Chapter 14
Event Triggered Multipath Routing in Wireless Sensor Networks

A. V. Sutagundar, S. S. Manvi and N. C. Debnath

Abstract Reliable communication, optimal usage of energy and bandwidth are the critical issues in wireless sensor networks (WSNs). Efficient utilization of WSN resources prolongs the network life time. In this paper, we propose an event triggered multipath routing algorithm for WSNs. The proposed scheme operates in the following steps. (1) The sensor node (first sensed) that detects an event (called as event node) triggers multiple path discovery from itself to the sink node. (2) Event node initiates the route initialization phase where it sends the beacon packet to neighbor sensor nodes. The beacon packet comprises of event type (critical/noncritical), node id, location information, residual energy, available bandwidth, and hop distance. (3) Sink node computes the node disjoint paths. (4) Sink node computes the path weight factor based on the energy efficiency, path efficiency, and bandwidth efficiency. (5) If event is noncritical, then sink node selects a path with highest weight factor (based on cost function) and sends the path information to event node. For critical information, multipath information is sent to event node. To test effectiveness of the proposed scheme, it is analyzed in terms of packet delivery ratio, energy consumption, overhead for critical and noncritical information.

Keywords Wireless sensor network • Multipath routing • Event triggered

A. V. Sutagundar (✉)
Department of Electronics and Communication, Basaveshwar Engineering College,
Bagalkot, Karnataka, India
e-mail: sutagundar@gmail.com

S. S. Manvi
Department of Electronics and Communication, REVA Institute of Technology
and Management, Bangalore, India
e-mail: sunil.manvi@revainstitution.org

N. C. Debnath
Winona State University, Winona, MN 55987, USA
e-mail: Ndebnath@winona.edu

14.1 Introduction

Wireless sensor networks (WSNs) comprises of a set of smart devices, called sensors, which are able to sense and transmit information about the environment on which they are deployed [1, 2]. Due to recent technological advances, the manufacturing of small and low-cost sensors become technically and economically feasible. Large number of sensors can be networked in many applications that require unattended operations like military applications, habitat monitoring, environmental monitoring, etc. These sensors have the ability to communicate either among each other or directly to an external base station (BS), called as sink. The deployment of more number of sensors allow sensing over larger geographical regions with greater accuracy. Using conventional methods of data gathering and processing in WSNs could lead to some of the problems like energy consumption, redundant data transmission, increased latency, bandwidth overheads, etc. Each sensor node has the capability to gather and route data either to other sensors or back to an external sink node. The critical issue in WSN is network lifetime which is mainly dependent on the sensor node battery. To tackle the problem, redundant transmissions can be minimized by certain techniques like data fusion, data aggregation, etc.

Routing in WSNs is very challenging due to the features that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks [3, 4]. Due to the relatively more number of sensor nodes, it is difficult to build and maintain the global addressing scheme for the deployment of a more number of sensor nodes as the overhead of ID maintenance is high.

Some of the related works are as follows. There are several requirements for a routing algorithm in WSNs. The main objectives of WSN routing algorithm are: both energy efficient and energy balancing are to be achieved in order to prolong the lifetime of sensor networks, algorithm should follow a distributed control for scalable WSN and it needs to be robust to diverse potential event generation patterns [5]. The work given in [6] presents a work to prolong the network lifetime of WSNs using multipath routing based on a family of flexible routes with soft quality of service guarantees in terms of the packets delivery latency. The reduction in the total energy consumption of WSNs in multi-hop data aggregation is done by constructing energy efficient data aggregation trees [7]. An energy efficient clustering routing (EECR) algorithm for WSNs is presented in [11, 12]. Sensor network topology is organized into several clusters and selection of cluster head is based on the weight value and the residual energy that leads to uniform energy dissipation among the sensor nodes. A routing protocol for WSNs to support an information-fusion application is presented in [8]. In [9], agent-assisted QoS-based routing algorithm for WSNs is described. Multi-agent system is used to monitor changes in-network topology, network communication flow, and each nodes routing state. Agents can participate in in-network aggregation, routing, and network maintenance. The Nonagent-based multipath routing (NABMR) in WSNs is a hazard aware multipath reliable routing algorithm [10].

