Energy Efficient Routing Strategy for Wireless Sensor Networks

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Abstract

Wireless Sensor Network (WSN) allows large scale deployment for environment monitoring applications, especially rural areas where people hardly reach. In these rural areas, not only infrastructure networks are unavailable but modification or maintenance of sensor nodes such as charging of batteries, placing sensor nodes to desired location etc. are not possible, once they are established. There are major issues which affect WSN. The first issue is- there is possibility that the whole network may be collapsed due lack of energy and the second issue is- the network may be collapsed as their network setup can be changed due to changes in position of sensor nodes. In this paper, these two problems are reduced and a WSN is shown, which is energy efficient. For studying the performance of the algorithm in WSN environment, we modify ns2 source code and simulate them using ns2 simulator.

Keywords: Wireless sensor networks (WSNs), Ad-hoc on-demand distance vector routing (AODV), Sensor node.

1. Introduction

In WSN [1], when there are data packets to send, a path is established between the source and the destination sensor node. After the path establishment, data packets are sent from source to the destination through the established path. Once sending of data packet is over or if there is any node failure through this path, connection is terminated.

WSNs are becoming an interesting research area, as this network supports application such as environment monitoring, habitat monitoring, and object tracking etc. where people hardly reach. As it is very difficult to provide infrastructure to those areas or to supply power to the batteries of the sensor nodes, energy efficient strategy is used for WSN.

The location of sensor nodes are not known, at the same time the nodes might not have sufficient energy, and on the hind sight the node position changes frequently, for which path establishment has been a major issue. Path is established using AODV routing protocol [2] which flooded the whole network. When the signal reaches to the destination, the destination node gives a feedback through the When the source node gets this response from the destination node, it starts data transfer through this path. The data transfer continues until data transfer completes or any node through this path fails. If a node gets damaged or if a node changes its initial position, a new route is re-established from source to destination and data transfer starts again.

To increase the lifetime of WSN, energy consumption [3-6] is reduced by keeping sensor nodes in sleep state periodically and by minimizing transmission range of each sensor node. All the sensor nodes maintain two states: sleep and idle state. In idle state, sensor node is active and able to send and receive data. As data transfer is required only when there is any exceptional environmental condition, as a result data transfer is required only for a short period of time. Therefore keeping sensor node idle will consume more energy of WSN. To reduce this energy consumption, sensor nodes change state from idle to sleep. In sleep state, sensor node is unable to send and receive data, but in this state power consumption is very less almost equal to zero. Again to make a node active for data transmission, state changes from sleep to active. If the nodes are able to cover maximum transmission range then WSN can be set up by using minimum number of nodes but the problem with using minimum number of nodes is that there will be excess consumption of energy. In this paper, WSN is setup with an objective of reducing the energy consumption which implies that the number of sensor nodes will be higher.

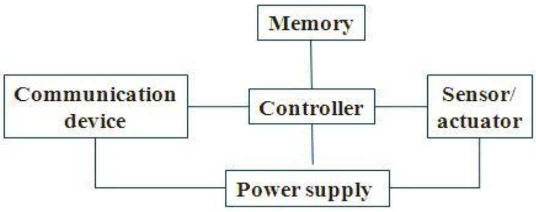


Fig 1. Architecture of a sensor node

2. Application of WSN

Recent advances in wireless communications and electronics have enabled the development of low-cost, low-power and multi-functional sensors that are small in size and communicate in short distances. Cheap, smart sensors, networked through wireless links and deployed in large numbers, provide unprecedented opportunities for monitoring and controlling environment, homes and cities. In addition sensor nodes can sense light, temperature, sound, motion etc. and able to transmit them to a remote base station. WSN has advantage for these types of applications because WSN consumes very less energy and WSN can handle node damages and node movement. Therefore once WSN is deployed it works for long time.

3. Routing protocols for WSN

The basic function of a routing protocol is to select the path from a set of available path that is most efficient. To maximize WSN lifetime, the path that consumes less power is selected. Three ad-hoc-routing protocols [7] DSDV, DSR and AODV are discussed in this paper.

3.1. Destination Source Distance Vector (DSDV)

Routing messages are exchanged between neighbouring mobile nodes. Updates are triggered in case routing information from one of the neighbours forces a change in the routing table. A packet for which the route to its destination is not known is cached while routing queries are sent out. The packets are cached until route-replies are received from the destination.

3.2. Dynamic Source Routing (DSR)

The DSR agent checks every data packet for source-route information. It forwards the packet as per the routing information. If it unable to find routing information in the packet, it provides the source route, if route is known, or caches the packet and sends out route queries if route to destination is not known. Routing queries, always triggered by a data packet route to its destination, are initially broadcast to all neighbours. Route-replies are send back either by intermediate nodes or the destination node, to the source, if it can find routing information for the destination in the route-query.

