Relative Degree Adaptive Flooding Broadcast Algorithm for Ad Hoc Networks

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***Abstract*—Broadcasting has been widely used in mobile Ad hoc networks as a communication means to disseminate information to all reachable nodes. Because radio signals are likely to overlap with others in a geographical area, straightforward broadcasting by flooding becomes very costly and results in serious redundancy, contention and collision, to which we refer as the broadcast storm problem. In this paper we propose the Relative Degree Adaptive flooding Broadcast (RDAB) algorithm for Ad hoc networks to efficiently reduce the broadcast overhead in the network. Based on the current situation of the network and the degree of the nodes, RDAB calculates the relative degree of the nodes, decides which nodes need to re-transmit and which nodes only need to receive. The higher the neighbor node's relative degree, the more uncovered nodes it can cover, hence these nodes can be selected to re-transmit broadcasting packets in the networks. We analyze the reliability and the validity of the RDAB algorithm to prove that the RDAB algorithm is a valid flooding broadcast algorithm. Simulation results show that the RDAB strategy outperforms the Ordinary Flooding Broadcast Method (OBM) and the Multipoint Relaying (MPR) protocol for Ad hoc networks.**

***Index Terms*—Ad hoc network, flooding broadcast, network degree, NP-Completeness, relative node's degree.**

I. INTRODUCTION

A WIRELESS Ad hoc network [1], [2] is a self-organizing and rapidly deployable network without fixed infrastructure. The applications of wireless Ad hoc networks range from collaborative, distributed mobile computing (sensors, conferences, conventions) to disaster recovery (such as fire, flood, earthquake), law enforcement (crowd control, search and rescue) and tactical communications (digital battlefields).

Broadcast is an important data transmission method used in Ad hoc networks to disseminate public messages and topology information of the network. Broadcast methods include flooding [4], spanning tree [4] and others. Flooding allows every node to retransmit the message to all its 1-hop neighbors when receiving the first copy of the message, while the spanning tree method requires that the source node know the whole network topology information to calculate the shortest path to the destination node. However, it is difficult to obtain the whole network topology information in Ad hoc networks because of the mobility of nodes and the scale of the networks. Thus, flooding is always used in Ad hoc networks, especially when it becomes necessary to find a route to a particular host. On-demand Distance Vector (AODV) [3] and Dynamic Source Routing (DSR) [4] protocols are the classical routing protocols used in Ad hoc networks when there is no path to a particular node. Flooding for route discovery is used to disseminate a route request (RREQ) packet throughout the network to find the destination node.

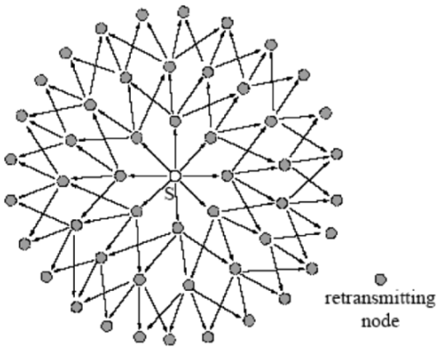

Fig. 1. Broadcast storm problem.

However, the simple flooding operation can trigger a large amount of packet forwarding that finally results in the collapse of the Ad hoc networks, due to redundant rebroadcast (when a mobile host decides to rebroadcast a broadcast message to its neighbors maybe all its neighbors already have the message), serious contention (after a mobile host broadcast a message, if many of its neighbors decide to rebroadcast the message, these transmissions may severely contend with each other), and collision (which will be introduced by the contention). We refer to the above phenomena as the broadcast storm problem [5]. Fig. 1 illustrates a broadcast storm problem in an Ad hoc network. Fig. 1 shows many redundant rebroadcast (some nodes will receive the same packet several times) and neighbors which decide to re-transmit almost at same time causing contention and collision.

The following techniques were recently explored to overcome the broadcast storm problems:

1) The Probabilistic scheme [5] is similar to Flooding except that nodes only rebroadcast with a predetermined probability. In dense networks, multiple nodes share similar transmission coverage. Thus, randomly having some nodes not rebroadcast saves node and network resources without harming delivery effectiveness. In sparse networks, there is much less shared coverage, thus nodes won't receive all the broadcast packets with the Probabilistic scheme unless the probability parameter is high. When the probability is 100% this scheme is identical to Flooding.

