A NOVEL RADIO-DISJOINT MULTIPATH PROTOCOL FOR RELIABLE DATA TRANSFER IN LOSSY WSNS

Jeongcheol Lee, Hosung Park, Seungmin Oh, Yongbin Yim and Sang-Ha Kim
Department of Computer Engineering, Chungnam National University, Daejeon, Republic of Korea

Keywords: Wireless Sensor Networks, Multipath Routing, Radio-disjoint Multipath, Geographic Multipath.

Abstract: Geographic multipath routing has been known as one of the most appropriate approaches that can improve the end-to-end reliability via multiple redundant paths for the wireless sensor networks that have frequent network dynamics such as both node and link failures. Studies in the literature have focused on how to make a completely disjoint-multipath. They consider it as a node-disjoint multipath that an intermediate node should be belonged by only a single path. However, if the paths are constructed too closely, there might bring the interference problems such as transmission failure or corrupted packet reception even the node-disjoint multipath schemes are used. Therefore, we propose a radio-disjoint geographic multipath protocol which can avoids the interferences between adjacent paths by separating each path by an interference range. To this end, we use a logical pipeline scheme for each path construction, which consists of entry and exit location of the pipe. We demonstrate that the proposed protocol shows better performance than the previous studies via extensive simulation in terms of end-to-end packet delivery ratio and the end-to-end delay.

1 INTRODUCTION

Multipath data delivery has known as one of the most effective strategy to improve the end-to-end reliability for the lossy wireless networks (Ganesan, 2001). It can provide useful opportunities for data packets to be arrived at the network gateway such as a sink by path redundancy. It also can reduce frequent routing update and provide either high data throughput or a distribution of traffic load over the network (Jones, 2005). A variety of multipath routing schemes (Wang, 2001 and Yang, 2010) are studied in wireless mobile ad hoc networks (MANETs), they however cannot be directly applied to WSNs because of their stateful control and deterministic construction of the paths. Namely, they need too much control overhead or even the deterministic paths are vulnerable to the network dynamics.

Recently, geographic multipath routing schemes (Oh, 2010) have been proposed for WSNs. Utilizing characteristics of high node density and location awareness, these schemes try to get geographical positions which are used for both entry and exit points of each multipath instead of maintaining node and link states of constructed paths. After acquiring such positions, source's data is delivered through these positions by using geographic routing when only the data is generated by a source.

To improve end-to-end reliability, the primary goal of the geographic multipath routing schemes is to construct complete disjointed multiple paths (Wang, 2001, Yang, 2010, and Oh, 2010). These schemes consider the complete disjoint paths as a node-disjoint multipath that an intermediate node in a path is allowed to belong to only a single path, not two or more. It is because that if multiple paths share the one node, the node may be congested by multiple traffics. The shared node has high possibility to break down by depletion of energy since the node suffers from the concentrated traffic load.

However, even if such node-disjoint multipath schemes are used in WSNs, there might be another significant problem such as transmission failure or corrupted packet reception. Since practical sensor nodes can communicate with other nodes by broadcast through omnidirectional antenna, there always exist possibilities to bring collisions if separate paths are too close to disrupt each other. Namely, if the multipath schemes that do not take the interference issues into account, their expensive exertion for improving the packet reliability

Lee J., Park H., Oh S., Yim Y. and Kim S..
A NOVEL RADIO-DISJOINT MULTIPATH PROTOCOL FOR RELIABLE DATA TRANSFER IN LOSSY WSNS.
DOI: 10.5220/0003906104110414
In *Proceedings of the 2nd International Conference on Pervasive Embedded Computing and Communication Systems* (PECCS-2012), pages 411-414
ISBN: 978-989-8565-00-6

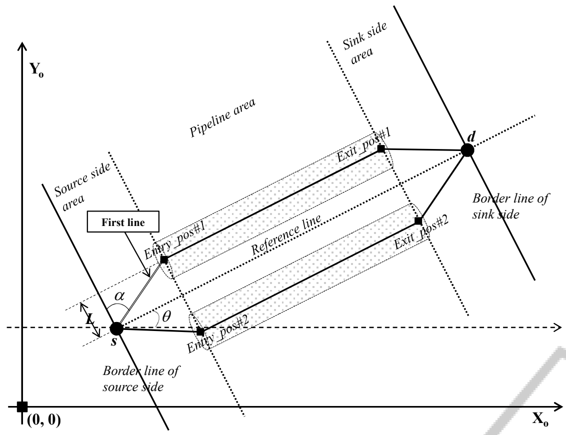


Figure 1: Calculating the entry positions in the proposed protocol.

becomes useless or even cause injury to the reliability.

