Enhancing Performance of Duo Coverage Broadcasting in MANET

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Abstract **- In today's developing environment in the field of Mobile Ad hoc Network, broadcast reliability plays vital role. In MANET when the forwarding nodes are not carefully designated, they are prone to the broadcast storm. To avoid the problem of broadcast storm, the Double Coverage Broadcasting (DCB) algorithm is introduced. The proposed scheme increases the delivery ratio though the redundancy is reduced. Other factors under consideration is that the proposed scheme has high delivery ratio, low forwarding ratio, low overhead and low end-to-end delay for a broadcast operation under a high transmission error rate. Among the 1-hop neighbours of the sender, only selected forwarding nodes retransmit the broadcasting the message. Forwarding nodes are selected in such a way that 1) the sender's 2-hop neighbours are covered and 2) the sender's 1-hop neighbours are either forwarding nodes or nonforwarding nodes covered by at least two forwarding neighbours. The retransmissions of the forwarding nodes are received by the sender as the confirmation of their reception of the packet. The nonforwarding 1-hop neighbours of the sender do not acknowledge the reception of the broadcast. If the sender does not detect all its forwarding nodes' retransmissions, it will resend the packet until the maximum number of retries is reached.**

Keywords— **Broadcast, double dominating set, forwarding node, mobile ad hoc networks (MANETs), performance evaluation, and reliability**

I. Introduction

A mobile ad hoc network (MANET) enables the wireless communications between participating mobile nodes without the assistance of any base station. Two nodes that are out of one another's transmission range need the support of intermediate nodes, which relay messages to set up a communication between each other.

The broadcast operation is the most fundamental role in MANET because of the broadcasting nature of radio transmission: When a sender transmits a packet, all nodes within the sender's transmission range will be affected by this transmission.

The advantage is that, if one node transmits a packet, all its neighbours can receive this message. This scenario is also referred to as "all neighbourhood nodes are covered or dominated by this transmitting node". On the negative side, one transmission may interfere with other transmissions, creating the exposed terminal problem where an outgoing transmission collides with an incoming transmission and the hidden terminal problem where two incoming transmissions collide with each other.

Blind flooding (BF), where each node forwards the packet once and only once, makes every node a forwarding node. If the forwarding nodes are not carefully designated, they will trigger many retransmissions at the same time, which might congest the network.

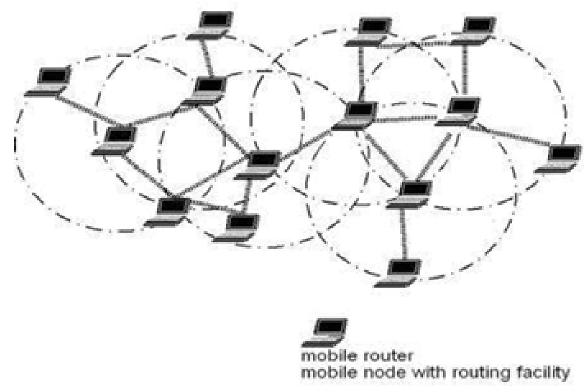

Fig 1 Mobile Ad Hoc Networks

This is referred to as the broadcast storm problem. The fact that only a subset of nodes forward the broadcast message and the remaining nodes are adjacent to the forwarding nodes can be used to reduce the broadcast congestion but still fulfil the broadcast coverage.

A MANET consists of randomly distributed nodes that result in some regions of the network being very dense and others being very sparse. A careful selection of forwarding nodes, i.e., selecting a similar number of forwarding nodes in both dense and sparse regions of the network, not only reduces the density of the network, but also balances the difference of the density among the different regions of the network. Basically, forwarding nodes form a connected dominating set (CDS).

To provide full coverage in an ideal error-free environment and very high delivery ratio in a high transmission error rate environment when selecting the forwarding nodes. Usually, acknowledgment messages (ACKs) are used to ensure broadcast delivery. However, the requirement for all receivers to send ACKs in response to the reception of a packet may become another bottleneck of channel congestion and packet collision, which is called the ACK implosion problem.