Manuscript received July 21, 2003; revised December 10, 2004. This work was supported by NSFC Project (60372048), key project (60496316), and TRAPOYT.

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Digital Object Identifier 10.1109/TBC.2005.847624

2) Area Based Methods [5] (such as Distance-Based Scheme or Location-Based Scheme) assume that nodes have a common transmission distance. A node will rebroadcast only if the rebroadcast will reach sufficient additional coverage area. A node using an Area Based Method can evaluate additional coverage area based on all received redundant transmissions. The Area Based Method only considers the coverage area of a transmission; it doesn't consider whether nodes exist within that area.
3) Neighbor Knowledge Methods (such as Multipoint Relaying or CDS-Based Broadcast Algorithm) [6]–[11] maintain the state on their neighborhood, via "Hello" packets. All nodes in the network can obtain their one-hop nodes and the two-hop nodes which are used in the decision to rebroadcast.

The above broadcast protocols are aimed to alleviate the redundant rebroadcast problem but they ignore the scale of the network and the degree of the nodes (although the MPR [10] algorithm selects retransmission nodes based on some degree of the node, it has some redundancy consideration). In this paper we present a novel flooding technique, called as Relative Degree Adaptive Flooding Broadcast Strategy—RDAB, which selects the re-transmission node adaptively and reduces the redundant rebroadcast based on the relative degree of the node.

The paper is organized as follows. Section II describes the RDAB protocol in detail. Section III proves the correctness of the RDAB algorithm. Section IV compares the performance of RDAB against the performance of native flooding (Ordinary Broadcast Method) and Multipoint Relaying (MPR). Section V concludes this paper.

II. RDAB ALGORITHM

In order to describe the RDAB algorithm conveniently we will introduce some definitions based on modeling the network as a graph $G = (V, E)$, where V represents the set of nodes (hosts) in the network, and E is the set of links. An edge $e = (u, v) \in E, u, v \in V$ exists if and only if u is in the transmission range of v and vice versa. All links in the graph G are bi-directional, i.e., if u is in the transmission range of v, v is also in the transmission range of u. The network is assumed to be in a connected state. If it is partitioned, each component is treated as an independent network. The length of the broadcasting packet is fixed.

A. Definitions

Assume v is a node in network G.

- $N(v)$: Set of neighbors of node v. It is a value that updates with repeated iterations of RDAB.
- $A\deg(v)$: Absolute degree of node v, i.e., the number of neighbors of node v.
- $R\deg(v)$: Relative degree of node v, $R\deg(v)$ is real-time value obtained using the RDAB algorithm and satisfying $R\deg(v) \leq A\deg(v)$.
- $Thops(v)$: Set of two-hop nodes of node v. i.e, the nodes which are the neighbors of node v's neighbors excepts for the nodes that are the neighbors of node v.

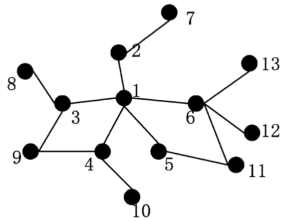

Fig. 2. Arbitrary network topology.

TABLE I
NEIGHBOR TABLE OF NODE 1

Neighbor node's ID	Neighbor nodes
2	1,7
3	1,8,9
4	1,9,10
5	1,11
6	1,11,12,13

- $T(v)$: Set of all neighbors and two-hop nodes of node v.
- $R(v)$: Set of neighbors of node v which need to re-transmit the broadcasting packet from node v.
- $C(v)$: Set of neighbors and two-hop nodes which have been covered by node v when the RDAB algorithm runs, i.e., the nodes that can receive the broadcasting packet from node v. When the RDAB algorithm ends, it obtains $C(v) = T(v)$.
- $NT(v)$: Table of one-hop nodes and two-hop nodes of node v.
- R set: Set of $R(v) \cup \{v\}$.

