A COMPARATIVE STUDY OF THE WIRELESS SENSOR NETWORKS ROUTING PROTOCOLS SCALABILITY

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ABSTRACT

The common goals of designing a routing algorithm is not only to reduce control packet overhead, maximise throughput and minimise the end-to-end delay, but also take into consideration the energy consumption.
Scalability is an important factor in designing an efficient routing protocol for wireless sensor networks (WSNs).
Three metrics (power consumption, time of transmission and packet loss rate) are used in order to compare three routing protocols which are AODV, DSDV and LEACH.

KEYWORDS

Wireless sensor networks, routing protocols, energy consumption, scalability.

1. INTRODUCTION

A wireless sensor network typically consists of a large number of low-cost sensor devices with limited battery energy deployed in an unattended manner.

Routing and data dissemination are an important issue in wireless sensor networks (WSNs). The essential function of a WSN is to monitor a phenomenon in a physical environment and report sensed data to a central node called sink, where additional operations can be applied to the gathered data.

Routing techniques in wireless networks are another important research direction for WSNs. Some early routing protocols in WSNs are actually existing routing protocols for wireless ad hoc networks or wireless mobile networks. These protocols are designed to support general routing requests in wireless networks, without considering specific communication patterns in WSNs. Nevertheless, the customization of these protocols for WSNs and the development of new routing techniques have become most important research topics [1].

The remainder of the paper is organized as follows: in section 2, we present a description of the three routing protocols and in section 3 we briefly describe the simulator used. Section 4 shows metrics which are used to evaluate the routing protocols and we present in part 5, the simulation results. The last section concludes this paper.

2. RELATED WORK

In [2], three routing protocols are used in order to evaluate scalability issue in wireless sensor network. These protocols are: flooding protocol, the beacon vector routing protocol, and the

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probabilistic geographic routing protocol. In [3], a performance comparison of three sensor network routing protocols, namely, Rumor routing, Stream Enable Routing (SER) and SPIN. In [4], a novel approach using multiple-sinks (gateways) to provide scalability, is introduced for wireless sensor networks, and is compared with GPSR and Flooding protocols in terms of average system lifetime, time of the first node termination and the average number of terminated nodes on destination unreachable. In [5], the scalable SELAR protocol is evaluated and compared with two very well-known protocols - LEACH (Low-Energy Adaptive-Clustering Hierarchy) and MTE (Minimum Transmission Energy).

3. ROUTING PROTOCOLS

In this part, we describe the three routing protocols mentioned above.

3.1. Destination-Sequenced Distance Vector (DSDV)

The Destination-Sequenced Distance Vector (DSDV) routing protocol (Perkins and Bhagwat 1994) is a modified version of the classic Distributed Bellman-Ford algorithm [6].

Its operating principle is as follows: the base station maintains a routing table that contains:
- All possible destinations.
- The number of nodes (or hops) necessary to reach the destination.
- The sequence number (SN: sequence number) which corresponds to a destination node.

The sequence number, used to distinguish between old and new roads, prevents the formation of routing loops.

The update depends on two parameters: time, i.e the transmission period, and events.
Update packet contains:
1 - The new sequence number incremented of sending node.
And for each new road:
2 - The address of the destination.
3 - The number of nodes separating the node of the destination.
4 - The sequence number (data received from the destination) as it has been stamped by the destination.

The DSDV eliminates the two problems of "routing loop", and that of the "counting to infinity". However, in this protocol, a mobile unit must wait until it receives the next update initiated by the destination in order to update the input associated with this destination in the distance table, which makes the DSDV slow.

The DSDV uses periodic updates and event-based, causing excessive control in the communication.

3.2. Ad-hoc On-demand Distance Vector (AODV)

The AODV protocol is essentially an improvement of the DSDV algorithm previously discussed. AODV protocol reduces the number of broadcast messages and this by creating roads when needed, unlike DSDV, which maintains all the roads.

AODV uses principles of sequence numbers in order to maintain the consistency of routing information.

In the case of node mobility, routes change frequently so that the roads maintained by some nodes, become disabled. The sequence numbers allow using the most new roads (fresh roads).

