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A Broadcast Engagement ACK Mechanism for Reliable Broadcast Transmission in Mobile Ad Hoc Networks

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SUMMARY How to safely or reliably flood a packet via broadcast scheme to all nodes in computer networks is an important issue. However, it is a big challenge and critical problem to broadcast data packets over mobile ad hoc networks reliably due to the unsettled wireless links, high mobility, and the lack of the acknowledgment (ACK) scheme. Many solutions deal with this problem by adopting multiple unicast transmissions to achieve reliable broadcast transmission in network layer. Unfortunately, it will cause severe duplicate transmissions and thus rapidly consume the limited network bandwidth. One simplest way to solve this drawback is to broadcast data packets in data link layer. But a serious problem will be arisen that replied ACK frames will collide at the sending node if we enforce each mobile node to reply an ACK after receiving the broadcast data frame. Therefore, in order to overcome the thorny problem, we proposed a broadcast engagement ACK mechanism (BEAM), which is completely compatible with the IEEE 802.11 protocol, for reliable broadcast transmission in the data link layer. We also show that the overhead of raising the reliability of broadcast transmission in network layer would be significantly reduced in data link layer. Simulation results show that the proposed BEAM can reach approximate 100% reliability even in heavy traffic load. We also indicate that the BEAM could be combined with other network layer broadcast schemes to approach higher flooding ratio as well as reduce bandwidth consumption effectively.
key words: *ad hoc, broadcast, network, MAC, reliability, wireless*

1. Introduction

A mobile ad hoc network (MANET) is constructed by several mobile handsets or laptops, which is used on-demand, and needs dynamic routing protocols when there is a packet needed to be transferred more than one hop. These approaches usually broadcast a *route request* (RREQ) packet, which is flooded through the network in a controlled manner, to perform a route discovery process and is replied by unicasting a *route reply* (RREP) packet from either the destination node or intermediate nodes that have a route to the destination. In point-to-point communication networks a large number of broadcast-routing protocols have been proposed [3], [6], [10], [15], [17]. However, unlike wired networks to which broadcast packets can be easily and safely delivered, it is a big challenge to transfer broadcast packets over MANETs due to the uncertain of the reception of broadcast transmissions and the unsettled wireless links.

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Flooding packets to all nodes in networks could be achieved by using multiple unicast transmissions in network layer or using broadcast transmissions in data link layer. The former solution, however, would cause many control overheads and degrade the performance of MANETs since too many duplicate packet transmissions are performed in one broadcast transmission [18]. Several approaches have been proposed and discussed in many literatures [1], [5], [7], [18].

In [1], the authors proposed a reliable broadcast protocol, named as AVR, based on replying acknowledgment (ACK) packets back to the sender. The basic idea of AVR is the provision for each mobile node to retain a so called *history* of messages broadcast to and received from its neighbor(s). A node which receives a broadcast packet replies an ACK to the sender via unicasting and updates its local history. If a sending node does not receive an ACK from a neighbor within a certain time, it timeouts and resends the packet. If a sender does not receive an ACK after several retries, it assumes that the link is broken and not transient and ceases sending the message. Obviously the exchange of local information and redundant broadcast retransmission would lead to the *broadcast storm problem* [18] and consume the network resources rapidly. Besides, the requirement of sending ACKs in response to the receipt of a packet for all receivers may cause channel congestion and packet collisions, which is called ACK implosion [5]. The ACK implosion problem may worsen the broadcast storm problem [18].

In order to alleviate the broadcast storm problem, Lou and Wu proposed a broadcast with selected acknowledgements (BSA) [7] protocol for reliable broadcast transmission in MANETs. When a node broadcasts a packet, it selects a subset of one-hop neighbors as its forwarding nodes to forward the broadcast based on a greedy manner. The selection scheme of forwarding nodes is based on neighbor-designating algorithm [8], [11]. Although the BSA can reduce the ACK implosion phenomenon, finding the forwarding nodes in a given graph is the NP-complete problem [8]. This drawback would consume the limited battery power of mobile nodes rapidly.

As mentioned above, we know that the wastage of redundant transmissions of a broadcast packet could be solved in data link layer since the broadcast frame is transmitted once by using broadcast identification. However, many medium access control (MAC) protocols such as IEEE 802.11 [4] adopt *blind broadcasting* mechanism to transmit broadcast frames and leads to unreliable broadcast problem because of the lack of ACK† scheme. The uncertain broadcast problem might not satisfy the requirement of reliable broadcast transmissions of higher layers.