The goal is to reduce the number of forwarding nodes without sacrificing the broadcast delivery ratio. Specifically, we propose a simple broadcast algorithm, called Enhanced Flooding Based Reliable Broadcasting (EFBRB) i.e. modified double covered broadcast (DCB), which takes advantage of broadcast redundancy to improve the delivery ratio in the environment that has rather high transmission error rate. Only a set of selected nodes will forward the broadcast message. The selected nodes, called forwarding nodes, meet the following two requirements: 1) they cover the sender's 2-hop neighbour set, and 2) they cover the sender's 1-hop nonforwarding neighbours at least twice. Also, the retransmissions of the forwarding nodes are received by the sender as the acknowledgement of their reception of the packet. Nonforwarding neighbours do not acknowledge the reception of the broadcast.

If the sender fails to detect all its forwarding nodes' retransmissions, it repeatedly resends the packet until it detects that all the retransmissions or the maximum number of retries is reached. The proposed algorithm has many merits, such as balancing the average retransmission redundancy, avoiding both the broadcast storm problem and the ACK implosion problem, recovering the transmission error locally, and increasing the broadcast delivery ratio in a high transmission error rate environment. Simulation results show that the algorithm provides high delivery ratio, low forwarding ratio, low overhead, and low end-to-end delay for a broadcast operation under a high transmission error rate environment.

II. Related Work

In this section we discuss the results obtained from other resources.

It was proposed in [14], which explained a novel approach to flooding, which relies on proactive compensation packets periodically broadcast by every node that are not rebroadcast. The receiver uses such a packet to recover a single lost data packet. The compensation packets are constructed from dropped data packets, based on techniques borrowed from forward error correction. This paper limited itself to simulation, and do want to emphasize that Mistral is a real system and that the code evaluated here is executable on real platforms with only minor modifications using a network of actual nodes. And also its requirement is that the data packet payloads be of a similar size.

In [8], that proposed a mobility management method i.e. based on the use of two transmission ranges. The neighbourhood information as well as the forward node set are determined based on a short transmission range while the broadcast process is done on a long transmission range. The difference between these two ranges is based on the update frequency and the speed of node movement. Using extended coverage condition to a dynamic environment where network topology is allowed to change, even during the broadcast process. In addition, connectivity, link availability, and consistency issues related to neighbourhood information of different nodes have also been addressed. A node with high relative mobility is more prone to unstable behaviour than a node with less relative mobility.

It was explained in [7], that a small subset of nodes to form a forward node set to carry out a broadcast process. The status of each node, forward or nonforward is determined by using coverage condition. By adjusting the four implementation issues like timing, selection, space, and priority, the generic distributed broadcast protocol can be well-adapted to different ad hoc network configurations. In this paper performance evaluation of the generic broadcast protocol is limited with packet collision and node mobility. And also investigate methods are needed to maintain high delivery ratio in those networks.

It was proposed in [17], that a simple broadcast algorithm that provides high delivery ratio while suppressing broadcast redundancy. This is achieved by requiring only some selected forward nodes of 1-hop neighbor nodes to confirm their receipt of the packet. The forward node set selection process provides some redundancy so that retransmissions can be remarkably suppressed when the transmission error is considered. Due to high transmission of broadcast message and ACK message will greatly increase the collision of the transmission that leads to high transmission error rate. In this method all receivers have to send ACKs in response to the reception of a packet may become another bottleneck of channel congestion and packet collision. The performance of the algorithm will be more vulnerable to the changes.

It was explained in [18], that unlike in a wired network, a packet transmitted by a node in an ad hoc wireless network can reach all neighbors. Therefore, the total number of transmissions (forward nodes) is generally used as the cost criterion for broadcasting. The major problem is finding the minimum number of forward nodes. Among various approximation approaches, utilizing 2-hop neighborhood information to reduce redundant transmissions. This ensures a high broadcast delivery rate when the host movement ranges from slow to moderate. In this paper coverage area is limited with 2-hop neighborhood information and it may extend from a coverage area of 2-hop neighbors to k-hop neighbours.

