Data collection method adapting density of sensor and node's priority in Triage Network

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ABSTRACT

Researches of sensor networks to collect vital data with computerized tags, called Triage Network, are developed. It is necessary to keep collecting data by sensors fixed in patients. But when sensor density is high, it becomes easy to press bandwidth. And, patients are transported sequentially in Triage Network. Sensor nodes transported later are easy to be out of battery because of existing in the network for a long time. So in this paper, we propose data collection method adapting to sensor density and node's priority. To keep data arrival rates and suppress the battery consumption totally, multiple routes are constructed by broadcast from the sink. And to suppress battery consumption of nodes existing in the network for a long time, sensor nodes with low priority change transmission intervals longer when sensor density is high. We evaluate our proposal by the computer simulation and show this effectiveness.

Keywords: Triage; Sensor Network; Data transmission interval; Saving battery; Route construction

1 Introduction

An emergency lifesaving method called triage has been introduced[1], [2] when a lot of patients are generated by large-scale accident such as traffic accidents or wide-scale disaster. In triage, patients are grouped into 4 groups (red, yellow, green, black) and a priority for medical treatments is decided. This decision of priority enables more patients to be saved because of efficient medical treatment or transportations of patients to a medical institution.

JR Fukuchiyama Line in 2006 is known as the first triage used and saved a lot of lives[3]. Tags used at triage scene for patients' grouping are now made of paper. Doctors fill in vital signs on this tag and a priority of patients is decided. However, no operation are possible with the tags other than grouping. Therefore, in making tags electronic, emergency lifesaving support systems that monitor patients' conditions by automatic operations are researched actively[4], [5], [6]. In this system, sensor network is constructed on triage sites by using this electronic triage tag equipped with a small wireless module[7]. Vital signs such as patients' number of pulses and level of oxygen in blood vessels are collected in a host PC through this constructed network. In using this system, vital signs can regularly be collected by automatic operations and prompt treatments and transportations to a medical institution become possible more than before. This network where vital signs are collected with such a sensor terminal is called Triage Network.

In Triage Network, it is necessary to maintain high arrival rates of vital data and to keep collecting patient's vital data. However, when the number of sensor terminals that exists in this network increases, sensor density rises. This cause amounts of traffic to increase. Data arrival rates decrease by the band pressure when amounts of traffic is too huge. To solve this problems, we proposed data transmission method DTaD[8]. In this method, sensor nodes transmit data adapting sensor density. When sensor density is low, all sensor nodes transmit data at short intervals since there is room in bandwidth. When sensor density is high, data transmission intervals of sensor nodes with low priority are lengthened because possibilities of the band pressure rises. Amounts of traffic are controlled by lengthening data transmission intervals, and high arrival rates of data are maintained in high sensor density.

However to keep monitoring patients' condition, we should consider consumption of battery power and avoid running out of battery. It is because if battery of a sensor node is run out of, it becomes impossible to collect vital data of a patients attached that sensor. Additionally, sensor node secede from Triage Network sequentially in order with high priority. Sensor nodes transported later are easy to be out of battery because remaining in Triage Network for a long time than sensor nodes transported early. And we should consider not only data transmission method but also route to host PC construction method to collect vital data. It is because failures of routes occurs frequently since sensor nodes secede from Triage Network sequentially. This cause the number of sending packet to reconstruct routes to increase. Therefore consumption of battery and packet collisions increase.

To solve this problem, we propose Data collection method adapting to sensor density and node's priority for triage network. This method is divided two phase, route construction phase and data transmission phase. In route construction phase, routes to each sensor node is created by Sink node which is host PC to collect vital data. As a result, consumptions of battery power can be suppressed. In data construction phase, sensor nodes transmit data based on DTaD. In DTaD,

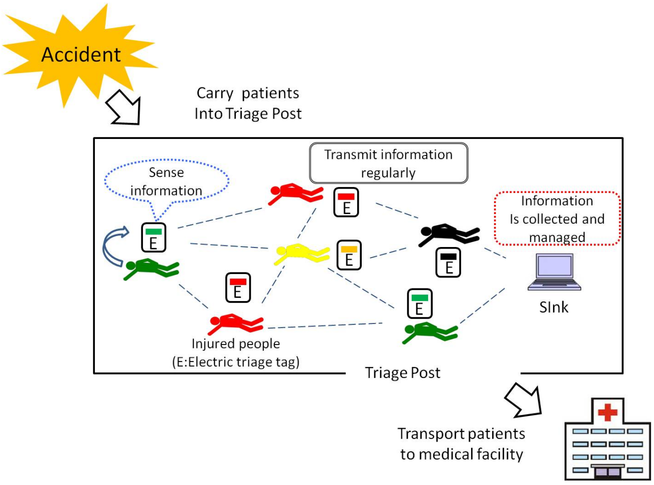


Figure 1: Triage support system

sensor nodes with low priority, which exist Triage Network long, lengthens data transmission intervals to decrease the number of transmission. Therefore, consumption of battery can be suppressed.

