Routing Algorithm to Decrease Transmission Delay and Traffic Quantity using Priority Area in Sensor Network of Hospital

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Abstract

Recently, demand of high-speed and high reliability wireless communication in hospital increases. In this paper, we propose the routing algorithm to communicate effectively using position estimation by each sensor or node. ***This propagation channel is modeled to by path loss or Non-line-of sight (NLOS)****. Geometric efficiency for communication is computed by position of destination node, transmission node and relay node, which are in the range of transmission (of each other). Moreover, Back-off time of carrier sense multiple access with collision avoidance (CSMA/CA) is computed under the influence of this efficiency. Then, by canceling communication for one relay node in the case of detecting transmission of (the) other relay nodes, traffic quantity can decrease. Furthermore, the arrival rate of emergency packet can be improved by adjusting the cancel process of communication for relay node.*

Keyword:

Ad-hoc network, Routing, Network in hospital, Position information

1. Introduction

Medical institutions or hospitals require medical networks for connecting among the medical devices. (In addition, higher reliability and higher throughput are desirable for the medical networks.) Medical network is focused on wireless network (with low cost implementation). One of the most attractive candidates for the low cost (implementation) is ad-hoc network. Ad-hoc network has inherent features, such as the absence of infrastructure, tolerance of link disconnection and flexibility of network topology. In the research of ad-hoc network, many routing algorithm studies as well as studies on positioning algorithm are discussed. Especially, we have introduced positioning system of sensor device for medical institute in ISMICT 2007. Therefore, we focus on routing algorithm that utilizes position information. This position information enables to improve communication efficiency or reliability in routing process. Here, there are several conventional routing algorithms being studied. Most basic routing algorithm is Flooding method. Roughly speaking, in flooding, when one node receives a data packet, the node (simply) retransmits the same packet. This algorithm can fulfill high packet arrival rate because all nodes in transmission range relay individually. However, this method increases traffic quantity of data packet excessively by the individual transmission of all nodes. As the next conventional routing algorithm, there is the Table driven algorithm which configures route utilizing link information with near node. This algorithm can diminish the traffic quantity of data packet, however, the traffic quantity of beacon increases because link table need to be kept newest information of network constantly. Furthermore, this algorithm has the problem of link disconnection by node's movement or reception power insufficiency in real situation. In order to avoid it, it is effective to communicate using strong connection node. However, system of such a method needs to communicate with short distance node inevitably. Therefore, hopping number increases and geometric efficiency is degraded. In other word, if high-reliability communication is desirable in table driven algorithm, packet arrival delay and traffic quantity increases necessarily compared with normal Table driven algorithm. As a last conventional method routing algorithm, there is packet relay control scheme based on priority region (PRCSPR) which is based on aforementioned Flooding algorithm and utilize position information. This method is that if one node detects other node's transmission of same packet, the detected node cancels its transmission. Additionally, according as distance between transmission node and reception node, the reception node is assigned priority of transmission. This enables to restrain traffic quantity in network. In this paper, we solve the problem of increase traffic quantity in Flooding method and link disconnection in Table driven method. Furthermore, we propose effective multi-hop routing method using the position information of each node. This method is based on PRCSPR and CSMA/CA as MAC protocol. This detailed method is described as follows. Firstly, one node senses other node's signal. Next, if it senses transmission finish of others, it waits back-off time and its transmission is started. If the packet same as reserved packet in one node is transmitted from other node, one node cancels its transmission in aforementioned at PRCSPR. In addition, back-off time is decided according as distance between transmission node position and reception node position. In other word, we model back-off time decision function (BOTDF) so as to communicate with multi-hop using the node which exists in geographically effective position. As the demerit of this method, packet arrival rate is degraded comparing with Flooding method. In general situation, if the route from transmission start node to the destination node cannot be configured, same data packet need to be transmitted again at other route. This causes the degradation of throughput and reliability.

Especially for the network in hospital, we must consider the emergency packet, for example, deterioration of patient's condition. In order to enhance the arrival rate of this emergency packet, we propose the postponement method of packet transmission cancel of PRCSPR. This method is able to improve packet arrival rate because possibility of a route disconnection could be suppressed by postponing node's transmission and compensating the route by using other route in case of link disconnection. In other word, one node does not cancel on sensing FIRST transmission of the other node but it cancels instead upon sensing the SECOND transmission of the other node. This process becomes redundant algorithm and enables to improve reliability of emergency packet's communication by restoring disconnected route.

