Comparison of Different Routing Protocols for Wireless Sensor Networks

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Abstract—**Wireless sensor network(WSN) is a heated research area of wireless communication and has a wide application future. Routing protocols design for wireless sensor network has much different with traditional wireless ad-hoc networks, which has become an open research area in wireless sensor networks. In this paper, the concept and architecture of wireless sensor network and the issues about it are introduced. And then this paper studies several traditional and novel routing protocols for sensor networks, as well as the features of these protocols. With configuration of relative parameters in NS2, the paper present the result of the simulation of the representative protocols in NS2. On the basis of the result, the paper makes a conclusion that the performance of these protocols. To sum up, the performance of these protocols differs under different circumstance, while in general, hierarchical routing protocols such as LEACH and LEACH-C are more effective than flat routing protocols such as MTE and Static Clustering.**

I. Introduction

As a typical application of pervasive computing, wireless sensor networks(Wireless Sensor Networks, referred to as WSNs) is a set of sensor nodes are deployed in the monitored area, these sensor nodes form a wireless communication self-organizing network, the perception of their coordination, collection and processing network coverage area in the perception of objects, and send to the observers. Sensor nodes, sensing object and the observer constitute the three elements of the sensor network. Wireless sensor networks combined with modern communications, MEMS and microelectronics, changing the interaction method between human and the nature, is widely used in military, environmental monitoring and Forecasting, health care, intelligent home, urban transport and other fields.

In wireless sensor networks, sensor nodes first by plane dispenser, manual layout or rocket deployed ejection, etc., then the node will send the collected data to the base station, and finally, the entire region with the base station data to the remote control center focus. In sensor networks, the vast majority of nodes only a small transmitter / receiver range, but the base station with a strong launch capability, it has a high energy, can send data back to remote control center. The base station gateway device can also be connected to the Internet or satellite, which achieve communication between task nodes and sensors. Figure 1 shows a typical wireless sensor network structure.

In WSN, micro-sensors play a vital role which are generally equipped with data processing and communication abilities. The sensing circuitry measures ambient conditions related to the environment surrounding the sensor and transforms them into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. The sensor sends such collected data, usually via radio transmitter, to a command center (sink) either directly or through a data concentration center (a gateway). The decrease in the size and cost of sensors, resulting from such technological advances, has fueled interest in the possible use of large set of disposable unattended sensors. Such interest has motivated intensive research in the past few years addressing the potential of collaboration among sensors in data gathering and processing and the coordination and management of the sensing activity and data flow to the sink. A natural architecture for such collaborative distributed sensors is a network with wireless links that can be formed among the sensors in an ad hoc manner. Networking unattended sensor nodes are expected to have significant impact on the efficiency of many military and civil applications such as combat field surveillance, security and disaster management. These systems process data gathered from multiple sensors to monitor events in an area of interest. For example, in a disaster management setup, a large number of sensors can be dropped by a helicopter. Networking these sensors can assist rescue operations by locating survivors, identifying risky areas and making the rescue crew more aware of the overall situation. Such application of sensor networks not only can increase the efficiency of rescue operations but also ensure the safety of the rescue crew. On the military side, applications of sensor networks are numerous. For example, the use of networked set of sensors can limit the need for personnel involvement in the usually dangerous reconnaissance missions.

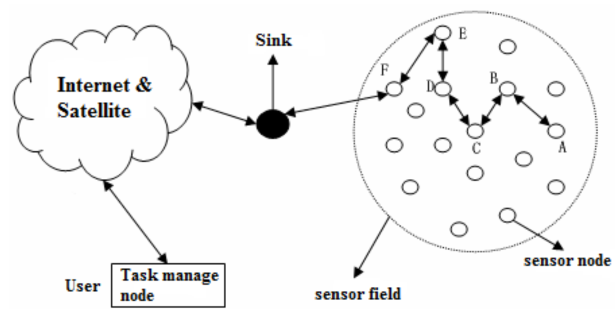

Fig. 1. A typical wireless sensor network structure

However, sensor nodes are constrained in energy supply and bandwidth. Such constraints combined with a typical deployment of large number of sensor nodes have posed many challenges to the design and management of sensor networks. These challenges necessitate energy awareness at all layers of networking protocol stack. At the network layer, the main aim is to find ways for energy-efficient route setup and reliable relaying of data from the sensor nodes to the sink so that the lifetime of the network is maximized.

