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Effective Flooding Based on Neighbor List Exchange Over Ad Hoc Network

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ABSTRACT

Recently very big earthquake and tsunami occurred in Japan. The communication infrastructure was out of order at that time, which does require a new infrastructureless communication environment. Mobile Ad hoc Network (MANET) must be one of the powerful platform to meet the requirement. Energy consumption is the critical issue for MANET. Prolonging a network lifetime without external energy source is one of the main goals in case of any disasters or emergency situations, because most of the MANET nodes are driven by battery. So, energy saving MANET is the key issue. Moreover, at the very beginning of MANET setting up, it is easily expected that nodes disconnected from the infrastructure have little information such as IP addresses of other nodes of possible MANET members. Bearing these points in mind, this thesis proposes two new broadcasting methods that will reduce power consumption by decreasing the number of re-broadcastings while keeping almost same packet penetration rate as in the Simple Flooding (SF) method. These ideas are based on using the neighboring node information exchange. The simulation results show the effectiveness of proposals in comparison with SF.

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1. INTRODUCTION

1.1 Background

Mobile Ad hoc Network (MANET) is a wireless infrastructure-less self-configured mobile network that is used for various purposes in virtue of easy deployment and decentralized network administration. Actually, the MANET is actively used by military, researchers and students to create a local network. This network carries out not only information exchange between local nodes, but also allows connecting to the Internet. And because the each node can move randomly, a network topology changes at will.

Because of boneless structure, user can move around the network and get the same personalized service without relation to changing location, switching between devices or sessions.

MANET is a kind of special wireless network mode. A MANET is a collection of two or more devices equipped with wireless communications and networking capability. Such devices can communicate with another device that is immediately within their radio range or one that is outside their radio range not relying on access point. A MANET is self-organizing, self-disciplining and self-adaptive. The main characteristics of MANETs are as follows[4]:

(1) Dynamic topology
Because nodes in the network can move arbitrarily, the topology of the network also changes. The bandwidth of the link is unstrained, and the capacity of the network is also tremendously variable. Because of the dynamic topology, the output of each relay node will vary with the time, and then the link capacity will change with the link change. At the same time, complete-collision and interference make the actual bandwidth of ad hoc networks smaller than their bandwidth in theory.

(2) Power limitation in mobile devices
Because of the mobility characteristics of the network, devices use batteries

as their power supply. As a result, advanced power conservation techniques are very necessary in designing a system.

(3) Security

The mobile network is more easily attacked than the fixed network. Overcoming the weakness in security and the new safety trouble in wireless networks are on demand.

According to [1] , MANETs can be used to create following:

- Community network
- Enterprise network
- Home network
- Emergency response network
- Vehicle network
- Sensor network

In case of using MANET, the network can be established in hours as alternative of weeks that is needed to make robust wired network.

Besides, in case of any emergencies, when public communication services, such as wired and cellular networks, are out of order, MANET can be quickly deployed for connecting rescue teams and victims. Ad-hoc network usually consist of a number of mobile nodes. It can be laptops or cellular phones that are in broadcasting area of each other. Advantages of MANET are that there is no need of network infrastructure and base stations and that each terminal acts as receiver, transmitter and re-transmitter. Development of MANET is one of important parts of self-defense organization in Japan because of frequent natural disasters.

1.2 Existing problems

1.2.1 Energy management

Besides of advantages mentioned in 1.1, MANET often faces with some critical issues of a network lifetime prolonging and a network penetration rate. The reason of lifetime problems is that often a public power infrastructure gets down too, and the ad-hoc terminals don't have external energy source, only an existing battery charge. The problems with the penetration rate are connected with a node location and natural or artificial barriers neighboring the node.

In accordance with [4], the main reasons for energy management in MANETs are as follows:

(1) Limited energy reserve
The MANETs have limited energy reserve. The improvement in battery technologies is very slow as compared to the advances in the field of mobile computing and communication.

(2) Difficulties in replacing the batteries
In situations like battlefields, natural disasters such as earthquakes, and so forth, it is very difficult to replace and recharge the batteries. Thus, in such situations, the conservation of energy is very important.

(3) Lack of central coordination
Because an ad hoc network is distributed network and there is no central coordinator, some of the nodes in the multi hop routing should act as relay node. If there is heavy relay traffic, this leads to more power consumption at the respective relay node.

(4) Constraints on the battery source
The weight of the nodes may increase with the weight of the battery at that node. If the weight of the battery is decreased, that in turn will lead to less power of the battery and thus decrease the life span of the battery. Thus, energy management techniques must deal with this issue; in addition to

reducing the size of the battery, they must utilize the energy resources in the best possible way.