Objectives of the proposed scheme are as follows. (1) Selection of disjoint paths from event node to the sink node. (2) Computation of the weight factors for

the available disjoint paths based on available residual energy, bandwidth, and distance. (3) Selection of path(s) based on the criticalness of an event.

The rest of the paper is organized as follows. Proposed event triggered multipath routing in WSNs is discussed in Sect. 14.2. Planned simulation is discussed in Sect. 14.3. Finally, Sect. 14.4 concludes the paper.

14.2 Proposed Work

In this section, we describe network environment, model for multipath routing in WSN for critical and noncritical data.

14.2.1 Network Environment

The network environment considered for data gathering, aggregation, and routing in WSNs is as shown in Fig. 14.1. It comprises of sensor nodes with diversified sensing competence and a sink node. Sensor nodes sense the data periodically and send it to sink node with multi-hop communication. In the proposed scheme an event node forms a cluster and is also called cluster head.

Some of the assumptions that are considered in this work are as follows.

- All nodes (sensors and sink nodes) in the network are static and have same initial energy.
- During deployment phase, each sensor node has full energy.
- All the sensor nodes are equipped with global positioning system (GPS), processor, and transceiver for the communication.
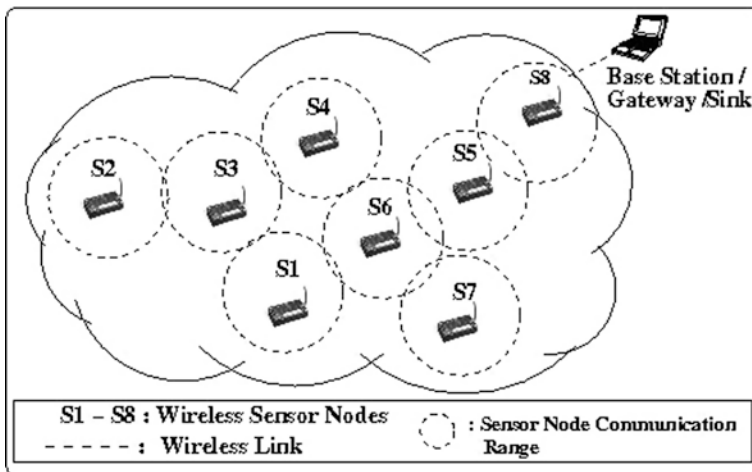

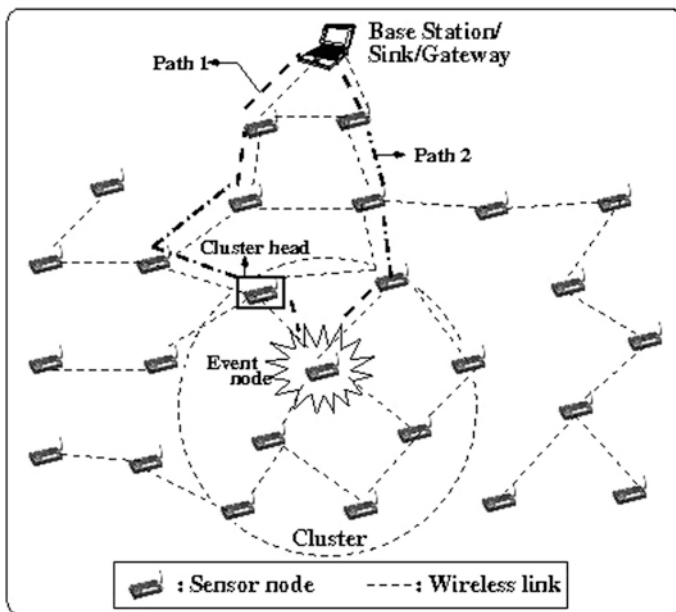**Fig. 14.1**   Network environment

Fig. 14.2 Event triggered multipath routing in WSNs

- All nodes reconfigure their transmission power.
- A sensor node (active node) participates in aggregation if and only if the sensed values in a particular time window drifts by a given threshold.
- A sensor node which detects the event forms the dynamic cluster.
- Cluster head gathers data from all sensor nodes within the cluster.