Fig. 2 illustrates some of the above definitions. In Fig. 2, we use node 1 as the example, which gives $N(1) = \{2, 3, 4, 5, 6\}$, $A\deg(1) = 5$, $Thops(1) = \{7, 8, 9, 10, 11, 12, 13\}$, $T(1) = \{2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13\}$. The numbers of nodes in $C(1)$ will increase and at last it will satisfy $C(1) = T(1)$. $R\deg(1)$ is less than or equal to $A\deg(1)$ and the value of $R\deg(1)$ is based on the results of the RDAB algorithm. In addition $NT(1)$ is shown in Table I.

B. RDAB Algorithm Description

RDAB is the abbreviation of Relative Degree Adaptive Broadcast, an algorithm that belongs to the category of Neighbor-knowledge Methods, because all nodes maintain the information of their neighbor nodes and two-hop nodes used in the decision to rebroadcast. The criterion for selecting rebroadcast nodes for the RDAB algorithm is the relative degree of the node which updates adaptively during the algorithm runs.

The relative degree of a node $v - R\deg(v)$ is the number of neighbor nodes of node v that have not received the broadcasting packet from node v. The value of relative degree $R\deg(v)$ is less than or equal to that of the absolute degree $A\deg(v)$, because the absolute degree $A\deg(v)$ is the numbers of all neighbor nodes of node v. The advantage of RDAB is reducing the redundant broadcast overhead. There are two strategies in RDAB to achieve this objective. The first strategy is part of the neighbors of node v have been selected as re-transmission nodes. Thus reduces broadcast overhead remarkably compared to the flooding method. The second strategy incorporates the notion of relative degree. If a neighbor node that has a larger absolute degree $A\deg(v)$ but a smaller relative degree $R\deg(v)$ is selected as a re-transmission node, it will cause unnecessary overhead because of repetitive transmission. RDAB can avoid this instance based on the criterion of selecting re-transmission nodes according to the relative degree.

The validity of first strategy is obvious. Here we give a simple example of the second strategy. We still use Fig. 2. From Fig. 2, when node 1 wants to send a broadcasting packet, it will run the RDAB to judge which nodes should be selected. From Table I, node 1 will select node 6 as a re-transmission node first, because node 6 has maximum neighbor nodes than other neighbors (from Table I, node 1 knows that the $A\deg(6)$ is 4 while for the other neighbors it is 3 or 2) and then more two-hop nodes can be covered if node 6 re-transmits. Thus, node 1 will know that node 11 must receive this packet from node 6 (from Table I again, node 1 knows that node 11 is the neighbor of node 6). Now, node 1 will update the other neighbors' relative degree. As for node 5, node 1 will delete node 11 from the relative degree of node 5 because node 1 thinks that node 11 has received the packet. This causes the relative degree of node 5 to change from two to one, i.e., $R\deg(5) = 1$, but the absolute degree of node 5 does not change, $A\deg(5) = 2$. Now although $A\deg(4)$ is the same as $A\deg(5)$, node 1 may select node 4 as a re-transmission node, because now $R\deg(4)$ is larger than $R\deg(5)$. From this example, we show that for RDAB, nodes with a higher relative degree have a higher opportunity to be selected.

In RDAB the nodes in the network broadcast a "Hello" packet periodically to advertise their presence. We refer to this "Hello" packet as SOP (Self Organization Packet). A SOP packet contains the information of the sender's neighbor nodes so that all nodes in the network can obtain the information about its neighbors and two-hop nodes. SOP packet need not to re-transmit. The RDAB algorithm makes the following **Assumptions** about network configuration:

A. Besides packets in the network, only Data packets need to be broadcast.
B. Data packets don't need acknowledge.
C. The network is connected; which means that there are no isolated nodes and no partitions in the network.
D. Every node has obtained the information about its neighbors and two-hop nodes when it executes the RDAB algorithm, i.e., the node has established its NT table.