(5) Selection of optimal transmission power

The increase in the transmission power increases the consumption of the battery charge. Because the transmission power decides the reachability of the nodes, an optimal transmission power decreases the interference between nodes, and that in turn increases the number of simultaneous transmission.

Figure 1.2.1 provides an overview of the network energy management schemes.

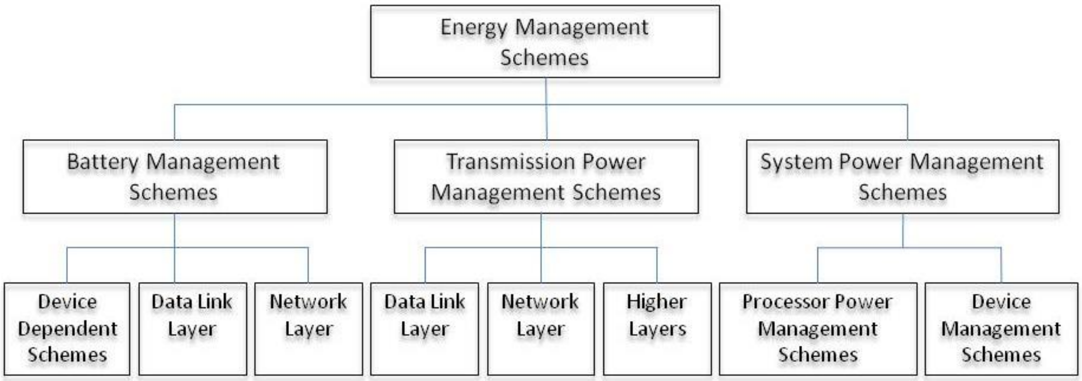


Figure 1.2.1 Classification of energy management schemes

1.2.2 Simple flooding

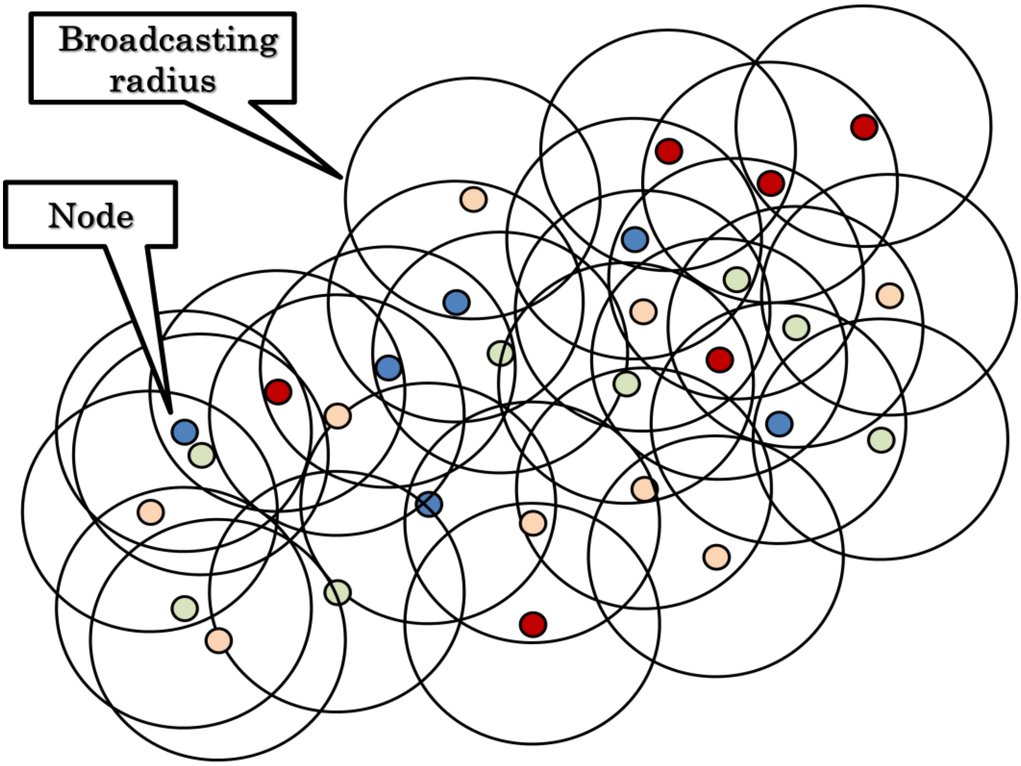
Mobile Ad Hoc Networks (MANETs) are the appropriate candidates to be used in case of emergency situation because the MANET does not need any infrastructure which may suffer from unavailability due to disaster. Just after the disaster, one of the most necessary functionalities of MANET is “Broadcasting” over all over the network to let disaster victims know where to evacuate, where the medical doctors are, where the shelters are, how their families are.

