A New Local Information Distribution System on Multi-Hop Wireless Networks

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Abstract: The studies of multi-hop wireless networks are active as the new communication media, which does not require any fixed communication infrastructure. One of application of the networks is local information distribution service, which is useful for daily activities in certain geographically restricted region or community within a radius of several kilometers. In this paper, MID-Net, which is the network enabling such distribution service, and effective information distribution algorithm MCMS are proposed. The behavior of the MID-Net is characterized by the waiting time function, three types of the functions are proposed in this paper.

1 Introduction

Distribution of local information required for daily activities among certain geographically restricted region within a "several km" is becoming important. Some examples of such services are event schedules of a shopping center, daily menus of restaurants, vacancy status of hotels, arrival/departure timetable of public transportation, traffic status of neighboring roads, advertisement of moving shopping vehicles and etc. Recent development of multi-hop wireless networks enables us to realize such distribution service of local information.

In multi-hop wireless networks, there are many severe restrictions such as network topology change, bandwidth constraints, battery life constraints, limitation of radio wave propagation and so on [1]. This paper presents a new system of information distribution in multi-hop wireless networks, which is called MID-Net (Meta-Information Distribution Network).

MID-Net realizes transmitting and receiving of local information smoothly and effectively, concerning electromagnetic environment, battery life, and so on. Moreover, although most people are satisfied by the outline of local information, some people wish to acquire more detail information on their interesting subjects. Proposed system is suitable for such multiple requirements. The outline of local information is called *Meta-Information*.

MID-Net consists of two sub-systems; one is the algorithm for meta-information distribution from one sender to every receiver in the restricted region, which is called algorithm MCMS, and another one is the method of peer-to-peer communication between information sender and receiver.

2 Algorithm MCMS

2.1 The Preconditions

We assume the following preconditions on multi-hop wireless networks, some of which are presently not possible but will be soon realized due to rapid development of technology. The preconditions of our study are as follows:

1) Maximum propagation range of emitted radio wave from each node is up to 100m.
2) Local information should be distributed within less than 2-kilometer range.
3) All nodes within the network can receive and send information (transmission capability).
4) All nodes are freely movable.
5) Each node is driven by a battery, and a battery is mainly consumed by radio wave radiation.
6) Receiving node can estimate the distance from the transmitting node when it received information.

2.2 Meta-Information Structure: INFO

The meta-information structure *INFO* is the structure, which is utilized by nodes with sending and receiving.

Name	Meaning
sid	information source node ID
iid	information ID
pid	parent node ID
dist	the distance from parent node
range	the propagation range of parent node
date	information released time
dlim	information available limit time
rdate	information received time
sdate	information transfer schedule time
hop	the hop count from information source node
maxhop	the number of maximum hop
transfer	if this is True, this information must transfer
data	local information (meta-information)

Each node maintain following information.

Name	Meaning
id	its own ID
life	battery life
range	EM wave propagation range
infolist	the list of local information INFO
cidlist	the list of child node ID (handled by peer-to-peer communications)

The *id* must not overlap *id* of other nodes. The plural number of local information may be send from one information sender. Therefore, the list of *INFO*, *infolist*, is prepared so that it can maintain plural *INFO*.

2.3 Overview of Algorithm MCMS

In order to distribute information to many nodes, flooding method is usually used. However, the flooding method usually causes heavy network traffic.

In this section, Algorithm MCMS (Maximum Coverage with Minimum Spheres) is proposed, which distributes meta-information to many nodes in a multi-hop network. Due to the algorithm utilizing the waiting time function, it can be distribute information more efficiently than flooding method. The types of the waiting time functions are introduced in the next section.

The basic idea of algorithm MCMS is to fill the targeted space with the minimum number of spheres, which represent wave front surfaces of radio wave emitted by transmitting nodes. Proposed method can achieve information distribution among as many nodes as possible with the minimum number of transmission nodes.

Algorithm MCMS consists of three procedures, *SEND*, *RECEIVE* and *TIMER*. The node wishing to provide information executes the procedure *SEND*. Then, the node which received *INFO* executes the procedure *RECEIVE*. The procedure *TIMER* transfers information and deletes the invalid information.

2.4 Procedure SEND

The information source node *sid* construct and send structure *INFO* with following procedure *SEND*.

Construction of INFO

- *sid*, *pid* ← self node's ID
- *iid* ← information identifier
- *data* ← local information
- *date* ← present time
- *maxhop* ← the number of maximum hop
- *dlim* ← information available limit time
- *hop* ← 0
- *range* ← self node's range

Transmission of INFO

Transmit *INFO* constructed as described above.