14.2.2 Event Triggered Multipath Routing

Figure 14.2 depicts event triggered multiple path discovery in WSNs. There are two paths that are computed by sink node that lead to event node or cluster head. Cluster head aggregates all the data of sensor nodes in the cluster, and sends to sink node. The discussion of aggregation is not in the scope of the paper.

14.2.2.1 Path Parameters

Sink node computes the path parameters (assuming n nodes in path) such as path length, the minimum and maximum of the path (Eqs. 14.1 and 14.2), path energy factor (Eq. 14.3), path distance factor (Eq. 14.4), and path cost function (Eq. 14.5).

$$E_{R\min} = \text{Min}\{E_R(1), E_R(2), \ldots E_R(n)\} \tag{14.1}$$

Where $E_{R\min}$ is the minimum residual energy among the nodes in a path.

$$E_{R\max} = \text{Max}\{E_R(1), E_R(2), \ldots E_R(n)\} \qquad (14.2)$$

Where $E_{R\max}$ is the maximum residual energy among the nodes in a path.
   Energy factor (E_{fact}) of path is given by Eq. (14.3).

$$E_{\text{fact}} = \frac{E_{R\min}}{E_{R\max}}. \qquad (14.3)$$

The distance factor (D_f) for each path is computed by using Eq. (14.4).

$$D_f = \frac{P_d}{P_{\text{hc}}} \qquad (14.4)$$

where P_d is the path distance and P_{hc} is the hop count.
   Cost function, C_f of each path is given by Eq. (14.5).

$$C_f = E_{\text{fact}} + D_f \qquad (14.5)$$

Sink node prioritize the paths by using C_f. For noncritical information transmission, a path with highest C_f is chosen whereas for reliable critical information transmission, paths with C_f in decreasing order are selected.

14.2.2.2 Operation Sequence

The sequence of the operation for the proposed scheme is as follows. (1) Sensor nodes read the neighbor node information, which can be used for aggregation. (2) A sensor node that detects an event, initiates the route discovery process from event node to sink node. Event node also acts as cluster head, which may aggregate the information within the cluster. (3) Event node floods the beacon packet toward the sink node. The beacon packets move from node to node and reach the sink node. If a beacon packet does not find sink node within given hops, such a beacon packet expires. Duplicate beacon packets will be rejected by the nodes. (4) Beacon packets that successfully reach the sink node deliver the path information to the sink node. The information comprises of: sensed information, type of information (critical or noncritical), residual energy in the traversed nodes, distance traveled, and hop count. (5) Sink node computes the multiple paths based on information received through beacon packets using shortest path algorithm (using hop count as metric) applying iteratively by truncating selected links for the path in every iteration. Multiple paths are ranked based on the cost function as discussed above. (6) Sink node checks and verifies the criticalness of the event. Discussion of verification is not in the scope of this work. (7) A path (single path) with highest C_f is chosen for critical information, whereas for reliable critical information transmission, paths with C_f in decreasing order are selected. Sink node sends the path(s) information over the chosen first path to event node. And, (8) Event node takes the action of sending data upon receiving the path information by using aggregation, if necessary. The forwarding nodes in the path may also aggregate the information.

14.3 Simulation

The proposed scheme has been simulated in various network scenarios using C++ programming language. A discrete event simulation is done to test operation effectiveness of the scheme. In this section, we describe the simulation model and the simulation procedure.