III. Preliminaries

We describe a MANET as a unit disk graph G = (V,E), where the node set V represents a set of wireless mobile nodes and the edge set E represents a set of bidirectional links between the neighboring nodes. Two nodes are considered neighbors if and only if their geographic distance is less than the transmission range r. In a localized broadcast protocol, a node v is equipped with a k-hop sub graph $G_k(v)$ for a small k, as k =2 or 3. $G_k(v)$, induced from the k-hop information of v, is $(N_k(v), E_k(v))$. $N_k(v)$ denotes the k-hop neighbor set of node v which includes all nodes within k hops from v (and also includes v itself). $H_k(v)$ denotes the k-hop node set of v which includes all nodes that are exactly k hops away from v. For convenience the 1-hop neighbour set $N_1(v)$ and the 1-hop node set $H_1(v)$ are represented as N(v) and H(v), respectively. $E_k(v)$denotes the set of links between $N_k(v)$, excluding those links between $H_k(v)$.

A. Double-Covered Broadcast (DCB) Algorithm

A network-wide broadcast requires a packet to be received by all nodes in the network. But, transmission interference and the movement of the nodes may cause some nodes to lose the broadcast packet. The redundancy of the broadcast packet can bring more opportunities for a node to receive the packet successfully. Moreover, if the sender can retransmit the packet, the number of nodes that receive the broadcast packet is also increased.

The proposed double-covered broadcast (DCB) algorithm works as follows: When a sender broadcasts a packet, it selects a subset of 1-hop neighbours as its forwarding nodes to forward the packet based on a greedy approach. The selected forwarding nodes satisfy two requirements.

1) They cover all the sender's 2-hop neighbours.
2) The sender's 1-hop neighbours are either forwarding nodes or nonforwarding nodes covered by at least two forwarding nodes.
3) After receiving a broadcast packet, each forwarding node records the packet, computes it's forwarding nodes, and rebroadcasts the packet as a new sender.

B. Forwarding Node Set Selection Process

A forwarding node v uses the FNSSP-DC (Algorithm 1) to determine its forwarding node set F(v): v uses the FNSSP algorithm (Algorithm 2) to find F(v) in H(v) to cover $N_2(v)$ - {v}. The FNSSP-DC algorithm guarantees that v's 2-hop neighbour set $N_2(v)$ (excluding v itself) is completely covered by v's forwarding node set F(v). Since v also transmits the packet to cover H (v), any nonforwarding node in H (v) is covered twice.

Algorithm 1: Forwarding Node Set Selection Process-Double Coverage (FNSSP-DC)

1. Each node v computes X = H (v) and U = N_2 (v) - {v}.
2. Node v uses the FNSSP to find F (v) in X to cover U.

Algorithm 2: Forwarding Node Set Selection Process Enhanced Double Coverage (FNSSP-EDC)

Each node v sets X = H(v) - N(u) and U = $N_2(v)$ -N(u) - N(F(u) - {v}).

2. Node v uses the FNSSP to find F(v) in X to cover U.

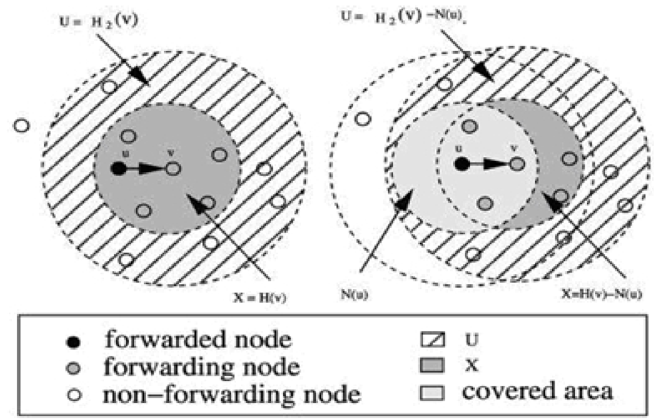

Fig. 2 Forwarding node set selection process of two algorithms

DCB algorithm uses the following symbols:

- F (v): the forwarding node set of node v.
- U (v): the uncovered 2-hop neighbour set of node v.
- X (v): the selectable 1-hop neighbor set of node v.
- P (v, F (v)): a unique broadcast packet P forwarded by node v that attaches v's forwarding node set F (v).
- Twait: the predefined duration of a timer for a node to overhear the retransmission of its forwarding nodes.
- R: the maximum number of retries for a node.