In the same manner as in the DSR [7], AODV uses the route request in order to create a path to a destination. However, AODV maintains routes in a distributed manner, keeping a routing table, at every transit node belonging to the path sought.

A node broadcasts a route request if it would need to know a route to a destination and that this route is not available. This might happen if the destination is not known beforehand or if the existing road to the destination has expired its lifetime and it has become defective.

The field sequence number of destination RREQ packet contains the last known sequence number associated with the destination node. This value is copied from the routing table. If the sequence number is not known, the zero will be assumed. The source sequence number of RREQ packet contains the value of the sequence number of the source node.

To maintain consistent routes, a periodic transmission of the message "HELLO" is performed. If three messages "HELLO" are not consecutively received from a neighbor node, the link in question is considered failing.

The AODV protocol does not present a routing loop, moreover, it avoids the problem "counting to infinity" of Bellman-Ford, which provides fast convergence when the network topology changes.

3.3. Low-Energy Adaptive Clustering Hierarchy (LEACH)

Low-Energy Adaptive Clustering Hierarchy (LEACH), one of the first clustering algorithms proposed for sensor networks, is a distributed, proactive, dynamic algorithm that forms clusters of sensors based on the received signal strength and uses local Cluster Heads (CHs) as routers to the sink [8].

The operation of LEACH is broken up into rounds. Each round consists of a setup phase and a steady-state phase. The setup phase is when the nodes organize themselves into clusters. A node decides to be a cluster head for that round independent of all other nodes. The node will select a random number and if that number is less than the threshold value then the node will become a cluster head. The threshold value is based on the suggested percentage of cluster heads for that round (determined a priori), the number of times the node has already been a cluster head and the amount of residual energy in the node. The cluster head will broadcast an advertisement message indicating that it is a cluster head. A noncluster head node will join the cluster of which it received the strongest advertised signal from the cluster head. Each node will send a message to its new cluster head informing the cluster head that it is joining its cluster [9].

After the clusters are formed, the cluster heads create a transmission schedule for its member nodes based on TDMA (Time Division Multiple Access). This allows member nodes to further conserve energy by turning off their radio except during their scheduled transmission time. Another feature of LEACH that helps conserve energy is that after all member nodes transmit their data to the cluster head, the cluster head will fuse these data into a single packet, thus transmitting less data.

After a certain time (determined a priori), this round ends and the next round begins, which allows the role of cluster head to rotate among all nodes.

There are several disadvantages to LEACH. For example, there is a large cluster formation overhead. All cluster heads must broadcast advertisement messages to all nodes in their radio communication. Another downfall is that all cluster heads must transmit data to the base station, which is a single hop but may be a long distance, requiring more energy [7].

4. SIMULATOR

There currently exist a vast number of simulators for networks. A survey conducted by Akhtar [9] lists a total of 42 different network simulators. Many network simulators are currently available such as SensorSim, TOSSIM [10], OMNeT++ [11], NS2 [12], OPNET [13], GloMoSim, J-Sim, SENS [14], SENSE [15]. However, we use the NS2 simulator to evaluate the protocols performance because it is an open-source event-driven simulator designed specifically for research in computer communication networks. Since its inception in 1989, NS2 has continuously gained tremendous interest from industry, academia, and government. Having been under constant investigation and enhancement for years, NS2 now contains modules for numerous network components such as routing, transport layer protocol, application, etc. To investigate network performance, researchers can simply use an easy-to-use scripting language to configure a network, and observe results generated by NS2. Undoubtedly, NS2 has become the most widely used open source network simulator [2].

5. METRICS

We present in this part the metrics which are used to evaluate the routing protocols. These metrics are power consumption, time of transmission and packet loss rate.

