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An Autonomous Intelligent Gateway for Mobile Nodes Using Quadratic Assignment Techniques in Wireless Sensor Networks

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ABSTRACT

Wireless Sensor networks are dense wireless networks of small, inexpensive, low-power, distributed autonomous sensors which accumulate and propagate environmental data to facilitate monitoring and controlling of physical environments from remote locations with better accuracy. With the advent of new technology and low production costs, wireless sensor networks (WSN) prove to be useful in myriad of diversified applications, although its original development was motivated by military applications, such as battlefield surveillance. This paper describes the software architecture of an intelligent autonomous gateway, designed to provide the necessary middleware between locally deployed sensor networks based on mobile node and a remote location. The gateway provides hierarchical networking, auto management of the mobile wsn (MWSN), alarm notification and SMS/Internet access capabilities with user authentication. The main concern of QoS-based quadratic assignment technique is to increase reliability of network along with lifetime of the network. Several factors such as energy lifetime, throughput, end to end delay, packet delivery ratio and network security have been taken into consideration. Simulation results shows that the protocol offers a better performance in terms of network lifetime and energy consumption.

Introduction

Recent developments in wireless communication and electronics have made possible the development of small, inexpensive, low power, distributive devices. These devices are capable of local processing and wireless communication and are known as sensor nodes. A sensor network can be described as a collection of sensor nodes which co-ordinate with each other to perform some specific function. The wireless sensor network (WSN) has been widely spread out in a variety of surveillance applications. Examples include environmental monitoring, smart home facility, seismic detection, military surveillance, inventory tracking, smart spaces etc. Limited energy is one of the key challenges, considering the motes are most often battery operated. Maintaining the network (e.g. replacing batteries) is a critical restriction as it is usually difficult to access to nodes due to their location. Power supply that harvests power from the environment such as solar panels may be added to the node depending on the appropriateness of the environment where the sensor will be deployed. However, external power supplies often have a non-continuous behavior, thus making the presence of the battery essential. A number of approaches have been proposed as a solution to the problem of energy efficient: Duty cycling, data driven, mobility, etc. The advances in mobile robotics allow us today to add the mobility concept into many different classes of Wireless Sensor Networks. Data mule has been considered as an alternative solution for this problem of data gathering. A mule is a mobile device that can visit locations within the communication distance of each of the static motes, download their measurements and return to a remote base station to load the collected data. The key benefit of this approach is that motes can conserve energy that they would otherwise use to forward data, thereby prolonging the network's lifetime. In addition to reducing the energy consumption during transmission (less power is needed), proximity also reduces the data loss rate, which results in smaller number of transmissions per byte. Most traditional WSN gateway nodes lack of flexibilities in applications, so it's difficult to apply in a certain environment. With the improvement of the traditional WSN gateway nodes, the users on the internet can access the data of the wireless sensor network flexibly through wired or wireless mode.

Related Work

There are several gateway architectures that were proposed for various implementation scenarios. One of the applications is for AC energy usage monitoring using 6LoWPAN. Jiang et al. discussed the application that uses Tiny OS and blip. Edge routers were used to route data to a database and uses a web server for visualization of the data. Wenbin et al. developed WSN gateway specifically to monitor forest environment. Information from the sensors is sent to a monitoring centre using GPRS module. Jara et al. introduced a WSN architecture that uses mobile nodes to collect healthcare information. 6LoWPAN gateway was used to connect the nodes to a database. All these solutions have little information on the gateway design and didn't provide the operation of the gateway. Dun-Fan et al proposed gateway architecture for environmental monitoring which connects WSN with external network and shares the data collected using web services. Gateway retrieves link layer MAC address from the destination address provided by the internal node. This is unnecessary process as the nodes can directly send the data using the destination address and it is not practical as not all global address generated using link layer MAC address. Zimmermann et al. introduces a one-to-one translation between link local address and global address at the gateway. They use a DNS-ALG like server to intercept the DNS query to assign link

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local address to internal node. If the DNS query could not be intercepted, communication would be disrupted. WPAN Gateway Modules Jin et al. proposed an interoperable architecture between NEMO and WPAN focusing on routing scheme. The nodes are configured with global IPv6 address and as such translation of header is not required. In our solution, we propose a solution for nodes that uses MAC address for communication. Besides that, we focus on the performance analysis on real test bed compared to the simulation results.

