An Efficiently Cluster Management using Secondary Leader in CBRP

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Abstract: Mobile Ad Hoc Network (MANET) is a network architecture, which has no backbone network and is deployed temporarily and rapidly in emergency or war without fixed mobile infrastructures. All communications between network entities are carried in ad-hoc networks over the wireless medium. Due to the radio communications being extremely vulnerable to propagation impairments, connectivity between network nodes is not guaranteed. Therefore, previously developed routing algorithms in wired networks cannot be used. And many new algorithms have been undergone.

This study proposes the secondary leader approach to the cluster based routing protocol(CBRP). In case, the primary leader becomes abnormal status so that the primary leader cannot participate the communications between network entities, the secondary leader immediately replaces the primary header without selecting process of the new primary leader. The performances of proposed algorithm ACBRP(Advanced Cluster Based Routing Protocol;CBRP using secondary leader) are compared with CBRP and results are presented in order to show the effectiveness of the algorithm.

Keywords: MANET, Ad-Hoc, CBRP, and Secondary Leader

1. INTRODUCTION

Mobile Ad Hoc Network (MANET) is network architectures, which is deployed temporarily and rapidly in emergency or war without fixed mobile infrastructures. All communications between network entities are carried in ad-hoc networks over the wireless medium. Due to the radio communications being extremely vulnerable to propagation impairments, connectivity between network nodes is not guaranteed. In fact intermittent and sporadic connectivity may be quite common[1,10]. Additionally, as the wireless bandwidth is limited, communications should be minimized. And, as some of the mobile devices are expected to be hand-held with limited battery power, the required transmission power should be minimized as well[2,3]. So, previously developed routing algorithms in wired network cannot be used. Therefore new algorithms are researched like distance vector algorithm[4,5], Dynamic Source Routing (DSR)[6,7] and Cluster Based Routing Protocol (CBRP)[10,11].

Especially in CBRP, efficient leader selection and management are very important hence, leader selection algorithm should make sure leader is selected during a certain period and selected leaders are accepted by other member nodes [8]. And this algorithm has to support robustness for fault, and when and who should be selected as the leader. Additionally, Mobile Host (MH), network performance, fault rate, traffic pattern, throughput and change in the network topology should be considered[9]. If a leader has problem, all communications inside its cluster will stop until a new leader is selected. In MANET, MH's mobility makes leader selections very often. This is very important factor for routing algorithms.

Therefore this paper proposes a secondary leader based clustering management with rerouting algorithm to recover rapidly and to minimize the problem when primary leader is moving out a cluster or get into an abnormal status so that a secondary leader performs an original lead's job in time.

2. SECONDARY LEADER FOR CBRP

In previous CBRP, a Cluster Leader (CL) is selected. The cluster is based on MHs' virtual cell, in which a CL can transmit messages and coordinate all communications between each pair of MH's. Hence, messages are transported via a CL. And all MHs(member MHs and gateway MHs) in a cluster routes packets depending on CL as Fig. 1. But if a CL has a problem, then packet cannot be transmitted inside this cluster until another new leader is selected.

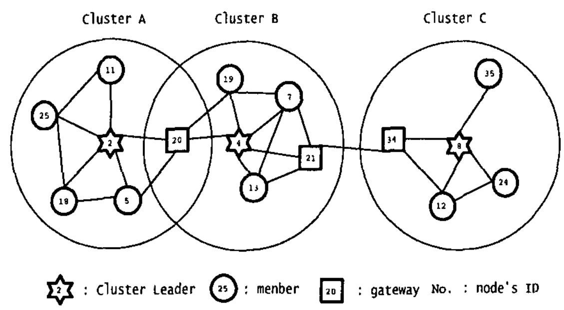

Fig. 1. Ad-hoc network model

In order to minimize the time lag we advocate that whenever a Primary Leader(PL) is selected, a Secondary Leader(SL) also is decided. The SL is always within 1-hop from PL in order to decrease the number of MHs that participates in possibly different clusters. And SL just keeps PL and related information before PL has problem. When PL has a problem, SL performs PL's job without any reselection of PL like previous CBRP.