We evaluate our proposal method using simulations and show our proposal method can improve data arrival rates and consumption of battery. The rest of this paper is organized as follows. Section Ⅱ discuss Triage network. Our proposal is discussed in section Ⅲ. To evaluate our proposal method, simulation results are examined in Section Ⅳ. Finally, section Ⅴ concludes this paper.

2 TRIAGE NETWORK

In this section, we introduce Triage Network. Triage Network is emergency lifesaving support network that monitor patients' conditions by using intelligent Triage tags. Vital signs such as pulses, level of oxygen, and a breathing rate are collected through Triage Network. Also, electronic systems using Triage Network to collect vital signs are called triage support system. Figure 1 shows Triage support system. First of all, each patients are carried into a place which called Triage post from accident site. In the triage post, patients are given electronic triage tag by doctors. Doctors input conditions of patients to the tag, and classify patients with red, yellow, green, and black in order with high priority. The electric triage tag regularly senses vital signs and transmits this data or relays data of another sensor to host server. In this host server, conditions of a lot of patients can be managed in real time. And patients who requires medical emergency treatment are transported to a medical institution in order or are treated in the Triage Post. In this paper, it is assumed that patients are called sensor nodes, and host PC which collects patients' data is called Sink node.

2.1 Requirement in Triage Network

For keeping collecting each patient's data,We should meet two requirements. First, it is necessary to maintain high ar-

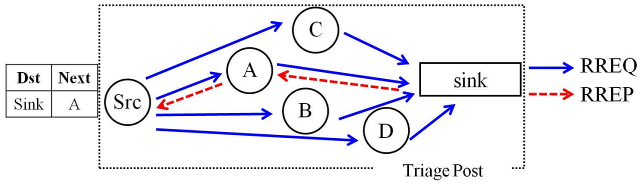


Figure 2: Route Construction in AODV

rival rates of data. It is because handled data in Triage Network is extremely important vital data. Next, it is necessary to consider a condition of battery power. It is because if battery of a sensor node is run out of, there is a possibility that it becomes impossible to collect not only data of a patient given that sensor node but also data of other patients given other sensor nodes using that sensor node as a relay node.

2.2 An Existing Data collection method and problems

To collect data in Sink node, there are two phases, route construction phase and data transmission phase. In route construction phase, sensor nodes construct some routes to Sink node by sending controlled packet, such as RouteRequest(RREQ) or RouteReply(RREP). AODV[9] is an efficiency method for constructing route in an existing routing method on a sensor network. Figure 2 shows a method of construction routes in AODV. We assume that Src is a source node, and sink is Sink node. If Src node does not have routes to sink, Src broadcasts RREQ packets to neighbor nodes first of all. When node A and B have received this RREQ packet, they broadcast that RREQ to neighbor nodes similarly because neither node A nor B are destinations. When sink receive RREQ, sink sends back a RREP packet to a route which RREQ arrived first has passed. Afterwards, Src receives that RREP packet, and a route to sink is constructed. In AODV, sensor nodes store only a relay node of next hop on a route to sink in routing table. Therefore, it can be said that AODV is a routing method with good efficiency of route restoration because only sensor nodes that have lost link to next hop has to search a new route.

However, there are two problems to apply AODV to Triage Network. In Triage Network, patients are transported to a medical institution in order with a high priority one by one and failures of route occurs frequently. In AODV, duplicate RREQ packets increase because each sensor nodes broadcast RREQ packets to construct routes. For example, in Figure 2, if node A is transported to medical institution, Src broadcast RREQ to reconstruct routes to Sink node. Therefore, the number of sending controlled packet to reconstruct routes and the consumption of battery power increase. Moreover, there is a problem that packet collisions occur easily because RREQ packets overflow in Triage network. Therefore, it is necessary to decrease the number of duplicate packets, and to suppress consumption of battery power and packet collisions.