Proposed Framework

In this paper, there are several sensor nodes available without the limitation of mobility in the entire wireless sensor networks. Here four groups are formed with the available 100 nodes. For each group a group head is selected by the sub nodes based on the distance coverage algorithm. And in each group the nodes will have connectivity with the neighbor nodes. Based on the highest connectivity of neighbor nodes, the Gateway is chosen using Enhanced Interior Gateway Routing Protocol from each group. The group head will have direct link with the gateway only and gateway monitors all the neighbor nodes. The energy is assigned by the group head to the gateway and the energy is equally distributed by the gateway to the neighbor nodes. Each group head will have connectivity with the other group heads. From the first group a source node is identified and it sends the data through the gateway to the destination. Here each gateway maintains the index table which contains the node details such as energy level, node ID, node Location ID to detect the IDS node based on IDS algorithm.

If energy level < 25 J, then the gateway will detect that misbehaving node and it will put that node into sleep mode. The remaining nodes will act as active nodes. Each group head detects the number of active nodes in the respective groups and it identifies the active node with maximum energy. The group head with maximum number of active nodes is first chosen for data transmission using energy aware protocol. Each gateway will verify the index table and identifies the node with highest energy level using Quadratic Assignment Techniques. Base station knows about the active nodes in the field and energy level of each node. BS determines the suitable number of clusters using that information. BS broadcasts the information about CHs. Then CHs construct their cluster and determines the head sets. At one time, only one member of head set is active and receives data from nodes. The task of transmission of aggregated data to base station is distributed uniformly to all the head sets. Along with the data, energy information of nodes is also send to BS for CH selection of next round. It identifies which CHs has maximum number of active nodes based on checking index table. Based on that CHs are allowed for data transmission. Then the gateway updates the status of the active nodes and it is sent to the group head. Again the source node starts sending the packets to the destination. Since some of the misbehaving nodes are put into sleep mode, we can save the energy of remaining active nodes with less energy level and hence we can improve the energy lifetime, throughput, end to end delay, packet delivery ratio and network security. The above problem can be solved by using Quadratic Assignment Problem.

Koopmans and Beckmann (1957) first introduced the quadratic assignment problem (QAP) as a mathematical model in the analysis of location of economic activities. The QAP stated as a facility location problem is to assign *N* facilities to *N* locations such that the total interaction cost of all possible flow-distance products between the locations to which the facilities are assigned plus the allocation costs of facilities to locations are minimized.

Consider the set N = {1,2,3,……n} and three nxn matrices F = (f_{ij}), D = (d_{ij}) and C =(c_{ij}). The Quadratic Assignment problem with coefficient matrices F, D, and C shortly denoted by QAP can be stated as follows :

$$\underset{x\in X}{Min} \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} f_{ik} d_{jl} x_{ij} x_{kl} + \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} x_{ij}$$

$$such\ that \sum_{i=1}^{n} x_{ij} = 1,\ i \in N, \sum_{j=1}^{n} x_{ij} = 1,\ \ j \in N\ , x_{ij} \in \{0,1\}, i, j \in N$$

f_{ik} denotes the amount of flow between facilities i and k, d_{jl} denotes the distance between locations j and l and c_{ij} denotes the cost of locating facility i at location j.

$$x_{ij} = \begin{cases} 1, & if\ facility\ i\ is\ assigned\ to\ location\ j \\ 0, & otherwise \end{cases}$$

Definition : Given a real number ε > 0, an algorithm γ for the QAP is said to be an ε -approximation algorithm if

$$\left| \frac{Z(F,D,\pi_{\gamma}) - Z(F,D,\pi_{OPT})}{Z(F,D,\pi_{OPT})} \right| \le \varepsilon$$

holds for every instance QAP(F,D), where π_{γ} is the solution of QAP(F,D) computed by algorithm γ and π_{OPT} is an optimal solution of QAP(F,D). The solution of QAP(F,D) produced by an ε -pproximation algorithm is called an ε -approximate solution.