2.1. Assumption

Assumptions we made in this paper are as follows.

MHs in MANET transmit packets as promiscuous mode, receives all packets without topology address filtering. Even though promiscuous mode increases CPU's load, but we expect hardware's performance is going up rapidly. So, transmission speed will be a more important factor in wireless topology's performance.

A MH or related equipment transmits packets in bi-directional ways.

Each MH has a unique ID, for instance IP address. MH that has the smallest ID out of 1-hop away neighbor MH's will be elected as PL. Even there are many different to select a Leader, but this paper considers a simple leader selection algorithm for the simplicity.

2.2. Experiment procedure

Each MH maintains a Neighbor Table like Fig. 2.

And each MH broadcasts HELLO message with its Neighbor table as shown below every HELLO_INTERVAL.

NEIGHBOR_ID	ROLE
Neighbor 1	LP/LS/MB
Neighbor 2	LP/LS/MB
....	....
Neighbor N	LP/LS/MB

LP: Primary Leader in cluster
LS: Secondary Leader in cluster
MB: ordinary member MH

Fig. 2. Structure of Neighbor Table

In Fig. 3, the first field specifies the ID of sender MH. The second field shows MH is PL, SL or cluster member. Undecided means a node is still in search of it host cluster.

MY_OWN_ MH's ID	MY_MEMBERSHIP_STATUS (LP/LS/MB /Undecided)
Neighbor Table	

Fig. 3. Structure of HELLO message

Upon receiving a HELLO message from its Neighbor MH B, MH A modifies its own Neighbor Table as follows.

1) It checks if MH B is already in the information table, if not, it adds one entry for MH B.

2) If MH B is PL or SL, marks MH B as PL or SL, if not, marks cluster member.

Each entry in the information table is associated with a timer. A table entry will be removed if a HELLO message from the entry's node is not received for a period of (HELLO_LOSS+1) * HELLO_INTERVAL, allowing HELLO_LOSS consecutive HELLO messages to be lost from that node.

CBRP could be viewed as a combination of the two following sub functions which will be discussed below.

[1] Cluster Formation

The Cluster Formation algorithm is a simple lowest ID clustering algorithm in which the node with a lowest ID is selected as the cluster leader. Each MH uses the information obtained from the HELLO message for Cluster Formation. A MH, that has the lowest ID among all its bi-directionally linked neighbors, is selected as PL. And another MH that has the next lowest ID within 1-hop from PL is selected SL.

The new PL or SL broadcasts HELLO messages with PL or SL information. All other MHs except PL and SL are cluster member. Fig. 4 is a sample cluster of this paper. In Fig. 4, PL is HM 2, and SL is MH5.

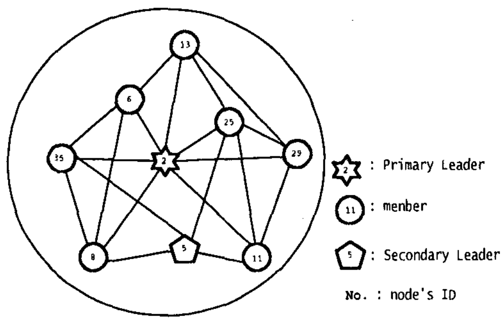

Fig. 4. Clustering in the proposed method

[2] Cluster Maintenance

PL and SL perform the following rules.

- Non PL MH cannot change current cluster PL's status. When MH X is moving to other cluster in which MH Y is PL then MH X cannot be PL, even if MH X has smaller ID than MH Y.
- SL checks HELLO message from PL periodically. If it cannot receive any HELLO messages from PL during a certain period, SL makes itself as the PL and selects a SL from Neighbor Table.
- If two different PLs are moving into one cluster and has 1-hop distance, then one loses its PL right and it's MY_MEMBERSHIP_ STATUS field's value becomes a member.
- PL checks HELLO message from SL. If it cannot receive this message during a certain period, PL selects new SL with has next lowest ID from its information table, promptly and informs to new SL. After receiving, New SL also broadcasts HELLO message to neighbor MHs.