In data transmission phase, there is a method CBR(Constant Bit Rates) in an existing data transmission method[10], [11]. In CBR, all sensor nodes transmit data at same interval. There-

Table 1: Simulation condition

Simulator	Qualnet5.0
Simulation area	50m × 50m
Number of sensor nodes	120
Carrying rate of sensor nodes	average 30(sec/sensor node)
Start Time of carrying node	0(sec)
End time of carrying node	3600(sec)

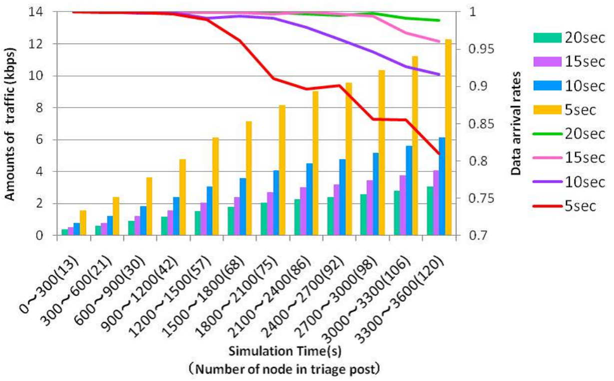


Figure 3: Amounts of traffic and data arrival rates

fore, mounting is easy. However, when applying CBR to Triage Network, it is unable to monitor patients with high priority regularly at short intervals, and to collect data with high priority positively in Triage Network since all sensor node transmit data at same interval. Additionally, since patients are carried into triage post in turn, density of sensor nodes rises in triage post. When density of sensor nodes rises, amounts of traffic increase and it becomes easy to generate the band pressure.

Figure 3 shows relation between amounts of traffic and data arrival rates under the condition in Table 1 when CBR is applied. We used Qualnet5.0[12] for the computer simulator and simulated CBR by the model that sensor nodes participates in the Triage Network at random. The bar chart shows amounts of traffic and the line chart shows data arrival rates respectively. A first vertical axis shows amounts of traffic, a second vertical axis shows data arrival rates, and a horizontal axis shows the number of patients in triage post. Data transmission intervals are changed, 5, 10, 15, 20(sec) in figure 3. In figure 3, it can be confirmed that amounts of traffic increases when the number of sensor nodes in the triage post, density of sensor in a word rises, and data arrival rates decrease at any transmission intervals. Moreover, it can be confirmed to maintain high arrival rates of data by lengthening transmission intervals and controlling amounts of traffic. Therefore it is effective to control amounts of traffic to maintain high arrival rates of data.

3 Data collection method adapting sensor density and node's priority

In this section, we propose data collection method adapting sensor density and node's priority. The purpose of our proposal is to maintain data arrival rates and suppress consumption of battery so that vital signs are kept collecting in Triage Network.

3.1 Outline of Proposal

Our proposal is divided into two phase, "route construction phase" and "data transmission phase". In Triage network, all sensor nodes transmit vital data to Sink node. In such a network, it is thought that it is more efficient for Sink node to construct routes to each sensor nodes than for each sensor node to search routes to Sink node like AODV. Therefore, in route collection phase of our proposal, Sink node broadcasts to sensor nodes in Triage network, and then multiple routes to Sink node are constructed. As a result, each sensor node does not need to broadcast RREQ packets, and then increase of consumption of battery power and packet collisions can be controlled. In data transmission phase, our proposal method is that each sensor nodes dynamically change data transmission intervals applying to sensor density and node's priority. When sensor density is low, it is assumed that there is room in the band, and all sensor nodes transmit data at short intervals. However, When sensor density is high, it is assumed that the possibility that band pressure happens rises and sensor nodes with low priority of transportation lengthen transmission interval. As a result, amounts of traffic is controlled when sensor density is high, and the high arrival rates of data can be maintained. And sensor nodes with low priority can suppress consumption of battery since the number of transmitting data can be controlled. This proposal is composed by the following two parts.

- Broadcast information in a triage post by Sink node.
  A Sink node calculates information in a triage post and broadcast it to each sensor node.
- Construct route and change data transmission intervals by each sensor node.
  Each sensor nodes construct routes to Sink node and change data transmission intervals based on node's priority and sensor density.