In order to solve this problem, a reliable MAC broadcast scheme named broadcast medium window (BMW) protocol is introduced in [12], [13]. The basic idea of the BMW protocol is that it treats each broadcast request as multiple unicast requests. Each node maintains three lists: Its neighbors, sending buffer, and receiving buffer, respectively. In BMW, when a node has a broadcast data to send, the sender places the packet into its sending buffer and sends out an request-to-send (RTS) control frame containing the sequence number of the upcoming data frame and the MAC address of the first node in its neighbor list. When a node receives a RTS containing its MAC address, it will check the list of its receiving buffer to see whether it has received all the data frames with sequence number smaller than or equal to the upcoming one. If all the data frames (including the upcoming one) have been received, the receiver sends a clear-to-send (CTS) with appropriate information to suppress the sender's data frame transmission. Otherwise, the receiver sends a CTS frame with all the missing data frame sequence numbers. This process would be terminated when all nodes in the neighbor list have been served.

Unfortunately, the BMW is inefficient since it requires at least n contention phases for each broadcast data frame where n is the number of its neighbors. Not only is each contention phase a lengthy time, but also the sender has to contend for the right of access to the medium with other nodes. It is possible that some other nodes win the contention and thereby interrupts and prolongs the ongoing broadcast process. Besides, the BMW also has a lot of overheads and does not guarantee the reliability of the transmission immediately, and needs to cost a maintenance of three lists. According to these mentioned drawbacks, we proposed a broadcast engagement ACK mechanism (BEAM), which is compatible with the IEEE 802.11 MAC protocol [4] for reliable broadcast in data link layer. The proposed BEAM is realistic and uses the network bandwidth efficiently.

The remainder of this paper is organized as follows. Section 2 introduces the operations of proposed BEAM and illustrates the frame format of the BEAM in detail. To evaluate the efficiency of proposed BEAM, we design three different simulation models: The random placement topology model, the designed fixed topology model, and the mobility model for comparison with blind broadcasting, AVR, and BSA approaches in Sect. 3. The simulation results are given in Sect. 4. We finally conclude our discussion in Sect. 5.

2. The Broadcast Engagement ACK Mechanism

The concept of replying an acknowledgment of a successful receipt of the broadcast data to improve the reliability of broadcast transmission in data link layer is originally proposed in [16]. However, this approach still misjudge the correct outcome since several replied signals may collide in a same minislot. This shortcoming leads the broadcasting node to rebroadcast and thus wastes the network bandwidth. To overcome this troublesome drawback, we develop the broadcast engagement ACK mechanism (BEAM) to avoid the collision problem of ACK signals.

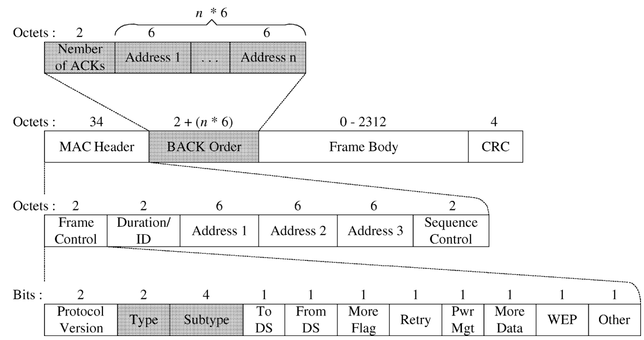

Fig. 1 The frame format of broadcast data frame where subfields of the Frame Control Type = 10 and Subtype = 1000, and an additional BACK Order field is designed for proposed BEAM.

