Path-overlap Avoidance in Multiple Route Construction for Mobile Relay on WSN

Yogi Anggun Saloko Yudo[1], Noritaka Shigei[2], and Hiromi Miyajima[3]

***Abstract*—Low energy consumption is very important in WSN (Wireless Sensor Network), since sensor nodes are powered by limited power batteries. In recent years, mobile relay has been studied in order to save the energy consumption on WSN. Initial route construction is needed for mobile relay to determine the sequence of relaying nodes. Battery-Aware Initial Route construction by Dijkstra's Algorithm (BAIR-D) has been proposed. BAIR-D employs Dijkstra's algorithm and takes into account node's battery level into the cost function to find the initial route. However, when applying it to multiple sources, the constructed paths are necessarily overlapped with high probability. Therefore, it increases the energy consumption of the nodes on overlapped paths. In this paper, we present battery-aware multiple route construction with path-overlap avoidance, which is referred as BMRC-POA. Unlike BAIR-D, BMRC-POA avoids path-overlap in multiple route construction for mobile relay. There are two steps for determining the initial route in BMRC-POA. First, the initial route construction for every source node is determined without path-overlap. Second, if the route construction for some sources failed, then path-overlap is allowed. This algorithm outperforms the conventional BAIR-D in terms of the network lifetime. We demonstrate the effectiveness of BMRC-POA by using numerical simulation.**

***Index Terms*— Dijkstra's algorithm, mobile node, initial route, multi-hop communication, overlapping of multiple paths, wireless sensor network**

I. Introduction

ENERGY is the most important resource in Wireless Sensor Network (WSN) [1], because it determines the lifetime of a sensor node. Since the sensor nodes are usually powered by limited power batteries, low energy consumption is very important, in order to prolong the network lifetime of WSN. In recent years, many researchers designed and developed techniques for prolonging the network lifetime of WSN [1,2]. One of the techniques is mobile relay [3,4,5]. The concept of mobile relay is that some movable nodes change their location so as to minimize the total energy consumed by both wireless transmission and locomotion. Mobile relay needs to determine an initial route, which describes the sequence of nodes used for relaying the data from a source node to a sink node, and then the relaying nodes change their location so as to reduce their energy consumption.

In previous studies, we have already proposed Battery-Aware Initial Route Construction-Dijkstra's algorithm (BAIR-D) for determining the initial route based on Dijkstra's algorithm [6]. This method can construct the optimal path in terms of given cost function. Further, the algorithm takes into account nodes' battery levels and avoids using nodes with low battery levels. However, when applying it to multiple sources, a problem arises. Since BAIR-D constructs the optimal path for each source, the constructed paths are necessarily overlapped with a high probability. The path-overlap increases the energy consumption of the nodes on overlapped paths. This makes the overloaded nodes go quickly down.

In this paper, we propose battery-aware multiple route construction with path-overlap avoidance (BMRC-POA). To overcome the problem in the conventional method, BMRC-POA finds the initial route for mobile relay with path-overlap avoidance. It avoids some nodes to be a relaying node for multiple source nodes. It also avoids the source node to be a relaying node to another source node. Avoiding path-overlap in multiple route construction can save the energy for some sensor nodes. Therefore, it can prolong the lifetime of sensor nodes. This method consists of two steps. First, the initial route construction for every source node is determined without path-overlap. Second, if some source nodes have no route, then the initial route construction is performed with a path-overlap scenario. We compare BMRC-POA and BAIR-D in terms of the number of operating rounds and the successful rate of initial route construction. Further, we compare both of the methods in terms of the total cost. The effectiveness of BMRC-POA is demonstrated by using numerical simulation.