If the network infrastructure becomes out of order just after the emergency situation happens, the MANET is a very useful means to keep communication. But at the very beginning of the MANET setting-up, it is easily anticipated that each node in the MANET has such little knowledge about other node as IP address. The most powerful means at that phase is “Broadcasting” which requires no specific destination addresses. The most popular broadcasting method is “Simple Flooding”. Broadcasting is organized as follows:

(1) An initiator node broadcasts the packet with a data.
(2) Each node that received this packet re-broadcasts it.
(3) If the packet had been received before and re-broadcasted, node doesn’t carry out the re-broadcasting.

Unfortunately, flooding has been shown to be susceptible to contention even in reasonably dense networks. Indeed, flooding leads to a large amount of redundant messages that consume scarce resources such as bandwidth and power and cause contention, collisions and thus additional packet loss. Every node receives the message from every neighbor within transmission range, except when messages are lost due to contention and collisions . This fact will cause excessive battery consumption leading the network to shorter lifetime. This problem is known as the broadcast storm problem. Because flooding is important in MANET applications, there is a clear need for storm-resistant flooding protocols that operate efficiently. However, reducing the number of redundant broadcasts leads to a lower degree of reliability. Hence, the challenge we face is to strike a balance between message overhead (i.e., the level of redundancy) and reliability .

When it is used, redundant re-broadcasts occur, increasing the chances of collisions and buffer overflows, and resulting in a considerable degradation in delivery quality. In case a packet is sent by an initiator node, all the nodes will re-broadcast once. As shown in Figure 1.2.2, if there are 30 nodes in the ad hoc network, 30 packets are generated which are completely identical. Hence, many packets are generated continuously, so-called flood is to be occurred and in some cases, collision and loss will be caused. And redundancy will cause excessive use of battery.



Note:
number of nodes: 30
number of packet generation node: 1
number of packets generated: 1
number of packets sent in total: 30

Figure 1.2.2 «Flood» in Simple Flooding

1.3 Objectives of this thesis

Making network lifetime without external energy source as long as possible is one of the main goals in case of any disasters or emergency situations. This research aims at proposing a new broadcasting method that allows reducing power consumption by decreasing a number of redundant re-broadcastings with keeping almost same packet penetration rate as in the SF method.

1.4 Structure of this thesis

This thesis consists of 5 chapters. After Introduction, in chapter 2, we show one example of related works that was made to solve existing issues in MANET. This work is “MISTRAL: Efficient Flooding in Mobile Adhoc Networks” by Stefan Pleisch, Mahesh Balakrishnan, Ken Birman, and Robbert van Renesse.

In Chapter 3, this thesis proposes a new method of effective flooding based on neighbor list exchange, "EFNEX". It is based on exchange of the information about neighboring nodes. In this case, previous broadcaster uses a selection method of next broadcaster based on the number of neighbors. Through simulation, this method allows decreasing of redundant broadcastings in 2 times, but with insignificant reachability degradation in 3-4% from SF.

In Chapter 4, an additional algorithm of effective flooding, "EFNEX-R" is proposed, that enables cutting of the redundant broadcastings in 7 times approximately with 12% of the reachability rate degradation in comparison with Simple flooding and EFNEX. In this proposed algorithm, the previous broadcaster selects next broadcaster among its neighboring nodes based on information about a number and names of their neighbors.

The Chapter 5 closes this thesis. In this part of work we bring advantages and disadvantages of proposed methods in comparison with other existing methods. Conclusions and supposed outputs will be determined as well.

2. RELATED WORK

MANET is a very popular field of research. And there are many works and inventions made by wireless communication scientific community. Among the large amount of papers, the author is interested in “Efficient Flooding in Mobile Adhoc Networks” by Stefan Pleisch, Mahesh Balakrishnan, Ken Birman, Robbert van Renesse. In their paper, they propose a novel approach to flooding, which relies on proactive compensation packets periodically broadcast by every node. The compensation packets are constructed from dropped data packets, based on techniques borrowed from forward error correction. Since this approach does not rely on proactive neighbor discovery and network overlays it is resilient to mobility.

This thesis clearly explains this algorithm to make understanding in current MANET trends.

2.1 Flooding in MANET

In any flooding mechanism, one must balance reliability against message overhead. On the one hand, increasing reliability generally involves sending a greater number of redundant messages and thus incurs a higher message overhead. In this worst case, the system risks provoking broadcast storms[5]. Yet redundant messages are needed to reach all nodes and to recover from packet loss, hence reducing the overhead will generally decrease reliability.