And it follows the previous CBRP management procedure to add and remove numbers of cluster [11].

In this paper, we have discussed SL selecting. In previous CBRP, there is only one leader. This makes overheads because of MH's mobility. With SL, PL's absence can be improved very quickly and CBRP's problem can be solved.

3. EXPERIMENTAL RESULTS

Throughout the experiment, it is assumed that all MHs represent set theory and calculate probability distribution of MH.

3.1. Calculate cost of reelection primary leader

This section calculates cost of reelection primary leader when primary leader is moving out a cluster or get into an abnormal status. Therefore, it is assumed circle which center is primary leader and a radius is R, and all MHs in circle exist uniform distribution.

In Fig. 5 presents secondary leader instead of primary leader when primary leader in a cluster is moving out a cluster or get into an abnormal status

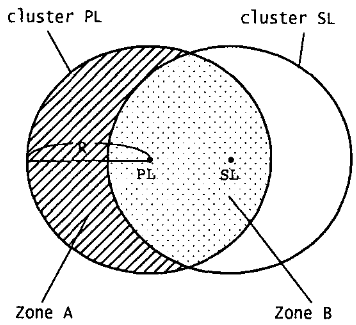

Fig. 5. Change cluster SL from cluster PL

In Fig. 5, cluster zone is circle, which center is primary leader and a radius is R.

If secondary leader in charge of the PL's job when PL is abnormal status, cluster zone will change cluster PL to cluster SL. At this time, MHs in zone B is not change routing, but MHs in zone A is member in other cluster or build up other cluster.

Therefore calculate area zone A and zone B for calculate number of zone A and zone B's MH. Fig. 6 presents coordinates that X-axis is line of PL and SL, the origin is PL for it.

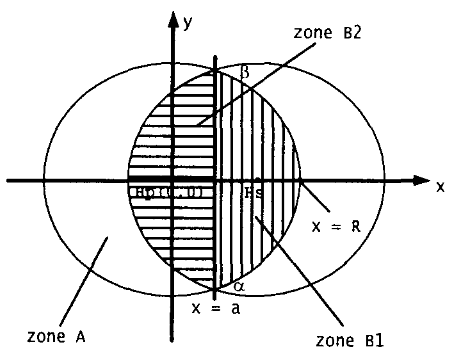

Fig. 6. Change cluster PL to cluster SL using coordinates

In Fig. 6, solve point α, β which cross point cluster PL and cluster SL, connect for calculation zone B area, and cut a zone B into two equal parts(zone B1 and zone B2) using line(X = a) connected α, β.

The area of zone A is circle area which center is PL and a radius is R without area of zone B.

In Fig. 6, we calculate α and β point value using circle equation in a radius R.

(1) is the equation of a circle.

$$x^2 + y^2 = R^2 \qquad (1)$$

(2) is a straight line through α and β in Fig. 6.

$$x = a \qquad (2)$$

We get (3) from (1) and (2). And we solve α and β from (3).

$$y^2 = R^2 - a^2 \qquad (3)$$

$$y = \pm\sqrt{R^2 - a^2}$$

$$\therefore\ \alpha = -\sqrt{R^2 - a^2}\ , \quad \beta = \sqrt{R^2 - a^2}$$

If the area of zone B is S(B), it express to (4) with $0 < a \le \frac{R}{2}$.

$$S(B) = 2 \times S(B1) = 2R^2 \sin^{-1}\left(\frac{\sqrt{R^2-a^2}}{R}\right) + 2R\sqrt{R^2-a^2}\cos\left\{\sin^{-1}\left(\frac{\sqrt{R^2-a^2}}{R}\right)\right\} - 4a\sqrt{R^2-a^2} \qquad (4)$$