3.2 Broadcast information in a triage post by Sink node

Broadcast information by Sink node is two "Maximum value of node's priority" and "Density of sensor nodes". In Triage Network, all sensor nodes that exist in a triage post transmit own data to one place which is Sink node. Therefore, Sink node can know sensor density and the color of prioritized sensor nodes in triage post. Sink node calculates the maximum value of priority and sensor density, and broadcast this information to each sensor node at constant intervals. As a result, each sensor nodes can know information to change transmission interval.

Maximum value of priority

Sink node calculates maximum value of node's priority L_{max}. Maximum value of node's priority L_{max} is a value which evaluated the color with highest node's priority in Triage post. Value : L_{color} according to node's priority is assumed to be $L_{red}, L_{yellow}, L_{green}, L_{black}$. Since the medical treatment priority in Triage is red $>$ yellow $>$ green $>$ black, L_{color} is $L_{red} > L_{yellow} > L_{green} > L_{black}$ in order. If there is $L_{red}, L_{yellow}, L_{green}, L_{black} = 4, 3, 2, 1$, when red, yellow, green and black node exists, L_{max} = $L_{red} = 4$.

Calculation of sensor density

Sink node calculates "The Number of sensor nodes in a triage post at time t : N_t" and "Maximum number of sensor nodes in a triage post : N_{max}". Sensor density depends on the number of sensor nodes which exists in the Triage post since Triage Network is assumed within the constant range in the triage post. Therefore when the number of sensor nodes in Triage post becomes the maximum, sensor density rises most. Each sensor nodes that receive information by the broadcast compares N_t with N_{max} and change transmission interval by using this result. We explain the method of calculating the maximum number of sensor nodes in a triage post N_{max} in detail here. N_{max} is calculated as expression (1). N_{premax} is the maximum number of sensor nodes in a triage post until time t. N_{limit} is the permissible number of sensor nodes in the triage post and is assumed a constant number that depends on the size of a triage post in this paper.

$$N_{max} = \begin{cases} N_{limit} & (N_t > N_{t-dt}) \\ N_{premax} & (N_t <= N_{t-dt}) \\ N_{limit} & (N_{premax} < N_t) \end{cases} \qquad (1)$$

We explain expression (1) by using figure 4. Figure 4 shows the relations between the elapsed times from triage beginning and the number of nodes in a triage post. The number of sensor nodes in a triage post increases because patients is carried into a triage post one by one after triage begins. Because at this stage patients' carrying ends when, and how many patients are carried cannot be understood, it is forecast $N_{max} = N_{limit}$. And in figure 4, because the transportation of sensor nodes is begun at time t_1, there becomes $N_t > N_{t-dt}$ since time t_1. Therefore, it is decided $N_{premax} = N_1$ and uses $N_{max} = N_1$ during time t_1 and time t_2. However, the value of N_{max} is updated because there becomes $N_t > N_{premax}$ at time t_2 and Moreover, since it is unknown when carrying of patients ends, it is forecast $N_{max} = N_{limit}$. And, because transportations of sensor nodes are begun at time t_3, it is decided $N_{premax} = N_2$, $N_{max} = N_{premax} = N_2$. Therefore, $N_{max} = N_2$ is used from time t_3 to time t_4 when the transportation of sensor nodes ends.

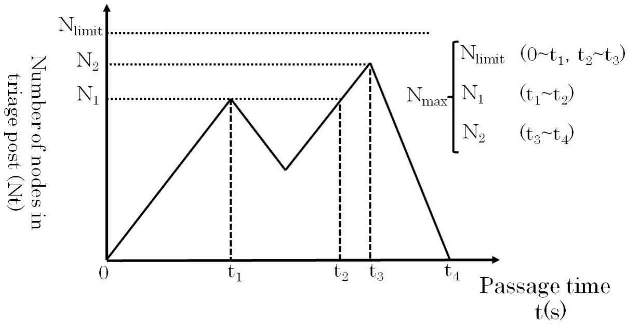


Figure 4: Calculation of N_{max}

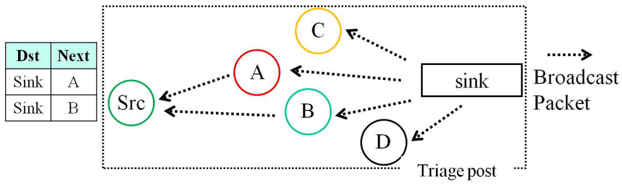


Figure 5: Creating and Updating of Routes

3.2.1 Broadcast of Calculation value

Sink node calculates L_{max}, N_t and N_{max} during dt section and broadcasts this values to each sensor node. This purpose is to enable each sensor nodes to know sensor density and transportation situations on each occasion. As a result, sensor nodes can change transmission intervals with using this values. This packets that the Sink node broadcast at dt intervals is called a broadcast packet in this paper.

