Opportunistic routing exploits the broadcast nature of the wireless medium and does not commit to a particular route before data transmission.

3 PROPOSED SCHEME

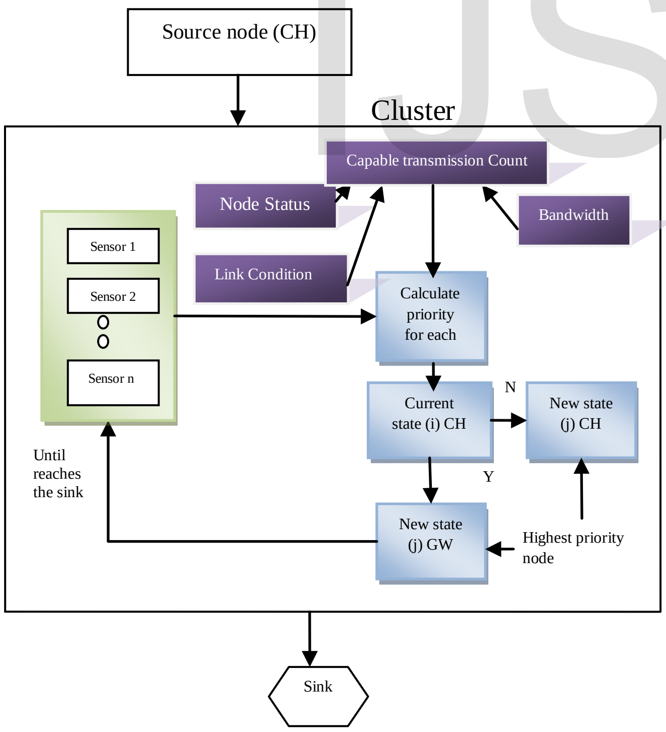

Fig 1: MLCM operation

This paper proposes a modified link aware clustering mechanism called an MLCM, to find an energy efficient routing path. It uses a novel clustering metric called capable transmission count (CTX). This metric considers node status, link condition and bandwidth to calculate the highest priority of nodes for clusterheads and gateways to form clusters.

4 METHODOLOGY

This section describes the procedure for highest priority calculation in modified link aware clustering mechanism (MLCM).

4.1 CAPABLE TRANSMISSION COUNT

The capable transmission count (CTX) is defined as the number of transmissions that clusterhead (CH) and gateway (GW) nodes conducts. It considers the transmit energy consumption, node status, quality of link and bandwidth to calculate the CTX of clusterhead or gateway node. A node with highest value of CTX is elected as a clusterhead or gateway node [1].

The condition of channel in wireless networks differs with time, the quality of link based on the channel condition. An MLCM uses the expected transmission count called an ETX, to calculate the level of link quality [5]. Assume ETX_{ij} be the ETX of link between two nodes named as i and j and it is defined as

$$ETX_{ij} = 1 / P_{ij}^{f} . P_{ij}^{r}$$

Where P_{ij}^{f} indicates the forward delivery ratio from node i to node j. It denotes that messages successfully arrives at the recipient and P_{ij}^{r} indicates the reverse delivery ratio from node j to node i. It denotes that acknowledgement messages are successfully received [1].

The highest priority value of CTX is calculated by these formulae,

$$q_{ij} = E_i^{res} + Bandwidth / ETX_{ij} . E^{tx}_{amp} (k, d_{ij})$$

Where q_{ij} denote the capable transmission count of a link, E_i^{res} is the residual energy, ETX_{ij} is the quality of link and E^{tx}_{amp} (k, d_{ij}) is the energy consumption for node i to transmit a k bit messages through distance d_{ij}.

4.2 PRIORITY CALCULATION

An MLCM evaluates the proper node (clusterhead or gateway) participants to forward data packets. A clusterhead node and a gateway node perform the following steps to determine the priority.

Step 1: Calculate the CTX value for each neighbor nodes.
Step 2: Divide set of neighbor nodes into two subsets($S_{sat}(I)$) and ($S_{sat}(I)^*$)

1. CTX values of all nodes in ($S_{sat}(I)$) $\geq N_{req}$
2. CTX values of all nodes in ($S_{sat}(I)^*$) $< N_{req}$

where N_{req} denotes the predefined threshold which piggybacks query messages send by sink.
Step 3: If $S_{sat}(I) \neq \emptyset$

1. Minimum CTX value in ($S_{sat}(I)$)
2. Maximum CTX value in ($S_{sat}(I)^*$)

An MLCM calculates the nodes satisfying the report quality required by sink. In step 3, the first point describes that the minimum CTX value of all CTX values in ($S_{sat}(I)$) as the highest priority of node. The second point describes that the maximum CTX value of all CTX values in ($S_{sat}(I)^*$) as the highest priority of node. This conditions can continuously supports the report quality and it selects the link that can support as high message delivery ratio.