The DCB algorithm (Algorithm 5) works as follows:

1. When a node s starts a broadcast process, s uses the FNSSP-DC algorithm to select its forwarding node set F(s) and broadcasts the packet P together with F(s).

2. When a node v receives P from an sender u, it records P. v also updates its X(v)=X(v)-N(u) and U (v) = U (v) - N (u) -N (F (u) - (v)). Note that X(v) and U(v) are initialized toH(v) and H(v). Then, v checks whether it is a designated forwarding node of u. If not, v drops the packet and stops the process; otherwise, v further checks whether P is ever received. If P is a new packet for v, v uses the FNSSP-EDC algorithm to compute its forwarding nodes F(v) and sends P with F(v). If v has already received P from another node, v will not forward P, but send an ACK to u to confirm the reception so that u will not retransmit the same packet at a later time.

3. When the sender u broadcasts P, it waits for a predefined duration Twait to overhear the retransmission of its forwarding nodes. If u overhears a retransmission packet from its forwarding node v, u regards this as an ACK from v. u may receive explicit ACKs from some of its forwarding nodes to confirmthe reception. If u does not overhear all of its forwarding nodes when the timer expires, it assumes that the transmission failure has occurred for this packet. u then determines a new F(u) to cover the rest of the uncovered U(u) and resends the packet until the maximal number of retries R is reached.

Algorithm 3: The Double-Covered Broadcast Algorithm (DCB)

1. When source s wants to broadcast P, it uses FNSSP-DC to find F(s) and broadcasts P(s, F(s)).
2. When node v receives P (u, F (u)) from u,
2.1 v records P (u, F(u)).
2.2 Updates X (v) = X (v) - N (u) and
U (v) = U(v) - N (u) - N (F (u) - (v)).
2.3 if v belongs to F (u) then

if the packet has not been received before then
v uses FNSSP-EDC to find F (v) that (v) & broadcasts P (v,F(v)).
else
v sends ACK to u to confirm the reception of P & drops packet.
end if
else
v drops the packet.
end if

3. When node u has sent the packet, it starts a timer Twait and overhears the channel. After Twait is expired, if u does not overhear all nodes in F (u) to resend P or to send ACKs, u retransmits P upto the maximal number of retries R.

IV. Problem In Dcb Algorithm

Double Covered Broadcast algorithm is sensitive to the node's mobility. When the node's mobility increases, the delivery ratio of the DCB drops significantly. The reason for this is that the high mobility of nodes makes node neighbour sets outdated quickly. This incorrect neighbour set information may lead to more nodes missing the broadcast packet.

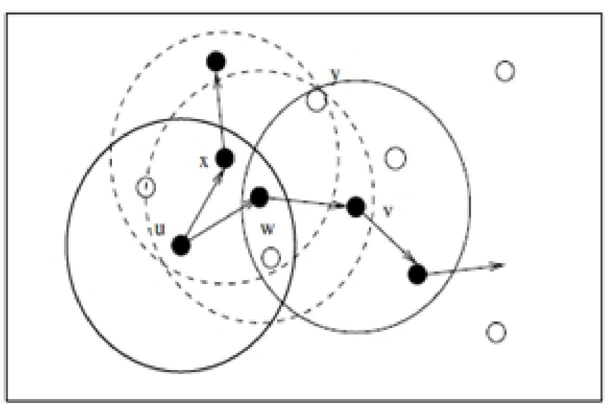

Fig 3 Forward node set in a MANET

In Figure 3, each circle corresponds to a one-hop neighbourhood of a node within a specified transmission range. When node w moves out of the transmission range of u, the nodes along the branch rooted at w of the broadcast tree will miss the message. This causes poor delivery ratio in the network.

V. Proposed Efficient Flooding Based Reliable Broadcasting Algorithm

The modified DCB algorithm called Efficient Flooding Based Reliable Broadcasting (EFBRB) algorithm, is based on two transmission ranges, r1 and r2, with r1 <r2. r1 is used to collect neighbour set and k-hop information through "Hello" messages, whereas r2 is used to perform actual transmission.