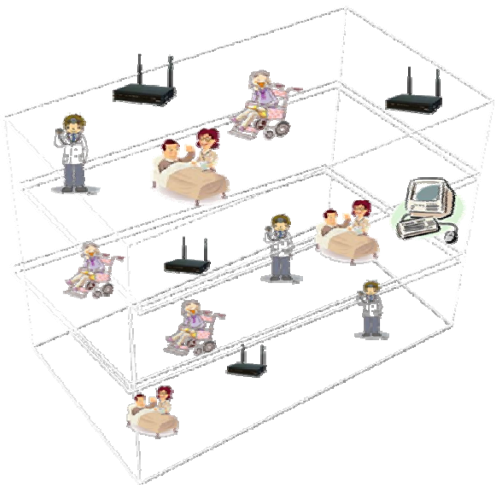

Figure 1. Network in Hospital

2. System Model and Routing Algorithm

2.1. System Model

The devices for communication consist of mobile nodes and anchored nodes. Mobile nodes estimate their own position information through communication with anchored node that has knowledge of its own position. Furthermore, it is assumed that all nodes know other nodes' positions mutually. Each node transmits signal at the same power constantly and therefore the max transmission range have to be constant. Some combinations of each node are under influence of non-line-of sight (NLOS). Therefore, this causes attenuation of received signal strength, shortening of max transmission range and link disconnection. In this paper, we configure the packet link propagation model for communication with neighbor node as the (model integrating these factors).

2.2. Simplified Propagation Model

Mentioned in section 2.1, there is the link disconnection of each node by several elements in real situation. In order to simplify it, we introduce the packet link propagation function (PLPF). PLPF is the function which shows whether nodes are connectable or not by distance between transmission node and reception node. Generally, link connectivity is decreased at long distance (near maximum transmission range). Furthermore, the longer the distance, the larger NLOS probability is. Therefore, we adopt exponential function as the probability distribution function of link connectivity representing these factors. This is shown in equation 1.

$$P_{link} = 1 - \exp\left(\frac{x-\alpha}{C_p}\right) \quad (1)$$

Where α is the maximum transmission range, x is the distance between transmission and reception node and Cp is a constant that represents propagation features. This equation is shown in figure 2.

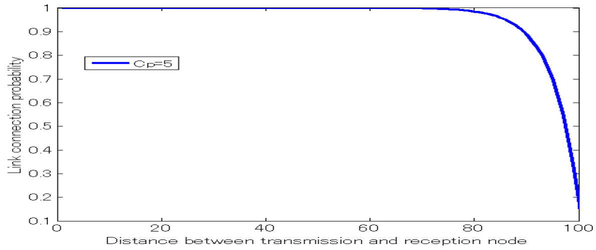

Figure 2. Connection Probability Function by Distance Between Nodes

2.3. Carrier sense multiple access with collision avoidance

This media access control (MAC) protocol is the method for multi-user coexistence communication. Firstly, one node checks the transmission of other nodes. If one node senses transmission of other nodes, it waits until the current transmission of other node to finish before attempting to start its own transmission. Additionally, it waits for a back-off time which is randomly defined by the system. Finally, one node transmits own packet after the back-off time.

2.4. Routing Algorithm

2.4.1. Flooding Algorithm

This routing algorithm is the basic algorithm in ad-hoc network. If one node receives data packet, it transmits the same packet around node. If one node receives the same packet from other nodes, it discards the packet and do not retransmit it again. Thus, this method allows the packet to arrive at the destination node by iteration of these processes. Since flooding method is the algorithm communicated by all possible nodes, the merit is that high packet arrival rate can be fulfilled. However, there is the problem where network traffic quantity increases, radio-wave utilization efficiency decreases and this would lengthen the packet arrival delay. This also causes degradation of throughput.