Next we assume that node v will run RDAB, and a data packet is received from node t, or node v is the source node of the packet. The steps of the RDAB algorithm from the point of node v are:

1. Initialization. $T(v) = \{v\} \cup N(v) \cup Thops(v)$. $R(v) = \varnothing$, $C(v) = \varnothing$.
2. For all neighbors $j \in N(v)$ of node v, update the relative degree of these nodes. Namely, deleting $N(v)$ and $N(t)$ from $N(j)$ because nodes in $N(t)$ have received the packet, nodes in $N(v)$ can receive the broadcasting packet directly from node v, i.e., for all $j \in N(v)$, do

$$N(j) = N(j) - N(j) \cap [N(v) \cup N(t)].$$

3. Delete node t from $N(v)$ because node t is the transmitter it has already received the packet; i.e.,

$$N(v) = N(v) - N(v) \cap \{t\}.$$

4. Selection of two-hop nodes which can communicate with v via a unique neighbor node, adding these tow-hop nodes to $C(v)$, adding one-hop nodes associated with these two-hop nodes in $R(v)$, adding this 1-hop node and its neighbor nodes to $C(v)$, i.e., for all m, $m \in Thops(v)$, $m \in N(q)$, $q \in N(v)$, $m \notin N(v)$, q is unique node for each m, do

$$R(v) = R(v) \cup \{q\} \quad C(v) = C(v) \cup N(q) \cup \{q\}.$$

5. For node i,$i \in N(v)$, $i \notin R(v)$, delete the nodes that have received the broadcasting packet in order to calculate the relative degree, i.e.,

$$N(i) = N(i) - \left[C(v) \cap N(i)\right] \quad i \in N(v) \quad i \notin R(v).$$

6. Selection of a neighbor node which is now not in $R(v)$; its relative degree is maximum and the node ID number is minimum (Selecting a minimum ID is just a procedure used to choose a node, other options like stochastic selection may be used). Add this node to $R(v)$ and then add this node and its neighbor nodes to $C(v)$, i.e. for all p, $p \in N(v)$ & $p \notin R(v)$, $\max R\deg(v)$ and $\min p$, do

$$R(v) = R(v) \cup \{p\} \quad C(v) = C(v) \cup \{p\} \cup N(p).$$

7. Repeat step 5 and 6 until all nodes are in $C(v)$, i.e, $C(v)$ equals to $T(v)$; this ensures that all nodes have been covered in the iterations.

Step 5 to Step 7 can be described using the following pseudo code in Fig. 3.

III. PROOF OF RDAB CORRECTNESS

To prove the correctness of RDAB algorithm we break the proof in two parts described here as reliability and validity. The reliability of RDAB means that the broadcasting packet can be disseminated to every node in the network. Namely, if the RDAB algorithm runs, it must guarantee that all nodes can receive it. The validity of RDAB refers to the computational complexity of calculating the R set of a node when it is running the RDAB algorithm.

A. Reliability of the RDAB Algorithm

Here we assuming that node s is the source node of a broadcasting data packet.

Definition:

- N is the set of all nodes in the connected network.
- C_i is the set of nodes that have received the broadcasting packet after the ith re-transmit.

```
While ( $C(v)!=T(v)$ ), do
    For all $p \in N(v)$ & $p \notin R(v)$ , max Rdeg(p) and min p, do
        $R(v)=R(v)\cup\{p\},\quad C(v)=C(v)\cup\{p\}\cup N(p)$
    Endfor
    For all $i, i \in N(v), i \notin R(v)$ , do
        $N(i)=N(i)-[C(v)\cap N(i)]$
    Endfor
Endwhile
```

Fig. 3. Pseudo code of steps 5–7 of RDAB.

- U_i is the set of nodes that have not received the broadcasting packet after the ith re-transmit

  $$U_i = N - C_i.$$

  It is obvious that

  $$C_0 = \{s\} \quad U_0 = N - C_0.$$

After the ith re-transmit, at least one node m that belongs to U_i, but do not belong to C_i is the neighbor of a node n that is in set C_i, i.e.,

$$m \in U_i \quad m \notin C_i \quad m \in N(n) \quad n \in C_i.$$

Based on RDAB, after every re-transmission, all nodes that belong to U_i and are the neighbors of the nodes that belong to C_i will be added to C_i. It is therefore apparent that C_i increases while U_i decreases. When there is no change with C_i and U_i, it means that the RDAB algorithm is over. Under this condition, there are two cases that should be considered:

1. $U = \varnothing$. This means $C = N$; namely all nodes in the network have received the broadcasting packet from source node s.
2. $U \neq \varnothing$. This means that there are some nodes that have not received the broadcasting packet. Namely, the nodes belonging to U_i now are not the neighbors of the nodes in C_i. This means that these nodes are partitions and do not communicate with the nodes that belong to C_i, implying that the network is not connected. This is in contradiction with the baseline assumption, so we can affirm that $U \neq \varnothing$.