Routing in sensor networks is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad hoc networks. First of all, it is not possible to build a global addressing scheme for the deployment of sheer number of sensor nodes. Therefore, classical IP-based protocols cannot be applied to sensor networks. Second, in contrary to typical communication networks almost all applications of sensor networks require the flow of sensed data from multiple regions (sources) to a particular sink. Third, generated data traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of a phenomenon. Such redundancy needs to be exploited by the routing protocols to improve energy and bandwidth utilization. Fourth, sensor nodes are tightly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management.

Due to such differences, many new algorithms have been proposed for the problem of routing data in sensor networks. These routing mechanisms have considered the characteristics of sensor nodes along with the application and architecture requirements. Current routing protocols can be classified as flat, hierarchical or location-based although there are few distinct ones based on network flow or quality of service (QoS) awareness.

Flat routing protocols distribute information as needed to any router that can be reached or receive information. No effort is made to organize the network or its traffic, only to discover the best route hop by hop to a destination by any path. Think of this as all routers sitting on a flat geometric plane.Heirarchical routing protocols often group routers together by function into a hierarchy. A hierarchical protocol allows an administrator to make best use of his fast powerful routers as backbone routers, and the slower, lower powered routers may be used for access purposes. In this way, the access routers form the first tier of the hierarchy, and the backbone routers form the second tier. Hierarchical protocols make an effort to keep local traffic local, that is, they will not forward traffic to the backbone if it is not necessary to reach a destination. Location-based protocols utilize the position information to relay the data to the desired regions rather than the whole network. The last category includes routing approaches that are based on general network-flow modeling and protocols that strive for meeting some QoS requirements along with the routing function.

In this paper, we will explore the routing mechanisms for sensor networks developed in recent years and make a comparison of their performance in NS2. Our aim is to help better understanding of the current routing protocols for wireless sensor networks and point out open issues that can be subject to further research.

II. The Protocols

A. LEACH

LEACH (low-energy adaptive clustering hierarchy) protocol as a node-based clustering protocol, it is the first to propose the wireless sensor network clustering routing protocol, its implementation process is cyclical, each round is divided into cycles cluster building phase and stable data communication phase. In the cluster setup phase, the adjacent nodes clusters dynamically, and using the following formula for the probability of randomly generated cluster head.

$$T(n) = \begin{cases} \frac{p}{1-p\times[r \bmod p^{-1}]} & n \in \mathbf{G} \\ 0 & \text{others} \end{cases}$$

where P is the desired percentage of cluster heads, r is the current round, and G is the set of nodes.

In the data transmission, the nodes in cluster send data to the cluster head, cluster head for data fusion and send the results to the sink node. Because cluster heads need to complete data integration, and base station communications, etc., so energy consumption si considerable. While LEACH algorithm could ensure equal probability of each node to serve as cluster head nodes in the network in order to make the balance of the consumption of energy.

B. LEACH-C

The introduction of central control mechanisms to ensure the cluster optimized distributed in the network to optimize network performance. This is the basis of LEACH-C protocol. LEACH-C protocol is also divided into set up phase and data transmission phase. In the cluster setup phase, all nodes have their location and energy information to the base station. The base station to calculate the average energy of all nodes, only the energy is greater than the average are eligible to become a cluster head node. Then the base station divides clusters using simulated annealing algorithm to select the cluster head node. Then broadcast to all nodes in the cluster head node ID information, each node receives the message according to judge their own identity. If the ID with their ID information are the same, a cluster head; otherwise, where the clusters are determined according to their own data transmission TDMA slot, and enter "sleep" state until the arrival of data transmission time slot. Data transfer phase, LEACH-C and LEACH same mechanism.

Due to LEACH-C head election mechanism, compared with LEACH, the cluster head election it is generated by the central control, energy and more protection, the resulting clusters are more evenly distributed. At the same time, by reducing non cluster head node and cluster head nodes of the communication distance, reducing the non-cluster head nodes transmit data to the energy consumed by cluster head in order to optimize the network energy consumption. However, the algorithm in the base station needs to know the location of each node and energy information, so that the network is not is a completely self-organizing network, the use of algorithms also subject to certain restrictions.

C. MTE

MTE protocol used to minimize transmission of energy to establish multi-hop transmission route. in the beginning of the simulation, it use correlation algorithm to determine its next hop neighbor node, which is nearest neighbor node in the direction to the base station, then data is sent to the base station through these hop neighbor nodes. In this way, nodes sense the environment to collecting information, but also for the other nodes to transmit data. When node sending data, the use of CSMA (Carrier Sense Multiple Access) mode monitor channel if the channel is busy, the node does not immediately send data; otherwise, it will send data to its next hop neighbor node. When a node dies, its upstream neighbor nodes send data to its downstream neighbor nodes to maintain network connectivity, which increases the energy consumption of the upstream neighbor node to send. If there is no correlation between the data (ie without data fusion), which is a way to minimize energy consumption.