If the value of a is 0 in (4), the result is as follows.

$$S(B)_{(a=0)} = 2R^2 \sin^{-1}(1) + 2R^2 \cos\{\sin^{-1}(1)\}$$

Also, if the value of is R/2 in (4), the result is as follows.

$$S(B)_{(a=R/2)} = 2R^2 \sin^{-1}\left(\frac{\sqrt{3}}{2}\right) + \sqrt{3}R^2 \cos\left\{\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)\right\} - \sqrt{3}R^2$$

Assuming that the area of zone A is S(A), it is as follows.

$$S(A) = \pi R^2 - S(B) \qquad (5)$$

In assumption, all MHs exists uniform distribution N(A) (number of MHs in zone A) and N(B) (number of MHs in zone B) can be shown at the next two equations. The n is the number of MHs in cluster.

$$N(A) = \frac{S(A)}{\pi R^2} \times n \qquad (6)$$

$$N(B) = \frac{S(B)}{\pi R^2} \times n$$

Next, calculate packets for reelection primary leader of proposed ACBRP and CBRP when primary leader abnormal status.

In this case the problems happen to primary leader at CBRP, the each mobile hosts generate HELLO message for reelection. And the each mobile host recognizes that the host becomes a primary leader using the message information. If one host is primary leader, it broadcasts to mobile hosts with HELLO message.

A packet for the reelection of leader at CBRP generates when mobile host recognizes the matter of leader in the cluster and is broadcasted to assign MY_MEMER-SHIP_STATUS value of HELLO message to UD. If so mobile host in the cluster excludes leader and is (n-1), HELLO message of (n-1) is generated.

So, PR(Packets for Reelection Header) for reelection of leader at CBRP is as follows.

$$PR(CBRP) = (n-1) + 1 = n \qquad (7)$$

But, secondary leader immediately play the role of primary header as Fig. 5 at the proposed ACBRP. So, nodes in zone B don't change and only nodes in zone A act the same as CBRP.

So, nodes in zone A can get the following equation from (7).

$$PR(A) = N(A)$$

Nodes in zone B become to broadcast the only packet that is changed secondary leader to primary leader. And they can express as follows.

$$PR(B) = 1$$

Also, δ that manage secondary leader can consider the kind of three. First, there is a packet that informs the election of secondary leader to the leader after making up a cluster. Second, there is a packet that informs the election of new secondary leader to the leader because of secondary leader trouble. Third, there is a packet that delivers a routing table of primary leader per hour to secondary leader.

So when primary leader is absent from ACBRP, PR(ACBRP) of generated packet number for primary leader reelection is shown in (8).

$$PR(ACBRP) = PR(A) + PR(B) + \delta = N(A) + 1 + \delta \qquad (8)$$

where δ is a packet for SL management

We calculate (9) from (5), (6), (7) and (8).

$$PR(ACBRP) = \left[1 - 2R\sin^{-1}\left(\frac{\sqrt{R^2-a^2}}{R}\right) + 2R\sqrt{R^2-a^2}\cos\left\{\sin^{-1}\left(\frac{\sqrt{R^2-a^2}}{R}\right)\right\} - 4a\sqrt{R^2-a^2}\right] \qquad (9)$$

If the number of mobile host become 100 at cluster in (8), (9), if radius R of the cluster is 2 km and if δ is 3, we get the following equation, (10) at $0<a\leq 1$

$$PR(CBRP)_{n=100} = 100$$

$$PR(ACBRP)_{n=100} = \left[1 - 4\sin^{-1}\left(\frac{\sqrt{4-a^2}}{2}\right) + 4\sqrt{4-a^2}\cos\left\{\sin^{-1}\left(\frac{\sqrt{4-a^2}}{2}\right)\right\} - 4a\sqrt{4-a^2}\right] \times 100 + 4 \qquad (10)$$

Table 1 show the value of PR(ACBRP).

It increases the value of a from 0 km to 1 km, R/2 at intervals of 0.1 km.