5.1. Power Transmission

Nodes in most wireless sensor networks (WSNs) are powered by batteries with limited energy. Prolonging network lifetime and saving energy are two critical issues for WSNs [16]. The power consumption in the entire network is the difference between initial energy and residual energy of all the nodes. Thus, the calculation of these energies is done as follows:

$$E_{TI} = \sum (E_I(i))$$

Where
E_{TI} is Initial Total Energy
$E_I(i)$ is Initial Node (i) Energy

$$E_{TR} = \sum (E_R(i))$$

Where
E_{TR} is Residual Total Energy
$E_R(i)$ is Residual Node (i) Energy
Then

$$Power\ consumption = E_{TI} - E_{TR}$$

5.2. Average Transmission Time

This metric represents the time run out between the moment when a package of data leaves the transmitter and the moment when it is received by the destination i.e the sink. It is calculated as follows:

$$D(i) = T_R(i) - T_S(i)$$

Where
D(i) represents the time between emission and reception of the packet
$T_R(i)$ represents the time of reception of the packet (i).
$T_S(i)$ represents the time of transmission of the packet (i).

We will calculate the time of transfer for all the packets and we divide on the number of these packets to obtain the transfer average time for each packet to the basic station. That is done as follows:

$$D_{average}(i) = (\sum D(i)) / number\ of\ packets$$

Where $D_{average}(i)$ represents the transfer average time of packet (i).

5.3. Packet Loss Rate

This metric represents the ratio of loss packets and sent packets.

6. Simulation and Results

Figures 1, 2 and 3 below show respectively power consumption, average transmission time and packet loss rate related to the number of nodes for the three routing protocols AODV, DSDV and LEACH.

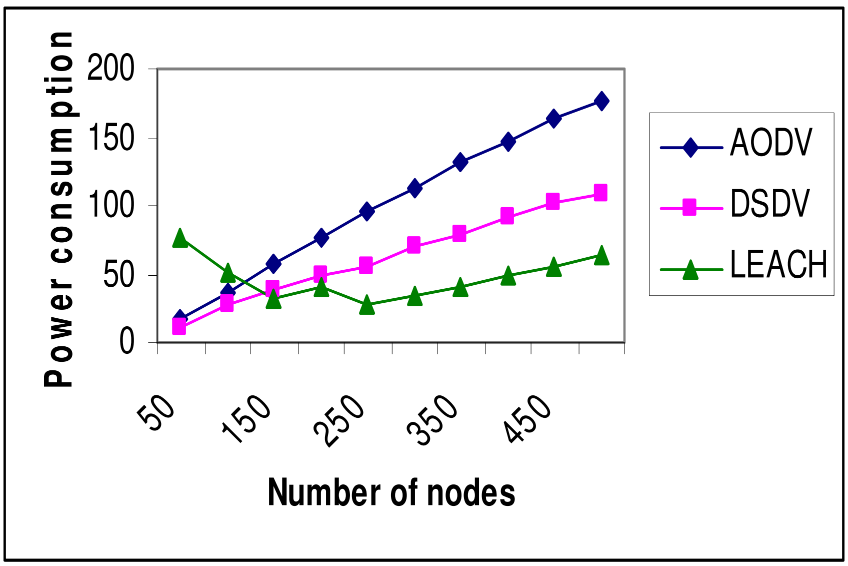

Figure 1. Power consumption

Figure.1 illustrates the influence of the network load on the quantity of power consumption by the network. One notices that the consumption of energy depends on the load of the network (i.e size of the network), this appears logical when the number of node increases; new nodes are deployed to collect and transmit the events.

We note that the two protocols DSDV and AODV consume both the energy in an almost identical way. On the other hand, protocol LEACH, consumes less energy than DSDV and AODV.

Thus, the results of simulation showed that LEACH can prolong from two to three times the lifespan of a sensors network compared to DSDV and AODV protocols.