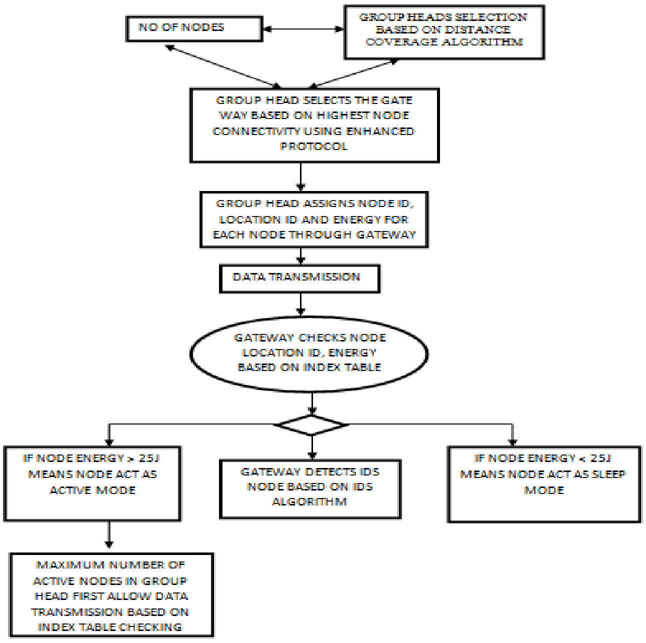
Theorem : The quadratic assignment problem is strongly NP-hard. For an arbitrary ε > 0, the existence of a polynomial time ε - approximation algorithm for the QAP implies P = NP.

Queyranne derives an even stronger result which further confirms the widely spread belief on the inherent difficulty of the QAP in comparison with other difficult combinatorial optimization problems. It it well known and very easy to see that the traveling salesman problem (TSP) is a special case of the QAP. The TSP on n cities can be formulated as a QAP(F,D) where F is the distance matrix of the TSP instance and D is the adjacence matrix of a Hamiltonian cycle on n vertices. Queyranne showed that, unless P = NP, QAP(A,B) is not approximable in polynomial time within some finite approximation ratio, even if A is the distance matrix of some set of points on a line and B is a symmetric block diagonal matrix.

Proposed Protocol

Enhanced protocol establishes the distance information among nodes is much easier to obtain than accurate global location information. Coverage is important for a sensor network to maintain connectivity. Connectivity can be defined as the ability of the sensor nodes to reach the data sink. From each group based on the highest connectivity of neighbor nodes, the gateway is chosen.

The neighbor table entry also includes information required by the reliable transport mechanism. Sequence numbers are employed to match acknowledgments with data packets. Each router keeps state information about adjacent neighbors. When newly discovered neighbors are learned, the address and interface of the neighbor is recorded. This information is stored in the neighbor data structure. The neighbor table holds these entries. There is one neighbor table for each protocol dependent module. When a neighbor sends a hello, it advertises a Hold Time.



We develop a technique to make these protocols energy-aware in order to increase the operational lifetime of mobile nodes which are operating on battery power alone and whose batteries cannot be recharged. Our techniques use a new routing cost metric which is a function of the remaining battery level in each node on a route and the number of neighbors of this node. The idea of the cost metric is to be able to route around the nodes that are running low in battery for which alternate routes are available. In addition, rerouting is done proactively when any node starts running low on battery while the route is being actively used. Further, we save energy by switching off the radio interfaces dynamically during the periods when the nodes are idle. Each round of data transmission network checks each node energy based on index table checking. A node has less than the approximate energy that acts as sleep mode, a node has greater than the approximate energy that act as active mode. They minimize either the active communication energy required to transmit or receive packets or the inactive energy consumed when a mobile node stays idle but listens to the wireless medium for any possible communication requests from other nodes.

The intrusion detection system continuously uses additional resources in the system as it is monitoring even when there are no intrusions occurring, because the components of the intrusion detection system have to be running all the time. Intrusion detection is a set of actions that determine, and report unauthorized activities. It detects the violation of confidentiality, integrity and availability. IDS with location detection based compares the current activity of the nodes with the stored attack profiles based on index table and generate an alarm based on the profile.