Therefore, we propose a novel radio-disjoint geographic multipath protocol. The design goal of the proposed protocol is to construct completely radio-disjoint multipath, which can avoid the collisions due to interferences without any additional interference metrics. The main idea of the proposed protocol is to allow multiple paths to keep a certain distance between each other.

2 NETWORK MODEL

We consider a wireless sensor network (WSN) that consists of randomly deployed N sensor nodes over a finite, two-dimensional planar region. We assume that each node knows its position and the positions of its neighbors within its transmission range R. These assumptions can be achieved by either an internal GPS device of sensor node or other localization protocols (Bulusu, 2000). When an event occurs in the WSN, sensor nodes that perceive the event locally elect one data source to prevent massive data duplication and collision. Also, we assume that every sensor nodes could know the unique sink node's position a priory. This assumption is generally satisfied in a variety of emergency applications. In other cases, the data source can obtain the position of a destination through location service protocols. The location of a node acts as its ID and network address.

3 PROPOSED PROTOCOL

3.1 Constructing the Multiple Pipelines

We define the straight line between a source and a sink as the reference line. We may also call the border line of source side as the vertical line to the reference line passing the source. Only the nodes at front area from the border line could be selected as a next hop node. On the other hand, the vertical line passing the sink referred as the border line of sink side. Suppose that the proposed protocol needs k number of multiple paths in order to satisfy the desired delivery ratio given by applications. Thus we also need k number of entry and exit positions. To establish fully distributed pipeline, we evenly divide the border lines into k+1 number of angles. For example, as shown in Fig. 1, when the protocol requires two paths, the border lines are divided by three angels of 60 degrees. In case of three paths are required, border lines could be divided by four angles of 45 degrees. We may call the first straight line from a border line of a source in a clockwise direction as a first line. We also define the angle between the border line and the first line as α . The y-axis distance between a source and an entry position is referred to L.

3.1.1 Obtaining Entry Positions

We first calculate an entry position of the first pipeline through the distance L and the angle α of the pipeline. After that, we calculate other entry and exit positions using the calculated entry position of the first pipeline. Since we calculate the reference points based on global coordinates, we should take a grade into account between the reference line (source to sink) and the absolute reference line (absolute x-axis). As shown in Fig. 1, we refer this angle as θ.

Therefore, we could get the distance of the first line through L and α .

$$Dist(S, Entry\_pos\#1) = (k-1) \cdot R / \cos\alpha. \tag{1}$$

We could know the coordinate variations between the source and the first entry position through θ.

$$\Delta x_1 = \sin(\alpha - \theta) \cdot (k-1) \cdot R / \cos\alpha, \tag{2}$$

$$\Delta y_1 = \cos(\alpha - \theta) \cdot (k-1) \cdot R / \cos\alpha. \tag{3}$$

Using the equation (2) and (3), we obtain the entry position of the first pipeline.

$$Entry\_pos\#1 = (x_s + \Delta x_1, y_s + \Delta y_1). \tag{4}$$

where (x_s, y_s) is the coordinate of the source.