D. Static clustering

Static clustering protocol using fixed cluster head to form a fixed cluster. It is equivalent to that LEACH-C after the first cluster maintain cluster head and the corresponding cluster unchanged. Member nodes within the TMDA slots send data to cluster head. Data fusion must be conducted before cluster head sends data to the base station. The advantage is no need to re-clustering algorithm, but the drawback is when the cluster head runs out of energy, the cluster members would lose connectivity with the base station.

III. Extension of NS2 for Routing Protocol for Wireless Sensor Network

Ns is a discrete event simulator targeted at networking research. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. Ns began as a variant of the REAL network simulator in 1989 and has evolved substantially over the past few years. In 1995 ns development was supported by DARPA through the VINT project at LBL, Xerox PARC, UCB, and USC/ISI. Currently ns development is supported through DARPA with SAMAN and through NSF with CONSER, both in collaboration with other researchers including ACIRI. Ns has always included substantal contributions from other researchers, including wireless code from the UCB Daedelus and CMU Monarch projects and Sun Microsystems.

NS2 is the version 2 of NS. The full name of NS2 Network Simulator Version 2. It is an object-oriented, discrete event driven network environment simulator mainly used for research to solve network problems, and has provided NS2 routing protocol for wireless sensor support. The LEACH protocol, for example, Figure 2 is a LEACH protocol structure in NS2, the protocol itself is realized by TCL Scripting language, the simulation can be seen from Figure 2, the process of LEACH protocol calls for each file the case. I nuamps.tcl the relative parameters of resource nodes are mainly set, including the general function and operation of the base station protocol required correlation function (compute the distance between nodes and compute statistics associated data (node energy consumption, the amount of data received by the base station and nodes survival)).

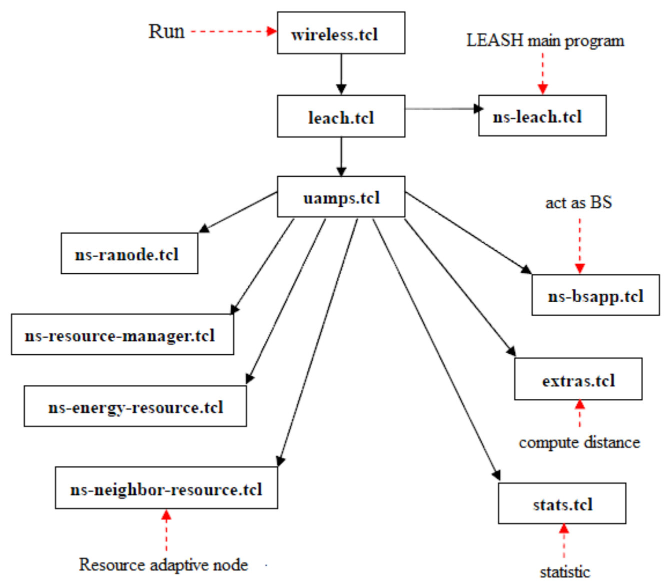

Fig. 2. A typical wireless sensor network structure

IV. Simulation

A. Set up environment

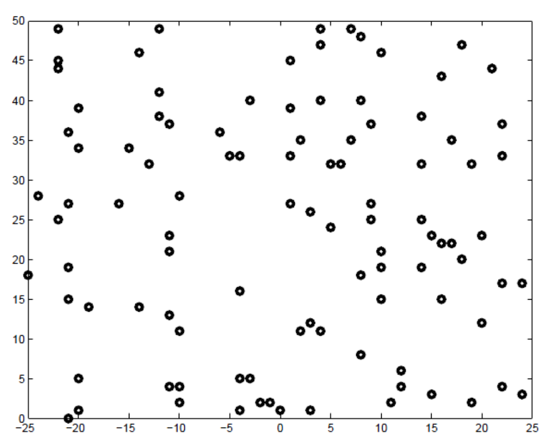

Fig. 3. 100 randomly distributed nodes (base station doesn't display)

Wireless sensor networks using NS2 simulation experiments to compare the performance of different protocols. Simulation, as shown in Figure 3, is a random arrangement of the 100-node network, and the base station is located at (50,175), which is identified in the figure. Simulation-related parameters are presented in Table I and Table II.