II. Mobile WSN

A. Mobile WSN Model

The WSN model considered in this study consists of N mobile nodes and one sink node. The mobile nodes can estimate their own location by an equipped GPS unit or other systems. Moreover, they can move by using equipped electric motors. We adopt the same energy consumption model as in [3]. The energy $E_M(d)$ is consumed when a mobile node moves through a distance d [m]:

$$E_M(d) = k \cdot d \qquad \text{[J]}, \tag{1}$$

where the parameter k [J/m] depends on the moving velocity. The energy $E_T(d, m)$ is consumed when a node

Affiliation: Graduate School of Science and Engineering, Kagoshima University, 1-21-40 Korimoto, Kagoshima 890-0065, Japan.
This work was supported by JSPS KAKENHI Grant Number 26330108.
[1] Y. A. S. Yudo (email: saloko215@gmail.com)
[2] N. Shigei (corresponding author to provide phone: +8199-285-8416; email: shigei@eee.kagoshima-u.ac.jp)
[3] H. Miyajima (email: miya@eee.kagoshima-u.ac.jp)

ISBN: 978-988-19253-2-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

transmits a data of *m* [bit] over a distance of d [m]:

$$E_T(d, m) = m(a + b \cdot d^2) \qquad [\text{J}], \tag{2}$$

where the parameters a and b depend on the environment. The energy $E_R(m)$ is consumed when a node receives a data of *m* [bit]:

$$E_R(m) = c \cdot m \qquad [\text{J}], \tag{3}$$

where the parameter *c* depends on the radio platform.

B. Mobile Relay

The mobile relay algorithms consist of two steps. The first step is to determine the initial route and the second step is to calculate the optimal position. Initial route construction in the first step is needed for determining the sequence of relaying nodes, which is provided to mobile relay algorithms. In the second step, the mobile relay algorithm calculates the location of intermediate nodes on the transmission path from the source to the sink so as to minimize a given cost function such as the total energy consumption of movement and transmission. Fig.1 shows an example of node movement. After the step two, the data outgoing from the source is relayed to the sink.

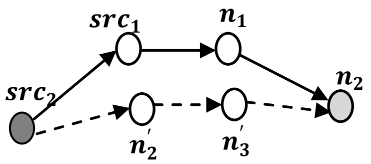


Fig. 1. An example of node movement in mobile relay: $n_1$acts as a source node, $n_4$acts as a sink node.n_2 and n_3 act as intermediate nodes. $n_2'$and n_3' show the optimal positions of $n_2$and n_3, respectively.

For the step two, several types of mobile relay algorithms have been proposed. The algorithms determine the optimal positions of relaying nodes in terms of a given objective function. In [3], the objective function is the total cost of movement and communication. In [5], the objective function takes into account not only the total cost but also nodes' battery levels. The latter one can save the energy consumption on nodes with low battery levels, and it is advantageous to prolonging the network lifetime. Therefore, in this paper, we use the latter one, battery-aware mobile relay algorithm.

III. CONVENTIONAL INITIAL ROUTE CONSTRUCTION

Mobile relay needs to be given initial routes, each of which describes the sequence of nodes used for relaying the data from a source to the sink [4]. In the conventional methods [6], each node selects specific nodes to be the relaying nodes to relay data according to some criteria in order to prolong the network lifetime of WSN.

The works in [5,6] proposed some initial route construction algorithms. The objective of the algorithms was to minimize the total energy consumed by both wireless transmission and locomotion. In the works, we have adopted greedy algorithm to determine the initial routes. In the conventional greedy algorithm, the energy consumption is proportional to the square of distance. The weight of a node n_a to a node n_b is as follows:

$$w(n_\mathrm{a}, n_\mathrm{b}) = d(n_\mathrm{a}, n_\mathrm{b})^2, \tag{4}$$

where $d(n_\mathrm{a}, n_\mathrm{b})$ is the distance between node n_a to node n_b.