Next, we prove that the broadcasting packet from source node s can be disseminated throughout a connected network.

B. Validity of the RDAB Algorithm

The validity of RDAB is defined as the computational complexity of calculating the R set of RDAB. However, we will see later in the paper that finding the R set with minimal size is NP-complete [12].

When a node v runs the RDAB to calculate its $R(v)$, from **Assumption** C, it has obtained its set of neighbors and the set of two-hop nodes. Then we can construct a graph $G' = (V', E')$, with $V' = \{v\} \cup N(v) \cup Thops(v)$.

Finding the R Set of graph G belongs to the class NP [12] because a nondeterministic algorithm can guess in polynomial time if it is an R set and if its size is less than an integer K. Now we will show that the R Set is NP-complete by reducing it to the known NP-complete problem known as the Dominating Set Problem (A dominating set is a collection S of vertices with the property that every vertex v in G is either in S, or there is an edge between a vertex in S and v.) [12].

Dominating Set Problem: Given a graph $G' = (V', E')$, $V' = \{v\} \cup N(v) \cup Thops(v)$ and an integer K. Dose G' contain a dominating set of size at most K? (A dominating set is a subset of vertices R' with the property that each vertex in G' is either in R' or has a neighbor is R').

For the reduction, we create a graph $G'' = (V'', E'')$, $V'' = \{v\} \cup R\{v\} \cup Thops(v)$. It is evident that we only need to consider the one-hop nodes of node v. Let $R' = \{v\} \cup N(v)$, which obviously is a Dominating Set in G'.

Claim: There exists an R Set in G'' of size $1 + |R(v)|$ if and only if there exists a Dominating Set in G' of size $1 + |R(v)|$. (Here, $|R(v)|$ is the cardinality of set R.)

To prove this claim, we separate the demonstration in two parts.

1. If R' is a Dominating Set in G' then R' is also an R Set in G''.

Proof: If R' is a Dominating Set in G', without loss of generality, the vertices in R' are also in G''. For an arbitrary node u, $u \in N(v)$, if $u \in R'$ and $u \notin R$, we can remove node u from R'. R' is still a Dominating Set because node u has a neighbor v in R'. Thus the new R' is an R Set in G''.

2. If R' is an R Set in G'' then R' is also a Dominating Set in G'.

Proof: If R' is an R Set in G'', for a node u, $u \in N(v)$, if $u \in G'$ and $u \in G''$, it is apparent that $u \in R'$; if $u \in G''$ but $u \notin G'$, because of $v \in R'$, node u has a neighbor in R'. We find that each vertex in G' is either in R' or has a neighbor is R', thus R' is a Dominating Set in G'.

Because the Dominating Set Problem is known to be NP-complete and the R Set of graph G' can be reduced to the Dominating Set Problem, we confirm that the R Set problem is also NP-complete.

Some solutions to solve NP-complete problems are described in [13]. In this paper, we get the results of our method through simulations.

IV. SIMULATION RESULTS

Two simulation metrics are used to discuss the performance of RDAB. 1) Average Transmission Delay (the average time from the time a broadcasting packet is generated to the time that the packet reaches all nodes in the network). 2) Average Forward Times (the average time required for a broadcasting packet to be relayed by all nodes in the network). Two different algorithms are used to compare the performance of the RDAB algorithm. The Ordinary Broadcast Algorithm and Multipoint-Relay Algorithm [10]. The first one represents the basic broadcasting mode and the second is a popular broadcasting algorithm used

Sop	Source Node	Number of Neighbors	Neighbor_1	Neighbor_2	......	Neighbor_x

Fig. 4. Format of SOP packet.

