Journal of Korea Multimedia Society Vol. 18, No. 8, August 2015(pp. 909-914)
http://dx.doi.org/10.9717/kmms.2015.18.8.909

Interference Aware Multipath Routing in Multi-rate Wireless Sensor Networks

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ABSTRACT

In wireless sensor networks, sensor nodes have a short transmission range and data is transferred from source to destination node using the multi-hop transmission. Sensor nodes are powered by battery and the link qualities are different, and the routing protocol in the wireless sensor network is one of the important technical issues. Multipath routing was proposed to reduce the data congestion and increase data throughput. In the multipath routing, however, each path can be interfered by the other path, and it can aggravate network performance. In this paper, we propose the multipath routing scheme for multi-rate wireless sensor networks. The multipath routing selects transmission paths to minimize transmission delay and path interference.

Key words: Wireless Sensor Network, Multipath Routing, Multi-hop Transmission, Routing Protocol

1. INTRODUCTION

Wireless sensor networks have various application services. Generally, wireless sensor network has short wireless links and make network using multi-hop transmission. In a multi-hop transmission, some links can be broken, some links can erroneous channel, and batteries of nodes can be out. The wireless sensor network has property of ad-hoc network and it is established easily and the nodes can freely join or drop out of the network [1,2]. A wireless channel suffers from time-varying fading caused by multi-path propagation and destructive superposition of signals arriving via different path. In those time-varying situations, if the nodes have battery out or drop out of the network, routing path cannot work and transmission is not possible. Traffic congestion also make serious problem and it can stop the data transmission. Especially in the multimedia transmission, increased amount of data can induce large transmission delay.

To solve these problems, various multipath routing techniques were proposed [3,4]. Multipath routing distributes traffic into different paths and can prevent overflow of traffic. Multipath routing also can provide space diversity gain. Diversity techniques are a widely applied to reduce detrimental effects of time-varying fading When one routing path is broken, data can be transferred via the other different path. When we design the multipath protocol, the important issues are which paths to be selected and how to distribute the traffic.

When we determine the multipath, we should consider the effect of interference among the paths. In a single path transmission, there is no performance degradation caused by path interference, but path interference can cause severe performance degradation in the multipath routing. To avoid path

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Receipt date : Jun. 30, 2015, Revision date : Jun. 30, 2015
Approval date : Jul. 17, 2015

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interference, location based multipath routing protocol were proposed [5]. In that protocol, additional equipment such as GPS (Global Positioning System) receiver or localization techniques [6, 7] are required to get the positional information, which increases the complexity, size and cost of nodes.

To cope with unreliable transmission, several standards support multi-rate transmissions. Transmission rate is deeply related with the transmission time and overall path delay. Earlier routing protocols considered only the minimum number of hops [8]. Some studies, however, considered the multi-rate in routing protocol[9]. In the multi-rate wireless sensor networks, minimum hop route might not mean the minimum route delay. In the multi-rate based multipath routing, it is required to set up the paths to increase the throughput considering the transmission rate and end-to-end delay due to the channel condition, and also minimize the path interference. In this paper, we consider wireless sensor networks with multi-rate capability and propose multipath routing scheme to minimize interference among the paths without any positioning system.

The rest of this paper is organized as follows. In Section II, we present the routing method considering multi-rate transmission in wireless sensor network. In Section III, we propose a multipath routing scheme to avoid path interference. Section IV shows the simulation environment and the results. Finally, we conclude our work in Section V.

2. ROUTING FOR MULTI-RATE WIRELESS SENSOR NETWORK

In this paper, we consider the IEEE 802.11b based transmission scheme. The IEEE 802.11b standard supports 4 different transmission rate such as 1Mbps, 2Mbps, 5.5Mbps, 11Mbps. The conventional AODV(Ad-hoc On-demand Distance Vector) [8] routing protocol set up paths considering minimum hop count and it is proper routing protocol to minimize the end-to-end delay when the transmission rate is fixed. In multi-rate transmission, however, end-to-end delay depends on both of hop count and transmission rate. Even though the number of hops is high, if the links can support highest transmission rate, the end-to-end delay becomes short. In this paper, we adopt basic concept of AODV protocol but do not select the paths according to the number of hops but the end-to-end delay.