The greedy algorithm in [5] has determined the initial route according to only the distance to the sink. When the battery levels are not uniform for all nodes, selecting a node with low battery level will shorten the network lifetime. Therefore, we incorporated node's battery levels into the cost function as in [6]. The weight of a node n_a to a node n_b is calculated by the following equation,

$$w(n_\mathrm{a}, n_\mathrm{b}) = \frac{d(n_\mathrm{a}, n_\mathrm{b})^2}{e_\mathrm{b}^{\alpha}}\ , \tag{5}$$

where e_b is the battery level of noden_b, and $\alpha > 0$is the parameter controlling the balance between distance and battery level. When using larger α, a node with higher battery level tends to be selected as a relaying node. When using smaller α, a node with lower communication cost to be selected as a relaying node. Therefore, we have to find an effective value for α. The effective value of α depends on the battery level, the number of sources, the number of nodes, the field size, etc.

In the following, the conventional route construction methods are introduced [5,6].

A. Route Construction Based on Greedy Approach

Starting with the source node, the route construction extends the relaying path to the sink node step by step. At each step, the extension of the path is determined in a greedy fashion by using the local information on the front line node. Let n_cur be the current node that is the front line of the path extension. The next front line node n_nxt is determined as follows:

$$d(n_\mathrm{nxt}, n_\mathrm{snk}) = \min_{n \in \mathrm{N}(n_\mathrm{cur})} d(n, n_\mathrm{snk}). \tag{6}$$

The algorithm requires only the number of communications, proportional to the relaying nodes. Therefore, it can be easily implemented in a distributed fashion.

B. Battery-Aware Initial Route Construction by Dijkstra's Algorithm (BAIR-D)

The drawback of the greedy route construction is that the optimality of the obtained route is not guaranteed. In this subsection, we introduce battery-aware initial route construction based on Dijkstra's algorithm (BAIR-D).

Dijkstra's algorithm is used for finding the shortest path from a node to the other nodes in the network [7]. The algorithm has been applied to the multi hop communication in WSN [8,9]. However, the methods are for fixed nodes and do not take into account node's battery levels. In this method, BAIR-D, Dijkstra's algorithm is used for mobile relay, and node's battery levels are incorporated into the cost function.

Algorithm BAIR-D($\mathrm{N}_{\mathrm{all}}, n_{\mathrm{src}}, n_{\mathrm{snk}}, w, \mathrm{N}$)

/* Inputs */
$\mathrm{N}_{\mathrm{all}}$: The set of all the nodes
n_{src} : Source node
n_{snk} : Sink node
$w(n', n")$ for all $n', n" \in \mathrm{N}_{\mathrm{all}}$:
the cost of edge $(n', n")$
$\mathrm{N}(n)$ for all $n \in \mathrm{N}_{\mathrm{all}}$:
the set of the nodes within the direct communication range of node n
/* Output */
R: the set of the edges of the route

begin
/* Initializations */
/* The sets of member nodes and selected edges are empty. */
$\mathrm{M} \leftarrow \emptyset$;
$\mathrm{E} \leftarrow \emptyset$;
/* Starting from the sink node */
$\mathrm{M} \leftarrow \{n_{\mathrm{snk}}\}$;
$W(n_{\mathrm{snk}}) \leftarrow 0$;

/* Main loop */
do
/* Find the non-member node with the minimum cost from the sink node. */
Find $n_{\mathrm{mem}} \in \mathrm{M}$ and $n_{\mathrm{non}} \in \mathrm{N}_{\mathrm{all}} \setminus \mathrm{M}$ s.t.
$n_{\mathrm{non}} \in \mathrm{N}(n_{\mathrm{mem}})$ and
$W(n_{\mathrm{mem}}) + w(n_{\mathrm{mem}}, n_{non}) =$
$\min_{n' \in \mathrm{M}, n" \in \mathrm{N}_{\mathrm{all}} \setminus \mathrm{M}} (W(n') + w(n', n"))$;

/* Add the non-member to members. */
$\mathrm{M} \leftarrow \mathrm{M} \cup \{n_{\mathrm{non}}\}$;

/* Add the edge to ones for the candidate routes. */
$\mathrm{E} \leftarrow \mathrm{E} \cup \{(n_{\mathrm{mem}}, n_{\mathrm{non}})\}$;

