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An Enhanced Timeliness for Energy Efficient Relocation of Gateway by AQM in Wireless Sensor Networks

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Abstract
In Wireless Sensor Networks (WSN) collected data are routed to multiple gateway nodes for processing. These gateways work collaboratively on a set of actions to serve the application-level requirements or to better manage the resource constrained in WSN. Applications of Wireless Sensor Networks that demand certain quality of Service (QoS) guarantees,new routing protocols have been proposed for providing energy-efficient real-time relaying of data. In this paper an efficient algorithm AQM (Active Queue Management) is used, which maintains a buffer among the gateways while repositioning individual gateway to avoid congestion and packet loss. Simulation results have demonstrated the effectiveness of AQM and positive effect on network longevity.

Keywords
AQM, End to End delay, Timeliness,QoS, Wireless Sensor Networks.

I. Introduction

Wireless Sensor Networks (WSN) has numerous applications in a variety of disciplines, both military and civilian [1] [2].The ability to remotely measure ambient conditions and track dynamic events become valuable especially in harsh environments where human intervention is risky or infeasible. Sensors are usually battery-operated and have a limited transmission and processing capacity. Such constraints have motivated lots of research on data fidelity, latency, and coverage so that the network can stay functional for the longest duration.

A typical WSN architecture involves large numbers of sensor nodes that report their measurements to locally deployed data collection centers often referred to as gateway node. Gateway is usually more capable in terms of their energy supply, radio range and computational resources.

Gateway relocation [3] [4] is one of the approaches pursued to improve the performance of the network. By relocating the gateway towards highly active sensors, the packet will be routed to the gateway through fewer sensors. The shortened data paths help in preserving sensors energy, lowering the packet loss rate and reducing delivery latency. In general, most gateway relocation techniques identify problem in the current network topology and tend to move the gateway close to the bottleneck positions. However, such performance-centric relocation may move the gateway dangerously close to one or multiple events in the environment and thus may expose the gateway to the risk of getting damaged, captured etc.

In this paper a significantly less energy constrained gateway node than all the sensors is deployed in the physical proximity of sensors. It is assumed to know the geographical location of sensors and it is responsible for organizing the activities at sensor nodes fusing collected data coordinating communication and interacting with the command node. Sensors are assumed to be within the communication range of the gateway node and capable of operating in an active mode or a low-power stand-by mode. The transmission power of the transmitter and receiver can be programmed so that the transmission can be turned on/off as required. This sensor acts as a relay node to forward data.

This paper also proposes the Active Queue Management (AQM) algorithm to the gateway relocation problem. The idea is to identify a better position for the gateway. The sensor nodes often have limited power resources. Therefore it is very crucial to reduce the energy consumption in certain real-time applications such as fire alarm monitoring, traffic monitoring, where information collected is valid only for a limited amount of time after that it become irrelevant information. Hence all the packets need to be conveyed to the sink within a certain deadline period. Therefore packet timeliness requirement also becomes an important issue for such real-time applications in wireless sensor networks.

The gateway chooses the shortest path to deliver the packets. The packet is selected in the area where the loaded number of nodes is minimum. Also the gateway has limited motion capability so that it is desirable to relocate the gateway close to an area of heavy traffic or near loaded hops in order to decrease the total transmission power and extend the life of nodes on the path of heavy packet traffic. This model is constructed only for stationary sensor nodes with gateway having limited mobility. The gateway remains stationary unless the network operation becomes inefficient. The gateway relocates to another position in-order to optimize performance metrics such as maximizing network life-time, minimizing energy consumption and achieving timeliness.