2.4.2. Table Driven Algorithm

This method is that one node transmits beacon to neighbor nodes and creates a table of connection of each other. The route from transmission node to destination node is created in the table. The merit of this method is it requires only minimal process of transmission in relation to data communication. However, since the link table of each node needs to be kept updated constantly, it is necessary for node to transmit beacon to each other at frequent intervals. Furthermore, this method has the problem of link disconnection. This link disconnection is caused, for example by non-line-of sight or by insufficiency of signal power. Relating to the insufficiency of power, in spite that one node estimates the link connectivity from the received beacon, there is the case that the required power for valid communication cannot be fulfilled and packet also cannot arrive at the node. In the case where it is impossible to configure a particular route to the destination node, it is necessary to reconfigure to another route and retransmit. The more these retransmission processes occur, the more the throughput decreases. In order to avoid it, it would be effective to adopt a multi-hop way of using the neighbor node that exists within short distance and has strong link connection power. However, such a method is ineffective geometrically because number of packet transmission increases.

2.4.3. Packet Relay Control Scheme Based on Priority Regions

This method is based on the Flooding method. Procedure of this algorithm works as follows. Firstly, a node estimates the distance between transmission node and reception node by position information from GPS or received signal strength. Secondly, priority of packet transmission is decided according to the distance estimated. The longer the estimated distance between nodes becomes, the shorter the back-off time of CSMA/CA becomes and the higher the priority of packet transmission is. This node reserves the packet transmitted from other nodes before forwarding it and waits for a certain back-off time. If one node senses the same packet from other nodes' transmission, this node would cancel its own packet transmission. This reduces the traffic quantity compared to Flooding method. The problem is the rate of link disconnection increases with this transmission cancellation process.

3. Proposed Method

In this section, we state our proposed method. This method is based on PRCSPR in sect 2.2.3. Firstly, relay node (named A) receives packet from transmission node (named B) which contains the position information of B and destination node (named C). The priority of transmission of each node in the selected route is determined by combination of A, B, and C position. Using this position information, priority of each relay node is decided by geographical efficiency of node distribution. To effectively apply the priority values, the back-off time of CSMA/CA for each node in route is determined according to the priority value. The way of geographical efficiency decision is explained as follows. First, the distance between A and B is configured as X_D. Taking the direction angle of node B to C as the reference angle $\theta=0$, the angle from B to A is configured as θ. B's position is configured as the center of circle with maximum transmission range, α as radius of this circle. Additionally, the projected distance of distance node B to relay node A on the transmission direction line towards destination node C is configured as X_S. This X_S represents the geometric efficiency toward C. These are shown in figure 3.

By the way, we consider the "random" distribution of relay node within the circle to be applied to the adaptation of back-off time of CSMA/CA at each node. Therefore, it is ideal that back-off time is allocated uniformly.

PRCSPR method uses nodes within the maximum transmission range. However, the necessary area to arrive at destination node for packet is only half of the disk area of destination node side. Therefore, by limiting number of relay node and back-off time distribution within the half-disk area, delay caused by back-off time can be decreased effectively. Next, in order to apply this uniform allocation of back-off time in the case of half-disk area, we create back-off time decision function such that back-off time is allocated uniformly versus X_S (distance to direction at destination node).

X_S represents geometrical efficiency toward destination node. X_S is shown in equation 2.

$$X_S = X_D \cos\theta \qquad (2)$$

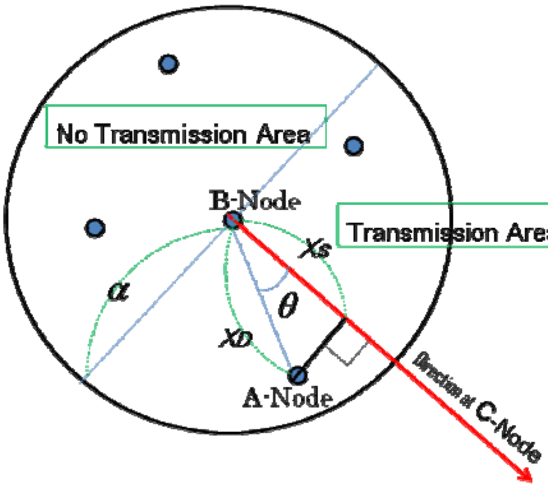

Figure 3. Processing Position Information

Here, it is necessary to calculate geometric area. In aforementioned, half-disk area covering the direction line to destination node C is illustrated. First, the chord line that intersects orthogonal to the Xs is drawn. The shaded area between the chord and the curve of the circle is calculated as As. Then, the ratio of the shaded area to the half-disk area, A is defined as back-off time decision function. "Former area away vertical line of Xs" is illustrated in figure 4.