/* Update the cost. */
$W(n_{\mathrm{non}}) \leftarrow W(n_{\mathrm{mem}}) + w(n_{\mathrm{mem}}, n_{\mathrm{non}})$;
until $n_{\mathrm{src}} \in \mathrm{M}$;

/* Extract the route from the source to the sink */
$\mathrm{R} \leftarrow \emptyset$;
$n_{\mathrm{cur}} \leftarrow n_{\mathrm{src}}$;
while $n_{\mathrm{cur}} \neq n_{\mathrm{snk}}$ do
Select $(n_{\mathrm{nxt}}, n_{\mathrm{cur}}) \in \mathrm{M}$;
$\mathrm{R} \leftarrow \mathrm{R} \cup \{(n_{\mathrm{nxt}}, n_{\mathrm{cur}})\}$;
$n_{\mathrm{cur}} \leftarrow n_{\mathrm{nxt}}$;
end of while

end.

Fig. 2. BAIR-D Algorithm

The algorithm starts with a sink node for calculating all the possible routes, and at each step it selects the node with the minimum total cost among the non-member of neighboring nodes to the member nodes and adds the selected node into the member nodes. The algorithm is shown in Fig.2.

The total cost $W(n_{\mathrm{b}})$ from the sink node to a node n_{b} is calculated by the following equation:

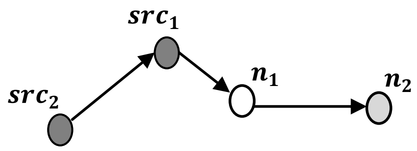
$$W(n_{\mathrm{b}}) = W(n_{\mathrm{a}}) + w(n_{\mathrm{a}}, n_{\mathrm{b}}), \qquad (7)$$

Unlike greedy fashion, the implementation of Dijkstra's algorithm requires global information on the network at each step of the calculation. However, this method determines the initial route for mobile relay by using path-overlap scenario. Some sensor nodes share the path for transmitting the data from source node to the sink node.

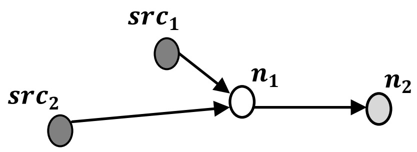
IV. Battery-aware Multiple Route Construction with Path-overlap Avoidance

In this section, we propose Battery-aware Multiple Route Construction with Path-Overlap Avoidance (BMRC-POA). The purpose is to reduce the energy consumption of the overloaded nodes on the overlapped path.

Unlike BAIR-D, BMRC-POA avoids the path-overlap as much as possible in the route construction. The path-overlap increases the energy consumption of the nodes on overlapped paths. This makes the overloaded nodes go quickly down. Further, the algorithm takes into account nodes' battery levels and avoids using nodes with low battery levels. The weight is calculated by eq. (5) and the total cost is calculated by eq. (7).



3.(a). An example of initial route construction of BAIR-D



3.(b). An example of initial route construction of BMRC-POA

Fig. 3. An example of initial route construction of BAIR-D and BMRC-POA. src_1 acts as a source node 1, src_2 acts as a source node 2. n_1 acts as intermediate node and n_2 acts as sink node.

Fig. 3 shows the difference of initial route constructions between BAIR-D and BMRC-POA. Fig. 3(a) shows that overlapping the source node is allowed in BAIR-D. Source node 1 (src_1) can be used as a member of relaying node for source node 2. On the other hand, in Fig. 3(b), the initial route obtained by BMRC-POA avoids the source node 1 (src_1) to be a member of relaying node for source node 2 (src_2).