The broadcast storm problem is so common in flooding algorithms that it has engendered a whole area of research. Storm-sensitive flooding approaches can be broadly classified into two classes: local-knowledge-based and overlay-based. Local-knowledge-based approaches decide on whether to rebroadcast or drop a flooded message solely on the basis of local information. Most commonly, they use information from received broadcasts to adaptively determine the forwarding policy. Such algorithms are a natural fit for MANETs, as they do not need to maintain any kind of complex node-to-node state that might need to be adapted in the event of mobility or other topology changes. In contrast, overlay-based approaches structure the node field according to some (local) topology, and then use topological information to efficiently implement flooding and reliability. The problem here is that if nodes have low quality connections to neighbors and/or are in motion, the overlay structure must be adapted. As a consequence, a high rate of management messages may be required, and if a flooded message is propagated while the overlay is out of date, that message may experience a high loss rate. In the worst case, the system might end up in a state of churn, constantly adapting the overlay but never managing to achieve the high quality of flooding that the overlay is intended to support.

By briefly overviewing existing work, they are assigned to the corresponding class. For reasons of brevity, this review is deliberately partial; focusing on results that inspired our work here, or that have been widely cited in the literature.

2.1.1 Overlay-based approaches

As just indicated, the term overlay is used very broadly. An overlay-based approaches is an algorithm that superimposes a routing structure onto the MANET in support of flooding and rebroadcast. Depending on the position of a node in this overlay, it decides to either rebroadcast a flooded packet, or to only process and then drop it. While overlays provide a convenient mechanism to reduce the message overhead of flooding and to increase reliability, they suffer from the need to reconfigure the overlay when connectivity changes or if the nodes are mobile. Restructuring adds overhead but also increases the likelihood that messages will be lost, and thus may decrease coverage of the flooding protocol.

Ni et al. propose to structure the nodes into clusters. Their solution rebroadcasts a packet in a manner that depends on the node's position in the cluster: only cluster head and gateway nodes rebroadcast.

The goal is to provide low-latency flooding. This is in part achieved by minimizing the collisions and interference. Gandi et al. show that an optimal solution to this problem is NP complete, instead, they propose an approximation algorithm. They construct a multicast tree and compute a rebroadcasting schedule such that the expected rate of collisions will be low.

Other approaches are based on the approximation of (minimal) connected dominating sets (MCDS). Informally, a dominating set (DS) contains a subset of all nodes such that every node not in the DS is adjacent to one in the DS. Thus, a DS creates a virtual backbone that can be used to efficiently flood messages. It has been shown that the creation of an MCDS is NP-complete. Thus, most approaches attempt to find a sufficiently good approximation to a MCDS.

A number of approaches rely on two-hop neighbor information to select nodes that rebroadcast the message. These approaches require that hello messages containing neighbor information are exchanged between the nodes.

For instance, in the Double-Covered Broadcast (DCB), node n collects information about the two-hop neighbor set. Among its one-hop neighbors it then picks nodes that rebroadcast the message (called forward node) such that (1) the rebroadcast by the forward node covers the two-hop neighbors, and (2) the one-hop neighbors that are no forward nodes are within range of at least two rebroadcasts by forward nodes. The reception of the message by the forward node is implicitly acknowledged when n overhears the rebroadcast.

The scalable broadcast algorithm (SBA) also uses two-hop neighbor knowledge, but employs a different approach to select the forward nodes.
With node mobility, the two-hop neighbor sets need to be updated frequently. Otherwise, the neighbor sets become outdated and reliability drops.

2.1.2 Local-knowledge-based approaches

Local-knowledge-based approaches generally decide on a per-node basis whether to rebroadcast a particular flooded message. In the simplest case, each node flips a coin and rebroadcasts messages with a certain probability p. This approach purely is probabilistic flooding (PPF).

There are a number of variants on this basic idea. For example, one set of algorithms base the rebroadcast decision either on the number of already overheard rebroadcasts, or on the distance or location of the overheard rebroadcast's sender. The idea underlying these schemes is that the additional coverage gained by rebroadcasting decreases with the number of overheard rebroadcasts and decreasing distance to neighboring rebroadcasting nodes. However, it takes time to collect these statistics, delaying the rebroadcast decision, hence a potentially high latency is introduced to every flooded message. In his work, Tseng et al. extend earlier approaches to allow nodes to dynamically adapt threshold values such as the rebroadcast counter.

Zhang and Agrawal propose an approach that is a combination of the counter-based and probabilistic methods. Instead of using a static rebroadcast probability p, they adjust p according to the information collected by the counters. While this makes p adaptable, it becomes dependent upon other fixed parameters that need to be carefully selected (e.g., timeouts).