As shown in Fig. 1, there are two paths from source node to destination node. Path 1 requires two hops to the destination node and it is less than that of path2. The links between the nodes has different rate, $R_{i,j}$ is the data rate of i-th path and j-th link. If the and are same data rate 1 Mbps and the links in the path 2 has 11Mbps data rate, path 2 has the less delay than the path 1 even if path 1 has smaller number of hops.

Data rate between the nodes is determined by the channel condition. After data rate between nodes i and j, $R_{i,j}$, is determined, the transmission delay $D_{i,j}(=1/R_{i,j})$ can be obtained. Receiving RREQ (Route Request) packet, the node add link delay $D_{i,j}$ to the accumulated delay $T_{i,j-1}$ and send the total delay $T_{i,j}$ by RREQ packet. If RREQ is received again through the different path, the node compares the total delay and if it is smaller than the prior path, the node update its routing information[10]. The following equation shows the path selection method using link delay.

$$path = \min_i \sum_{j=1}^{N_i} D_{i,j} = \min_i \sum_{j=1}^{N_i} \frac{1}{R_{i,j}} \tag{1}$$

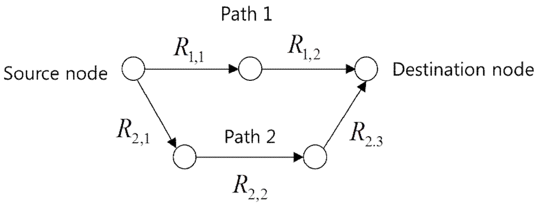

Fig. 1. Routing path in multi-rate wireless sensor networks.

where N_i is the number of hops in the i-th path.

3. INTERFERENCE AWARE MULTIPATH ROUTING

3.1 Transmission range and interference range

In the wireless sensor networks, the distance between transmitter and receiver node should be less than specific distance to communicate each other. Transmission range is the range that node can transmit data without error. Even though one node is outside of the transmission range of transmitter node and cannot receive the transmitted data, the node can be interfered by transmitted data. The interference range is the range that transmitting node can interfere with the other nodes. As shown in Fig. 2, interference range is larger than transmission range and it depends on the channel condition. Generally interference range is considered to be 1.8 times larger than transmission range[11].

Transmission and interference range is determined by the received signal power and it can be calculated by the following simple path loss model.

$$P_r = KP_t\left(\frac{d_0}{d}\right)^r \tag{2}$$

where $d_0$is the reference distance for the antennal far field, K is constant path-loss factor and r is path-loss exponent. P_t and P_t are transmitted power and received power respectively. Path-loss exponent is determined by channel environment and it is about 1.6~1.8 in the LOS (line of sight) channel environment[12].

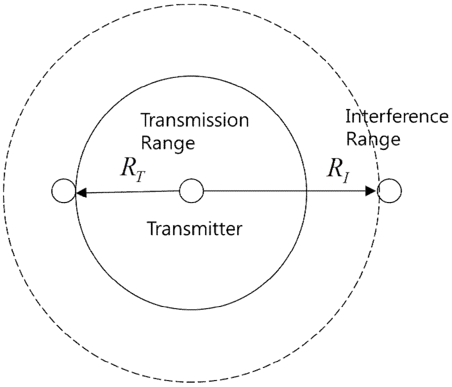

Fig. 2. illustration of Transmission range and interference range.