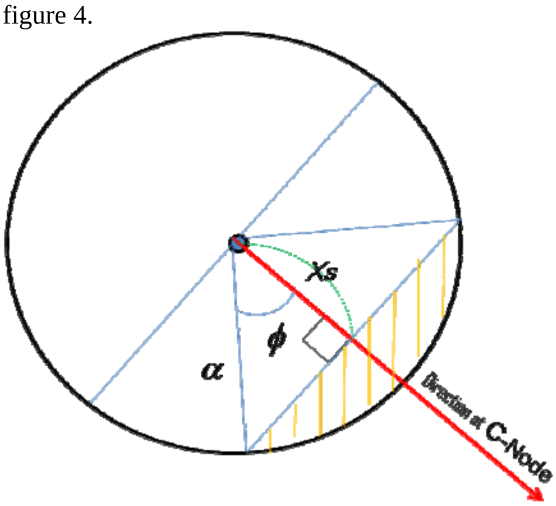

Figure 4. Back-off Time Decision Process

Where, ϕ represents the angle between the line of Xs and the line connecting the node B to the relay node A. Square measure of this striped area in figure 4 is calculated as "fan-shape area – rectangle area".

Each square measure is shown as follows.

Half circle: $\frac{\alpha^2\pi}{2}$

Fan shape: $\alpha^2\phi$

Rectangle: $\alpha X_S \sin\phi$

Striped area: $\alpha^2\phi - \alpha X_S \sin\phi$

Ratio of striped area versus half disk:

$$F(Xs) = \frac{2\alpha\phi - 2X_S \sin\phi}{\alpha\pi} \qquad [\phi = \arccos(\frac{Xs}{\alpha})]$$

$$F(Xs) = \frac{2}{\pi}\arccos(\frac{Xs}{\alpha}) - 2X_S\frac{2Xs}{\alpha\pi}\sqrt{1-\frac{Xs^2}{\alpha^2}} \qquad (3)$$

This ratio *F(Xs)* shows that back-off time in each node is distributed randomly and uniformly by geographical efficiency distance *Xs*. Additionally, the nearer the distance to destination node, the shorter the back-off time becomes. Range of *F(Xs)* is 0~1. Accordingly, back-off time decision function (*BTDF*) is shown as

BTDF(*Xs*)=*MB***F*(*Xs*)

where *MB* is Max back-off time defined in system.

In the case where a relay node is in the opposite half disk area away from the destination node (*Xs* is negative), received packet is discarded and further transmission is not performed at this relay node. By repeating these processes at each node, it is possible to configure the route using only geographical effective nodes toward destination node in many cases. Additionally, packet arrival delay can be shortened due to decrease of back-off time by calculating geometric efficiency. Furthermore, it is effective for this system to cancel superfluous transmission of packet from the perspective of the decrease of traffic quantity and power consumption.

3.2. Packet Arrival Rate Improvement for Emergency Packet in Real Situation

As stated in section 2, there is the case that one node is impossible to connect with neighbor node inside the transmission range. This is caused by, for example, node's movement exceeding the transmission range, NLOS, and insufficiency of received signal strength. This degrades packet arrival rate and reliability. It is especially serious for table driven algorithm because of the route construction at one line. Concretely speaking, a route to destination node is constructed but one of the links in the route between one node and another node is disconnected, then it is necessary to retransmit packet using another route. This increases packet arrival delay and degrades throughput. Propagation model of connection probability by distance was shown in figure 2 at section 2.2.

When link disconnection happens, Flooding method, PRCSPR and our proposed method can search other route automatically unlike table driven algorithm. However, degradation of packet arrival rate is inevitable. Especially in the case of medical usage, it is necessary to transmit emergency packets, e.g. health deterioration data. Accordingly, it is necessary to improve packet arrival rate in such propagation situation. In order to improve the reliability of emergency packet transmission, we change multi-hop cancellation process at each node in PRCSPR. Concretely speaking, in the case of receiving the FIRST reserved packet, the cancellation process is not performed, however, in the case of receiving the SECOND reserved packet, the cancellation is performed. In other words, this process is to postpone the cancellation. By performing this postponement process for emergency packet only, packet arrival rate can be improved and packet retransmission process can be reduced. Therefore, packet arrival delay can be improved. However, traffic quantity increases slightly compared to default proposed process.