Specifically, the proposed method consists of two stages:

• Forward node selection: Select a small forward node set using an existing method where each neighbor set is based on transmission range r1.

• Forwarding process: Whenever a node receives a message for the first time, if it is a forward node, it forwards the message using transmission range r2.

A set of nodes within the range of r1 (Normal Transmission Range) is called neighbour set of u. The set of nodes within the range of r2 (Reduced Transmission Range) is called effective neighbour set of u.

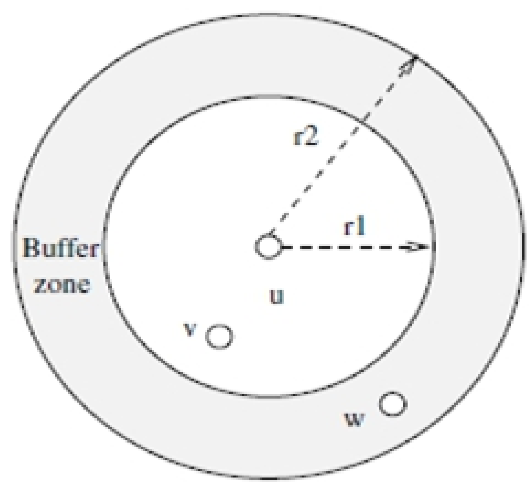

Fig. 4 Forward node selection & forwarding process on two transmission ranges

The buffer zone is used to nullify bad effects like inconsistency of number of 1-hop neighbour nodes caused by node's mobility and transmission delay. The selection of the buffer zone width is based on the mobility level to balance the delivery ratio and redundancy.

A. Implementation Details

1) Creating Wireless Network Topology

Wireless Model essentially consists of the mobile node at the core. Mobile nodes have ability to move within a given topology. Each mobile can ability to receive and transmit signals to and from a wireless channel, etc. In wireless network topology routing mechanisms and the routing protocols are implemented and creations of network stack that allowing channel access in Mobile Node.

2) Creating Node Movements

Mobile node is move in a three dimensional topology. Starting position of the node and its future destinations may be set using the following APIs

$node set X_ <x1>
$node set Y_ <y1>
$node set Z_ <z1>
$ns at $time $node
setdest <x2> <y2> <speed>

Node-movement-updates are triggered whenever the position of the node at a given time is required.

3) Setting Network Components

Link Layer - An ARP module is connected to it which resolves all IP to hardware (Mac) address conversions.

- Address Resolution Protocol - Receives queries from link layer and writes hardware address for destination into the Mac header of the packet.
- Interface Queue - Gives priority to routing protocol packets , inserting them at the head of the queue.
- Network Interfaces - hardware interface which is used by Mobile node to access the channel.

4) Evaluation of EFBRB Algorithm

When source s wants to broadcast packet P, then find forwarding node set F(s) within transmission range r1 and then broadcasts packet with forwarding node set P (s, F(s)) within transmission range r2, where r1< r2. Compare the result of Number of Nodes Vs Broadcast Delivery Ratio of both existing system and proposed system. Prove that EFBRB algorithm overcomes the problem of existing DCB algorithm (i.e.) when the node's mobility increases, the delivery ratio of FBRB does not affected.

B. Simulation Results

1) Sensitivity to Network Size

The network has low mobility, where V_{max} is 1 meter per second (m=s), and low transmission error rate(P_{err} = 1%). The data traffic load CPR is 10 packets per second (pkt=s), the hello interval THELLO is 1 second (s), and the waiting time T_{wait} is 50 milliseconds (ms).

Identify the effect of network size n to each metric. The network under this environment can be considered a static error-free network. Most of the packet losses come from transmission collisions.