First, we add a broadcast ACK (BACK) Order field, shown in Fig. 1, which is an MAC header extension, into the MAC header of the broadcast frame to announce each receiver that they have to reply their ACK frames according to the order indicated in the BACK Order field if they successfully receive the frame. To do so, we use the subfields Type (= 10) and Subtype (= 1000), which is a reserved number of the IEEE 802.11 protocol [4], of the Frame Control field of the MAC header. The frame format is shown in Fig. 1. The length of BACK Order field is several octets long and is determined by the number of its neighbors, which can be easily obtained by persistently monitoring the transmission activities around its transmission range, e.g., using a neighbor table to record the MAC address from the transmitter address (TA) field of each control (RTS or CTS) or data frame and maintain for a period. A neighbor node's address will be removed from the table when there is no transmission of the node after a specific time period. Since the number of neighbors varies by time, we use a subfield Number of ACKs, see Fig. 1, to indicate how many nodes n should respond to the broadcast frame. The subfield's length is 2 octets long (for supporting maximum $2^{16} - 1 = 65{,}535$ neighbors). We notice that the More Flag will be set 1 as the length of BACK Order plus broadcast data frame exceeds the boundary of maximum length of the frame body. This measure is to solve the problem caused by exceeding the length limitation of frame body (2312 octets). However, in general case, we emphasize that this situation is seldom happened.

After receiving the broadcast frame, nodes which are specified in the BACK Order will reply their BACKs one by one according to the order of the list indicated in the frame body. Thus the broadcast node could use the conditions of acknowledgment to confirm the reception of each node. If nodes, which are intended to receive the broadcast frame,

†We notice that the ACK control frame is an MAC control frame, which is provided in data link layer.

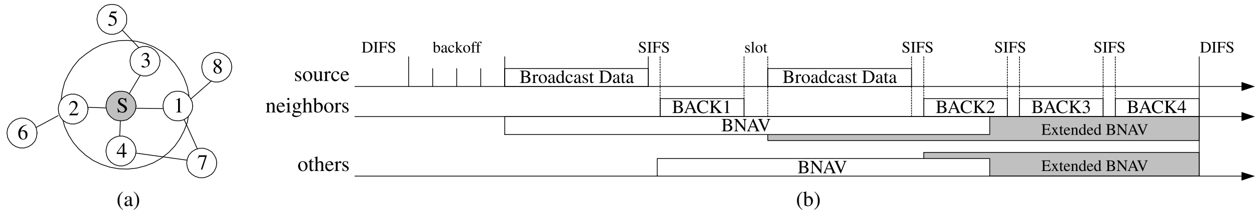

Fig. 2 An example of broadcast transmission process (a) the network topology (b) the time line of the proposed BEAM in ad hoc networks.

do not receive the transmitted frame due to collisions or interferences, they will not be aware of the broadcast transmission and, certainly, not reply ACK frames to the sender. The broadcast sender will note this situation and rebroadcast the frame again. The broadcast frame will be retransmitted immediately if the sending node does not receive any of the prospective BACK frames within an idle slot time (e.g., 20 μs in direct sequence spread spectrum (DSSS) system). This process would be terminated after receiving all BACKs of its recorded neighbors. However, the sender may not receive all its neighbors' BACKs due to the mobility or communication interference. This problem could be solved by adopting bounded maximum rebroadcast times.

The duration of broadcast transmission includes the broadcast data frame transmitting time plus $n \times$ (SIFS + BACK) in general condition. The duration will be extended if a corrupted data frame or missing a BACK frame occurs. We use the *broadcast network allocation vector* (BNAV), which is recorded in the Duration field of the MAC header in each broadcast data frame and BACK frame, to indicate the duration of the broadcast transmission. The major purpose of the BNAV is to prevent other nodes including hidden terminals to disturb this transmission. The duration will be recalculated if a broadcast retransmission is performed. We note that the duration of new recalculated BNAV denoted as extended BNAV equals the length of the transmission time of the broadcast data frame plus remaining nodes $m \times$ (SIFS + BACK).

Figure 2 illustrates an example of the proposed BEAM. The network topology, shown in left side, consists of a sender, four receivers, and four hidden terminals. The duration of original broadcast data frame equals the data frame length plus four SIFSs and BACKs. Assume node 1 receives the broadcast frame and reply its BACK frame (BACK1) to the sender S successfully but node 2 does not receive the broadcast frame (interrupted by node 6) and does not reply a BACK. After one idle slot, node S rebroadcasts the data frame and recalculates the new duration of the retransmission as extended BNAV. The length of extended BNAV is the data frame length plus the remaining three SIFSs and BACKs. Finally all remaining nodes receive the broadcast data successfully and reply their BACKs accordingly. The broadcast transmission algorithm is shown in Fig. 3 where nBACK represents the number of BACKs and the reception algorithms is given in Fig. 4.

```
Procedure TRANSMIT_BROADCAST()
BEGIN
  nBACK := number of neighbors;
  RetryCount := 0;
  Sends the broadcast data and waits the BACKs;
  WHILE nBACK > 0 and RetryCount < MaxRetry DO
  BEGIN
    waiting the BACKs;
    IF missing a BACK THEN
      rebroadcast the data frame;
      RetryCount := RetryCount + 1;
    ELSE receiving a BACK THEN
      nBACK := nBACK − 1;
    END IF
  END
END
```