Description	Parameter	Value
Cross-over distance for Friis and two-ray ground attenuation models	$d_{crossover}$	$\frac{4\pi H_r h_t}{\lambda}$
Transmit power	P_t	$\varepsilon_{friis-amp} R_b d^2$, $d < d_{crossover}$ $\varepsilon_{2ray-amp} R_b d^4$, $d \geq d_{crossover}$
Receive power	P_r	$\frac{\varepsilon_{friis-amp} R_b G_t G_r \lambda^2}{(4\pi)^2}$, $d < d_{crossover}$ $\varepsilon_{2ray-amp} R_b G_t G_r h_t^2 h_r^2$, $d \geq d_{crossover}$
Minimum receiver power needed for for successful reception	$P_{r-thresh}$	$6.3nW$
Radio amplifier energy	$\varepsilon_{friis-amp}$ $\varepsilon_{2ray-amp}$	$\frac{P_{r-thresh}(4\pi)^2}{R_b G_t G_r \lambda^2}$ $\frac{P_{r-thresh}}{R_b G_t G_r h_t^2 h_r^2}$
Radio electronics energy	E_{elec}	50nJ/bit
energy for beamforming	E_{BF}	5nJ/bit
Bit rate	R_b	1Mbps
Antenna gain factor	G_t, G_r	1
Antenna height	h_t, h_r	1.5m
Signal wavelength	λ	0.325m
Cross-over distance for Friis and two-ray ground attenuation models	$d_{crossover}$	87m
Radio amplifier energy	$\varepsilon_{friis-amp}$ $\varepsilon_{2ray-amp}$	$10pJ/bit/m^2$ $0.0013pJ/bit/m^4$

TABLE I
RADIO MODEL PARAMETER VALUES

Nodes	100
Network size	$100m \times 100m$
Base station location	(50,175)
Radio propagation speed	$3 \times 108m/s$
Processing delay	$50\mu s$
Radio speed	1Mbps
Data size	500bytes

TABLE II
RELATED PARAMETERS IN TEST NETWORK

B. Simulation results and analysis

In the simulation experiment, each node in the network has an initial energy of 2J, with no restricion of the amount of data sent to the base station. The nodes send data, receive data and conduct data fusion will reduce its own energy. After the nodes run out of energy (death), they no longer send or receive data. Experiment assumes that the node in the static case consume no energy, so as carrier sense. Figure 4,5,6 shows using four protocols, the base station to receive the total amount of data over time, the total energy consumption of nodes over time, under a given energy the amount of data received by the base station.

Figure 4 shows by the four protocols,the amount of data received by the base station changes over time. From the figure, we could find in the same time, the amount of data sent to the base station under the MTE protocol is the least, which is due to the use of MTE protocol to send data is multi-hop manner, leading to a more time consumption on the transmission path. While the other three data transmission protocols are single-hop mode, even with data fusion, thus, the base station will receive more effective data with smaller capacity.

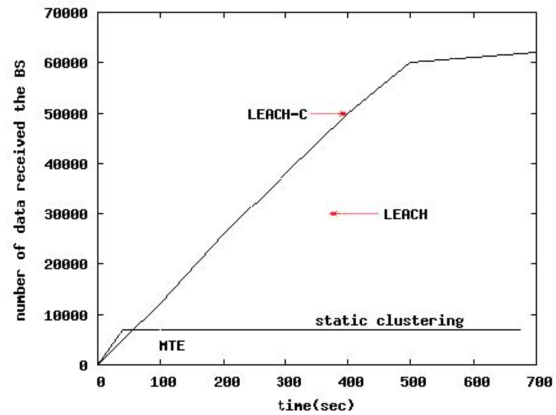

Fig. 4. Total amount of the data the base station receives

Figure 5 shows the total energy consumption of network nodes changes over time using four protocols. From the figure, it is obvious that LEACH, LEACH-C and the MTE protocol exhaust the total available energy of the network: 200J (2J/node * 100 nodes = 200J), and static clustering protocol consumed only 20J throughout the simulation process. This is because due to the premature death of cluster head, cluster members are unable to take full advantage of the effective residual energy, that is, cluster members will not work after the death of the cluster head. On the other hand, MTE protocol energy consumes energy fastest, this is because no data fusion and multi-hop transmission lead to a lot of redundant data transmission.