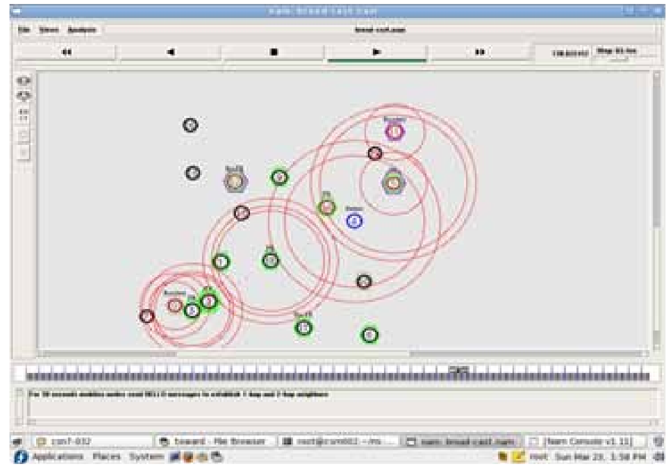

Fig. 5 Sensitivity to Network Size

2) Sensitivity to Transmission Error Rate

The performance of the algorithms under different transmission error rates. In this case, n = 100, V_{max}= 1m=s, CPR=10 pkt=s, THELLO=1s, and T_{wait}=50ms.

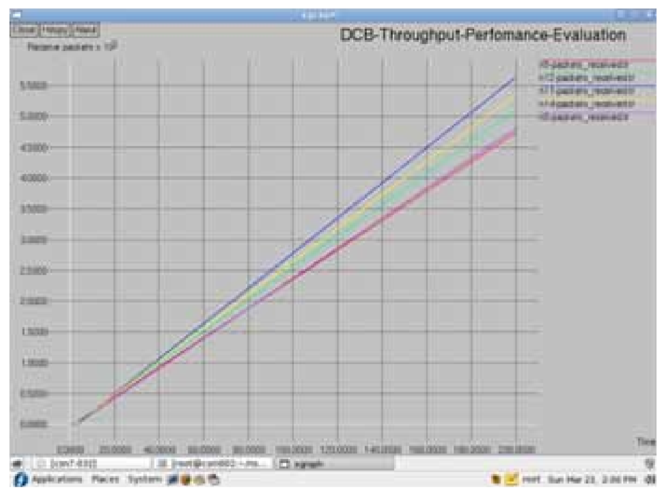

Fig. 6 Sensitivity to transmission Error rate

We change the transmission error rate Perr from 1 percent to 20 percent to see its effect on each metric.When Perr increases, the delivery ratio drops for all algorithms. But, the EFBRB are much better than AHBP-EX and BF when P_{err} increases. The RB has a similar delivery ratio to EFBRBs even when P_{err} is high, but the forwarding ratio of RB is much higher than EFBRBs and AHBP-EX, as is the overhead.The end-to-end delay of EFBRB is longer than AHBP-EX and BF due to the retransmission mechanism. As we can see, RB has the largest value for forwarding ratio, overhead, and end-to-end delay. From this simulation, we conclude that EFBRBs outperform AHBP-EX and BF when P_{err} becomes high. This is due to the retransmission mechanism of EFBRB. Compared with RB, EFBRB uses much less broadcast overhead to provide a comparable delivery ratio while RB needs the high forwarding ratio, large overhead, and long end-to-end delay to reach a high delivery ratio.

3) Sensitivity to Mobility of the Node

The effect of the node's mobility on the performance of broadcast operation. In this case, n = 100, CPR = 10 pkt=s, P_{err} = 1%, THELLO = 1 s, and T_{wait} = 50 ms. we change the maximum speed of each node Vmax from 1 to 40m=sto show the effect of the node's mobility to each metric. The delivery ratios of BF and RB are almost 100 percent while those of EFBRBs and AHBP-EX drop as the node's mobility increases. EFBRBs are even a little worse than AHBP-EX when the node's mobility increases. EFBRBs and AHBP-EX have almost the same forwarding ratio and their value decreases as the node mobility increases. The value of forwarding ratio for the BF and RB is always close to 100 percent.