14.3.1 Simulation Model

WSN is generated in an area of $l \times b$ square meters. It consists of N number of static nodes, placed randomly. Each node is associated with energy E_f joules and transmission range R meters. The communication environment is assumed to be contention-free. The transmission of packets is assumed to occur in discrete time. A node receives all packets heading to it during receiving interval unless the sender node is in nonactive state. We assumed the channel as error free. Sensor MAC protocol (S-MAC) [13] is used for media access. Free space propagation model is used with propagation constant β.

14.3.2 Simulation Procedure

Simulation inputs for proposed scheme are as follows: $l = 5{,}000$ m, $b = 5{,}000$ m, number nodes $N = 300$, transmitting nodes $(Nt) = 40$–200, $\beta = 2.5$, $R_c = 300$–500 m, $E_f = 1$ kJ, $T_{\text{rpkts}} = 256$ per second, $BW_{\text{single-hop}} = 5$ Mbps, size of sensed data at each node $S_d = 5$ Kbytes, size of the processing code $S_{\text{proc}} = 3$ Kbytes.

Simulation procedure for the proposed scheme is as follows.

1. Topology generation: Generate the WSN in the given area by placing nodes randomly. Each node maintains a data structure to store the information as specified by the scheme.
2. Sensor node gets the neighbor node information.
3. Apply the proposed scheme.
4. Compute performance parameters of the system.

14.3.3 Results

Figure 14.3 presents packet delivery ratio for given number of nodes involved in transmission. The amount of data generated increases with increase in number of nodes. As the number of nodes increase, the amount of data generated from source sensor nodes will increase. Hence, available bandwidth may not be sufficient for
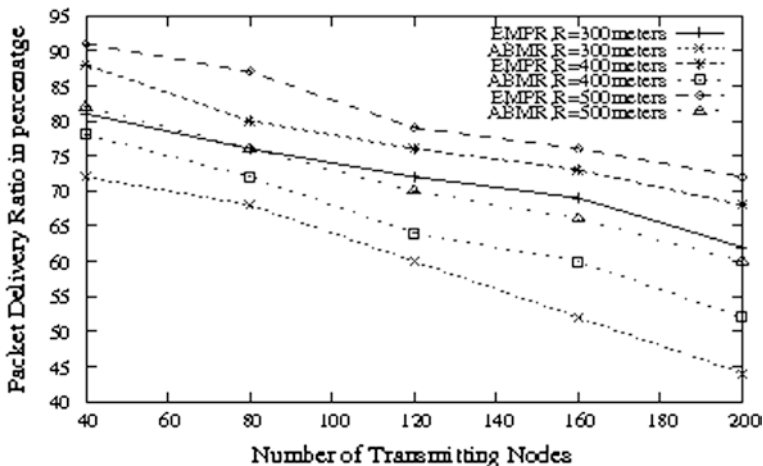
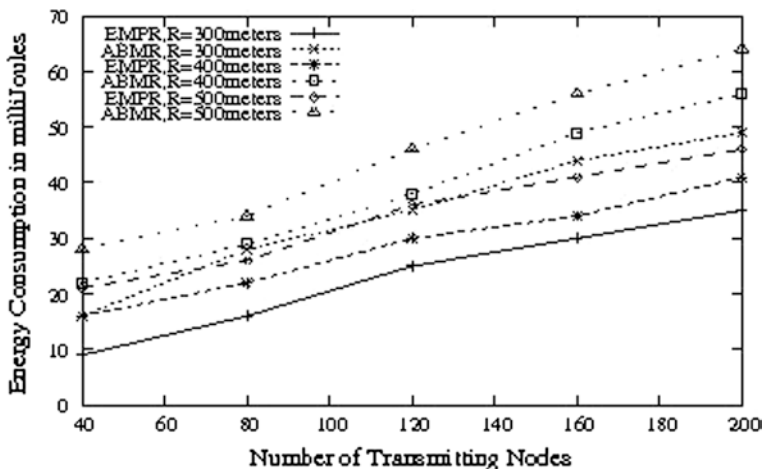**Fig. 14.3**   Packet delivery ratio versus number of transmitting nodes

Fig. 14.4   Energy consumption in millijoules versus number of transmitting nodes

successful transmission of the data thereby causing decrease in the packet delivery ratio. We can also notice from the results that the proposed EMPR performs better compared to ABMPR.