Algorithm BMRC-POA($N_{all}, N_{src}, n_{snk}, w, N$)

/* Inputs */
N_{all} : the set of all the nodes
N_{src} : the set of source nodes

n_{snk} : Sink node
$w(n', n'')$ for all $n', n'' \in N_{all}$:
the cost of edge (n', n'')
$N(n)$ for all $n \in N_{all}$:
the set of the nodes within the
direct communication range of node n

/* Output */
$R(n)$ for all $n \in N_{src}$: the set of edges of
route for source n

begin

$N_{av} \leftarrow N_{all}$;
for each n_{src} of N_{src} do
/* Find route of n_{src} without
overlapping */
(A) $\mathrm{BAIR-D}(N_{av}, n_{src}, n_{snk}, w, N)$;

if $R(n_{src})$ is no route then

/* Find route of n_{src} with
overlapping */
(B) $\mathrm{BAIR-D}(N_{all}, n_{src}, n_{snk}, w, N)$;

if $R(n_{src})$ is no route then
terminate the algorithm as
failed construction;
else
// Update available node set
Let N_{used} be the set of used
nodes in (B);
$N_{av} \leftarrow N_{all} \backslash N_{used}$;
end if

else
/* Update available node set */
Let N_{used} be the set of used
nodes in (A);
$N_{av} \leftarrow N_{av} \backslash N_{used}$;
end if

end for
end.

Fig. 4. BMRC-POA Algorithm

Unlike BAIR-D, this algorithm tries to avoid the path-overlap in the route construction. The nodes already used have to be excluded from the available nodes for the next construction paths. Further, if some source nodes cannot find the neighboring nodes to be the next node, then overlapping the path is allowed. All the nodes can be used in order to obtain the successful of route construction. The algorithm is shown in Fig.4.

V. NUMERICAL SIMULATION

In order to show the effectiveness of the proposed method, we perform numerical simulations. In the simulation, N = 100 mobile sensor nodes are initially randomly distributed in a 150m x 150m square field. N mobile sensor nodes contain N_{src} source nodes and a sink node. The maximum range of wireless communication is set to 35m. The batteries of mobile nodes are initially randomly charged in the range $10\ \mathrm{kJ} \sim 150\ \mathrm{kJ}$. It is assumed that the sink node can use the unlimited energy source. The parameter setting used for energy model is as follows: for mobility, we used $k = 2\ \mathrm{J/m}$ as an optimal speed of the node has been discussed in [2,3,4,10]. For transmission, we used $a = 0.6 \times 10^{-7}\ \mathrm{J/bit}$ and $b = 4.0 \times 10^{-10}\ \mathrm{Jm^{-2}/bit}$ as the standard setting which is consistent with the empirical measurements on a CC2420 mote [11]. For the reception, we used $c = 1.4 \times 10^{-7}\ \mathrm{J/m}$ [2,3]. The size of data initiated from the source node in one round is referred as the chunk data size m.

In the simulation, we perform the two steps described in the section 3. For the step one, we perform BAIR-D and BMRC-POA for determining the initial route. For the step two, where the optimal position of relaying nodes is determined, we use battery-aware mobile relay algorithm as in [4]. Then, the data is transferred from the source node to the sink node.

In the battery-aware methods, α is used for controlling the balance between distance and battery-level.
In the battery-aware methods, BAIR-D, BMRC w/o PO and BMRC-POA, α is an important parameter which controls the balance between the communication cost and the battery level. A larger α makes a longer route from a source to the sink, but avoids nodes with low battery levels. On the other hand, a smaller α makes a shorter route, but fails to avoid nodes with low battery levels. In the following, an effective α = 4.5 found in [6] will be used.