Data	Source Node	Send Node	Source Sequence	Send Sequence	Broadcast Mode	Number of Re-transmit Nodes
Re_transmit Node_1	Re_transmit Node_2	......	Re_transmit Node_n			

Fig. 5. Format of data packet.

recently in Ad Hoc networks. From comparisons with these two algorithms, we can determine whether the RDAB algorithm improves performance or not. In our simulations we abbreviate these two algorithms as OBM and MPR. We assume that the data packet arrival follows a random model, and that the length of the packet is 2048 byte (which will be fragmented in the link layer by a MAC protocol). We assume that the channel capacity is 1 Mbit/s and that IEEE 802.11 MAC is used [14].

A. Packet Formats

In the RDAB architecture the traffic consists of data and SOP packets discussed below.

1) SOP Packet: SOP (Self-Organization Packet) packet is a control packet which contains the information of the node's neighbors. A SOP packet is only transmitted to the neighboring nodes, so from the exchanging of SOP packets, all nodes in the Ad hoc network can obtain the information of its neighbors and two-hop nodes; and using this information update the Neighbor Table. Simply speaking, the function of a SOP packet is similar to the "HELLO" packet of other "Neighbor Knowledge Broadcasting Methods". The format of SOP is shown in Fig. 4 which illustrates that it lists all neighbors for a particular node.

2) Data Packet: A Data Packet is defined as a message that will be broadcast to all nodes in the network. The format of a Data Packet is shown in Fig. 5.

Fig. 5 shows that in a Data Packet there are fields to indicate the source node ID and the destination node ID. The sequence of the source node or send node is the packet number to mark the packet and thus can uniquely identify a packet in the network. The Broadcast Mode is used by nodes to select the broadcast method (RDAB, OBM or MPR). And the number of re-transmit nodes filed is used to indicate that how many neighbors are selected to re-transmit by this node and the ID of these nodes are listed is in the following. Because different node will select different number of nodes to re-transmission in RDAB, that means the list of re-transmission node may has different length, the field of number of re-transmission node can help the receive nodes to decide how many items in the following list.

B. Simulation Results

Three different scenarios are discussed to show the diversity of performances. These scenarios are different network scale, different average node degree and different transmission radius.

1) The Influence of Different Network Scale: We simulate three different network scales to compare the performance of RDAB and OBM. The network includes 200, 500, and 1000 nodes, which are assumed to be randomly distributed over an area of 1 km $*$ 1 km, 5 km $*$ 5 km, and 10 km $*$ 10 km with uniform density. The valid transmission radius of a node in the network is 300 meters.

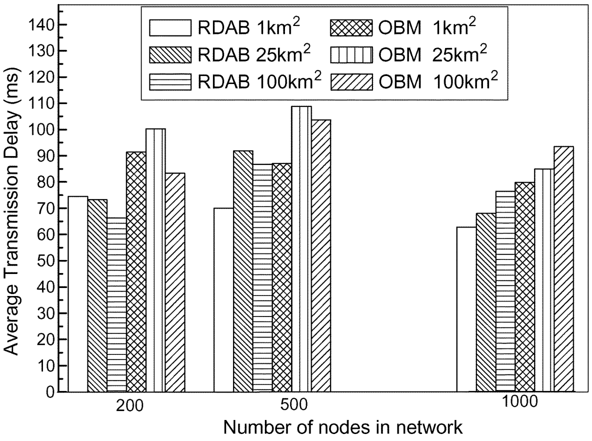

Fig. 6. Average transmission delay vs. different network scale.

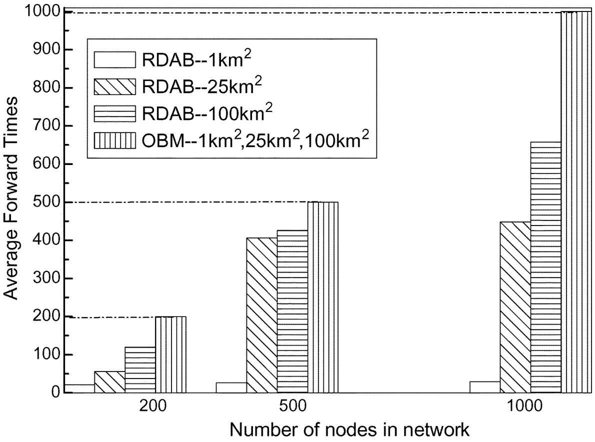

Fig. 7. Average forward times vs. different network scale.