Table 1 PR(ACBRP) according to a change of the value a

a	0	01	02	03	04	05	06	07	08	09	
PR(ACBRP)	400	885	1340	1771	2178	2565	2936	3292	3638	3976	4310

At ACBRP and CBRP algorithm, the number of reelection about abnormal status of PL is shown in Fig. 7.

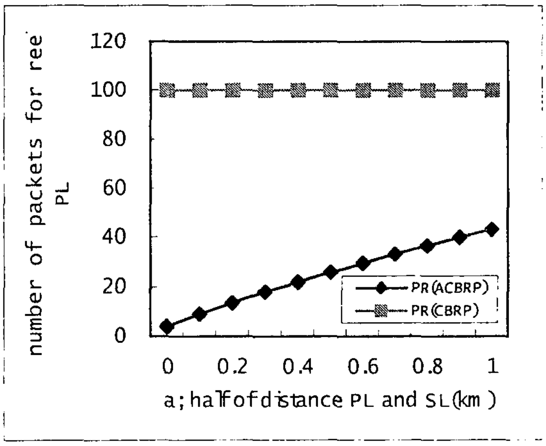

Fig. 7. The number of packets for reelection of PL according to a (half of distance PL and SL)

As Fig. 7, we know that the number of packet for leader reelection is always fixed in the conventional CBRP, but is considerably decreased in the proposed ACBRP. Specially, if the distance of between primary leader and secondary leader is 0 (a=0), it is not generated to a packet for the reelection of primary leader, and only confirms packets for informing new primary leader and managing secondary leader.

The cost for reelection of primary leader considers the only generation of a packet.

It assumes all the cost for managing received packet to k. Then, the cost for reelection of primary leader in the cluster, CRHp(Cost for reelection Hp), is calculated as (11) and (12).

$$CRHp(ACBRP) = PR(ACBRP) \times k \qquad (11)$$

$$CRHp(CBRP) = PR(CBRP) \times k \qquad (12)$$

All cost about unit packet, k is as follows.

k = (Cost defining a packet) + (Cost broadcasting to the neighbor mobile host) + (Cost managing the received packet)

If the value of k is 1, the management cost of reelection of primary leader is the same as Fig. 7. In this paper, so, we can know that ACBRP is superior in performance to CBRP.

3.2. Calculate cost of rerouting

The communication between two target nodes can be broken during exchanging messages. But in this paper, only node's problem on the connection route is considered. In Fig. 1, in order to make a connection between node 18 and node 24, node 2,20,4,21,34 and 8 should be member of communication route. So, If some member nodes go out of cluster or get into abnormal state, connection route can't work any more. And if gateway node 20,21and 34 have some problem, host cluster primary leader must look for other possible gateways and remake another route. But if there are no possible gateways, old route just will be removed. But if three is problem in cluster primary leader node 2,4, and 8, the communication between node 18 and 24 is stopped during selecting new primary leader. Therefore, CRR(Cost for ReRouting) is calculated by re-selection cost of cluster's Primary leader and the number of clusters which are involved in the communication between target nodes.

In Fig. 1, if primary leader node 2 and/or 4 go out of cluster during communication between node 18 in cluster A and node 13 in cluster B and also get into abnormal state, node 18 and 13 can't exchange messages any more before new primary leaders are selected. The possibility of problem in cluster A's primary leader node2 is called $P(C_2)$ and CRR(ACBRP) can be calculated with (11).

$$CRR(ACBRP) = P(C_2) \times CRHp(ACBRP)$$

Also CRR(CBRP) can be calculated with (12).

$$CRR(CBRP) = P(C_2) \times CRHp(CBRP)$$

And with two cluster A and B new $CRR(ACBRP_2)$ can be calculated again

$$CRR(ACBRP_2) = \{P(C_2) + P(C_3) - P(C_2 \cap C_3)\} \times CRHp(ACBRP)$$

In $ACBRP_2$: 2 is the number of cluster

$P(C_2)$: the possibility of problem in cluster A's primary leader

$P(C_2 \cap C_3)$:the possibility of problem both in Cluster A and B

And $CRR(CBRP_2)$ can be

$$CRR(CBRP_2) = \{P(C_2) + P(C_3) - P(C_2 \cap C_3)\} \times CRHp(CBRP)$$

If 3 clusters are involved in the communication between target nodes, in Fig. 8 the cost of re-routing can be calculated as below(where cluster number is 1,2,3…).