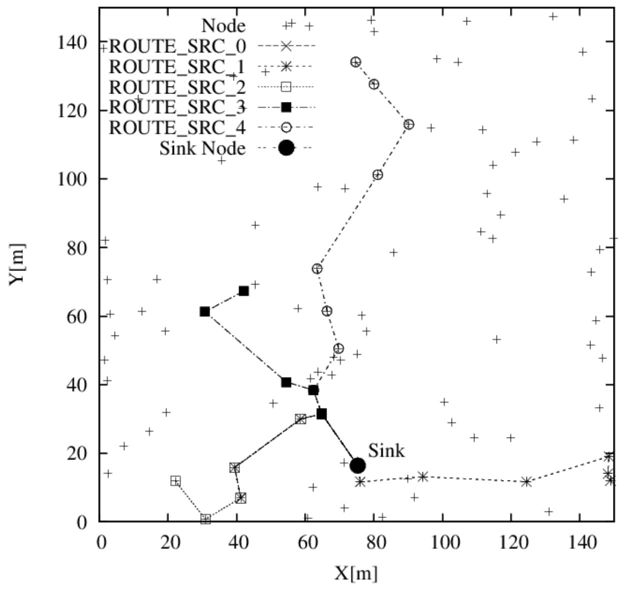


Fig. 5. An example of route construction by BAIR-D for 5 source nodes and α = 4.5.

ISBN: 978-988-19253-2-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

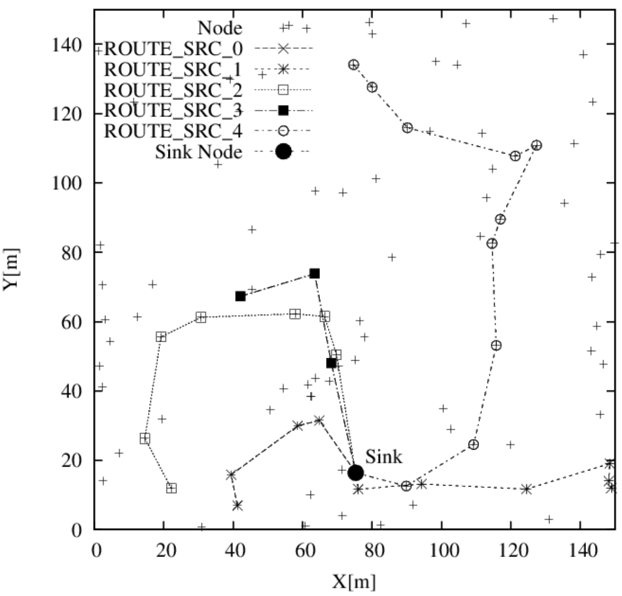


Fig. 6. An example of route construction by BMRC-POA for 5 source nodes and α = 4.5.

TABLE I
RESULTS OF SUCCESSFUL RATE (α = 4.5)

# Sources	Successful Rate (%)		
	BAIR-D	BMRC w/o PO	BMRC-POA
1	100	100	100
3	99.6	98.8	99.6
5	99.6	88.2	99.6
7	99.6	64.2	99.6
10	99.6	25.4	99.6
12	99.6	10.6	99.6
15	99.6	1.4	99.6

TABLE II
AVERAGE OF TOTAL COST (α = 4.5)

# Sources	Average of Total Cost		
	BAIR-D	BMRC w/o PO	BMRC-POA
1	1.74E-18	1.74E-18	1.74E-18
3	1.95E-18	2.35E-18	2.33E-18
5	2.24E-18	4.97E-18	5.32E-18
7	2.08E-18	6.87E-18	8.20E-18
10	2.02E-18	8.97E-18	1.16E-17
12	1.96E-18	1.36E-17	1.31E-17
15	1.88E-18	1.53E-17	1.36E-17

In the first simulation, the initial routes obtained by BAIR-D and BMRC-POA are compared. Figs. 5 and 6 show the initial routes obtained by BAIR-D and BMRC-POA, respectively. In the initial route obtained by BAIR-D, the