II. Related Works

SPEED [5] protocol is a highly efficient and scalable protocol for sensor networks where the resources of each node are scarce. SPEED that supports soft real-time communication based on feedback control and stateless algorithms for large-scale sensor networks. SPEED helps balance the traffic load to increase the system life-time. Speed also utilizes geographic location to make localized routing decisions. Speed algorithm is to support a soft real-time communication service with a desired delivery speed across the sensor network. SPEED provides three types of real-time communication services, namely real-time unicast, real-time area multi-cast, and real-time area any cast for sensor networks. SPEED satisfies the following design objectives such as, stateless architecture, soft real-time, minimum MAC layer support, QoS routing and congestion management, Traffic load balancing, Localized behavior, void avoidance. However, the drawback of SPEED protocol provides only one network-wide speed, which is not suitable for differentiating various traffic with different deadlines. It has used to only a single path routing then on demand algorithm is less suitable for real-time applications.

Multipath and Multispeed (MMSPEED) [6][7] protocol is designed to provide relies on the premise that the underlying MAC protocol can perform the following functions prioritized access to shared medium depending on the SPEED layer .Reliable multicast delivery of packets to multiple neighbors supporting measurement of average delay to individual neighbors. MMSPEED differentiates

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packets depending on their reliability requirement and thus we can drop more packets with low reliability requirements than SPEED. However the major drawback of this protocol is increase the overall power consumption by sensor node radio modules.
MAC [8][9] layer multicast protocol which uses a separate Request to Send/Clear to Send (RTS/CTS) hand shake for each of the recipients, followed by data transmissions and another sequence of Request to Acknowledge (RAK)/ACK handshakes to ensure the reliable delivery to all multicast recipients. However, this incurs a long sequence of resulting in a long delay for each multicast. This MAC protocol ensures the reliable frame transmission only to primary recipient expecting successful eavesdropping by all other recipients.
Weighted Fair Queuing (WFQ) [10][11] method is flow based by considering each imaging sensor node as a source of different real-time flow with only one real-time queue to accommodate the real-time data coming from these multiple flows. The service ratio "r" is the bandwidth ratio set by the gateway and is used in allocating the amount of bandwidth to be dedicated to the real-time and non-real-time traffic on a particular outgoing link .However the drawback of WFQ buffer management is very poor. So they cannot reduce the end-to-end delay the energy consumption is very high.

III. Proposed Protocol

A. Sensor Architecture

The numbers of sensor nodes deployed are generally equipped with data processing and communication capabilities. The sensors send its collected data, usually via radio transmitter to a command center either directly or through a base station. The gateway can perform fusion of the sensed data in order to filter out erroneous data and anomaly to draw conclusion from the reported data over a period of time.

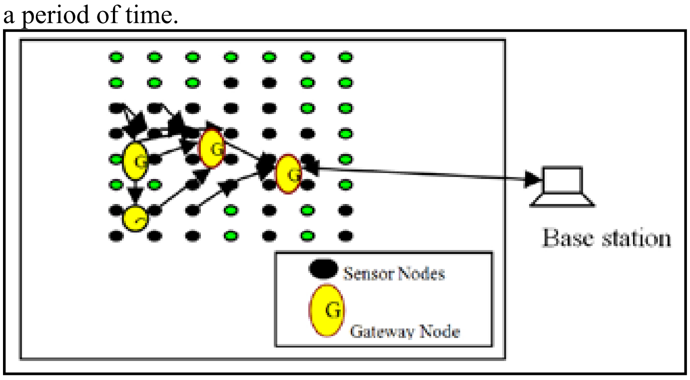

Fig. 3.1: System Model

The system architecture of sensor network system is depicted in fig 3.1. A sensor network share resources between sensor nodes. The sink may communicate with the task manager node via internet or satellite. Sensor node usually consists of four subsystems such as computing subsystem, communication subsystem, Sensing subsystem and power supply subsystem. The gateway is assumed to know the geographical location of deployed sensors. The gateway is responsible for organizing the activities at sensor nodes contingent to achieving a mission fusing data collected by sensor nodes coordinating communication among nodes and interacting with base station.