3.3 Construct routes and Change data transmission intervals by each sensor node.

Each sensor node construct routes to Sink node and changes data transmission intervals based on the broadcast packet from Sink node.

Constructing and Updating of Routes

We explain constructing and updating method of routes. Each sensor node constructs and updates routes by using broadcast packet from Sink node. In our proposal, Each sensor nodes store all routes that all broadcast packet has passed in receiving a packet. Figure 5 shows an example of constructing and updating of routes. Src stores relay nodes A and B of next hop on two routes, "Src $\longrightarrow$ A $\longrightarrow$ sink" and "Src $\longrightarrow$ B $\longrightarrow$ sink" in its route table. When it becomes impossible to use A course, it changes to stored B. If sensor nodes cannot construct routes, it searches and constructs routes to Sink node itself. There are two reasons to store multiple routes in a route table like this. One reason is to increase relay nodes as candidates in selecting routes to decide one relay node. Another reason is for each sensor node to be able to use the other

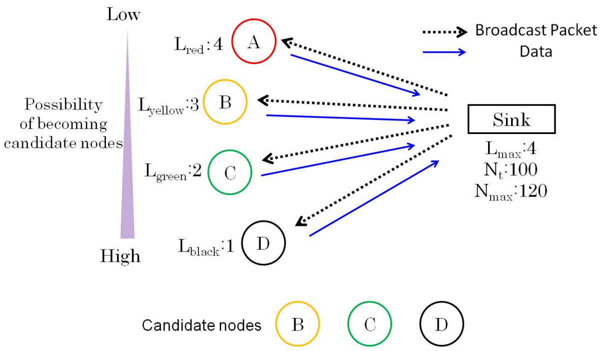


Figure 6: Decision of candidate node

route without searching routes again.

Decision of candidate node

In our proposal, sensor nodes change data transmission interval adapting to sensor density and node's priority. We call this sensor nodes which changes transmission intervals candidate nodes. After constructing route to Sink node, Each sensor nodes compare L_{color} with $Lmax$ which is contained in broadcast packet. Sensor nodes that meets $L_{max} > L_{color}$ becomes candidate nodes.

Figure 6 shows an examples of candidate nodes to decide. In figure 6, red, yellow, green, black node exists in a triage post and since there becomes $L_{max} = L_{red} = 4$, candidate nodes are yellow, green, and black sensor node. The nodes with high priority don't become candidate nodes easily because the value of L_{color} grows in sensor nodes with high priority and are able to maintain data transmission intervals shortly. As a result, sensor nodes with high priority can be observed at short intervals.

Candidate nodes Change data transmission interval

Candidate nodes change transmission intervals long at probability P from initial transmission intervals α at each transmission. We assume that this probability P is change probability, and is shown in expression (2).

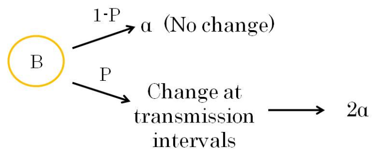
$$Change\ probability : P$$
$$= \frac{\text{Number of sensor nodes in triage post at time } t\text{:}N_t}{\text{Maximum Number of sensor nodes in triage post:}N_{max}} \quad (2)$$

Change probability P lowers when sensor density is low at time t and probability of maintaining the initial transmission interval α rises. Oppositely, P rises when sensor density is high at time t and probability of changing data transmission interval longer is rises.

Data transmission interval of candidate nodes is selected from among an use intervals based on change probability P. We assume that the use intervals is transmission intervals that each sensor node uses according to the node's priority when each node changes interval. Moreover, each node has recommended intervals that are transmission intervals recommended at high sensor density in use intervals. Use intervals and recommended intervals are summarized in table 2.