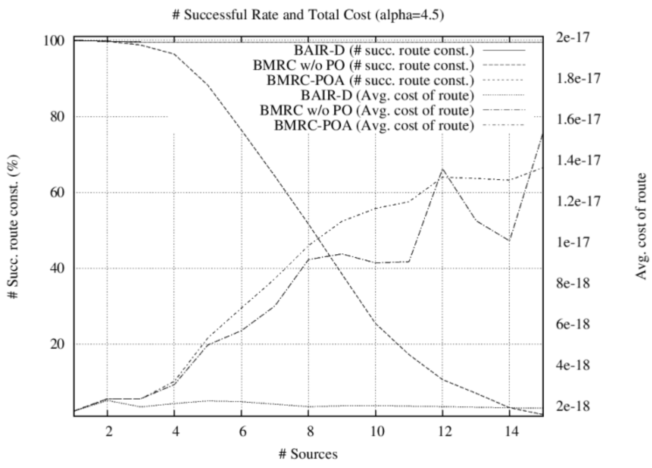


Fig. 7. Successful rate and total cost

TABLE III
NUMBER OF OPERATING ROUNDS (α = 4.5)

# Sources	# Operating Rounds (chunk data size = 10 MB)	
	BAIR-D	BMRC-POA
1	3800.026	3800.026
3	2232.51004	2778.118474
5	1726.263052	2302.536145
7	1536.572289	1972.965863
10	1325.180723	1570.190763
12	1291.11245	1528.610442
15	1226.801205	1443.064257

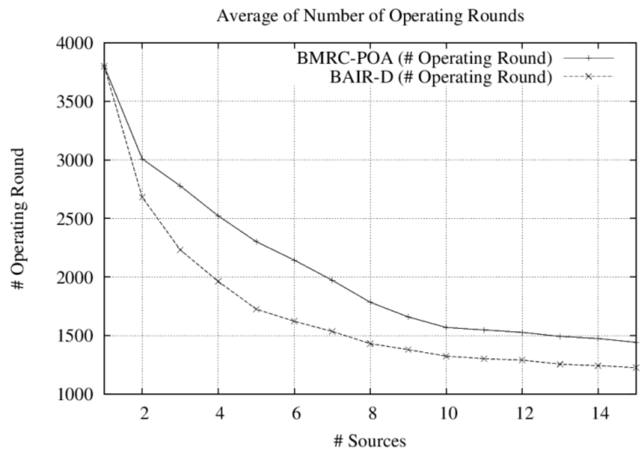


Fig. 8. Number of Operating Rounds

source node is allowed to be a member of relaying node to another source node. Therefore, the source node transmits not only its data but also other data from the other source node. On the other hand, the initial route obtained by BMRC-POA shows that nodes already used for the initial route of a current source node cannot be used as a relaying node to another source node. Each source node only transmits its own data to the sink node.

In the second simulation, the methods are evaluated in terms of the total cost and the successful rate of initial route construction. The total cost means that cost of the successful route construction for every source node. The evaluation values are calculated from 500 runs. The successful rate is defined by the following equation.

$$\frac{(\text{\# of runs with successful initial route construction})}{500} \quad (10)$$

In this simulation, in addition to BAIR-D and BMRC-POA, we perform also the strict version of BMRC-POA, which never allows any path overlap. The method, Battery-aware Multiple Route Construction without Path Overlap (BMRC w/o PO), calls the function BAIR-D of (A) in BMRC-POA, but if the route construction for some sources fail then the algorithm terminates as a failed construction.

In our methods, the higher successful rate of route construction is very important, because the sensor nodes send the sensing data through the relaying node (route). If the route construction fails or there is no route, then the source node can not send the sensing data to the sink node.

According to the results shown in Tables.1 and 2, and Fig.7, we can observe the following tendencies:

(1) The successful rate of BMRC w/o PO rapidly decreases with the number of sources. The degradation is very critical. For example, the rate for N_{src} = 10 is 25.4% and the one for N_{src} = 15 is 1.4%.

(2) Unlike BMRC w/o PO, BMRC-POA achieves the same successful rate as for BAIR-D. Although the successful rate still degrades with the number of sources, the degradation is mild. For N_{src} = 15, the successful rate is 99.6%.

(3) In terms of the total cost, BAIR-D is always the best among all methods. As the number of sources increases, the difference becomes slightly larger.