3.3. Ad-hoc On-demand Distance Vector Routing (AODV)

AODV is the combination of both DSR and DSDV protocol. It uses route discovery and route maintenance strategy of DSR and hop-to-hop routing strategy of DSDV. AODV allows nodes to pass messages through their neighbours to nodes with which they cannot communicate directly.

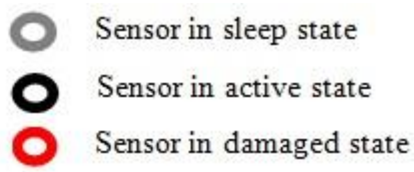


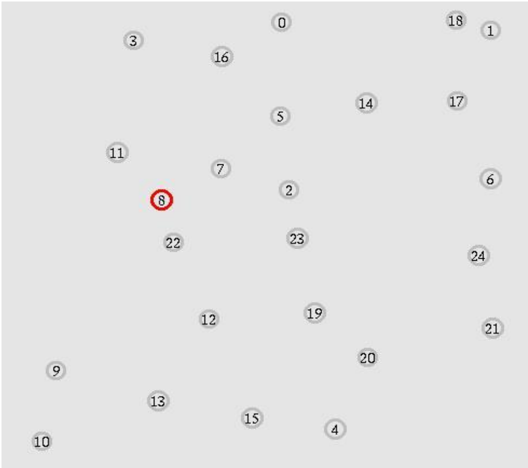
Fig 2. Three states of a sensor node

4. Network Simulator-2 (ns-2)

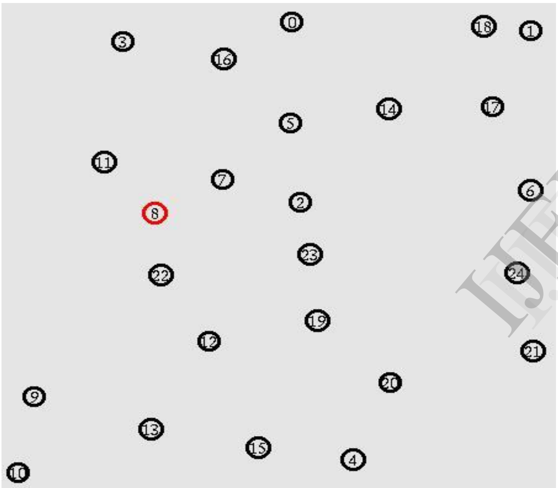
Here network simulator ns-2.34 is used for WSN implementation. ns-2 simulation environment offers great flexibility in investing the characteristics of WSN. In ns-2 environment, a WSN can be built with many of the set of protocols and characteristics as those available in the real world. This environment also supports node movement and energy constraints. ns-2 is an object oriented, event driven network simulator written in c++ and object oriented TCL (OTCL) script.

5. Implementation Details

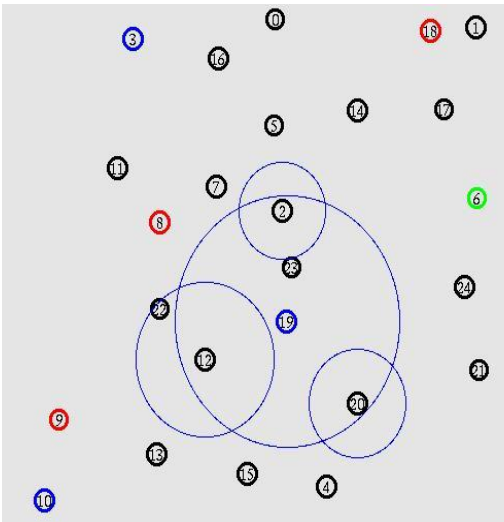
Here IEEE 802.15.4 [8] standard is followed for WSN implementation. Initially all the nodes are in sleep state. Sensor nodes with sufficient energy change state from sleep to active after a stipulated time. Here sleep time is set to 0.2 sec. After this sleep time, nodes are activated and if there is any data to send, the source node broadcast whole network using REQ message for path establishment. This broadcasting takes place from the source node to the neighbouring node which is within its transmission range and from this neighbouring again to neighbour's to neighbour. This process continues until it reaches to the destination. Once destination node receives this signal, the destination node reply with the acknowledgement message REP in the reverse path and ultimately reaches to the source. Once source node gets this acknowledgement from the destination, path is established and data transfer starts.