In accordance with the definition of the proposed protocol, the second entry position is located far away from the first entry position as much as 2R. So we could get the second entry position through the following expressions.

$$\Delta x_2 = 2R \cdot \sin\theta, \tag{5}$$

$$\Delta y_2 = 2R \cdot \cos\theta, \tag{6}$$

$$Entry\_pos\#2 = (x_s + \Delta x_1 - \Delta x_2, y_s + \Delta y_1 - \Delta y_2). \tag{7}$$

Consequently, the general expression for an entry position is:

$$\begin{aligned} &Entry\_pos\#k \\ &= (x_s + \Delta x_1 - (k-1)\cdot\Delta x_2, y_s + \Delta y_1 - (k-1)\cdot\Delta y_2). \end{aligned} \tag{8}$$

3.1.2 Obtaining Exit Positions

In the proposed protocol, sensor nodes that can directly receive the broadcast message of a sink should become exit nodes of logical. We call these nodes as candidate nodes. Among these nodes, the closest node from a source has to be selected as an exit node of a pipeline in order to reduce the communication costs. It is because that the path from the closest node to the sink is the shortest path. However, since the source cannot know information of the candidate nodes a priori, we exploit a heuristic approach. We consider the worst case that exit positions of each pipeline are on the border line of sink side. Since a data packet is forwarded from an entry position to an exit position by geographic routing, if the packet meets a candidate node, the node may be the closest node from a source node. After that, the packet is stopped and the candidate node becomes a practical exit node.

We define the coordinate variations between an entry position to its exit position as Δx_3 and Δy_3.

$$\Delta x_3 = \{x_d - (x_{Entry\_pos\#first} + x_{Entry\_pos\#final})/2\}, \tag{9}$$

$$\Delta y_3 = \{y_d - (y_{Entry\_pos\#first} + y_{Entry\_pos\#final})/2\}. \tag{10}$$

Using the equation (9) and (10), the general expression for an exit position is:

$$Exit\_pos\#k = (x_{Entry\_pos\#k} + \Delta x_3, y_{Entry\_pos\#k} + \Delta y_3). \tag{11}$$

3.2 Data Transmission

Above mentioned, the area between a source and a sink is divided into three parts: a source side area, a collision-free pipeline area, and a sink side area. In other words, we use three phase geographic routing according to these areas: the source to an entry position, the entry position to an exit position, and finally the exit position to the sink. We set the height of a pipeline to R, and each pipeline is set to stay away from each other by R. In the pipeline area, the data packet includes the height of a pipeline and the position of its own entry and exit points. Since the entry and exit positions are located in the middle of height of the pipeline, each forwarding node could know the region of its own pipeline when it receives the packet. Namely, only the nodes within its own pipeline could be selected as a next hop node for data forwarding. However, it is unreal to assume that a next hop node is correctly located at the entry or exit position. So the proposed protocol selects the nearest sensor node from the position as the entry node or exit node of a pipeline.

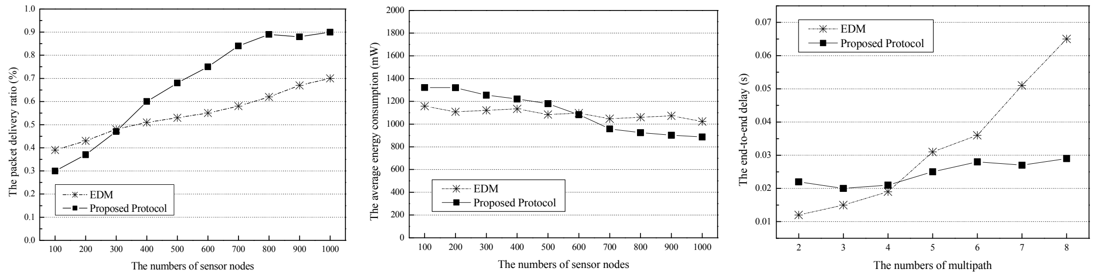
4 PERFORMANCE EVALUATION

We evaluate the performance of the proposed protocol in terms of the packet delivery ratio, the average hop counts, the average energy consumption, and the end-to-end delay with EDM (Oh, 2010), a representative node-disjoint geographic multipath routing protocol in wireless sensor networks.