First, CRR(ACBRP) is

$$CRR(ACBRP_3) = \{P(C_1) + P(C_2) + P(C_3) - P(C_1 \cap C_2) - P(C_2 \cap C_3)\} \times CRHp(ACBRP) \quad \text{-----------------------------} (13)$$

and CRR(CBRP) is

$$CRR(CBRP_3) = \{P(C_1) + P(C_2) + P(C_3) - P(C_1 \cap C_2) - P(C_2 \cap C_3)\} \times CRHp(CBRP) \quad \text{-------------------------} (14)$$

Based on (13) and (14), General CRR(ACBRP) is

$$CRR(ACBRPn) = \left(\sum_{i=1}^{n} P(C_i) - \sum_{i=1}^{n-1} P(C_i \cap C_{i+1})\right) \times CRHp(ACBRP)$$

And general CRR(CBRP) is

$$CRR(CBRPn) = \left(\sum_{i=1}^{n} P(C_i) - \sum_{i=1}^{n-1} P(C_i \cap C_{i+1})\right) \times CRHp(CBRP)$$

If $P(C_i)$ is 0.5 and $P(C_i \square C_{i+1})$ is 0.025 and CRHp is assumed a's middle value in Fig. 7 as 0.5km, CRR can be calculated as Table 2 and Fig. 8 based on the number of cluster.

Table 2 CRR(ACBRP) and CRR(CBRP) according to a number of clusters for rerouting

Clusters	2	3	4	5	6	7
CRR(ACBRP)	25.01	37.20	49.38	61.57	73.76	85.94
CRR(CBRP)	97.5	145	192.5	240	287.5	335

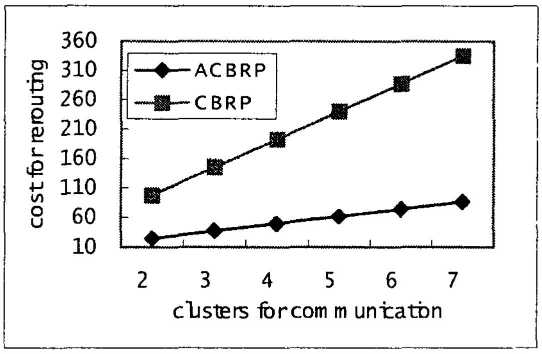

Fig. 8. CRR(ACBRP) and CRR(CBRP) according to a number of clusters for rerouting

As Fig. 8, CRR is increasing based on the number of cluster. And ACBRP can re-route with smaller cost than CBRP.

4. CONCLUSIONS

Mobile Ad Hoc Network (MANET) is a network architecture, which is deployed temporarily and rapidly in emergency or war without fixed mobile infrastructure. All communications between all network entities are carried in ad-hoc networks over the wireless medium. Due to the radio communications being extremely vulnerable to propagation impairments, connectivity between network nodes is not guaranteed. Therefore, previously developed routing algorithms cannot be used. And many new algorithms are researched.

This study introduces Secondary Leader, in cluster based routing protocol(CBRP) that reduces the overhead from reelection new cluster leader and the cost of rerouting.

The performances of proposed algorithm ACBRP(Advanced Cluster Based Routing Protocol;CBRP using secondary leader) is compared with CBRP and results are presented in order to show the effectiveness of the algorithm as shown Fig. 7 and Fig. 8.

Acknowledgments

This work was partially supported by grant of Multimedia Research Center, Univ. of Incheon

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