4.3 CLUSTER STATE TRANSITION

It depends upon receiving messages of a node. It determines the change in current state of a node.
Step 1: Initialize the nodes that is named as IN node.
Step 2: It receives data from either a CH or GW node.
Step 3: It changes its state as that of sender.
Step 4: If sender is CH node, then IN node becomes GW_R.
Step 5: If sender is GW node, then IN node becomes CH_R.
Step 6: Calculate the priority of nodes based upon procedure of priority calculation
Step 7: The highest priority value of CTX becomes CH or GW node

4.4 OPERATION OF MLCM

The operation of modified link aware clustering mechanism (MLCM) is shown in Fig 1. The source node has to transmit the sensed data to the sink. The source node elected as a clusterhead node because it does not have the CH neighbor nodes. Neighbor nodes are receiving packets from the source node (clusterhead node), it enters into the gateway ready (GW_R) state. Then each node makes an evaluation to determine the highest priority value node becomes a GW node. If neighbor nodes are receiving packets from the gateway node, it enters into the clusterhead ready (CH_R) state. It performs the same evaluation to determine the highest priority value node becomes a CH node. It forms cluster and finds an energy efficient routing path that supports the good report quality. This process continuous until the sensed data reach the destination called sink.

5 SIMULATION RESULTS

This section shows the simulation result of MLCM operation. The simulation is done in network simulator tool NS2. The NS2 version 2.28 is used with C++ programming language and Object Tool Command Language (OTCL).The simulation are showed in an output trace files and graphical representation.

TABLE-1
SIMULATION PARAMETERS

Simulator	ns 2.28
Radio Propagation model	Two ray ground
No. of mobile nodes	100
MAC layer protocol	IEEE 802.11
Packet size	100 bytes
Antenna model	Omni antenna
Channel Type	Wireless channel
X dimension	2169m
Y dimension	522m
Link layer type	LL
Communication range	250m
Initial energy	2J
Predefined threshold	8

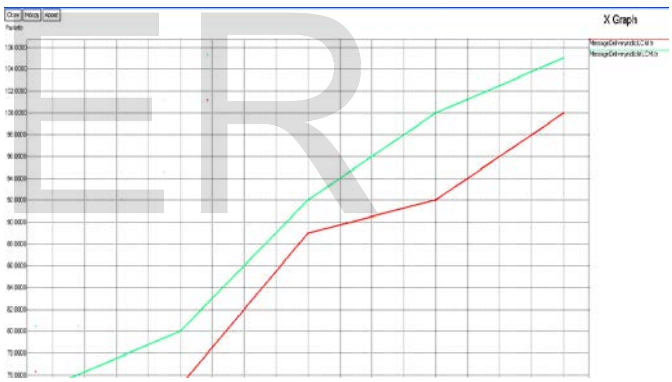

Fig 2.Message delivery ratio

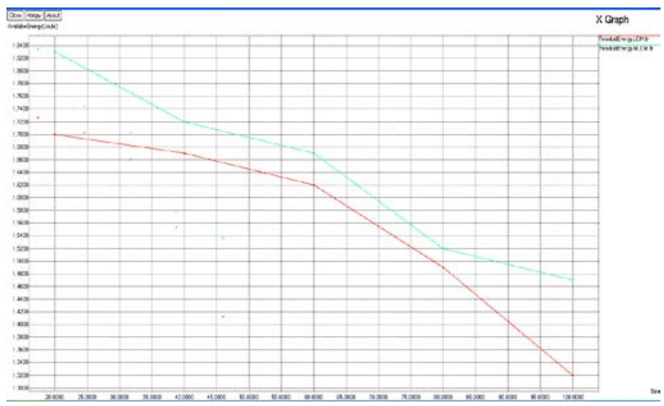

Fig 3.Residual energy

Fig 4.Delivery latency

The above graphs show that the performance analysis of wireless sensor networks in clustering mechanisms. The parameters have taken with respect to message delivery ratio, residual Energy and delivery latency.

The comparison graphs shows that the proposed MLCM achieves better message delivery ratio, higher residual energy and reduces the transmission latency than the existing mechanisms in clustering. It's done under scenarios with different number of sensor nodes and report frequencies. The proposed MLCM uses a novel clustering metric CTX, to find the highest priority of CH or GW node. It determines an energy efficient routing path that guarantees the report quality.

6 CONCLUSION AND FUTURE WORK

This paper introduces the modified link aware clustering mechanism called MLCM, to find an energy efficient routing path in wireless sensor networks. The MLCM uses a novel clustering metric called capable transmission count (CTX), to optimize the CH or GW node based on highest priority. It supports in forming cluster structure and construct an energy efficient routing path that ensure better report quality. From the simulation results it is shown that this proposed MLCM achieves better message delivery ratio, residual energy and transmission latency. The future work of this proposed MLCM is to find an energy efficient routing path in other communication type called geocasting.

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