2.5 Procedure RECEIVE

The information *INFO* which was sent from a node will be received by all nodes within the propagation range of the node. The procedure *RECEIVE* is executed on each node which received the information as follows.

Ignoring of invalid information

When this node received *INFO* from itself, that is *sid*=*id* or *pid*=*id*, terminate this procedure after dropping received *INFO*.

Setting up of each time

- *rdate* ← present time
- *dist* ← distance from node which send this *INFO*
- *sdate* ← arbitrary value which determined by certain waiting time function

Preparation of transmission

- *hop* ← *hop*+1
- *transfer* ← True if *hop*<*maxhop and* same *INFO* (which has same *sid*, *iid*, *date*) is not exist in *infolist*, otherwise False.

Addition of INFO

- Add *INFO* updated as described above to *infolist*.

2.6 Procedure TIMER

Each node execute following procedure *TIMER* periodically. By this procedure, transmission of information and deletion of invalid *INFO* in infolist will be done.

Deletion of invalid information

- Delete *INFO* whose *rdate*+*dlim* passed over the present time from *infolist*.

Searching of transmission prepared information

- The *INFO* that *transfer* member value is true is candidate of transmission. If the present time has passed over the *sdate* member time, set its *transfer* as false, and execute following operation.

Preparation of INFO for transmission

- Prepare copy of the *INFO* for transmission, and change members as follow:
  Set self node ID *id* to *pid*. Set self node's propagation range to *range*.

Transmission of information

- Transmit *INFO* updated as described above.

3 The Waiting Time Function

In this paper, three principles concerning to radio wave radiation in multi-hop wireless networks are presented, namely the principle of better electromagnetic environment, the principle of fairness and the principle of robust communications. The first principle is to keep space with lower radiation intensity that results the lowest consumption of battery power in the network. The second one is to achieve fair power consumption ratio of each node with respect to each battery life. The last one is to keep robust connection for peer-to-peer communication.

These principles are easily implemented by means of three types of the waiting time functions.

3.1 FFNL System

a) The principle of better electromagnetic environment

In order to satisfy the principle, it is necessary to minimize the total radiation power from all the nodes in the network. For that purpose, FFNL (Far First Near Last) system is proposed. The node located far from sender node has shorter waiting time than the node located near to the sender node. By this scheme, far-node rapidly forwards receiving meta-information to other nodes and other nodes cancel their forwarding queue when they received the same meta-information during their waiting period. Consequently, the ratio of the number of nodes sent the information to the number of nodes actually received decreases. In other words, meta-information can be distributed among the maximum number of nodes by as small number of transmission nodes as possible.

In this system, waiting time function is determined by following formula, where *dist* is the distance between sending node and receiving node (meter), and *r* is the maximum propagation range from sending node (meter);

$$wait = A + B\left(1 - \frac{dist}{r}\right)$$

Parameters A and B are determined according to condition of applications. For instance, if A=50 and B=100, then waiting time is determined within 50msec to 150msec. FFNL system reduces total electromagnetic wave radiation power remarkably, since only "the far-node" located at marginal rim of each range radiates electromagnetic wave, and all "inner nodes" keep silence.

3.2 FBC System

b) The principle of fairness of battery power consumption

Since most nodes in multi-hop wireless network are driven by batteries, reliability and robustness of the network are heavily depending upon life-time of each battery. Moreover, utilization of each battery is only justified by goodwill of individuals. Therefore, the principle of fairness of battery power consumption should be esteem in multi-hop wireless networks.

Depending on the geographical distribution of nodes, information transmission may concentrate on some nodes. Consequently, their power consumption becomes very high. Moreover, the node with low battery life should not be transferring node. These problems are solvable by FBC (Fair Battery Consumption) system, where the waiting time is determined by decreasing function of the battery life. By this scheme, statistical deviation of all node capacities in a network decreases.

In this system, waiting time function is determined by following formula, where *reslife* is residual battery lifetime, and *maxlife* is maximum battery lifetime;

$$wait = A + B\left(1 - \frac{reslife}{maxlife}\right)$$

In BFC system, the node which can afford to consume its battery willingly becomes the forwarding node. Consequently, fairness of battery power consumption can be achieved and battery lifetime of each node in the network is converging to equal value.

3.3 MD System

c) The principle of robustness

The FFNL system keeps total electromagnetic wave radiation power in the network in the minimum state. However, the system is not suitable for peer-to-peer communication, because a node at the marginal rim of propagation range is most likely chosen as the sending node, then slight deviation of the node may cause disconnection of communication. In order to avoid this defect, MD (Moderate Distance) system is proposed, where newly defined value "*critical distance* d_γ" is utilized as a virtual border of propagation range.