Finally, we compare BAIR-D and BMRC-POA in terms of the number of operating rounds. An operating round means the round where all source nodes successfully transmit the sensed data to the sink. The number of operating rounds is evaluated after when the relaying nodes are placed at the optimal position determined by battery-aware mobile relay algorithm [4]. The evaluation values are calculated from 500 runs.

In Fig. 8, BAIR-D and BMRC-POA are compared in terms of the number of operating rounds. BMRC-POA achieves approximately 12∼33% improvement against BAIR-D for $2 \leq N_{\text{src}} \leq 15$. Although the improvement ratio decreases with $N_{\text{src}} \geq 6$, the degradation is mild. For example, the improvement ratio for N_{src} = 12 is 18.4% and the one for N_{src} = 15 is 17.6%.

The simulation results show that BMRC-POA can enhance the network lifetime of WSN.

VI. Conclusion

In this paper, we proposed battery-aware multiple route construction with path-overlap avoidance (BMRC-POA). The path-overlap increases the energy consumption of the nodes on overlapped paths. This makes the overloaded nodes go quickly down. BMRC-POA avoids the path-overlap as much as possible in the route construction. Therefore, it can prolong the lifetime of sensor nodes. The simulation result showed that BMRC-POA is more effective than BAIR-D in terms of the number of operating rounds. In the future work, we will consider the refinement of BMRC-POA.

References

[1] J. Yick, B. Mukherjee and D. Ghosal, "Wireless Sensor Network Survey", Computer Networks, Vol. 52, pp. 2292-2330, 2008.

[2] C.Hua and T. P. Yum, "Optimal routing and data aggregation for maximing lifetime of wireless sensor networks," IEEE ACM Trans, Netw., vol.16, no. 4, pp. 892-903, 2008.

[3] F. El-Moukaddem,E. Torng, G. Xing and S. Kulkarni, "Mobile Relay Configuration in Data-intensive Wireless Sensor Networks", Proc. of. Int. Conf. on Mobile Adhoc and Sensor Systems, pp. 80-89, 2009.

[4] F. El-Moukaddem, E. Torng, and G.Xing, "Maximing Data Gathering Capacity if Wireless Sensor Networks using Mobile Relays", Proc. of Int. Conf. on Mobile Adhoc and Sensor Systems, pp.312-321, 2010.

[5] N. Shigei, I. Fukuyama, H. Miyajima and Yogi A. Saloko Yudo , "Battery-Aware Algorithm for Mobile Relay and Route Construction on Wireless Sensor Network", IAENG Int. Journal of Computer Science, vol. 39, no. 3, pp. 321-328, 2012.

[6] Yogi A. Saloko Yudo, N. Shigei and H. Miyajima, "Effective Initial Route Construction for Mobile Relay on Wireless Sensor Network", Proc. of Int. Symposium on Artificial Life and Robotic, pp.311-316, 2014.

[7] M. Sniedovich, "Dijkstra's algorithm revisited: the dynamic programming connecxion", Control and cybernatics, vol. 35, no. 3, pp. 600-619, 2006.

[8] N. Pushpalata and Dr. B. Anuradha, "Shortest Path Position Estimation between Source and Destination nodes in Wireless Sensor Networks with Low Cost", Int. Journal of Emerging Technology and Advanced Engineering, vol. 2, pp. 6-12, 2012.

[9] Ambreen and Haque Nawaz, "Wireless Sensor Network Through Shortest Path Route", Int. Journal of Emerging Technology and Advanced Engineering, vol. 3, pp. 158-161, 2013.

[10] G. Wang, M. J. Irwin, P. Berman, H. Fu, T. La Porta, "Optimizing Sensor Movement Planning for Energy Efficiency", in *ISLPED*, pp. 215-220, 2005.

[11] M. Sha, G. Xing, G. Zhou, S. Liu, and X. Wang, "C-MAC: Model-driven Concurrent Medium Access Control for Wireless Sensor Networks", Proc. of IEEE Conference on Computer Communications (*INFOCOM)*, pp. 1845-1853, 2009.

ISBN: 978-988-19253-2-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)