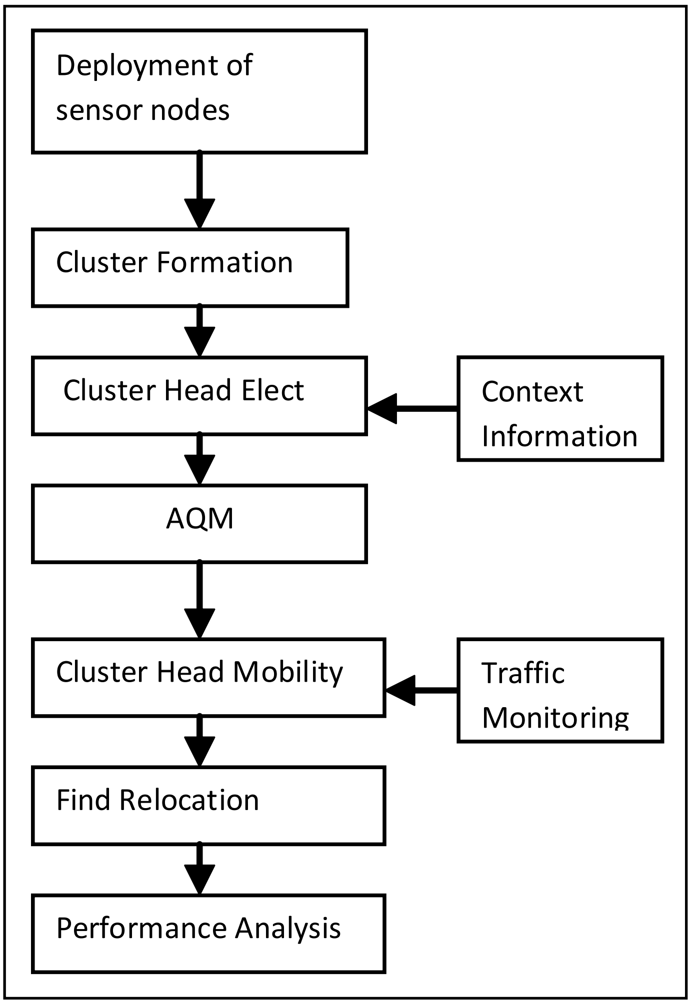

Fig 3.2: Process flow diagram of gateway relocation

II. Cluster Formation

The sensors are uniformly deployed and the cluster is formed using the location based clustering algorithm. Once the nodes are deployed the sensor nodes form the cluster members and elect a cluster head using location based clustering algorithm. This algorithm fully utilizes the location information of routing to reuse the routing cost. The cluster is formed by following equation (1).

$$T(n) = \begin{cases} \dfrac{s}{1 - s(r \bmod (1/s))} & n \in F \\ 0, & \text{Otherwise} \end{cases} \qquad (1)$$

Where,
T (n) – Threshold
S - Percentage of cluster heads over all nodes in the network
r - The number of rounds of selection
F - The set of nodes that are not selected in round 1/s

III. Gateway Election

Gateway Election is more important in wireless sensor networks. Gateway is also called as cluster head. Gateway is elected for the context information of all the sensor nodes which is based on all the sensor node energy and bandwidth coverage.

IV. AQM Implementation

In order to solve the buffer management problem and decrease the end-to-end delay. AQM based phenom routing protocol for sensor networks. AQM provides congestion signal for flow control not only based on the queue length but also the channel condition and the transmission rate. It uses priority based queue management to improve performance in congested area. When congestion is occurred it can help to detect congestion by using the values of transmitting capacity and minimize congestion by reassigning traffic. It includes three properties such as performance isolation, local stability and fairness. It can be modeled as a nonlinear system via the utility based approach.

V. Relocation Approach to Enhance the Performance

There are three phases in gateway relocation which is depicted in fig 3.2. These are when to relocate the gateway, where to put it and how to handle its motion without disrupting data traffic and negative effect.