Fig. 3 The algorithm of broadcast transmission procedure.

```
Procedure RECEIVE_BROADCAST()
BEGIN
  IF a new broadcast frame THEN
    according to BACK Order to reply BACK;
    calculate the BNAV;
  ELSE a rebroadcast frame THEN
    according to BACK Order to reply BACK;
    recalculate the BNAV;
  END
END
```

Fig. 4 The algorithm of broadcast reception procedure.

3. Simulation Models

In order to evaluate the performance of BEAM with other schemes, four kinds of simulation models are designed to investigate the effect of these approaches base on the distributed coordination function (DCF) of the IEEE 802.11 protocol [4] for wireless LANs as the MAC layer protocol. We have developed a simulator in C++ to evaluate the performance of BEAM. The request-to-send (RTS) and clear-to-send (CTS) control frames [2], [9] are used for "unicast" data transmission to a neighboring node. The RTS/CTS handshake precedes data frame transmission and implements a form of virtual carrier sensing and channel reservation to reduce the impact of the well-known hidden terminal problem [14]. A data frame transmission is followed by an ACK frame. Each "broadcast" data frame and RTS control frame is sent using physical carrier sensing. An unslotted carrier sense multiple access (CSMA) technique with collision avoidance (CSMA/CA) is used to transmit

Table 1 System parameters in simulations.

Parameter	Normal Value
Channel bit rate	2 Mb/s
Transmission Range (2 Mb/s)	120 m
RTS frame length	160 bits
CTS frame length	112 bits
ACK frame length	112 bits
Broadcast data length	25 bytes
Preamble and PLCP header	192 μs
MAC header	34 octets
A slot time	20 μs
SIFS	10 μs
DIFS	50 μs
aCWmin	31 slots
aCWmax	1023 slots
MaxRetry	3 times
Air propagation delay	1 μs

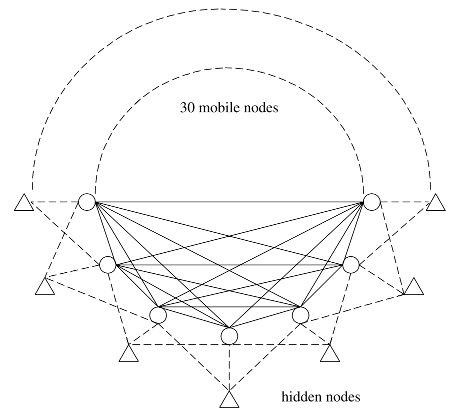

Fig. 5 The environment of full connected with some hidden nodes.

these packets [4]. Simulation parameters follow the IEEE 802.11 Standard and are listed in Table 1.

Three simulation models are given as follows:

- S1: The full-connected model is simulated as the wireless LAN.
- S2: The randomized model is simulated as a temporary multihop ad hoc network.
- S3: The mobility model is designed to investigate the effect of mobility upon the broadcast transmission.

3.1 The Traffic and Mobility Models

The traffic generation model, the frame arrival rate of each mobile node, follows the Poisson distribution with a mean λ, and the frame length is an exponential distribution with a mean of L octets, which including PHY and MAC header. The direct sequence spread spectrum (DSSS) system, long physical layer convergence protocol (PLCP), and PLCP protocol data unit (PPDU) format are used through all simulation models. There are two kinds of data frames that are considered in the simulation. One kind is unicast data frame and another one is broadcast data frame. The mean length of the data packet is 512 bytes and the length of broadcast packet is a fixed length and equals 25 bytes. The source-destination pairs are spread randomly over the network. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network.

The mobility model uses the random way point model [3] in a rectangular field. Here, each mobile node starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0–20 m/s). Once the destination is reached, another random destination is targeted after a pause. We vary the pause time, which affects the relative speeds of the mobiles. Each simulation run lasts 600 seconds ($\approx 3 \times 10^7$ slots) and each simulation result is obtained by averaging the results from twenty independent simulation runs.