We implement the proposed protocol in the Qualnet 4.0 network simulator. The model of sensor nodes are followed by the specification of MICA2 (Polastre, 2005). The transmission range of sensor nodes and sink are 40 *m* and 120 *m*, respectively. 700 sensor nodes are randomly and uniformly distributed in a 500 *m* × 500 *m* sensor field. The size of a data packet is 256 bytes. A source generates the data packet every two seconds. The number of paths is three. Each simulation lasts for 600 seconds.

4.1 Impact of the Number of Sensor Nodes

Fig. 2(a) indicates the packet delivery ratio for increasing the number of sensor nodes. As we can see, with the increase of sensor nodes, the packet delivery ratio also increases. Because the number of nodes is associated with the node density, so a node could has the more neighbor in its forwarding area as the number of nodes increases. We observe that the packet delivery ratio of the proposed protocol is lower than EDM when the few number of nodes are deployed in sensor fields. It is because that a node in a pipeline of the proposed protocol may not find a next hop node if the number of sensor nodes is small. However, the graph rapidly increases in the proposed protocol as the number of sensor nodes increases. Because if the network could guarantee a certain degree of node density, a transmission fail is only occurred by interferences between paths. As



(a) (b) (c)

Figure 2: Simulation results in terms of data delivery ratio, average energy consumption, end-to-end delay.

shown in Fig. 2(b), we observe that the proposed protocol consumes less energy than EDM when the number of nodes is large although the proposed protocol has more hop counts. It is because that the receiving cost for redundant message at an interference area significantly be increased as the node density increases.

4.2 Impact of the Number of Multipath

In Fig. 2(c), we can observe that the end-to-end delay of EDM rapidly increases as the number of path increases. It means the case that many individual paths are constructed within the narrow area. Thus in the case, the queuing delay of each node in this area may be significantly increased. However, since the proposed protocol constructs geographically separated paths, each node has low queuing delay than EDM. Also, we observe that the proposed protocol has more delay than EDM only when there exist little number of multipath. It is because that if the queuing delays of both EDM and the proposed protocol is similar to each other, the proposed protocol that has the more average hop counts may take more delay times.

5 CONCLUSIONS

In this paper, we introduce a radio-disjoint geographic multipath scheme to effectively avoid the interferences between each path via multiple logical pipelines between a source and a sink pair. By separating each pipeline, geographically collision-free paths could be constructed. We have studied the performance of the proposed protocol relative to EDM, a representative node-disjoint geographic multipath protocol. We observe the proposed protocol shows better performance in the packet delivery ratio and the end-to-end delay.

REFERENCES

Ganesan, D., Govindan, R., Shenker, S., and Estrin, D., 2001. Highly-Resilient, Energy-Efficient Multipath Routing in Wireless Sensor Networks, *Mobile Computing and Communications Review*, Vol. 1, No. 2.

Jones, E. P. C., Karsten, M., and Ward, P. A. S., 2005. Multipath Load Balancing in Multi-Hop Routing in Wireless Sensor Networks, *IEEE WiMob*, pp. 158-166, Oct.

Wang, L., Shu, Y., Dong, M., Zhang, L., and Yang, W., 2001. Adoptive Multipath Source Routing in Ad Hoc Networks, in *Proc. of IEEE International Conference on Communications (ICC)*, Jun.

Yang, W., Yang, X., Liu, G., and Yu, W., 2010. An Interference Avoidance Multipath Routing Protocol based on Greedy Forwarding in MANETs, in *Proc. of IEEE International Conf. Wireless Communications, Networking and Information Security (WCNIS)*, Jun.

Oh, H. W., Jang, J. H., Moon, K. D., Park, S., Lee, E., and Kim, S., 2010. An Explicit Disjoint Multipath Algorithm for Cost Efficiency in Wireless Sensor Networks, in Proc. of 21st *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC*), pp. 1899-1904, Sep.

Bulusu, N., Heidemann, J., and Estrin, D., 2000. Gps-less low cost outdoor localization for very small devices, *IEEE Personal Communications Magazine*, vol.7, no. 5, pp.28-34, Oct.

Polastre, J., Szewczyk, R., and Culler, D., 2005. Telos: Enabling Ultra-Low Power Wireless Research," *IEEE IPSN*, pp. 364-369, Apr.