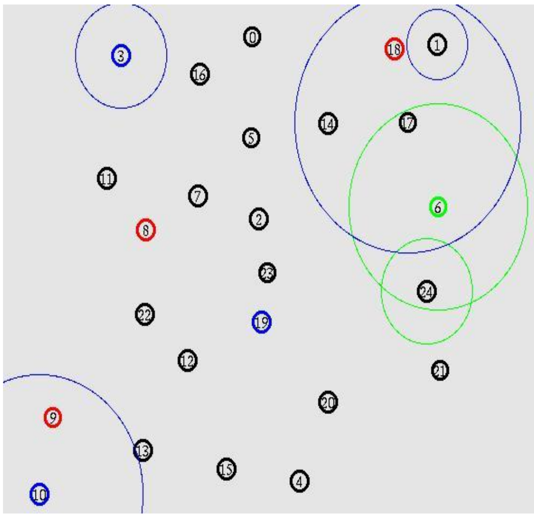
(a) Node 8 in damaged state and other nodes in sleep state



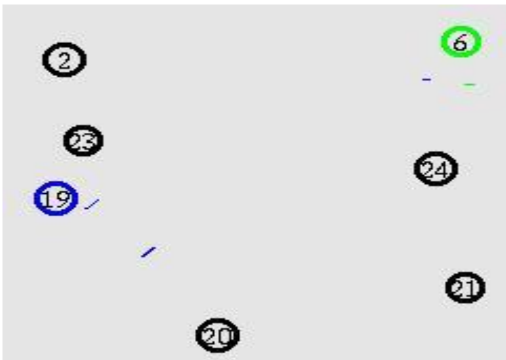
(b) All sleeping nodes waken up



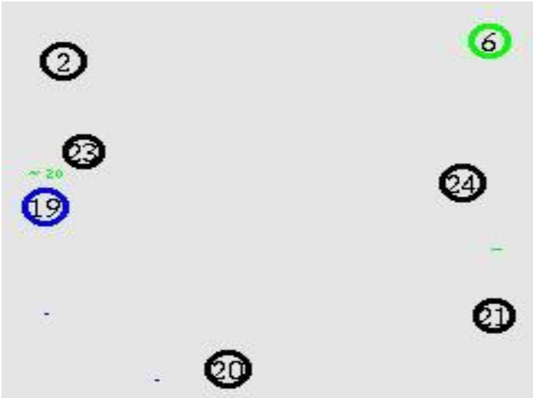
(c) Node 19 broadcasting request message (REQ) for destination node 6



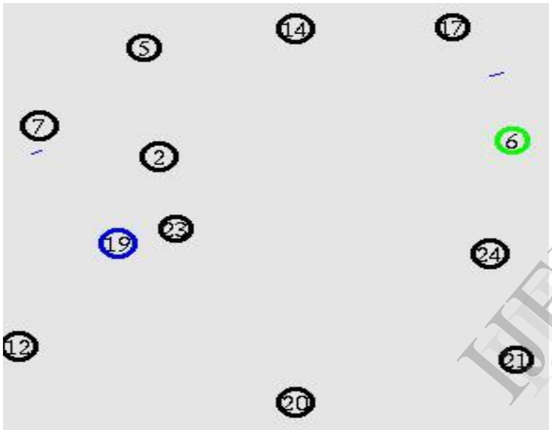
(d) Once REQ reaches to the destination node 6, node 6 immediately sending reply message (REP) for source node 19



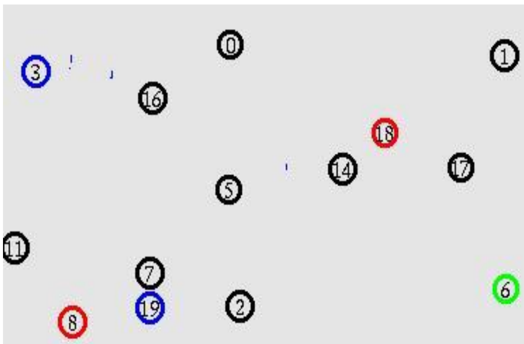
(e) Data packet transmission through 19→20→21→24→6



(f) Node 20 changed state to sleep and identified by neighbouring node 19



(g) Data packet retransmission from node 19 to 6 through 19→7→5→14→17→6



(h) Node 19 changing position and data packet transmission from 3 to 6 through 3→16→5→14→17→6

Fig 3. Data packet transmission using energy efficient approach with routing protocol as AODV