4. Numerical Analysis

In this section, we analyze our proposed method to comparing with Flooding method, Table driven method, and PRCSPR.

4.1. Simulation Parameters

Simulation parameters are shown in table 1.

Trial number	20000
1 slot time	25[μs]
Packet length	90 slot
DIFS time	2 slot
Max back-off time (MB)	31 slot
Field	500x500[m]
Transmission Range	100[m]
Distance between first node and destination node	400[m]
Propagation model constant ***Cp***	1

Table 1. Simulation Parameters

4.2. Packet Arrival Delay versus number of nodes

In order to confirm improvement of communication efficiency of our method, we analyze packet arrival delay (PAD) time versus the number of nodes existing in the field. It is showed that the smaller the PAD, the more the throughput is improved. In this analysis, packet arrival delay is defined as average the delay value only in the case where the packet arrives at destination node. The result is shown in figure 5.

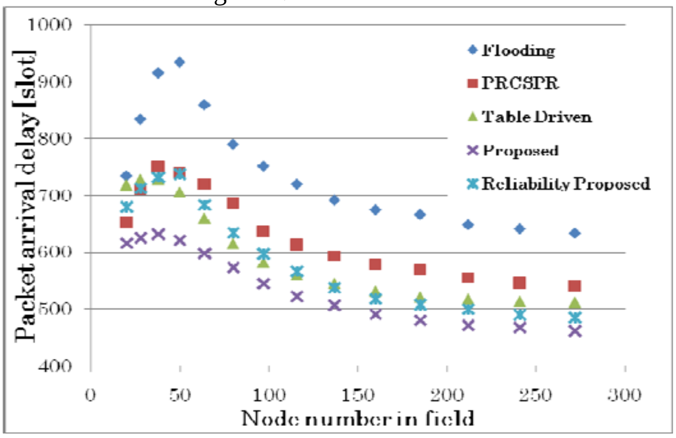

Figure 5. Packet Arrival Delay versus Node Number in Field

Figure 5 shows as follows. Firstly, PAD of flooding method is degraded from the cause of increasing the wait status opportunity of other node's transmission in CSMA/CA protocol. Comparing with flooding method, PRCSPR can reduce the delay due to additional back-off time by canceling redundant transmission in case where repeated transmission by other nodes is sensed. Therefore, PAD can also be reduced. Furthermore, nodes transmit minimal number of packets only in table driven method. Therefore, there is no additional delay by own packet transmission and PAD becomes small. In our proposed method, PAD can be reduced most effectively by shortening back-off time of node in geographical effective position. Finally, the proposed method that enhances reliability (i.e. Reliability Proposed) by retransmission, results in a slightly increased PAD but almost identical PAD characteristics as that of table driven method.

4.3. Packet arrival error rate versus node number

In this section, we analyze packet arrival error rate (PAER) and evaluate its reliability. The smaller PAER is, the more retransmission of packet can be reduced. This improves the throughput. This result is shown in figure 6 in the case of ideal situation where all of nodes can connect to each other, and shown in figure 7 in the case of *Cp=1* of the propagation function.
PAER of flooding method can fulfill smallest value theoretically because almost all nodes relay the packet. PAER of PRCSPR is reduced by cancellation of redundant packet transmission. Furthermore, the case for proposed method is also the same as PRCSPR. PAER of table driven method is the same value as flooding method in the ideal case. However, PAER is reduced extremely in the case of applying the link disconnection propagation model. Finally, reliability proposed method improves PAER.