4. Performance Results

In our experiments, we investigate two major metrics as the performance of broadcast transmission:

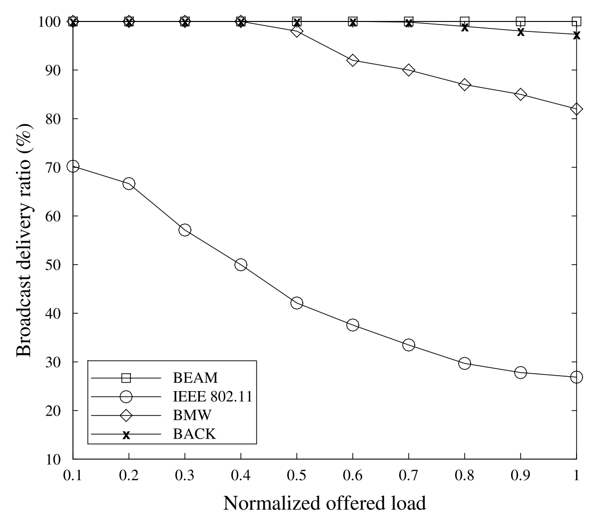

Fig. 6 The broadcast fractions of the BEAM and traditional IEEE 802.11 by varying the offered load.

- Broadcast delivery ratio: The ratio of the number of nodes that successfully receive the broadcast packet to the number of nodes in the network.
- Broadcast forwarding ratio: The ratio of the number of nodes that forward broadcast packets to its neighborhood to the number of nodes in the network.

The first simulation model (S1), shown in Fig. 5, simulates the network of 30 nodes acting within a 300 m $\times$ 300 m space. All nodes are full connected with each other and each node has 3 hidden terminals around it. These hidden terminals are used to act the potential disturbing source of ongoing broadcast transmissions and the data arrival rate of each hidden terminal is 10 pps (packets per second). The unicast data arrival rate of each node (consider as background traffic) is 2 pps, and the broadcast arrival rate of each node is considered from 0.5 pps to 2.5 pps.

Figure 6 shows the mean broadcast fractions obtained by pure IEEE 802.11 broadcast [4], BMW [13], BACK [16], and BEAM schemes under different offered load. The offered load is calculated by the data packet arrival rate and the broadcast requests of both hidden terminals and full-connected nodes. We can see that the broadcast delivery ratio of IEEE 802.11 lowers from 70% to 27% gradually due to the interference of hidden terminals. However, Among BMW, BACK, and BEAM get higher broadcast delivery ratio than IEEE 802.11 since they all have the mechanism to check the reception of the broadcast data and thus reduce the impact of hidden terminals. The broadcast delivery ratio of BMW, nevertheless, starts to decrease when offered load reaches 0.4. Although BMW has the RTS/CTS and retransmission schemes, it cannot suppress the problem of hidden terminal effectively. Besides, BACK has higher broadcast delivery ratio but it may increase unnecessary rebroadcast times so that wastes the network bandwidth. On the other hand, the proposed BEAM uses the BACKs scheme to prevent hidden node phenomenon and reaches approximate 100% reliability even in heavy traffic load.

Afterward, we focus on the network layer to evaluate the performance of BEAM in detail. The second simulation model (S2) is taken to simulate the multihop ad hoc environment. The working space is enlarged to 600 m × 600 m and each node's transmission radius is 120 m. Different numbers of nodes (range from 20 to 100) are randomly placed in this area. To avoid the network topology being partitioned, the first node is always located in the center of the area and the remaining nodes will be randomly allocated until it has at least one neighbor. The data arrival rate of each node is 1 pps and the broadcast data arrival rate of each node is considered as 2 pps. Four broadcast flooding schemes: blind flooding, AV reliable broadcast (AVR) [1], broadcast with selected acknowledgments (BSA) [7], and BACK are evaluated to compare with BEAM.