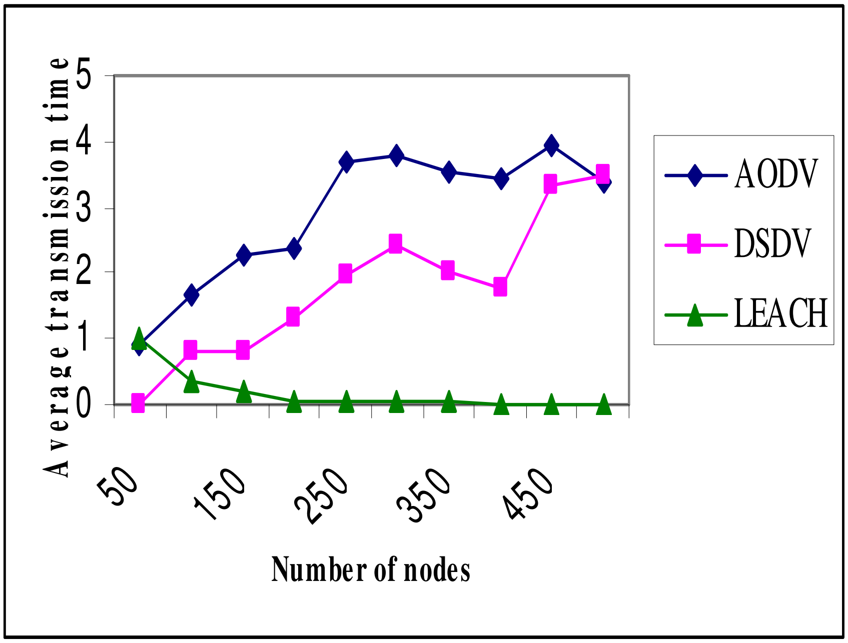

Figure 2. Average transmission Time

The figure.2 shows clearly that average transmission time for the two protocols (DSDV and AODV) is directly proportional with the load of the network. The increase in the time is due to the operation of the protocol. For example, if a node A receives a message and must transmit it to a neighbour B, according to protocols' DSDV and AODV, it uses the table of routing to determine the optimal road after having made calculations within each node to look for the shortest way. So a packet at the time of its passage by several nodes can undergo a more or less long delay. But for LEACH protocol, we see that time of transmission is inversely proportional with the number of nodes.

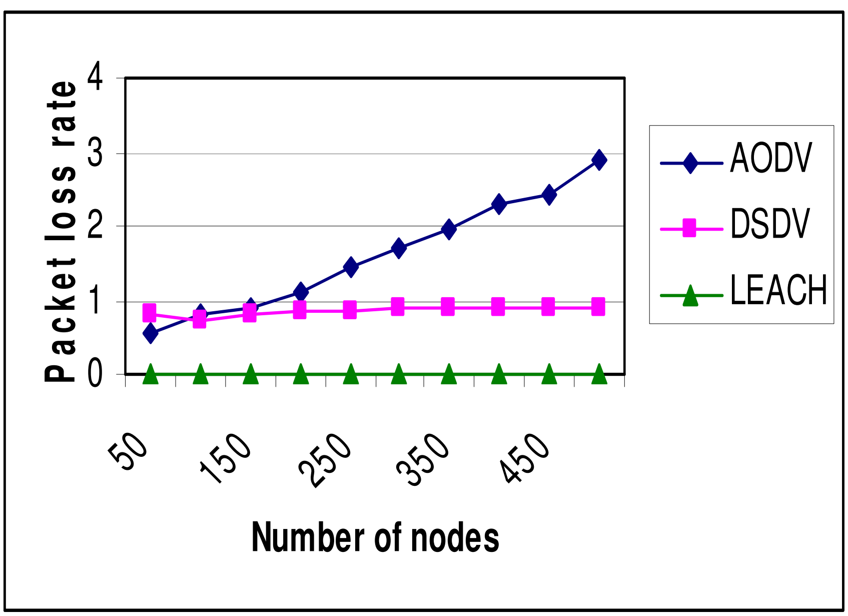

Figure 3. Packet loss rate

Figure.3 shows that packet loss rate for AODV protocol increases rapidly with the load of the network, whereas it remains constant for DSDV protocol. LEACH protocol does not present any loss of packet.

7. CONCLUSION

In this paper, we have evaluated the performances between protocols DSDV, AODV and LEACH in large scale by using the simulation tool NS2 (Network Simulator). The Protocol LEACH has a great capacity of conservation of energy, since it makes it possible to reduce half consumption of energy. It also presents a tiny average time of transmission compared to the protocols DSDV and AODV. This implies that LEACH is faster.

Following these simulations, we clearly note the optimality and the effectiveness of protocol LEACH compared to the protocols DSDV, AODV and this in term of consumption of energy and time of transfer.

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