Phase I: The time when gateway should be relocated

Step 1: Always relocation is decided based on the missed ratio.
Step 2: The missed ratio is indirectly related to finding proper r-value in the above equation (1).
Step 3: Real time routing finds the r-value by considering all the paths from the source of real time traffic to the gateway.
Step 4: In cases where a proper r-value between 0 and 1 cannot be found, the connection is simply rejected and the path is not established
Step 5: Even where proper r-values are found, the miss ratio may start to decrease.
Step 6: The gateway sets a threshold value for the maximum level of miss ratio and maintains such statistics periodically when such threshold is reached the gateway is to a better location.
Step 7: The gateway can be relocated more than once whenever necessary during the data traffic cycles is shown in fig. 3.3.

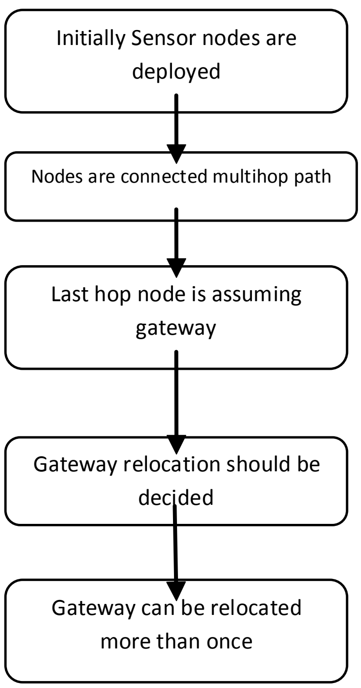

Fig 3.3: Relocation of gateway to avoid data traffic

Phase II: The position in which the gateway should be relocated

Step 1: After deciding that the gateway is to be relocated then a new location is searched for it.
Step 2: The gateway is moved towards the loaded nodes in terms of real time traffic so that the end-to-end delay can be decreased.
Step 3: Then searches the last hop nodes.
Step 4: The biggest r-value is considered for relocating the gateway at the position of that hop.
Step 5: Decrease the average end-to-end delay since the number of hops for data packets to travel will be decreased.
Step 6: Breaking the ties when multiple alternative nodes with the same r-value are found
Step 7: If the gateway is still reachable by the nodes Y and Z they just increase their transmission range of uninterrupted data delivery.

Phase III: The way to relocate the gateway

Step 1: After determined the new location, the gateway explores two options based on the information of whether it will be out of range at the new location or not.
Step 2: If the gateway detects that it would go out of the transmission range of last hop nodes and cannot receive the data from other relay nodes at the new location.
Step 3: Then explores the option of employing sensor nodes to forward the packets.
Step 4: The miss ratio for real time data periodically to detect situations where there is need for relocation.
Step 5: Then final gateway are communicating with command node.
Step 6: Next gateway checks whether it can still be reachable by the last hopes while traveling on the next stride and inform yet last hop nodes about its situation.
Step 7: Once, it detects that forwarder nodes are needed, the routes are extended by those nodes and that information is sent to relevant nodes in fig 3.4.

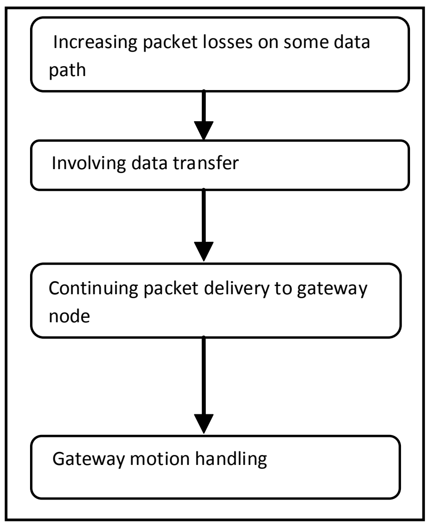

Fig 3.4: The way to relocate the gateway

IV. Performance Results

In this section the performance results were shown from the below fig 4.1 to 4.4 with and without repositioning the gateway. In order to see the effect of repositioning the gateway on total

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remained energy and average remained energy, then looked at the average lifetime of a node, time for first and last node to die and average energy consumed per packet. The results depicted in fig4.1 have shown that the proposed approach of repositioning the gateway calculate total remained energy significantly especially by increasing the average lifetime of the node and time for last node to die. In this proposed approach, since the gateway is relocated close to heavily loaded nodes, less energy is consumed for communication thus leading significant amount of energy savings. On the other hand, the latency of the packets from those nodes to the gateway will be decreased, causing the decrease delay per packet to decrease drastically. There is also a slight increase on the throughput due to smaller packet drop probability since packets travel shorter distances.
Table 1 describes the simulation environment settings.