In this experiment, we observe the broadcast delivery ratio, shown in Fig. 7, Fig. 8, and Fig. 9, of BEAM, blind flooding (BF), AVR, BSA, and BACK under different maximum retry counts (MaxRetry). We can see that the BF scheme cannot flood data frames to all nodes in the network efficiently since it lacks the ACK mechanism. From Fig. 7, we also observe that AVR, BSA, and BACK schemes get lower broadcast delivery ratio than the BEAM when the number of nodes increases. We remind that AVR achieves reliable broadcast transmission via one-by-one 'unicast' retransmission if it does not receive the prospective ACK packets after the broadcast transmission. Thus, under the constrain of MaxRetry, AVR obtains not good performances in broadcast delivery ratio even though it increases the value of MaxRetry (see Fig. 8 and Fig. 9). Unlike AVR, BSA only selects several critical node to forward the broadcast packets. However, this scheme will cost a lot of computation power and has no effective method to avoid interruptions from other nodes. Besides, BACK has higher broadcast delivery ratio but its drawback is to waste the network bandwidth when node misjudges the correct outcome of broadcast transmissions. On the contrary, BEAM can get higher broadcast delivery ratio owing to the effect of the BNAV to prevent other nodes (or hidden nodes) to influence the on-

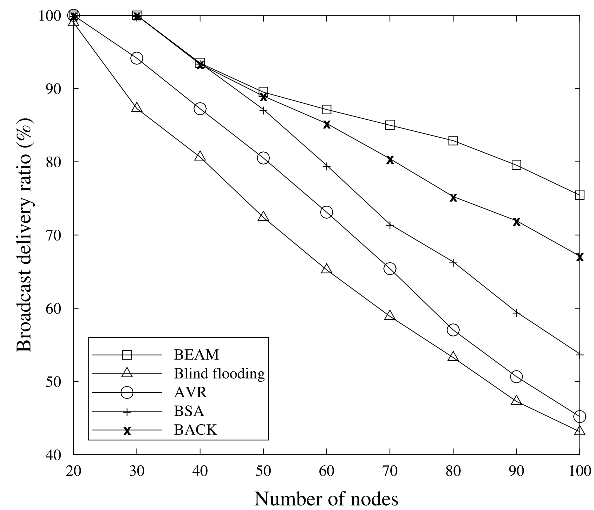

Fig. 7 The broadcast delivery ratio of BEAM, BF, AVR, and BSA by varying the number of nodes (MaxRetry = 1).

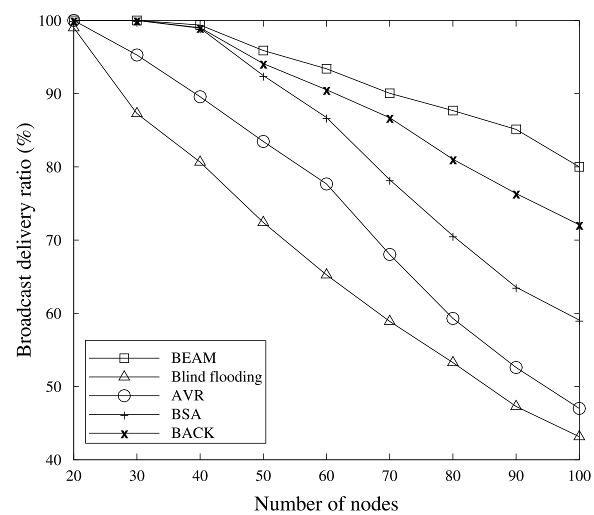

Fig. 8 The broadcast delivery ratio of BEAM, BF, AVR, and BSA by varying the number of nodes (MaxRetry = 2).

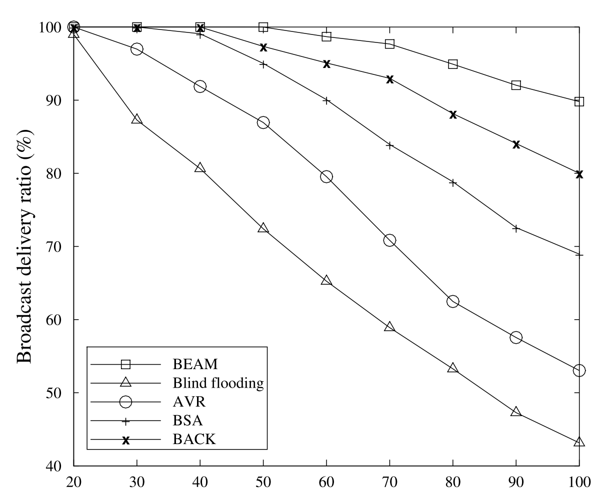

Fig. 9 The broadcast delivery ratio of BEAM, BF, AVR, and BSA by varying the number of nodes (MaxRetry = 3).