3.2 Multipath routing for multi-rate wireless sensor networks

After first path was built, if we establish the second path using the same manner with first path and the path 2 in Fig. 3 has shorter delay than path 3, the path 2 will be selected as second path for multipath transmission. However, some nodes in path 2 are in interference range of path 1, and sever interference between the paths will happens and it will degrade the routing performance. Even though path3 has a longer route and larger delay than path 2, it is interference free route and path 3 should be the second path for multipath routing instead of path 2. As a result, to build second path for multipath routing, we need routing schemes different from routing method used to establish the first path

To build second path, node in interference region should not participate in second path. However each node doesn't know if it is in interference region or not. In this paper, we propose the scheme that the nodes in interference region notice their region using the RREP (Route Response). When the RREQ packet arrives at destination node, des-

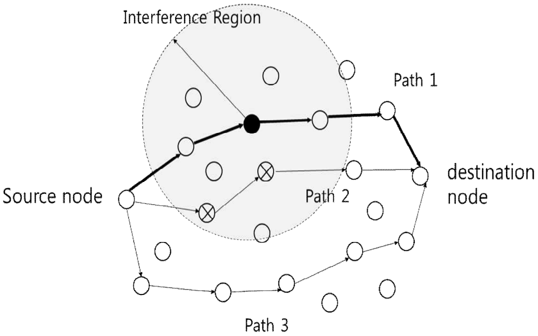

Fig. 3. Illustration of path selection to avoid interference.

tination node transmits RREP to establish first routing path. To build the second path, source node transmits RREQ packet again. The nodes heard RREP for first routing should ignore the RREQ and should not participate in second routing. The nodes which heard RREP are in transmission range of first path. The nodes in the interference range also should not participate in second routing. However the nodes don't know whether they are in the interference range of first path or not. To solve this problem, we propose RREP transmission with increased power. If the transmitted power of RREP is increased and the packet can arrive at the interference range, the nodes in interference region can know that they are in the interference region.

To receive RREP packet at the boundary of interference range, the transmitted power should be increased. If we assume that the interference range is α times longer than interference range, the transmitted power P_t' should satisfy the following relationship [11].

$$P_r = KP_t\left(\frac{d_0}{d}\right)^r = KP_t'\left(\frac{d_0}{\alpha d}\right)^r \tag{3}$$

To transmit packet up to interference range, the transmit power should be

$$P_t' = \left(\frac{1}{\alpha}\right)^r P_t \tag{4}$$

If we assume that the interference range is 1.8 times longer than transmission range and node transmits data in LOS (Line of Sight) environment, about 2.56 times stronger power is required to transmit packet to the interference region. In this case, more power is consumed to transmit RREQ, but RREQ is a very short packet compared with data packet and nodes don't have to transmit RREQ after establishing the route, and power consumption due to the increased power of RREQ is not serious. Using the RREP with increased transmit power, nodes adjacent to the first routing path can recognize whether they are in the interference range or not. If they are in interference range, they don't participate in building the second path and the paths can avoid interference.

4. SIMULATION AND RESULTS

Simulations are performed to evaluate the proposed multipath routing scheme. Nodes are uniformly distributed in 1x1 km^2 rectangular areas. Simulations are performs with different number of nodes and the number of nodes is from 144 to 625. The average distance of adjacent nodes is 40~80m. IEEE802.11 standard at MAC layer is used, and the MAC delay at each link is calculated as 1.04msec [13].

Hop based routings are based on the conventional AODV routing protocols which select paths with minimum hop count. In the delay-based single path routing, routing scheme considers the multi-rates and selects the path with minimum end-to-end delay is selected. Fig. 4 and 5 shows the end-to-end delay according to the distance between source and destination node. As shown in Fig. 4 and Fig. 5, multipath routing shows much less end-to-end delay than single path routing, and the delay-based multipath routing has the less end-to-end delay than hop-based multipath routing. As the distance between source and destination increases, delay difference between single path and multipath gets larger. It shows that the multipath routing is more effective when the distance between source and destination node gets longer.