Table1: Simulation Environment Settings

Terrain	500mx500m
Node number	50
Node placement	Uniform
Bandwidth	100 kbps
Inter-column spacing	82m
Inter-row spacing	70m
Simulation duration	10s
Transmission rate	10ms/pkt

Table 2 describes the movable gateway.
Table 2: For the Movable Gateway

ST (sec)	ARE (joules)	PDR (bits/s)	AE2ED (sec)	TH (bits/s)
10	107.0	98.03	0.157	2989.23
20	212.9	98.69	0.109	2274.34
30	318	99.02	0.085	2036.23
40	423	99.22	0.071	1917.13
50	528.1	99.35	0.062	1845.73
60	633.1	99.44	0.056	1798.60
70	739	99.51	0.051	1764.80
80	843.5	99.57	0.047	1738.00
90	948.6	99.61	0.044	1718.00

Table 3 describes the fixed gateway.

Table 3: For the Fixed Gateway

ST (sec)	ARE (joules)	PDR (bits/sec)	AE2ED (sec)	TH (bits/sec)
10	106.9	97.69	0.1563	1567.49
20	212.0	97.30	0.1227	1539.23
30	317.9	97.17	0.1122	1531.25
40	423	97.5	0.1072	1531.71
50	527.5	97.69	0.1041	1531.62
60	634	97.82	0.1017	1532.90
70	738.1	97.91	0.1007	1533.46
80	843.1	97.88	0.0995	1532.02
90	949.8	98.03	0.0983	1534.04

Where,
ARE - Average Remaining Energy
ST - Simulation Time
PDR – Packet Delivery Ratio
AE2ED – Average End to End Delay
TH - Throughput

Average Remaining Energy
In this proposed work the average remaining energy is more in movable gateway when compared with fixed gateway. In this approach 30% more remaining energy in movable gateway.

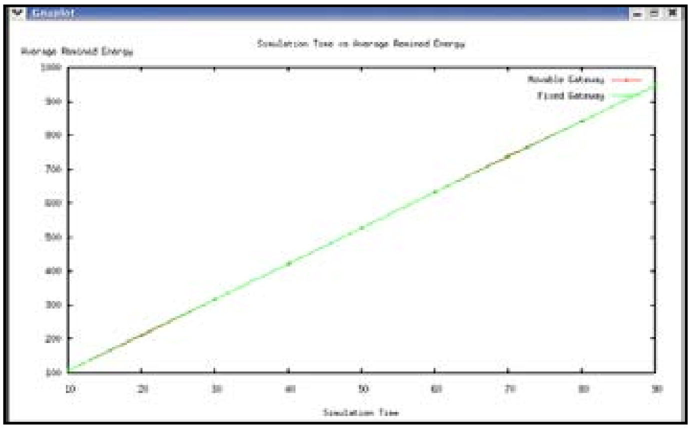
Fig 4.1: Average Remaining Energy

Packet Delivery Ratio
In this proposed work packet delivery ratio is increased for movable gateway when compared with fixed gateway. In this approach 20% packet delivery ratio is increased in movable gateway.