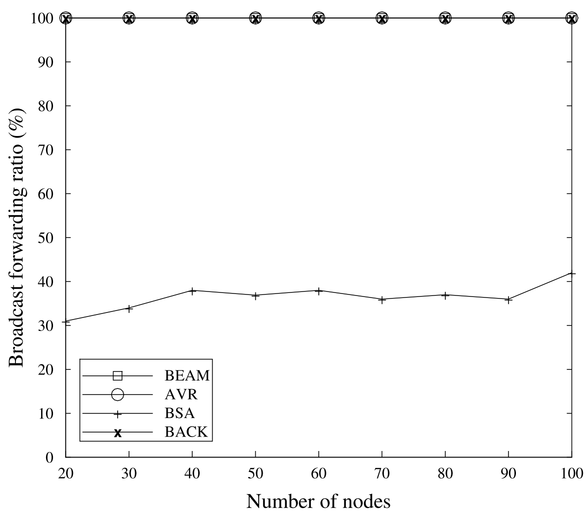

Fig. 10 The broadcast forwarding ratio of BEAM, AVR, and BSA by varying the number of nodes (MaxRetry = 3).

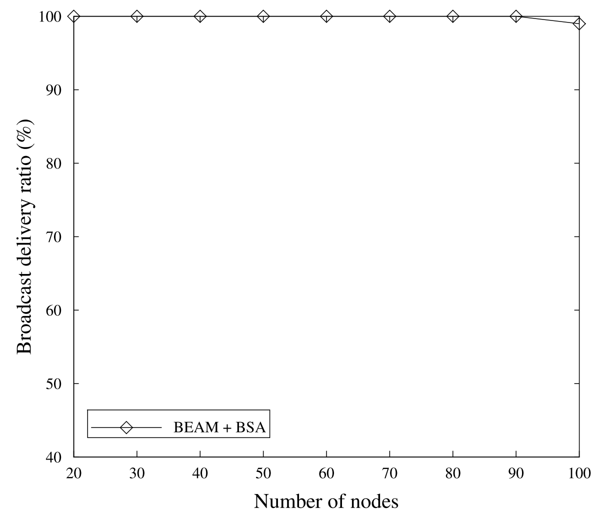

Fig. 12 The broadcast delivery ratio of BEAM+BSA by varying the number of nodes (MaxRetry = 3).

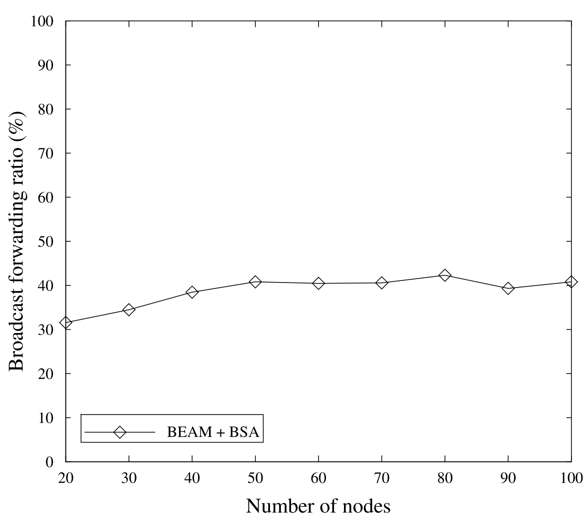

Fig. 11 The broadcast forwarding ratio of BEAM+BSA by varying the number of nodes (MaxRetry = 3).

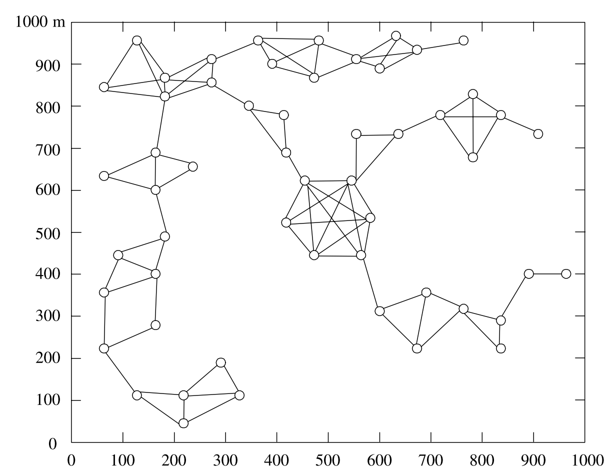

Fig. 13 A randomly generated topology with 54 nodes.

going broadcast transmission.