Table 1. Simulation Parameters

Parameters	Value
Data rates (Mbps)	1, 2, 5.5, 11
Packet size (byte)	512
Average MAC delay (ms)	1.04ms per hop
Terrain size (m^2)	1000×1000
Radio signal transmission range (m)	110
Interference range (m)	198
node density (nodes/km^2)	625, 400, 256, 196, 144

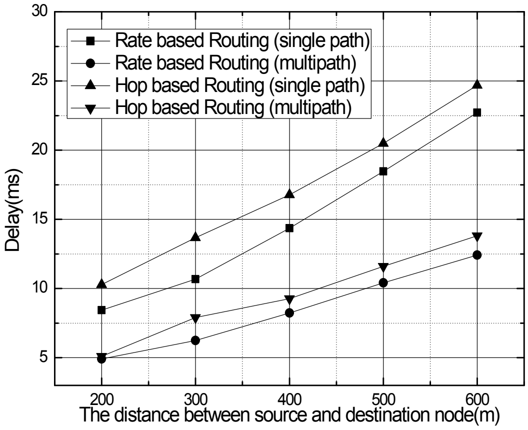

Fig. 4. End-to-end delay according to source-destination distance. Average distance between adjacent nodes is 60m.

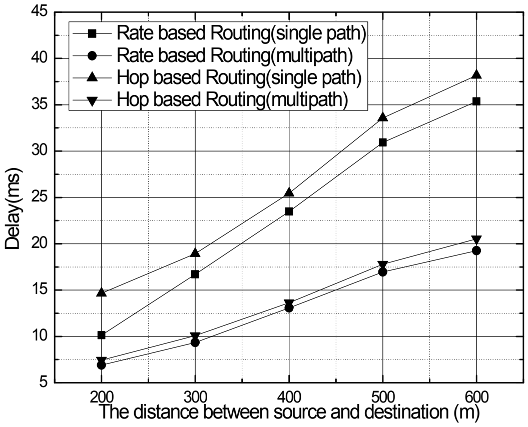

Fig. 5. End-to-end delay according to source-destination distance. Average distance between adjacent nodes is 80m.

Fig. 6 shows the end-to-end delay according to the average distance between adjacent nodes. It is the case that the distance between source and destination node is 400m. As the average distance of adjacent nodes increases, the delay difference between hop-based routing and delay-based routing gets smaller. If the distance between adjacent nodes increases, the data rate gets smaller and it increases the transmission delay. As the distance between adjacent nodes becomes near the transmission range, the data rate decreases abruptly and hop-based routing induces high end-to-end delay.

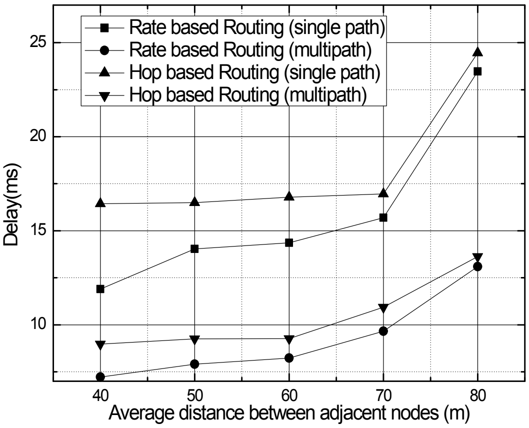

Fig. 6. End-to-end delay according to average distance between adjacent nodes.

5. CONCLUSION

Nowadays, lots of services are developed in the wireless sensor networks. To enlarge serve areas of wireless sensor networks, multipath routing protocol is one of the important technical issues. In this paper, we proposed the interference aware delay-based multipath routing in the multi-rate wireless sensor networks. The proposed multipath routing considers channel conditions and link data rates are used to determine the routing paths, and the second path is established to avoid path interference by using the raised powered RREP packets. Simulation results shows that the proposed routing protocol has less end-to-end delay and multipath routing also shows the more enhanced delay performances than the conventional hop-based routing protocols.

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