Figure 14.4 explains the energy consumption for the given number of transmitting nodes. With increase in the number of nodes and communication range, the energy consumption increases. Energy consumption is due to gathering of partial topology information, path computation, path information transmission, and reception. The proposed scheme uses PDA for partial topology information gathering and SMA for path computation. The packet delivery ratio increases
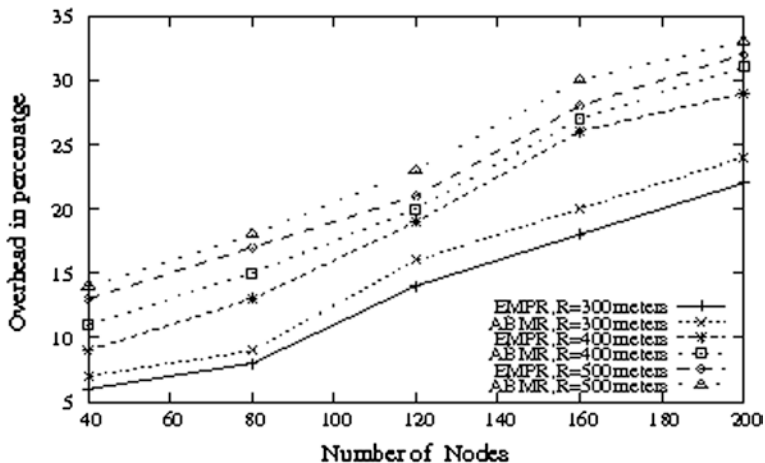
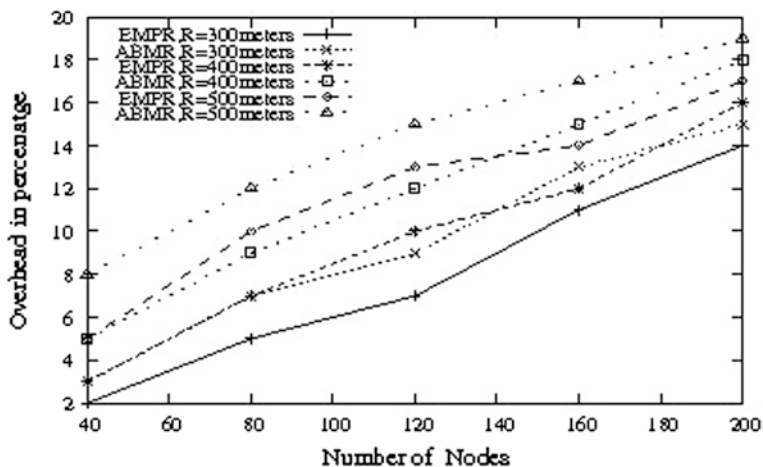**Fig. 14.5** Overhead in percentage versus number of nodes (critical)

Fig. 14.6 Overhead in percentage versus number of nodes (noncritical)

with increase in transmission range since number of isolated nodes will be very less. LEDMPR performs better compared to ABMPR since LEDMPR uses partial topology information whereas ABMPR uses the total topology information.

Figures 14.5 and 14.6 presents the overhead with the given number of nodes and communication range for critical and noncritical data communication. For critical information communication, proposed scheme uses the multipath routing in order to achieve the reliable communication, whereas noncritical information communication uses the single path with highest weight factor. For increase in the number of nodes and communication range, the number of transmissions and computations will increase.

14.4 Conclusion

In this paper, we have proposed an energy efficient reliable event triggered multipath routing in WSNs. Multipaths are computed based on the path cost function depending on path energy factor and path distance factor. The proposed scheme is tested in terms of packet delivery ratio, energy consumption, overhead for critical and noncritical data. However, there are some limitations with respect to security and validation. We are planning to employ certain strategies based on certificates and digital signatures for path security and validation of beacon packets.

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