Proposed Algorithm

Distance Coverage algorithm can be designed using only distance information between two nodes. Second, by requiring complete coverage, excessive overlap may occur. By reducing the coverage requirement, substantial savings can be achieved. In the localization scheme may require a fairly large number of anchor nodes to be heard by any node who needs accurate location. In this scheme requires nodes to estimate their distances to the beacon nodes which are out of communication range. Finally, localization can be calculated from distance information among the neighbors. However, the process is not straightforward. Building the global location system with distance information requires the graph to be globally rigid. In fact, it is proven in that even when both distance and angle information are available with a small amount of errors, the localization is still NP-hard. First, we present a scheme that estimates the distance between any two neighboring nodes using only local information. Since no localization is performed, there is no need for anchor node or angle information. The estimation scheme assumes random node placement, homogeneous nodes and circular communication and sensing range. The impact of irregular communication is also investigated and simulation results show that while the absolute error increases with irregularity, the error is still relatively low. If there is no available route from a sensor node to the data sink then the data collected by that node cannot be processed. Each node has a communication range which defines the area in which another node can be located in order to receive data. This is separate from the sensing range which defines the area a node can observe. The two ranges may be equal but are often different.

Performance Metrics

Fault tolerance, scalability, production cost, operating environment, network topology, hardware constraints, transmission media, power consumption are the important factors that is to be considered in the design process of sensor networks. The performance of the network is then measured based on experimental parameters called performance metrics.

Transmission Delay (end to end delay) : Delay of individual packet is the difference between times a packet takes to reach the final destination node from originating time of a packet from the source node. Therefore transmission delay (or end to end delay) is the ratio of sum of all such delays of each packet to the number of packets transmitted from source to destination.

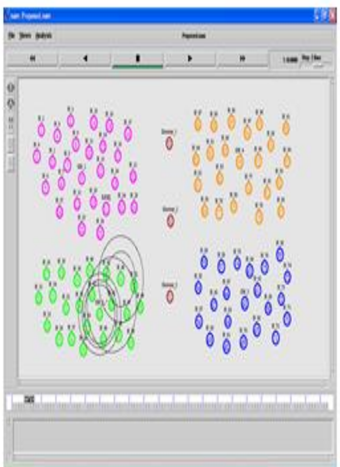
Network Lifetime: Network lifetime is defined as the number of data aggregation rounds till x% of sensors die where x is specified by the system designer. Depends on the application the definition may change.

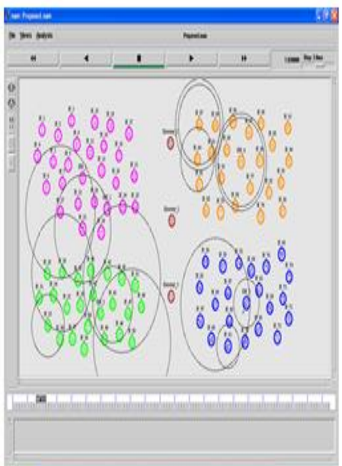
Node Energy Consumption: The node energy consumption measures the average energy dissipated by the node in order to transmit a data packet from the source to the sink.

Packet delivery ratio: the ratio of the data packets delivered to the destination to those generated by the sources.

Throughput: It can be defined as the number of packets received correctly at sink node over unit period of time (usually a second). Throughput is measured in kbps. It can also be defined as ratio of number of correctly delivered data packets at sink node to the number of all data packets transmitted.

Simulation Model





Simulation Setup Graphs

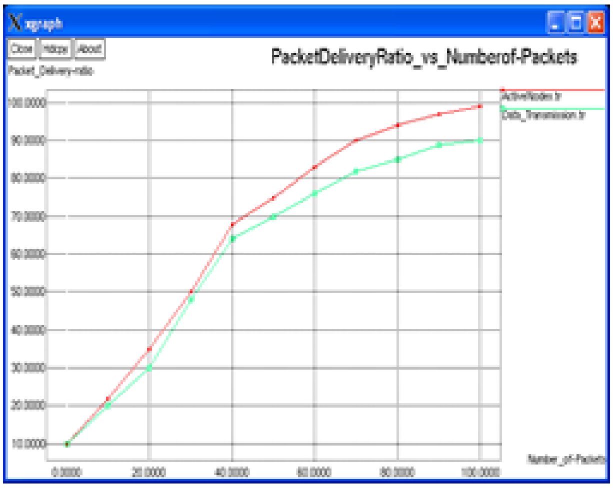
1. End-End Delay

In x-axis number of packets and y-axis Delay

Network Size	1800x900
Number of Nodes	100
Range	600m (100m – 600m)
Throughput	5 Mbps (7.5 Mbps, 15 Mbps)
Bandwidth	3.5 Mbps
Frequency	5 Hz
Average Speed of nodes	2.0 m/s
Data Transmission	1000 Bytes
Packet Rate	100 Packets per second (pps)
Mobility Factor	50 seconds
Initial Energy Assigned	100 Joules
Energy Consumption	10 Joules
Gateway	Three
Group Header	Four
Node Status	Active and Sleep nodes mode
Protocol	EQGOR Protocol
Simulation Time	900 seconds