Here node 19 is the source node (blue colored) and node 6 is the destination node (green colored). Source node 19 broadcasted the whole network to establish path from node 19 to node 6 using AODV routing protocol (blue color sensing shown in Fig 3(c)). When it is ultimately transmitted to the destination node 6, it responds with the acknowledgement signal to the source node 19 along the reverse path it came using Address Resolution Protocol (ARP) (green color sensing shown in Fig 3(d)). In this process path is established. Now the path for data transfer is 19→20→21→24→6 (shown in Fig 3(e)). Data transfer continues until there is any node failure or link failure. Here data transfer continues for 0.3 sec and then few nodes go to sleep state. The node failure is identified by the neighboring node and failure node's number is shown (shown in Fig 3(f)). Here node 20 has changed state into sleep and it is identified by its neighboring node 19 (number 20 arises above node 19). Now data transfer stops between 19 and 6 because there is node failure along this path. Here we are considering node 19 is changing its position or node 19 is moving [9], therefore after few seconds, when node 19 has data to send it cannot send the data through the previous path. Now again there is path establishment phase and after reestablishment, path is: 19→7→5→14→17→6 (shown in Fig 3(g)).

Each node of the WSN [10] is configured with the routing protocol, link layer, media access control etc. shown below-

Table 1. Configuration of simulation environment

Parameter	Value
Routing Protocol	AODV
MAC Type	Mac/802_15_4
Interface Queue Type	Queue/DropTail/PriQueue
Interface Queue Length	50
Antenna Type	Antena/OmniAntenna
Propagation Type	Propagation/TwoRayGround
Physical Type	Phy/WirelessPhy/802_15_4
Average transmission range	15 meter
Data transmission rate	1.0Mb
Initial energy	100 Joule

Here AODV routing protocol and FTP traffic is implemented. Using energy model, we have shown how energy consumption is reduced using AODV routing protocol.

5. 1.Setting up transmission range

As we have seen in [3], energy consumption is dependent on distance. Therefore to decide average transmission range for which energy consumption is minimal, experiments have been done. Our experiment shows, energy consumption is minimal when the distance is 15 meter.

$$e(d) \propto d^2 \quad (1)$$

e(d) is the energy consumed to transmit a unit of data over a distance d and d is the average transmission range.

Transmission range is set in a way that it is possible to transmit from source to destination and such transmission should be in such a way that it covers maximum nodes. If there is less nodes through transmission path then each node looses more energy for transmission. Therefore transmission range is set to minimal distance which can cover its neighboring node.

Here for distance d=4 meter (m), transmission is not possible. For distance d=10m, though some nodes cover neighboring node but total transmission from source to destination is not possible. For distance d=20m, though transmission from source to destination is possible but each node looses much energy. Therefore transmission range is set in between 10m and 20m which is exactly 15m.

Table 2. Residual energy for different transmission range

Distance (in meter)	Transmission from source to destination	Initial energy of each node (in Joule)	Average residual energy of each node after end of transmission (in joule)
5	Not possible	1000	1000
10	Not possible	1000	98.240632
15	Possible	1000	98.205898
20	Possible	1000	98.121955

In trace file when first request packet transmission takes place from node 19, energy (residual energy) is 99.595783 joule, ei (energy consumption at idle/active state) is 0.402 joule, es (energy consumption at sleep state) is 0.000 joule, et (energy consumption at transmission time) is 0.000 joule and er (energy consumption at receiving time) is 0.000 joule.

5. 2.Setting up sleep time

As we know from [3], energy consumption is not only dependent on distance, but also on the time period for which a node is in active state.

$$e(d) \propto d$$
$$e(d) \propto t$$
$$e(d) \propto d.t$$
$$e = k.d.t \quad (2)$$

k is the constant

Where e is the energy consumption, d is the distance, t is the time in active state, E is the total energy.

Residual energy, $e_r = E - e$
$= E - k.d.t$

e_{r_1} is the residual energy of sensors with more energy and e_{r_2} is the residual energy of sensors with less energy.

$$\text{Now,} \; e_{r_1} - e_{r_2} = k(d_2 t_2 - d_1 t_1) \quad (3)$$

Assuming
$d_1 = d_2 =$ d (say)

$$t_2 - t_1 = \frac{1}{k}(e_{r_1} - e_{r_2}) \quad (4)$$

This is the sleep time difference between more powerful nodes and less powerful nodes. In trace file, for sleep time t, residual energy e_r of the nodes are shown. For some given values of t_1 and t_2 , e_{r_1} and e_{r_2} can be calculated from trace file and ultimately we get the value of the constant k.