Dynamic Gossip relies on local density awareness to adjust the rebroadcast probability p of the one-hop neighbors. Its correctness and suitability relies on the assumption that the nodes are uniformly distributed. Density information is collected using a relay-ping method.

In his work, Kowalski and Pelc propose a broadcasting algorithm with optimal lower bounds in their model. They consider only stationary nodes and adjust the broadcast probability accordingly.

Haas et al. study what they term a phase transition phenomena. This work shows that purely probabilistic flooding in an ad hoc network has a bimodal delivery distribution. Their simulations reveal that either almost every node receives the message, or virtually none. To reduce the likelihood of the latter case, they explore a variety of approaches, such as adapting the rebroadcast probability to the density or the distance to the flooding source. Sasson et al. theoretically explore the same phenomena based on percolation theory and conclude that there exists a threshold $\bar{p} < 1$ such that for any $p > \bar{p}$ the node coverage is close to 1, while for $p < \bar{p}$ the coverage is very low. Hence, increasing p much beyond $\bar{p}$ is not very useful.

Any approach that bases rebroadcast decision on observation of neighbors and on overheard broadcasts is at risk of using stale information if nodes might move before the information is used. MANETs, of course, can have a high degree of mobility, hence neither of these approaches is ideal.

Mistral's compensation mechanisms is orthogonal to these approaches. Indeed, were we building a production deployment of flooding in a real-world setting, we would be inclined to combine Mistral with one of these others (as should be clear, the ideal choice of underlying mechanism depends upon the anticipated density of nodes and level of mobility; no single solution stands out as uniformly superior to the others). By using such a hybrid scheme, we could parameterize the underlying solution to keep overheads low, accepting a modest risk that flooded packets would fail to reach some nodes. Compensation packets could then be used to overcome this low level of residual losses.

2.2 MISTRAL

Traditional flooding suffers from the problem of redundant message reception, once per neighbor. Even in a reasonably connected network, the same message is received multiple times by every node, which is inefficient, wastes valuable resources, and can create contention in the transmission medium.

Selective rebroadcasting of flooded messages is a way to limit the number of redundant transmissions. Instead of simply rebroadcasting the message a node evaluates a local function F and then uses the outcome of this computation to decide whether to forward the message. In its simplest form, this function returns its result based on some static probability (corresponding to PPF). More complex functions take into account additional topological (e.g., the number of neighbors) or statistical information (e.g., the number of overheard rebroadcasts). The downside of selective flooding is that a flooding may no longer reach all intended nodes. In particular, if a node has only few neighbors, none of these neighbors may rebroadcast the message. Selective flooding thus balances message overhead against reliability.

Mistral finds some middle ground by introducing a new mechanism that allows us to fine-tune the balance between message overhead and reliability. The key idea is to extend selective flooding approaches by compensating for messages that are not rebroadcast. This compensation is based on a technique borrowed from forward error correction (FEC). Every incoming data packet (dp) is either rebroadcast or added to a compensation packet (cp). The compensation packet is broadcast at regular intervals and allows the receivers to recover one missing data packet.

2.3 Conclusion

In this chapter, existing effective flooding methods are reviewed briefly, mainly focusing on MISTRAL, which is a good basis for discussion in this thesis.

3. EFNEX (Effective Flooding Based on Neighbor List Exchange Over Ad Hoc Network)

3.1 Method Description

As described so far, MANET is needed in case of emergency and most convenient way of information distribution is broadcasting, that is flooding, just after the emergency happens.

However, existing Simple Flooding (SF) causes redundant message transmission that results in performance degradation and waist of finite battery resources. To solve these problems, this thesis proposes a new effective flooding algorithm, named "Effective Flooding based on neighbor exchange (EFNEX)" .

In this method, a previous sender selects the node that has biggest number of neighboring nodes as next broadcaster. The node will never broadcast the message twice. For these purposes, the packet consists of a data that need to send, a packet ID and names of previous broadcasters and name of next broadcaster.

3.1.1 Initialization Phase

Initialization phase of this procedure is as follows:

1. Each node broadcast a hello message with its name.
2. Each node that received hello message records the name of broadcasting node and make own neighbor list (NL) to count the number of neighboring nodes.
3.

[Note] NL contains names of all nodes within a radio range that sent hello/ response massages to this node and the number of these nodes' neighbors.

3.1.2 Working Phase

1. The node checks its NL to find and selects a neighboring node that has biggest number of neighbors in its NL.
2. The node appoints selected node as next broadcaster by including its name in a sending packet.
3. The node broadcasts a packet.
4. Each node that received the packet checks the name of next broadcaster. And if name is equal to its own name, the node repeats procedures 1-3 above. And reminds that it is obligatory to rebroadcast all messages coming from that node in case of any additional instructions absence.