From Fig. 6 and Fig. 7, we find that no matter what the network scale is, the performance in average transmission delay and average forward times of RDAB is always better than that of OBM. At the same time, it seems that the performance of average transmission delay of both broadcasting algorithms has no direct relationship with the network scale while the performance of average forward times of both algorithms shows linear increase. That is to say, it does not mean the more number of nodes in the network, the larger area covered of these nodes. Maybe the network is dense so that there are many nodes distribute in a relative small area. Thus the average transmission delay has no direct relation with the number of nodes. While the average forward times directly depend on the number of nodes in the network, especially for the OBM algorithm. The forward times are equivalent to the number of nodes in the network when OBM algorithm used. From these figures, we find that the key factor that influences the performance of delay of broadcasting algorithm is not the scale of the network. The following parts will discuss the essential factors that influence the network performance of broadcasting algorithm.

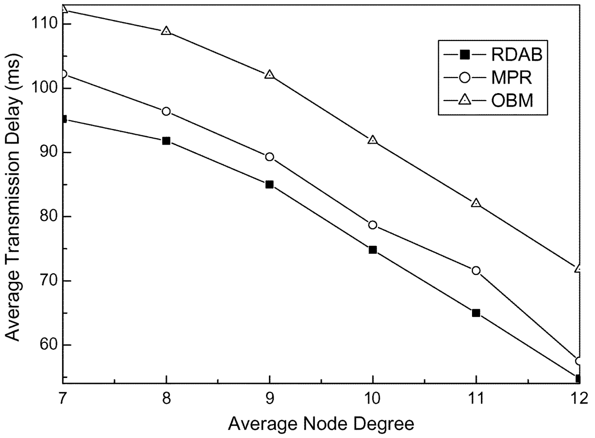

Fig. 8. Average transmission delay vs. average node degree.

2) The Influence of Different Average Node Degree: We define the concept of "average node degree" for analysis of the essential problems that influence the network performance under broadcasting. The average node degree σ is here defined as the average number of neighbors of a node in the network; that is

$$\sigma = \frac{\sum_{i=1}^{N} A\deg(i)}{N} \tag{1}$$

where N is the number of total nodes in the network, $A\deg(i)$ is the absolute degree of node i. It is evident that the larger the average node degree, the larger the density of the network. The following simulations illustrate behavior for different average degrees in a network with 500 nodes. The initial positions of the nodes are chosen from a uniform random distribution over an area of 5 km × 5 km. The transmission radius is 300 meters and the network is connected which means that no isolated nodes and no partitions exist in the network (if the unconnected situation happens in our simulation, an error message will be triggered to create another network again). When the average node degree of network increases, the number of neighbor nodes of a given node increases too. Without loss of generality, each node has fewer hops to the other nodes in the network. Thus, the average transmission delay and the average forward times of a broadcasting packet decrease (Note that the average forward times of OBM do not increase with the number of nodes). Fig. 8 and Fig. 9 show that the simulation results are in agreement with the preceding analysis. The simulations show that the performance of RDAB is the best of these three algorithms. The more dense of the network, the more higher performance of RDAB obtains.

3) The Influence of Different Transmission Radius: The influence of transmission radius is important in wireless Ad hoc networks when a broadcasting method is used to disseminate messages. In this subsection we discuss the effect of different transmission radius under different network scales. A different transmission radius covers a different transmission area, thus changing the degree of each node. From above, the degree of a node seems to be a key factor to influence the performance of the RDAB algorithm.

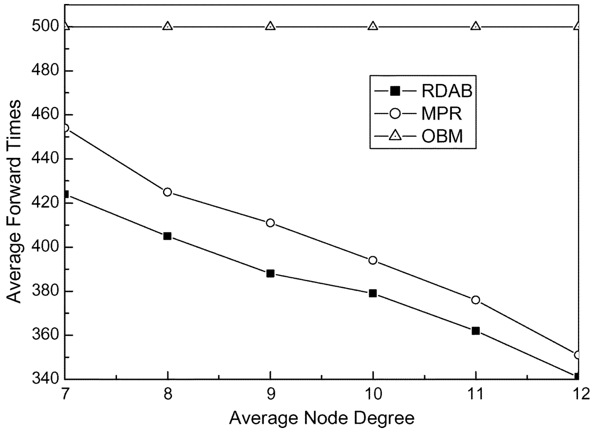

Fig. 9. Average forward times vs. average node degree.