To make the network energy efficient, sleep time of each node is properly used. Sleep time is the time a node is sleeping which means that it is not working. It is the time a node is not in active state. To transmit data from source to destination, neighbouring nodes should be within each other's transmission range but at the same time all the nodes should not be in active state because participation of all the nodes in transmission is not required. If all the nodes are in active state, data can be transmitted but large numbers of nodes who are not participating in data transmission but are in active state means that they will continuously loose energy. Therefore some of the sensors are in active state and others are in sleep state. We need to categorize the sensors who are in active state and who are in sleep state and also the amount of time node will be in active or sleep state. After categorizing the sensors are placed in two groups: sensors with more energy and sensors with less energy. Sensors with more energy will work more means these sensors will sleep less. Sensors with less energy will sleep more. Now sleep time of each node is determined-

In nam file (.nam), the animated scenario of the whole network such as node movement, sleep state of a node, active state of a node, damage state of a node and request packet, reply packet and data packet transmission is shown. Grey colored node are sleep state, black colored nodes are in active state, red colored nodes are in damage state, blue colored nodes are the sender node and green colored nodes are receiver node. Here node 19, node 10 and node 3 are the sender and node 6 is the receiver or destination. Request packet flooded from sender node 19 and it is shown using blue color. Reply packet comes from destination node 6 towards sender node 19 and it is shown using green color. Once reply packet reaches to the sender node, data packet transmission takes place and it is also shown using blue color and when data packet successfully reaches to the destination, destination node reply with the acknowledgement packet and it is shown using green color.

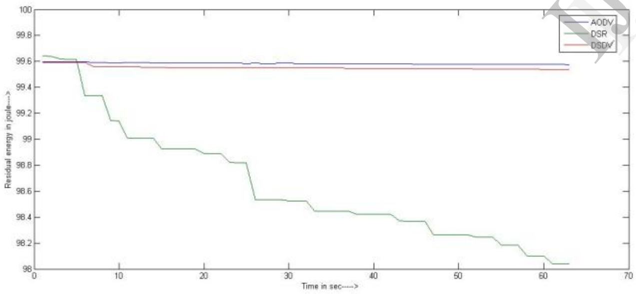


Fig 4. Comparisons on residual energy among AODV, DSDV and DSR routing protocols

5. 3.Performance comparison

All three routing protocols: AODV, DSR and DSDV are compared in terms of energy consumption. Considering same topology and same nodes for each of these routing protocols, AODV performs best. Residual energy falls very rapidly in case of DSR and DSDV, but not for AODV. Residual energy for each of these protocols is compared in the fig-4.

6. Conclusion

In this paper, how energy efficient WSN can be deployed in rural areas are studied. An IEEE 802.15.4 compliant WSN has been simulated in ns2. Delay and packet delivery ratio meet the desired parameter. In future energy consumption can be reduced using cluster based approach.

Acknowledgment

I am highly grateful to Mr Swastik Sinha, In-charge Computer Centre, Indian Association for the Cultivation of Science, Jadavpur, Kolkata who has been instrumental in supporting me and helping me come out of any tough situation which I faced during my research.

References

[1] I. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, A survey on sensor networks, IEEE Communications Magazine 40 (8) (2002) 102–114.

[2] Chia-Hung Tsai, Yu-Chee Tseng, A Path-Connected-Cluster Wireless Sensor Network and Its Formation, Addressing, and Routing Protocols, IEEE Sensors Journal, Vol. 12, No. 6, 2012.

[3] Ahmed E.A.A. Abdulla, Hiroki Nishiyama, Nei Kato, Extending the lifetime of wireless sensor networks: A hybrid routing algorithm, Computer Communications 35 (2012) 1056–1063.

[4] Der-Chen Huang, Hsing-Chien Tseng, Der-Jiunn Deng, Han-Chieh Chao, A queue-based prolong lifetime methods for wireless sensor node, Computer Communications 35 (2012) 1098–1106.

[5] Raquel A.F. Mini, Antonio A.F. Loureiro, Energy-efficient design of wireless sensor networks based on finite energy budget, Computer Communications 35 (2012) 1736–1748.

[6] Young-Long Chen, Jia-Sheng Lin, Energy efficiency analysis of a chain-based scheme via intra-grid for wireless sensor networks, Computer Communications 35 (2012) 507–516.

[7] Kevin Fall, Kannan Varadhan, The ns Manual, The VINT Project, 2011.

[8] Nicolas Fourty, Adrien van den Bossche, Thierry Val, An advanced study of energy consumption in an IEEE 802.15.4 based network: Everything but the truth on 802.15.4 node lifetime, Computer Communications 35 (2012) 1759–1767.

[9] Jae-Young Seol, Seong-Lyun Kim, Node mobility and capacity in wireless controllable ad hoc networks, Computer Communications 35 (2012) 1345–1354.

[10] The Network Simulator–ns-2, <http://www.isi.edu/nsnam/ns/>.