3.1.3 Packet Structure

The sending packet consists of following parts:

(1) Data: data is information that needs to be sent.

(2) Names of previous broadcasters: there is a list of all previous broadcasting nodes. Each broadcaster adds its name to the list names of previous broadcasters. It enables to determine and exclude the neighboring nodes, which have broadcasted this packet before, and then make the selection of next broadcaster.

(3) Packet ID: packet name that needs to determine sequence of receiving and re-broadcasting packets.

(4) Name of the next broadcaster: Neighboring node's name that selected as next broadcaster.

Figure 3.1.1 shows a possible packet structure.

Figure 3.1.1 Packet structure

After transferring pass creation there is no need to include (2) and (4). And the packet is sent without additional optional information, it enables to bit decrease a packet size.

3.1.4 Explanation by an example

Consider that there is a node Q. The node Q has neighboring nodes K, S, P, G expressed in Q's NL. Also Q node knows names of neighbors of K, S, P, G.

Node K has S, P, A neighboring nodes.

Node S – K, P, G, A, L, W.

Node P – G, N, T, D, Y.

Node G – S, G.

To select next broadcaster of a packet, Q compares its NL with its neighbors NL to determine the number of neighboring nodes. Table 3.1.1 expresses NL:

Table 3.1.1 Neighbor list of node

Number of neighbors	Q	K	S	P	G		
3	K	S	P	A			
6	S	K	P	G	A	L	W
5	P	G	N	T	D	Y	
2	G	S	P				

As you can see, node S has the biggest number of neighboring nodes. Node S is selected by node Q as a next broadcaster. After selection, node Q broadcasts the packet with a name of the next broadcaster and list of previous broadcasters. This method of selection of next broadcaster is used further.

3.2 Evaluation

To evaluate our proposal, a trial simulation on Excel was executed.

The simulation conditions are:
Number of nodes: 100 randomly located immobile nodes
Network area: 1,000m*1,000m
Radio area: 200m radius
After 5 times trials, we have got following results.

Table 3.2.1 shows evaluation results of EFNNEX with comparison with SF.

Table 3.2.1 Evaluation Results

Type of broadcasting	SF	EFNEX
Initialization phase	0	200 (2 hellos/node)
Aver. penetration rate	100%	94.7%
Aver. number of broadcastings per packet	100	51

This result shows that our proposal can reduce the number of rebroadcasting down to a half of that of Simple Flooding for every packet sent by a source. Although there is some overhead before starting the procedure, the reduction effect becomes very large if the continuously sent packets become large. Table 3.2.2 expresses growth of number of broadcastings per packet, which shows effectiveness of our proposal.

Table 3.2.2 Growth of number of broadcastings per packet

# of packets	1	10	100	1,000
SF	100	1,000	10,000	100,000
EFNEX	251	710	5,300	51,200

The defect is degradation of packet penetration rate.

3.3 CONCLUSION

A new effective broadcasting method "EFNEX" is proposed and evaluated through a simulation that results in very high effectiveness (almost 50% decreasing of broadcastings) with relatively low degradation in penetration rate.

The simulation method considers no physical collision, no moving of terminals so that computer network simulation may be needed for further study item.

4. EFNEX-R (Effective Flooding Based on Neighbor List Exchange Over Ad Hoc Network - Recreated)

4.1 Method description

To solve the Simple Flooding problem, we propose a new algorithm, “Effective Flooding based on neighbor list exchange (EFNEX)" in the previous chapter that allows reducing the power consumption of network by cutting the number of the rebroadcastings.

Here, this thesis proposes the refined EFNEX named “Effective Flooding based on neighbor list exchange - Recreated (EFNEX-R)". In EFNEX, only the number of NL is used for decision of next broadcaster. Here we use the names of neighbor nodes.

It is achieved when each node generates a list of neighboring nodes (NL) and exchanges its NL with all neighboring nodes in initialization phase of network. After NL exchanging each node knows not only names of neighboring nodes, but also names of its all neighboring nodes in current network position. When node wants to broadcast a packet of data to all existing network, the packet is re-broadcasted only by node that has biggest number of different neighbors from its neighbors. Thus, a packet is re-broadcasted only by one node selected by previous broadcaster. This method keeps out from redundant messages transmission that leads to network overloading and huge power consumption.