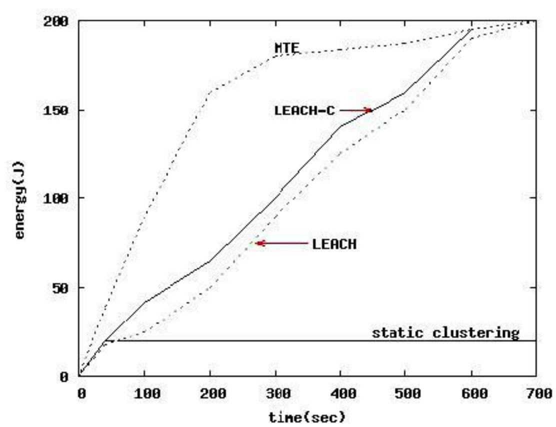

Fig. 5. The total energy consumption of network nodes

Figure 6 shows under a given amount of energy, the amount of data received by the base station changes. From the figure, in per unit energy consumption, LEACH and LEACH-C send more data to the base station, MTE protocol run out of energy with only 7,000 units of data sent, this is because it can not utilize local computation to reduce the amount of data sent, and the protocol spend too long time in the transmission path, so it consumes energy rapidly. Static clustering protocol sent a total of 8000 units of data with a energy consumption of 20J, after the death of the first cluster, cluster members are no longer working.

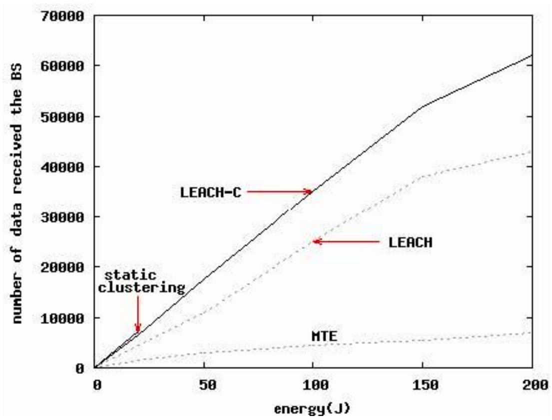

Fig. 6. The total amount of data received by the base station under a given amount of energy

Generally speaking, from 4, 5, 6, LEACH and LEACH-C are more efficient. And LEACH-C sent 40% more data to the base station than LEACH consuming per unit energy, mainly due to the location and energy information of all nodes reside in the base station, so that it can form a low energy consumption and better data transmission clusters.

Figure 7 and 8 shows the number of nodes alive changes over time in the network and when the amount of data received has been given, the number of nodes alive changes. As drawn from Figure 7, MTE protocol nodes survive longer, mainly due to less amount of data sent to the base station. As drawn from Figure 8,since nodes in LEACH use energy more efficiently, it is able to send 10 times more data to base stations than MTE protocol nodes with the same mortality rate. Therefore, rotation of cluster heads and the corresponding clusters have obvious advantages. Under static clustering protocol, the cluster is fixed. After the death of the cluster head, other nodes stop working, so the system also greatly shortened life expectancy.

V. Conclusion

Wireless sensor network routing protocol is now a heated issue, this paper uses NS2 network simulation platform for wireless sensor networks under the four routing protocols LEACH, LEACH-C, MTE and Static Clustering for the simulation, the results of four experimental protocols for performance are analyzed and compared. From the experimental results we could conclude that the four protocols have advantages and disadvantages in different environments, but it is undeniable that hierarchical routing protocols such as LEACH and LEACH-C are more effective than flat routing protocols such as MTE and Static Clustering.

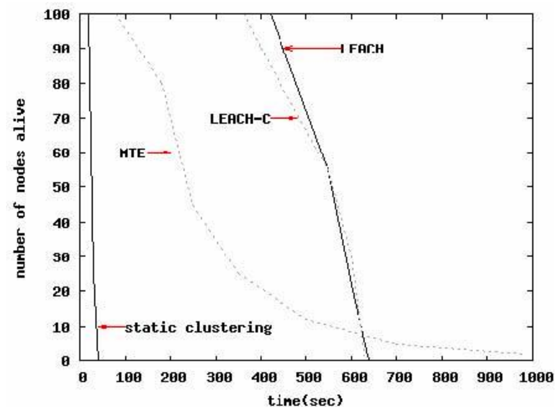

Fig. 7. The number of nodes alive in the network

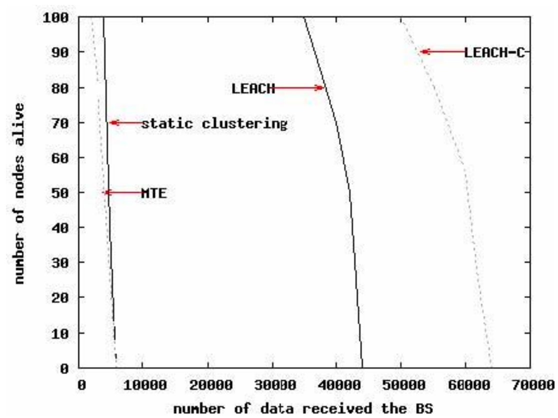

Fig. 8. The number of nodes alive when the amount of data received has been given

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