In the system, any node nearly located at the critical distance d_γ is most likely chosen as the transferring node, and therefore reliable communication is assured. The waiting time function is determined by following formula;

$$wait = \begin{cases} A + B\left(1 - \dfrac{dist}{d_\gamma}\right) & 0 \le dist < d_\gamma \\ A + B\left(1 - \dfrac{(r - d_\gamma) + (r - dist)}{2(r - d_\gamma)}\right) & d_\gamma \le dist \le r \end{cases}$$

4 Algorithm for Peer-to-Peer Communication with MCMS

Meta-information is able to send from any nodes in a MID-Net, and each node receiving their information can obtain the summary of information, namely meta-information, currently sent from surrounding nodes. If a user of the node wants to see detail information, it is necessary to communicate with information source node in peer-to-peer way. Utilizing the routing algorithm described in this section, it is possible to establish peer-to-peer communication with any sender based only upon neighboring data acquired from MCMS algorithm. In the case of route failure in a network or moving node environment, proposed routing algorithm guarantees robust peer-to-peer communications, where alternative routes can be easily established based on the neighboring data already obtained from MCMS algorithm.

When a node received a *INFO* from the source node *sid* in a MID-Net, the path from the received node *rid* to the source node *sid* is already made by parent ID member *pid* of corresponding *INFO* of nodes that received same *INFO*. Then, the received node can send data to source node immediately. When data sent from node *rid* to node *sid*, each transferred node records the pair of received node's ID *rid* and child node's ID *cid* into each node's *cidlist*. By this operation, the path from *sid* to *rid* is made. Consequently, the peer-to-peer communication between source node and received node is established.

When the path is broken cause of movement of nodes, power off of nodes and so on, alternative route can be obtained by the duplicate *INFO* in *infolist* because the parent node ID *pid* of duplicate *INFO* are absolutely different.

5 Experiments

5.1 Conditions of Experiments

In this section, features of proposed algorithm MCMS and the three type of waiting time functions are investigated by simulation. This simulation program compiled by Borland Delphi6 and executed on Microsoft Windows XP. Conditions of the experiments are as follows. We investigated the features by two comparisons.

1) Comparison of the number of transmission nodes

Nodes are uniformly distributed on 2km x 2km square and not movable, and one node is put in center position, which node is information sender. The radius of radio wave propagation range of all nodes is 100m. Failure of transmission by interference of a radio wave is not considered. The initial battery life of each node is random, and the critical distance is 60m. "The number of nodes", "transmission waiting time" and "the number of maximum hops" are given as parameters. Each parameter's detail is as follows:

- The number of nodes: The range of number of nodes is 4000 to 40000. This range corresponds to node density range of 100 to 1000/km^2.
- Transmission waiting time: The range of transmission waiting time is 50 to 150 milliseconds; this time is determined by random number, FFNL system, FBC system or MD system.
- The number of maximum hops: The range of number of maximum hop is 1 to 10. When the number of maximum hops is 10, the theoretical information distribution limit is 1km in radius.

2) Comparison of battery consumption

Nodes are uniformly distributed on 1km x 1km square and moving arbitrary direction and speed. The speed is up to 10km/h. The number of nodes is 5000. 50 of the nodes are transmitting information every 5 seconds, and the number of maximum hop is 5. The initial battery life of each node is random, and 0.0016667% of battery capacity is consumed by one packet transmission. The transmission waiting time is determined by FFNL system and FBC system.

5.2 Results

1) Comparison of the number of transmission nodes

The Fig. 6-1 shows the number of transmission nodes by FFNL system. We see from this figure that even if the node density becomes very high, the number of nodes