First of all let’s define what “different neighbor node” means:

Let’s imagine there are a number of nodes in local area. And there are node A and node B, which are in broadcasting radius of each other. We call them as neighboring nodes or simply neighbors. Each node has a number of neighboring nodes. And besides each other, A and B have some nodes in their broadcasting area. And these nodes which are in broadcasting area of A and B both, we define as similar nodes. Otherwise, each of similar nodes is neighboring to A and B together. Also A has a number of nodes, which are only in its broadcasting area in comparison with neighbors of node B.

Node B also has such kind of neighboring nodes. We call them as different neighboring node. Thus, each node has the similar and different neighboring nodes with each neighboring node.

4.1.1 Initialization Phase

(1-1) Each node broadcast a hello message with its name.
(1-2) Each node that received hello message records the name of broadcasting node and made own neighbor list (NL).
(1-3) Each node broadcasts its NL.

For clear understanding let’s consider next example:

One node wants to create network, but there are not any nodes around it. The node sends Hello message with its names and waits for response from other nodes. After receiving responses, node generates own NL using an information from respond messages. In this case, NL sets up ZERO, because nobody responded.

After a while, another node wants to create or enter the network. As before, this node broadcasts Hello message with its name and waits for response. After receiving hello message from another node, first node broadcasts response message. Response message includes names of requesting and responding nodes and responding node’s NL. After receiving the response message, second or requesting node creates its NL and broadcast it. The first of responding node updates its NL by adding the information from second node’s NL.

Initialization phase enables nodes to create its NL that contains names of all nodes within a radio range that sent hello messages to this node and names of these nodes’ neighbors. Information in NL helps node to determine next broadcaster.

4.1.2 Working Phase

(2-1) before a packet is broadcasted by a initiating node, the node compares the its own NL with all the neighbors' NLs and selects a node as a next broadcaster that has biggest number of different neighbors from its own neighbors
(2-2) The initiating node creates the "list of previous receivers" by adding /merging its neighbors' names.
(2-3) The initiating node broadcasts a packet, which contains data, a packet ID, a name of next broadcaster selected in (2-1), list of previous receivers.
(2-3) The next broadcaster compares its neighbors and list of previous receivers to determine the neighboring nodes, which have received this packet before. These nodes can't be considered as next broadcaster;
(2-4) the procedures (2-1) through (2-3) are repeated regarding an initiator as previous broadcaster.

[note] Within the procedure, nodes selected at once are never selected.
Node's NL includes list of neighbors except this node.

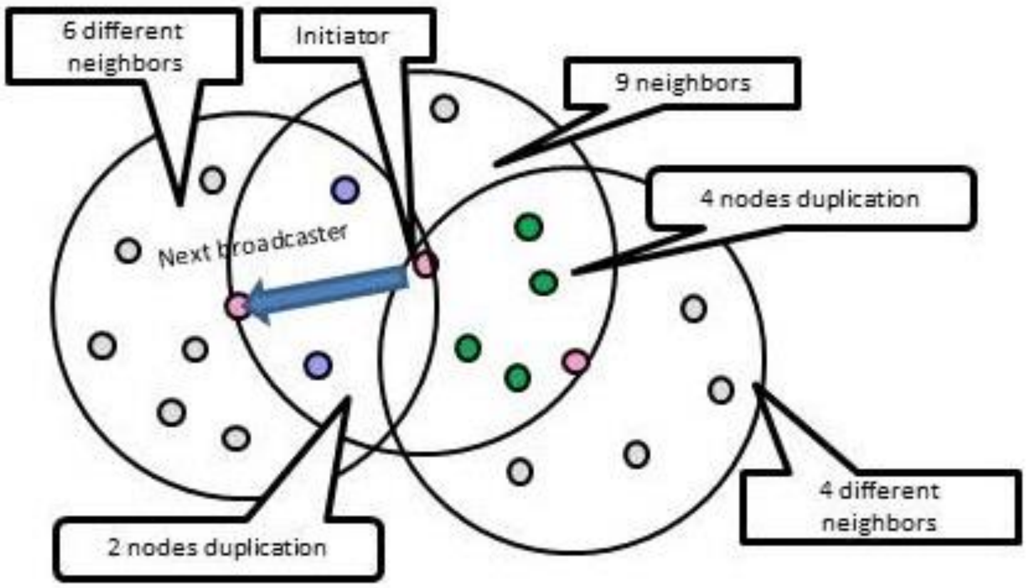


Figure 4.1.1 Next broadcaster selection method (EFNEX-R)

4.1.3 Explanation by an example

Please consider that there is a node Q. The node Q has neighboring nodes K, S, P, G. that expressed in Q's NL. Also Q node knows names of neighbors of K, S, P, G.
Node K has S, P, A neighboring nodes.
Node S – K, P, G, A, L, W.
Node P – G, N, T, D, Y, M.
Node G – S, G.
To select next broadcaster of a packet, Q compares its NL with its neighbors NL to determine the number of different nodes. Table 4.1.1 expresses NL:

