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A SCALAR BASED ROUTING PROTOCOL APPLIED TO WIRELESS SENSOR NETWORKS

Kailash Subramanian
School of Computer Science and Engineering
VIT University, Chennai, Tamil Nadu, India

Abstract— **Wireless Sensor Networks motes have a small size, which leads to severe power supply restrictions. Much of the work on conserving power has been undertaken in the domain of routing protocols which deals with sending data in an efficient manner. In this paper a new scalar based protocol is proposed with a combination of multiple sub-base stations, that seeks to enhance the efficiency of protocol in terms of consumption of power and node failure tolerance. All the nodes are divided into regions, with each region having a sub- base station(sBS) and an arbitrary scalar value. Each sBS has lesser power supply and computation power compared to main station, but more of the mentioned metrics with respect to the sensor motes. Previous studies have described various paradigms and metrics for routing protocols and the placement of base stations. In this paper, the said algorithm is proposed, and its efficiency is analysed.**

Keywords— **wireless sensor networks, scalars, regions, base stations, nodes.**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are autonomous, distributed sensor motes which are deployed over a fixed area in fields that are conventionally considered dangerous for humans to be present in, and are connected via a wireless network. They have gained exponential popularity over the past decade, owing to the many applications it has in novel fields. The use of standards such as ZigBee and 6LoWPAN, implemented in the ubiquitous Internet of Things (IoT), with the emergence of open source operating systems for the sensor motes, such as Contiki OS, led to a huge boom in the number of novel applications in the past few years. Some application domains include healthcare, environmental monitoring, structural-health monitoring, outer space exploration, underwater supervision and other such monitoring and surveillance use-cases. The network has a base station which is equipped with an internet connection where the sensed data is processed and sent to the outer world. A basic sensor mote consists of the following units:

- A power supply;
- A processing unit or a CPU;
- A sensor, which acts a unit that converts real-world data to electrical signals that are predominantly digital;
- A communications unit which sends the sensed/incoming data to a target node or the base station; and
- A memory or storage unit.

Unfortunately, sensor networks have severe power restrictions that shorten their lifespan. Once deployed, the nodes are stationary, and are expected to have a lifetime of a few months to a year. Several protocols and architectures have been proposed to reduce the power consumed by these networks. In the proposed work, a new algorithm is discussed, and its efficiency is analysed.

II. LITERATURE STUDY

Previous work done in the routing protocols can be categorised broadly into various types based on network organisation, namely location, flat or hierarchical-based routing, or data-centric, node-centric or geo-centric routing. As many as 11 protocols are in publication at the time of writing the paper; we discuss them and their drawbacks in the forthcoming section.

A. "SPIN" [1]:

The authors of [1] propose a series of adaptive protocols, known by the name of **S**ensor **P**rotocols for **I**nformation via **N**egotiation, that floods or spreads data to sensors in a network limited by energy. The nodes, according to the authors, have high level descriptors called meta data to name their data. It is classified as a flat-based protocol. The protocol follows a query-based multipath approach, with data aggregation on a limited power usage. While the protocols do not provide Quality of Service, they perform close to the theoretical maximum. The authors of [1] claim that SPIN- second version disseminates 10 percent more data for each unit of energy consumed, compared to SPIN-first version, 60 percent more data for each unit of energy consumed than the conventional flooding, and both SPIN first and second version significantly outperformed gossiping. One drawback here is the uncertainty of whether the data packet forwarded from source will reach the destination, thereby rendering it less efficient for nodes of high density.

B. "Directed Diffusion"[2]:

It is a popular data aggregation paradigm, put forth by Ramesh et al.[2] It is a data-centric protocol where nodes of a network are application aware. By choosing paths that are empirically good, enabling data processing and caching within the network itself, we achieve greater energy savings. It consists of the elements, namely interests, reinforcement, data message, and gradient. The interest message is like a query, to specify the user requirement, and a briefing of the sensing action to be performed by the sensor network to acquire the data, which is nothing but the sensed action of the physical event in real world. The data can potentially be an event. Data is named using attribute-value pairs. The advantage of this method is that no node addressing mechanism is needed, as it is data-centric and it follows a neighbour to neighbour communication. It is based on-demand, thus it turns out to be highly energy efficient. One disadvantage is that it does not perform well for monitoring based applications, such as environment-based, as it requires continuous delivery of data and the sink would not perform optimally in an on-demand data model, which is primarily query driven.