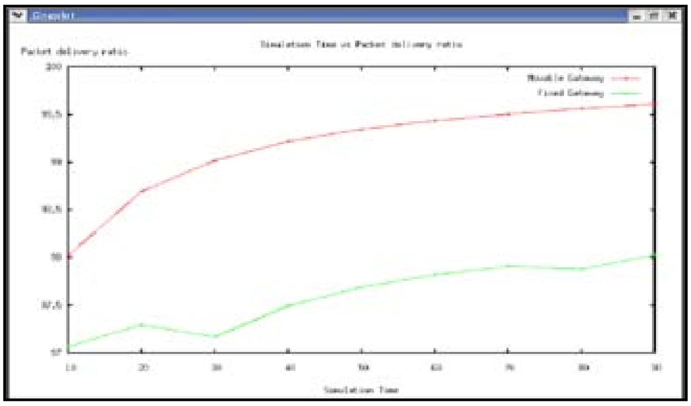
Fig 4.2: Packet Delivery Ratio

Average End to End Delay
This performance metric is used to measure the average end-to-end delay of data packet transmission. The end-to end delay implies the average time taken between a packet initially sent by the source, and the time for successfully receiving the message at the destination. Measuring this delay takes into account the queuing and the propagation delay of the packets. In this proposed work average end to end delay decreased for movable gateway when compared with fixed gateway. In this proposed relocation approach significantly decreases average end to end delay per real-time packet and provide at least 30% decreased in the end to end delay.

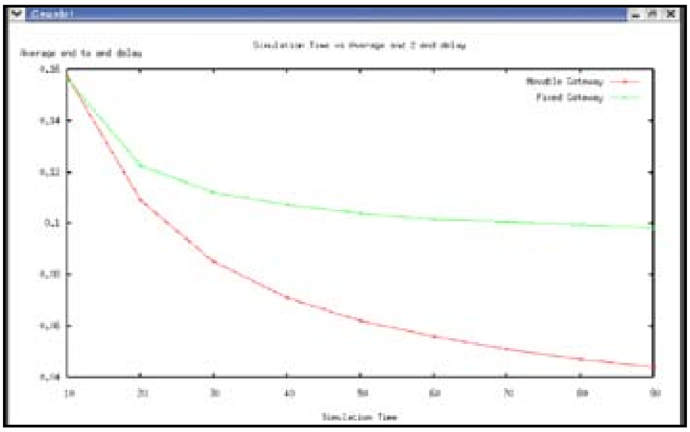

Fig 4.3: Average End to End Delay

Throughput

The end-to-end network throughput measures the number of packets per second received at the destination x-axis contain simulation time and y axis contains throughput. In this proposed work throughput is increased for movable gateway when compared with fixed gateway. It observes that relocating the gateway 20% increased real-time data throughput as shown in fig 4.4.

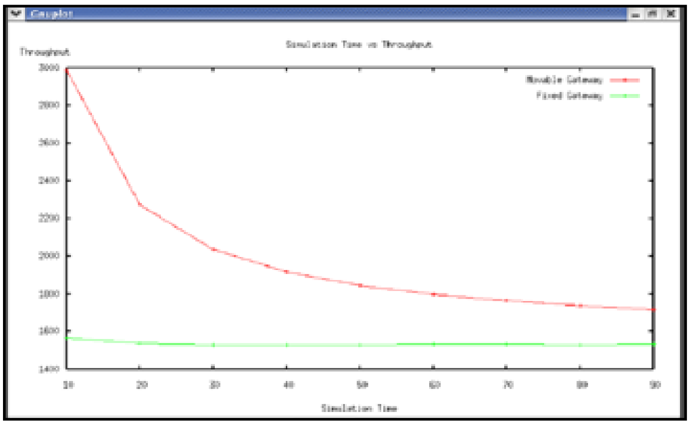

Fig 4.4: Throughput

V. Conclusion

In this paper, a repositioning approach is presented for the gateway in order to enhance the overall performance of wireless sensor networks in terms of popular metrics such as packet delivery ratio, delay and throughput.

The presented approach considers relocation of the gateway by checking the traffic density of the nodes that are one-hop away from the gateway and their distance from the gateway. Once the total transmission power for such is guaranteed to reduce more than a certain threshold and the overhead of a moving the gateway is justified, the gateway starts to move to the new location. The gateway is moved in the routing phase so that the packet relaying will not be affected. Simulation results have shown that such repositioning of the gateway 30% increases the average lifetime of the nodes by decreasing the average energy consumed per packet. Moreover, the average delay per packet is decreased significantly.

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Author's Profile and Image

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