Packet Delivery Ratio

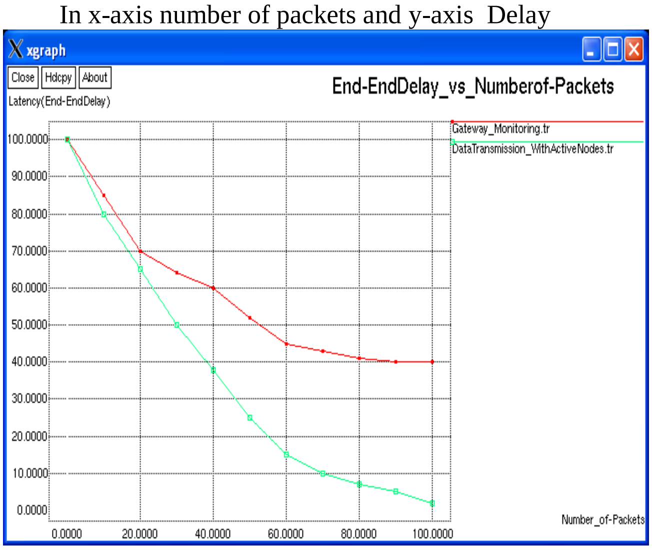
In x-axis number of packets and y-axis packet



Graphs

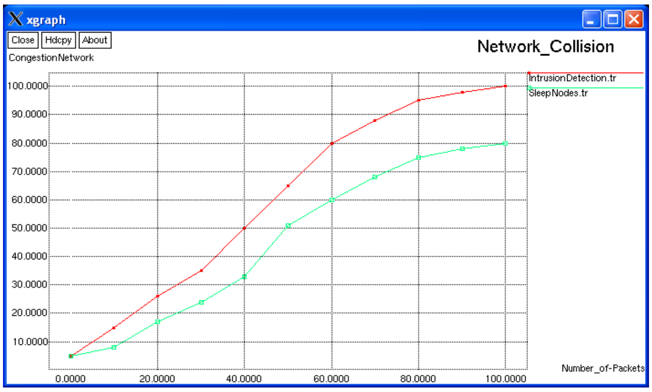
End-End Delay

In x-axis number of packets and y-axis Delay



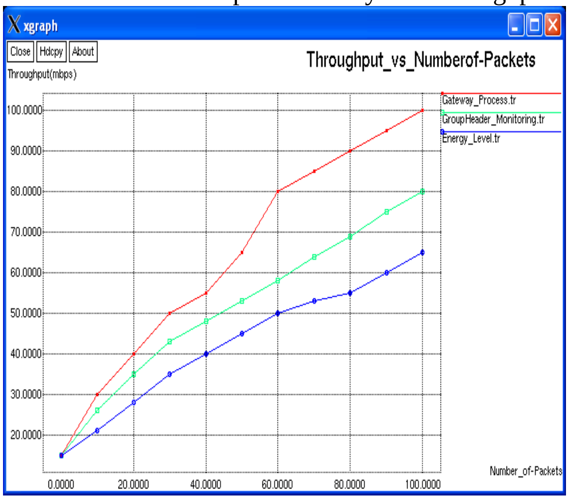
Network Collision

In x-axis number of packets and y-axis collision



Throughput

In x-axis number of packets and y-axis throughput



Conclusion

In this paper we proposed an autonomous intelligent gateway for mobile nodes using quadratic assignment techniques, Maintaining the network (e.g. replacing batteries) is a critical restriction as it is usually difficult to access to nodes due to their location. In each group based on the highest connectivity of neighbor nodes the Gateway is chosen using Enhanced Interior Gateway Routing Protocol Since some of the misbehaving nodes are put into sleep mode, we can save the energy of remaining active nodes with less energy level and hence we can improve the energy lifetime, throughput, end to end delay, packet delivery ratio and network security. Simulation results that our proposed scheme has higher node energy efficiency and lower average delay. In general, the proposed routing protocol provides high delivery ratio and spends less energy consumption if autonomous intelligent gateway is used.

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