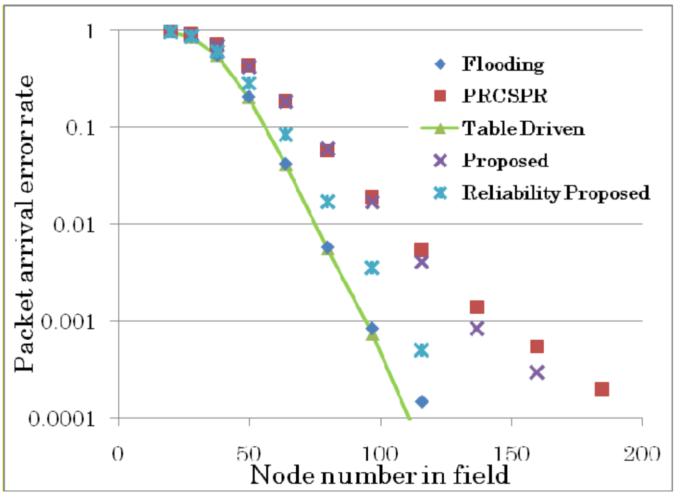

Figure 6. Packet Arrival Error Rate versus Node Number in Field : Ideal Situation (No Apply Connection Probability Function)

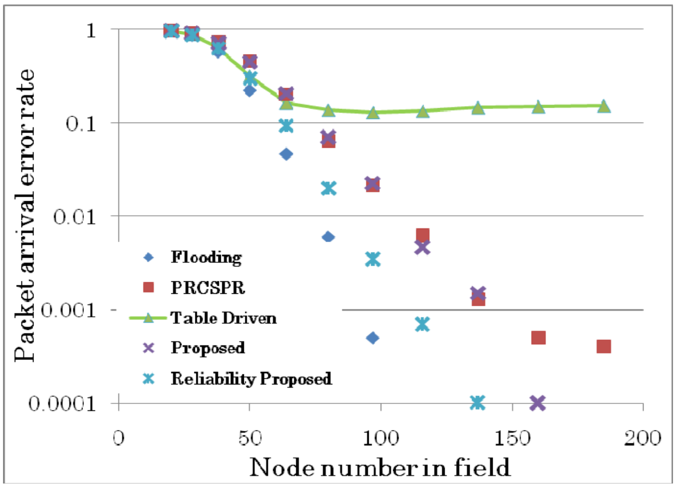

Figure 7. Packet Arrival Error Rate versus Node Number in Field : Real Situation(Connection Probability Function *Cp=1*)

4.4. Transmission number versus node number
In this section, we analyze transmission number with respect to number of nodes. If the transmission number is small, low power consumption or improvement of network efficiency can be fulfilled. This is shown in figure 8. In flooding method, traffic quantity increases largely by increase of number of nodes. PRCSPR can reduce traffic quantity effectively compared with flooding method. Furthermore, Reliability proposed method could achieve a smaller traffic quantity than that of PRCSPR. Table driven method can communicate by multi-hop with only minimal number of nodes. Therefore, smallest theoretical transmission number could be achieved. However, as aforementioned, traffic of beacon increases because system needs to maintain latest link table constantly. Finally, our proposed method achieves transmission number near that of table driven method.

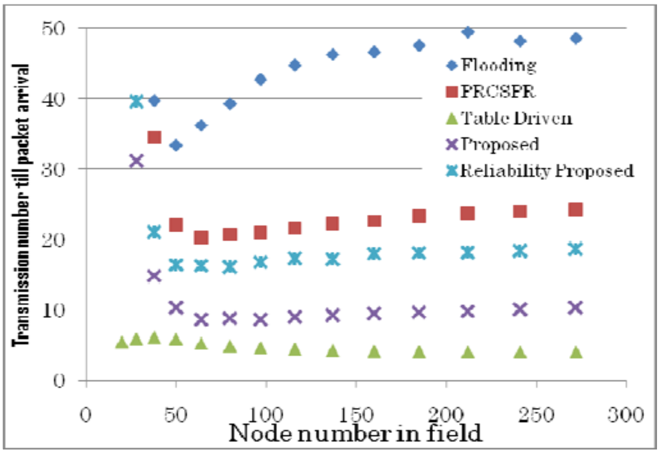

Figure 8. Transmission Number till Packet Arrival Time versus Node Number in Field

5. Result

In this paper, for the network used in hospital, we proposed back-off time adjustment routing method based on priority area. This enables us to reduce traffic quantity and to shorten packet arrival delay. Furthermore, packet arrival rate can be decreased and reliability is improved by postponing cancellation process.
In the future works, it is necessary to analyze the case of other propagation situation, or the extension to 3-dimension situation.

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