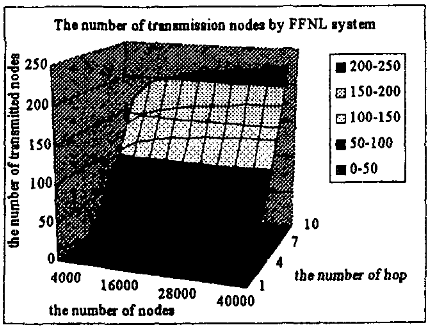

Fig. 6-1: The number of transmission nodes by FFNL system

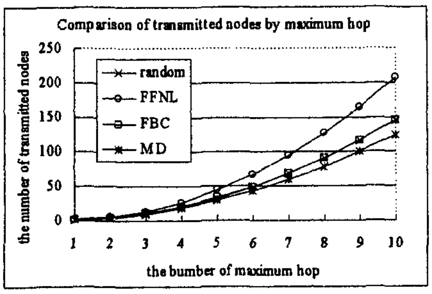

Fig. 6-2: Comparison of transmitted nodes by maximum hop

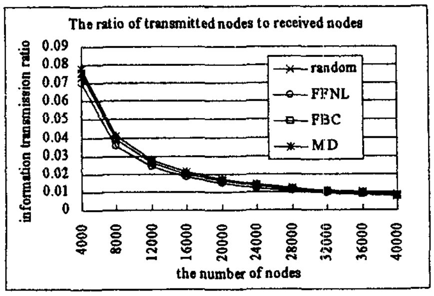

Fig. 6-3: The ratio of transmitted nodes to received nodes

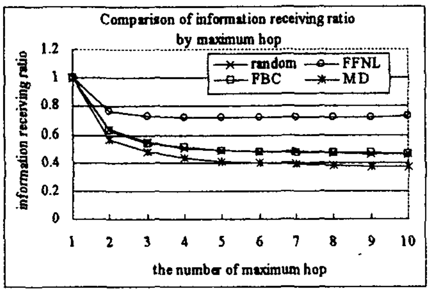

Fig. 6-4: The information receiving ratio

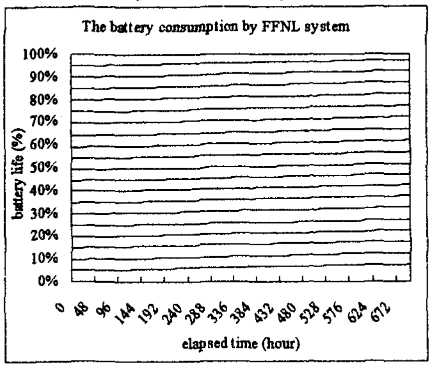

Fig. 6-5: The battery consumption by FFNL system

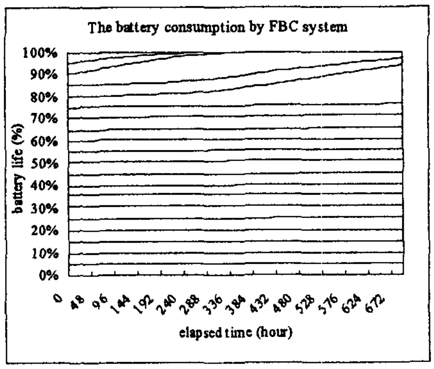

Fig. 6-6: The battery consumption by FBC system

transferring local information hardly increases. The FBC and MD system also have this nature. This result means proposed algorithm MCMS is not influenced of node density. Therefore, this algorithm is applicable in places where the node density may become very high, such as downtown or shopping quarter.

Next, the waiting time functions are compared. Comparison of transmitted nodes by maximum hop is shown at Fig. 6-2. This graph shows the number of transmitted nodes is larger on FFNL system. Only by this comparison, the FFNL system does not seem to work well. However, if the ratio of the number of transmitted nodes to the number of received nodes is shown, it turns out that consideration was not right. The graph is shown at Fig. 6-3. This graph shows the FFNL system is effective on the information transmission ratio. Consequently , the difference of the number of transmitted nodes appears in the ratio of information receiving ration, which is the ratio of the number of receiving nodes to the number of nodes within theoretical limits of information distribution area. The graph is shown at Fig. 6-4. This graph shows the FFNL system can distribute information to many nodes under the limitation of the number of maximum hop.

These three graphs show that the FBC system and random value system are completely same result, because the battery life of each node is random value.

2) Comparison of battery consumption

Fig. 6-5 and 6-6 shows the transition of distribution of battery life by time when the FFNL system and the FBC system applied, respectively.

If FFNL system is applied as the determination method of transmission waiting time, the nodes having battery life of from 0% to 5% increase gradually. On the other hand, If FBC system is applied as the determination method, the nodes hardly increase. The graph shows the nodes with much battery residual quantity transmitted information.

6 Conclusions

A local information distribution system, MID-Net, is proposed. MID-Net can distribute abstracted local information within restricted area by the algorithm MCMS. The algorithm is applicable in places where the node density may become very high, such as downtown or shopping quarter.

In the algorithm, the waiting time function is important to determine how to propagate the information. If the FFNL system is applied, MID-Net can distribute information to many nodes under the limitation of the number of maximum hop. The FFNL system is effective considering the standpoint of the whole network. However, depending on the geographical distribution of nodes, information transmission may concentrate on some nodes, whose power consumption become very high.

FBC system selects transmission nodes that have a margin in battery residual quantity as much as possible. Therefore, FBC system is optimum method from the individual's point of view.

MD system ensures robust peer-to-peer communication. MID-Net enables users to retrieve detail information by peer-to-peer communication routing algorithm with ease.

References

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