Table 2: Use intervals and Recommend intervals

	Red	Yellow	Green	Black
Use interval	α	2α	$2\alpha, 3\alpha$	$2\alpha, 3\alpha, 4\alpha$
Recommend interval	α	2α	3α	4α



	α	2α
N_t:20 N_{max}:120	5/6	1/6
N_t:100 N_{max}:120	1/6	5/6

Figure 7: Data transmission interval and the probability of change(yellow sensor node)

In table 2, it is confirmed that recommended intervals has shortened in order with high priority. The purpose of this is to observe sensor nodes with high transportation priority at short intervals when sensor density is high, and to collect the data positively.

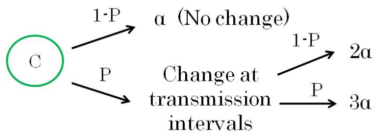
We explain data transmission intervals and change probability of taking a yellow node as an example of figure 7.

When N_t and N_{max} in the received broadcast packet are 20, 120 respectively, a yellow node that is a pertinent sensor node maintains initial transmission interval α at a probability $P = 100/120$, and changes transmission intervals 2α, use interval of yellow node, at a probability $P = 20/120$.

Similarly, when N_t and N_{max} are respectively 100, 120, a yellow node that is a pertinent sensor node maintains initial transmission interval α at a probability $P = 20/120$, and changes transmission intervals longer at a probability $P = 100/120$. Like this, the probability of lengthening transmission intervals rises when sensor density is high and maintaining α rises when sensor density is low.

Since green and black node has two or more use intervals, the transmission interval is selected based on change probability P. Data transmission intervals and the probability of using it are shown in figure 8 as an example of a green node. The initial transmission interval is maintained from figure 8 when sensor density is low. It is confirmed that the probability of selecting recommended interval rises as sensor density rises. Recommended as sensor node with high priority interval shortens because recommended interval is decided based on node's priority. Therefore, the probability of shortening transmission intervals after sensor nodes with high transportation priority changes compared with sensor nodes with low priority rises.

Thus, amounts of traffic can be controlled in the proposal



	α	2α	3α
N_t:20 N_{max}:120	5/6	5/36	1/36
N_t:100 N_{max}:120	1/6	5/36	25/36

Figure 8: Data transmission interval and the probability of change(green sensor node)

method when sensor density is high because each sensor node dynamically changes the transmission interval in proportion to sensor density. And sensor nodes with low priority can suppress consumption of battery since the number of transmitting data can be controlled. Moreover, it is possible to observe it at intervals short like the sensor node with high priority because the probability of becoming an interval short like the sensor node with high priority rises at transmission intervals after it changes.

4 Simulation Evaluation

In this section, we evaluate our proposal method. We constructed our proposal method in a network simulator Qualnet 5.0.

4.1 Simulation Condition

Table 3 shows simulation parameters.

Table 3: SIMULATION PARAMETERS

Simulator	QualNet5.0
Simulation area	50m × 50m
Number of sensor node	100
Allowable number N_{limit}	150
Broadcast interval	300sec
Initial transmission interval	5sec
Participation time of sensor node	0sec
Priority (red, yellow, green, black)	4, 3, 2, 1
Carrying end time of sensor node	3600sec
Beginning Transportation time of sensor node	7200sec
Simulation time	10800sec
Node carrying rate	Random
Communication range	30m
Packet size	64bytes
Number of trials	10times

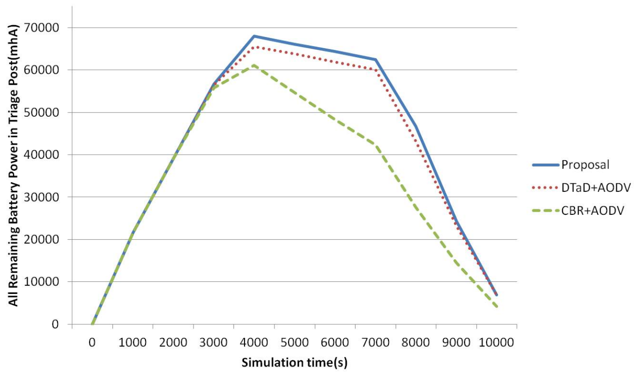


Figure 9: All battery remain in triage post

This proposal assumes a crash site where the hundreds of patients are generated within a specific range like train accidents. After a triage post is established, Triage Network is composed. Each sensor nodes participate in Triage Network and nodes with high priority secedes from network in tern after the fixed time. Additionally ZigBee [13]is used for the communication standard to use the sensor that is called SunSPOT[14] for sensor nodes. In accordance with wireless telecommunications chip TI CC2420[15], we assume that initial electric power of nodes is 750mAh, transmitting power is 17.4mA and received power is 19.7mA. The object of comparison is existing data collection method based on AODV and CBR whose transmission interval is 5(sec) and data collection method based on AODV and DTaD which we proposed before.