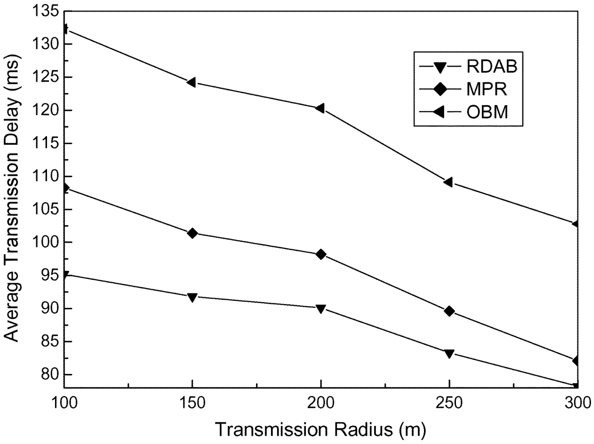

Fig. 10. Average transmission delay under 500 nodes vs. transmission radius.

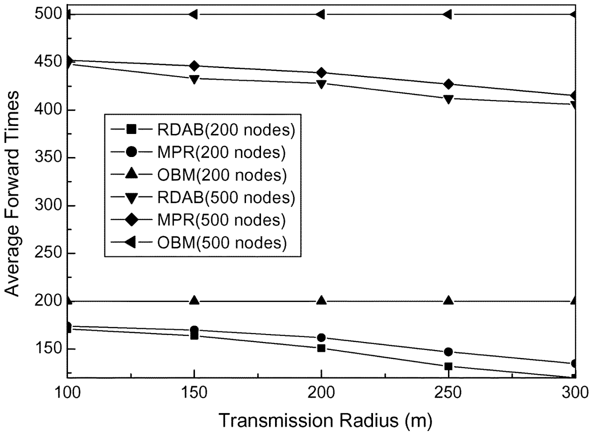

Fig. 11. Average forward times vs. transmission radius.

In our simulation, there are 500 nodes in the network, whose initial positions are chosen from a uniform random distribution over an area of 5 km × 5 km. The results are shown in Fig. 10 and Fig. 11. From Fig. 10 we find that no matter what the network scale is, the average transmission delay decreases with the increase of transmission radius. However, RDAB maintains its superior performance compared to the other two algorithms. It is apparent that as the transmission radius increases, so does the average node degree of the network. Increasing the average node degree implies an increase in the average number of nodes covered by a single node, increasing the density of the network. Notice also that the larger the transmission radius, the better the performance of RDAB.

Besides the performance of 500 nodes, the performance of 200 nodes is shown in Fig. 11. We also observe that RDAB outperforms OBM and MPR. This is because the RDAB algorithm selects some nodes with no redundancies to forward the new broadcasting packet to reduce the network traffic and the delay for each forward process. As the transmission radius increases, so does the average node degree of the network. Increasing the average node degree increases the average number of nodes covered by a single node, thus reducing the hops to the farthest node. It is apparent that no matter what the network transmission radius is, the performance of forward numbers of RDAB is the best among the selected options.

V. CONCLUSION

In this paper, we addressed the problem of flooding broadcast in a wireless Ad hoc network. We developed a novel algorithm—RDAB that makes use of the concept of relative node degree to improve the relay efficiency. Because the RDAB algorithm reflects the real-time condition of the network and selects the relay nodes according to the relative node degree, it has obvious predominance than other Neighbor Knowledge Methods for broadcast. In the future we will study the RDAB algorithm considering scenarios with moving nodes and two-layer network.

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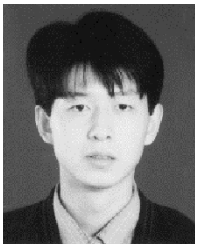

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