C. "Rumour Routing"[3]:

Rumour routing is a tunable routing scheme for queries to be sent to events in the sensor network. Rumour routing offers a trade-off between the setup overhead and delivery reliability. Rumour-routing preserves only a single route between the source node and the destination node, as compared to **B**, wherein multiple paths are used to send data at much lower cost. When the events are sent through the network using flooding paradigm, a node senses the event, maintains or updates its event table, which contains information about the source node, previous hop and events, and forms an agent, whose primary job is to disseminate information about local events to distant nodes. The advantage of this method is that it can handle node failure smoothly, and is very reliable when it comes to delivering events to nodes in a vast network. It also has greater energy savings as compared to event flooding.

D. "Gradient Based Routing"[4]:

This algorithm improves the directed diffusion, by extracting the total minimal hops, apart from least time. For the conventional gradient least hop count or minimum hop count algorithm, the sole metric to determine how the quality of the route is, is hop count. This scheme gracefully handles the node failure and frequent change of topology of the network. Another better optimisation of this scheme considers the remaining energy of each node, other than hop count, while flooding the data from source to destination. Simulation results of [4] show that at times where the back off wait time (Tb) is very high, count of messages needed to set up the network will be lesser by count. While the Tb is efficient to conserve energy, it has the disadvantage of delaying the establishment of routes, where the delay is proportional to Tb.

E. "Low Energy Adaptive Clustering Hierarchy"[5]:

It is one of the first hierarchical protocols which is self-organising and adaptive, meaning the sensor nodes self-organise into local clusters. The members of the cluster elect the cluster head, whose responsibility is to collect data from its cluster members. This avoids excess energy drain and includes data aggregation to decrease the number of packets or messages directed towardsBS, to elevate the network lifespan time. When the node in the network fails, LEACH protocol is used in the network. To reduce the collisions within and outside the clusters, LEACH uses TDMA/CDMA approach. The LEACH protocol is used for continuous monitoring by the network. While the decision to elevate a node to the position of cluster head is done dynamically at particular time intervals, the collection of data is periodic. The cluster head floods the information to the remaining nodes in the sensor network. In order to conserve on energy, the cluster heads mutate randomly over a span of time, to stabilise the energy levels.

F. "Power Efficient Gathering in Sensor Information Systems"[6]:

PEGASIS, short for "**P**ower **E**fficient **G**athering in **S**ensor **I**nformation **S**ystems" is an improvement over E, and it is a near optimal protocol. It is a chain-based protocol. Rather than form multiple clusters, PEGASIS places nodes randomly in a playfield, thereby constructing a node chain The nodes communicate only to close neighbours, and take turns in transmitting the data to the BS, thus reducing the power spent in each round of data transfer. The simulation results show that PEGASIS fares better than LEACH, by 100 percent to 300 percent, when 1 percent, 10 percent or 20 percent of the nodes die, for various network sizes and topologies. This eliminates the overhead of forming a cluster, which was observed in LEACH. When choosing a routing path, the algorithm does not take into account, the energy needed for the next hop. When the number of nodes in a sensor network is high, the delay of data transmission is bound to be higher. Thus, PEGASIS has a disadvantage of not scaling very well and thereby being sub-optimal for sensor networks where global knowledge is hard to obtain.

G. "Threshold sensitive Energy Efficient sensor Network protocol" [7]:

TEEN, short for "**T**hreshold sensitive **E**nergy **E**fficient sensor **N**etwork protocol", is an energy efficient protocol for on re-active sensor networks, based on LEACH[5]. It finds usage in temperature sensing nodes in a network. It is based on the hierarchical routing paradigm, which splits sensors twice to combine clusters to detect the changes in the scenario. The cluster head is then separated into second-level cluster head to use two levels of threshold - hard and soft - to sense immediate and changes. The hard threshold then allows the nodes to transmit data only when the sensed attribute is within the range of required values, thereby acting as a high-pass filter. The soft threshold decreases the count of transmissions by eliminating all changes that may have been allowed, when there is little to no change in the attributes that are sensed, acting as a low-pass filter. This is best suited for crucial applications, ranging from intrusion to blast detection, and the like. One disadvantage is that TEEN is not applicable for situations where user requires data on a periodic basis.

H. "Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol"[8]:
APTEEN, short for "**A**da**p**tive **T**hreshold Sensitive **E**nergy **E**fficient Sensor **N**etwork Protocol" is an extension of TEEN protocol, that tries to bridge the gap between collection of data at regular intervals and for critical applications as well. In this protocol, once the cluster heads are fixed in each cluster period, the cluster sends attributes like threshold, schedule and time to count to the nodes. The comparison between TEEN, APTEEN and LEACH show the following rankings in terms of energy usage and longer life span of the network (highest number is best):

1. LEACH
2. LEACH-c
3. APTEEN
4. TEEN

While TEEN transmits only time-critical data, APTEEN improves this by supporting regular transmission for time-critical data. The prime disadvantage of this is the overhead and time taken to form clusters.