Table 4.1.1 Neighbor list of node

Different nodes with Q	Similar nodes with Q	Q	K	S	P	G		
1	2	K	S	P	A			
3	3	S	K	P	G	A	L	W
5	1	P	G	N	T	D	Y	M
0	2	G	S	P				

As you can see, node P has the biggest number of different nodes. Node P is selected by node Q as next broadcaster. After selection, node Q broadcasts the packet with a name of the next broadcaster and list of previous receivers. This method of selection of next broadcaster is used further.

4.1.4 Packet Structure

The sending packet consists of following parts:
[1] Data: data is information that needs to be sent.
[2] Names of previous receivers: there is a list of all previous broadcasters' neighboring nodes. Each broadcaster merges its neighbors' names with the names of previous broadcasters to generate this list. It enables to determine and exclude the neighboring nodes, which have received this packet before, and then make the selection of next broadcaster.
[3] Packet ID: packet name that needs to determine sequence of receiving and re-broadcasting packets.
[4] Name of the next broadcaster: Neighboring node's name that selected as next broadcaster.
After transferring pass creation there is no need to include [2] and [4]. And the packet is sent without additional optional information, it enables to bit decrease a packet size.

4.2 Evaluation

In order to evaluate our proposal, a pilot simulation on Excel was executed.

The simulation conditions are:
Number of nodes: 100 randomly located immobile nodes
Network area: 1,000m*1,000m
Radio area: 200m radius
After 5 times trials, we have got following results.

Table 4.2.1 shows evaluation results of EFNEX-R with comparison with SF and EFNEX . Table 4.2.2 expresses growth of number of broadcastings per packet.

Table 4.2.1 Evaluation Results

Type of broadcasting	SF	EFNEX	EFNEX-R
Initialization phase	0	200 (2 hellos/node)	200 (2 hellos/node)
Aver. penetration rate	100%	94%	88.2%
Aver. number of broadcastings per packet	100	51	15,2

Table 4.2.2 Growth of number of broadcastings per packet

# of packets	1	10	100	1,000
SF	100	1,000	10,000	100,000
EFNEX	251	710	5,300	51,200
EFNEX-R	215	350	1,720	15,400

4.3 Conclusion

From the results, it is clear that the proposed method allows cutting the number of re-broadcastings down to cover network. It means that fewer nodes involved in sending message, and other nodes can save its power. This way provides longer network lifetime than Simple Flooding and EFNEX

The simulation method considers no physical collision, no moving of terminals so that computer network simulation may be needed for further study item.

5. CONCLUSION

This thesis tried to clarify appropriate network configuration in case of emergency when existing infrastructure does not work well. The most powerful candidate to that situation is Mobile Ad hoc Network (MANET).

This thesis focuses on the case where the MANET is introduced just after the crisis happens, where sufficient information like IP addresses to construct a unicast-oriented network is not well known to nodes in the MANET. In this situation broadcasting is the only tool to distribute information all over the network without use of IP addresses.

But existing broadcasting, namely Simple Flooding (SF) may produces many redundant duplicated packets that cause the congestion, loss, delay and waist of battery resources of each node.

So, this thesis tries to propose new methods of efficient flooding that reduces redundant reproduction of packets and so reduces waist of battery.

This thesis consists of 5 chapters. After Introduction of chapter 1, in chapter 2, we showed one example of related works that was made to solve existing issues in MANET. This work is “MISTRAL: Efficient Flooding in Mobile Adhoc Networks” , which is a good basis for discussion in this thesis.

In Chapter 3, this thesis proposed a new method of effective flooding based on neighbor list exchange, "EFNEX", which is based on exchange of the information about neighboring nodes. In this case, previous broadcaster uses a selection method of next broadcaster based on the number of neighbors. Through simulation, this method allows decreasing of redundant broadcastings in 2 times, but with insignificant reachability degradation in 3-4% from SF.

In Chapter 4, an additional algorithm of effective flooding, "EFNEX-R" was proposed, that enables cutting of the redundant broadcastings in 7 times approximately with 12% of the reachability rate degradation in comparison with Simple flooding and EFNEX. In this proposed algorithm, the previous broadcaster selects next broadcaster among its neighboring nodes based on information about a number and names of their neighbors.

The Chapter 5 concludes this thesis. In this part of work we bring advantages and disadvantages of proposed methods in comparison with other existing methods.

6. ACHIEVEMENTS

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