4) Sensitivity to Hello Interval

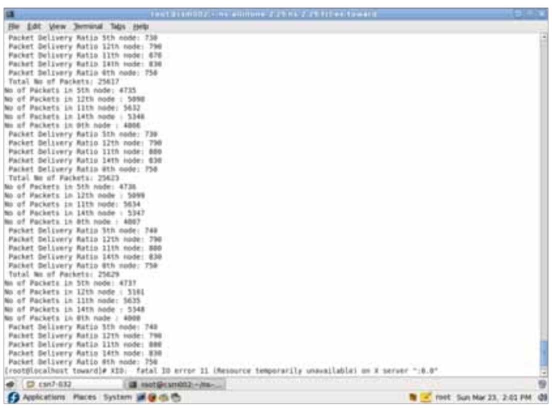

Fig. 7 Sensitivity to Hello Interval

In order to investigate the effect of the hello interval on the performance of the EFBRB algorithm, we set the hello interval THELLO at 0.2, 1, and 5 s. Here, we use the EFBRB-SD algorithm; other EFBRB algorithms have similar results. In this case, n = 100, P_{err} = 1%, CPR = 10 pkt=s, and T_{wait} = 50 ms. Vmax ranges from 1 to 40 m=s. This is because, as the node's mobility increases, the neighbor set information each node maintains becomes stale more quickly. The short hello interval causes the neighbor information to be kept more accurately in the dynamic network environment. Simulation results show that updating too infrequently causes the neighbor information to be inaccurate while updating the HELLO messages too frequently generates large overhead.

5) Sensitivity to Number of Retries

We test the performance of the EFBRB under different values of R. In this case, n = 100, V_{max} = 1 m=s, CPR = 10 pkt=s, THELLO = 1 s, and $_{Twait}$ = 50 ms. RT_{max} is set from 0 to 3. The transmission error rate Perr is changed from 1 to 20. The delivery ratio can be improved when a retransmission mechanism is applied (comparing between the curves of "EFBRB-SD, retry=0" and "EFBRB-SD, retry=1"). On the contrary, increasing the number of retries (comparing between the curves of "EFBRB-SD, retry=1" and "EFBRB-SD, retry=2") only slightly improves the delivery ratio, or can even decrease the delivery ratio (comparing between the curves of "EFBRB-SD, retry=1" and "EFBRB-SD, retry=3").

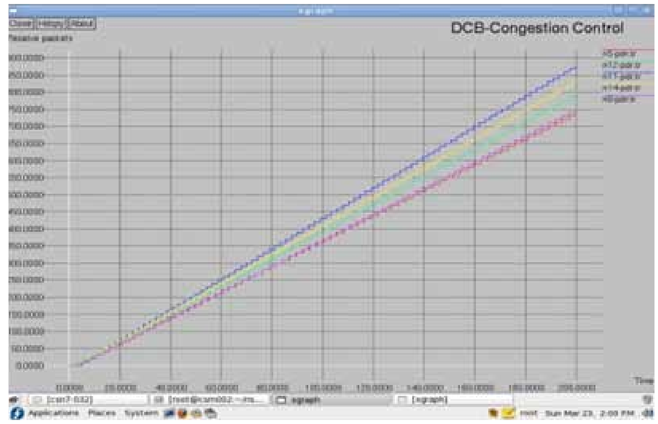

Fig. 8 Sensitivity to Number of Retries

VI. Conclusion And Future Work

Using mobility management method based on the use of two transmission ranges under coverage condition to a dynamic environment where network topology is allowed to change, even during the broadcast process. The difference between these two ranges is based on the update frequency and the speed of node movement. When the node's mobility increases, the delivery ratio of the DCB does not drop. In addition, connectivity, link availability, and consistency issues related to neighborhood information of different nodes have also been addressed. Good balance between delivery ratio and broadcast redundancy by adjusting the value of r1 based on the network mobility level. The simulation results show that the double-covered broadcast algorithm has high delivery ratio, low forwarding ratio, low overhead, and low end-to-end delay for a broadcast operation under a high transmission error ratio environment.

The DCB provides full reliability for all forwarding nodes but not for nonforwarding nodes. In order to provide full reliability for all nonforwarding nodes, we can use the NACK mechanism such that a nonforwarding node will send a NACK message when the node notices a packet loss during the continuous broadcasting transmissions. Our future work is to investigate the strategies of applying the NACK mechanism and the effects when the NACK mechanism is applied.

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