I. "Hierarchical Geographic Adaptive Fidelity" [9]:
HGAF, short for Hierarchical Geographic Adaptive Fidelity, is an improvement for an adaptive fidelity algorithm for geographic regions, called GAF. It saves battery of the nodes, by placing a high number of nodes in an observed area, and selecting only a few nodes to send data, thereby reducing number of nodes required to form a network. HGAF conserves even more battery cell life, by increasing the physical size of a GAF cell, and adding a new layered structure form to select one active node in every cell. Since active nodes act as cluster heads, the connectivity between two cells must be guaranteed. Due to this limitation, there should be an active node in all areas, with their maximum size being R raised to the power 2/5. By limiting the location of the active cell and synchronising its location with all cells, the connectivity between two active nodes can now be guaranteed for large cells, compared to GAF. HGAF fares better than GAF with respect to count of survived packets, packet delivery ratio with a high node density. HGAF extends the life of randomly distributed and dense networks over GAF, by a factor of 200%.

J. "Efficient N-to-1 Multipath routing protocol"[10]:
This is a algorithm based on converge cast traffic pattern routing for sensor networks. This is implemented by discovering a multiple node disjoint path from all nodes simultaneously. In a stage called branch aware flooding, the sink node discovers a route by sending a message to update the route and creates a spanning tree. Every sensor node that gets the message elects the sender of that message as a parent node directed at the sink node. If the node in between snoops the route updating message, it creates a new alternative route to the spanning tree, following which new paths are discovered using multipath extension flooding technique. This can derive benefit from having multiple paths, to improve reliability of packet delivery. Concurrent or simultaneous data transmission over the same constructed path can affect the network performance in a negative way.

K. "Multipath Multispeed Protocol"[11]:
MMSPEED, short for Multipath Multispeed Protocol, is an extension to the SPEED protocol. In this protocol, the packets as assigned appropriate speed layers, which are segregated into speed queues based on their category, following which FCFS (First Come First Serve) is used to serve the data packets. MMSPEED takes advantage of the path diversity of multipath, thereby guaranteeing the requirements of reliability for every packet. This protocol controls the active paths and sends many copies of the authentic data over different paths. Each node in between chooses the next-neighbour hop and forwards data to the destination. One downside is that since the data transmission over long range worsens the energy requirements, this protocol cannot be applied reliably for long lifespan applications.

L. Multiple Object Metrics for multiple base stations[12]
The authors of [12] propose a multiple object metric that focuses mainly on four aspects. They claim that the placement of multiple base stations is not constrained to a single object metric; it is, instead considered to be a multiple object metric. The four proposed metrics are:

* The ratio of nodes that can communicate with BS, irrespective of single or multiple hop, indicates the coverage span of the nodes.
* The mean ratio of nodes post failure of a BS is the fault-tolerance level of the sensor network.
* Mean distance of a node and the nearest BS indicates energy usage of the network.
* Last, but not the least, the standard deviation of degree of the BS shows the mean delay of a network due to traffic congestion.

III. PROPOSED ALGORITHM

In this study, a scalar-based dissemination paradigm of data is proposed; it seeks to better optimise the traditional flooding paradigm. Since the network can contain up to hundreds or thousands of nodes, the nodes can potentially be divided into regions, with each region containing an arbitrary number of nodes. The scalar value of a region is hardcoded as an integer to all nodes of the region. Each region has a special node called the sub Base Station. It has a significantly higher processing and power capacity, as compared to the nodes, but not so much as the main base station itself. One region has one and only one sub Base Station. All the sub Base Stations are connected to each other, as well as the Base Station, across the regions. The proposed algorithm works as follows:

0. Start
1. Set source node and destination node.
2. Forward the data packet from source (can be a node, BS or sBS), to 'v' nearest neighbour nodes, where v is the scalar value associated with the region. If the reached node is the destination node for either of the data packets, go to step 7. Else, go to step 3.
3. From the v nodes reached, compare the distance from each of them to the sBS, and choose the minimal distance. If for either of the data packets, the reached node is sBS itself, move to step 5, else move to step 4.
4. Forward to sink node (sBS) of that region, by repetitively sending for 'v' nodes within that region, by looping step 3.
5. Forward from sBS to the main base station or sBS of the next region.
6. Loop from step 2, till Base station or desired target node is reached.
7. Stop

IV. CONCLUSION

The above stated scalar dissemination paradigm can be used for a wide range of applications; although yet to be tested in real life, the author believes that it is worthy of further study, review and implementation. In a future review, an improvement to reduce the forwarding time, based on the direction of the data packet to be forwarded will be proposed. Hard coding a directional ability onto the nodes will include a local positioning system, and an ad-hoc labelling system as well.

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