4.2 All remaining battery power in triage post

Figure 9 shows all remaining battery power in Triage Post. A vertical axis shows Remaining Battery in Triage Post, and a horizontal axis shows simulation time. It can be confirmed that data transmission method DTaD can suppress consumption of battery compared with the method CBR. This is because sensor nodes always transmits data at constant intervals in CBR. Against this, in our proposal Data transmission method, sensor nodes with low priority lengthens the data transmission interval and the number of data transmission and reception controlled. Therefore, DTaD can suppress consumption of battery of sensor nodes transported later further. Moreover, it can be confirmed that out proposal data collection method in this paper is able to suppress battery remain than data collection method based on AODV to construct route. This is because sensor nodes broadcast RREQ to construct a route to Sink node again when route failure occurs in AODV. Therefore, the number of sending or receiving controlled packet increases in AODV. Against this, in our proposal method, the number of reconstructing routes is a little. It is because Sink node creates routes and each sensor node stores multiple routes in its route table in our proposal method. As a result, overall consumption of battery power in triage post was able to be suppressed.

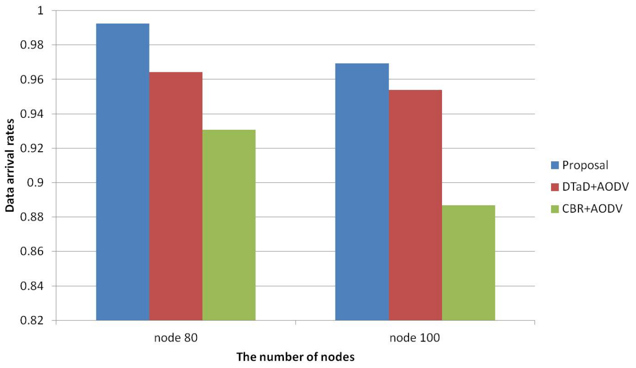


Figure 10: Data arrival rates in Sink node

4.3 Data arrival rates

Figure 10 shows data arrival rates. A vertical axis shows data arrival rates, and a horizontal axis the number of nodes. In data collection method based on CBR, data arrival rate has fallen as the number of nodes increases. Against this, it can be confirmed that DTaD method is able to maintain data arrival rates than CBR method. This is because sensor nodes change data transmission interval in proportion to a sensor density and control amounts of traffic. Moreover, it can be confirmed that out proposal data collection method is able to improve data arrival rates than data collection method based on AODV in route construction phase. In AODV, sensor nodes broadcast RREQ to reconstruct routes again when routes failure occurs. Therefore, the number of controlled packets in Triage network increases, and packet collisions increase. Against this, in our proposal, because sensor nodes store multiple routes in their route table, the number of sending RREQ decrease and packet collisions can be controlled. As a result, our proposal method can improve data arrival rates.

5 Conclusion

In Triage Network, high arrival rates of data are needed and we should consider battery remaining to keep collecting data. However, data arrival rates decrease by the band pressure because amounts of traffic increases when the number of patients increases. And sensor nodes transported later are easy to be out of battery because of remaining in Triage Network for a long time and consume more battery power than sensor nodes transported early since sensor nodes secede from Triage network sequentially. To solve this problem, we proposed data collection method adapting sensor's density and node's priority in this paper. This proposal is divided two phase, route construction phase and data transmission phase. In route construction phase, multiple routes to Sink node are constructed by using broadcast from Sink node. As a result, each sensor node does not need to broadcast RREQ packets, and then increase of consumption of battery power and packet collisions can be controlled. In data transmission phase, all sensor nodes transmit data at short intervals when sensor density is low. When sensor density is high, the sensor node with low priority lengthens the transmission interval. As a result, the data transmission frequency is controlled and decrease of data arrival rates because of the band pressure can be prevented. Moreover, sensor nodes with low priority, which exist Triage Network long, lengthens data transmission intervals decrease the number of transmission.Therefore, consumption of battery of sensor nodes transported later can be suppressed. As a result of evaluations by computer simulations, overall consumption of battery power in Triage post was able to be suppressed. And our proposal was able to maintain data arrival rates to about 95 % by suppressing amounts of traffic even if sensor density rises.

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