For the comparison of broadcast forwarding overhead, we observe each broadcast forwarding ratio of BEAM, BSA and AVR, respectively. From Fig. 10, we can see that BSA obtains lower broadcast forwarding ratio than BEAM, AVR, and BACK since it only selects some forward node to broadcast the data. To improve the drawback of BEAM we can combine BSA (network layer) with BEAM (data link layer) to reduce the forwarding overhead. Figure 11 shows that, after combining with BSA, the forwarding ratio of BEAM is lowered from 100% to about 40%. Furthermore, in Fig. 12, the broadcast delivery ratio of BEAM plus BSA is enhanced (compared with Fig. 9) well even if the number of nodes is large. This result indicates that BEAM is an efficient reliable broadcast mechanism in data link layer and can combine any network layer broadcast algorithm to achieve highly reliable broadcast delivery.

In the following experiment, we run the simulation in a randomly generated network topology, which is shown in Fig. 13, with 54 nodes in a 1000 m × 1000 m square area. To compare the broadcast performance in mobility, we apply the mobility model to this experiment (S3). We set each mobile node with different speeds from 0 to 5 m/s (the walking speed) in each simulation run. All mobile nodes follow the random way point model to decide their moving direction as we mentioned above if they are in moving state. The data arrival rate of unicast and broadcast per each node are 1 pps and 2 pps, respectively. We can see that, from Fig. 14, due to the mobility, the delivery ratio of four protocols decreases as the mobility increases. However, the broadcast delivery ratio of BEAM does not fluctuate by the mobility very much since BEAM can suppress the hidden terminal problem well (at least 95%).

In the following experiments, different from previous scenario, we change the simulated area's shape from square to 1500 m × 300 m rectangle. The long and narrow configu-

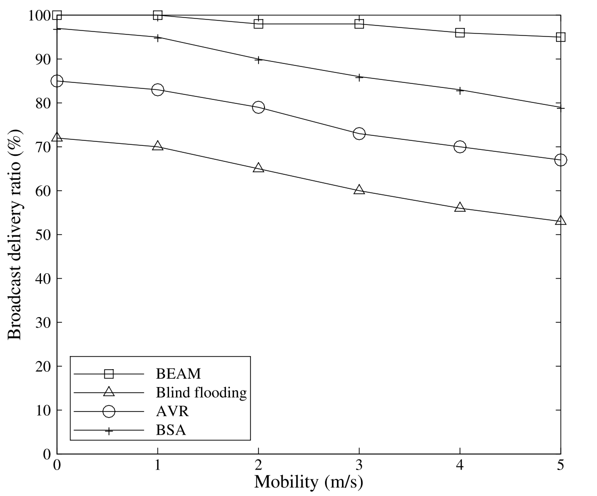

Fig. 14 The broadcast delivery ratio of BEAM, BF, AVR, and BSA in fixed network topology (MaxRetry = 3).

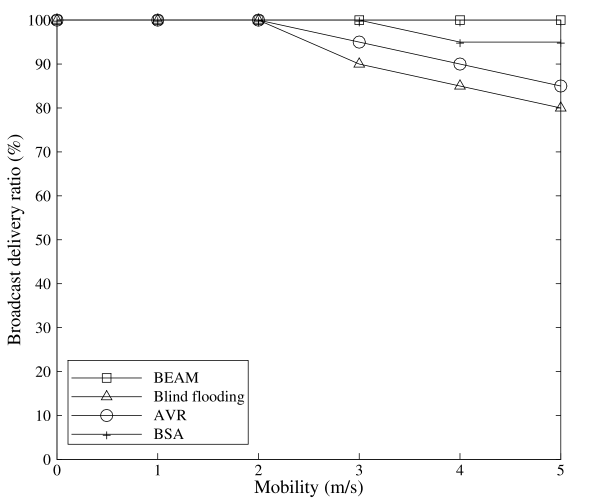

Fig. 15 The broadcast delivery ratio of BEAM, BF, AVR, and BSA where MaxRetry = 3 and number of nodes = 10 in walking environment.

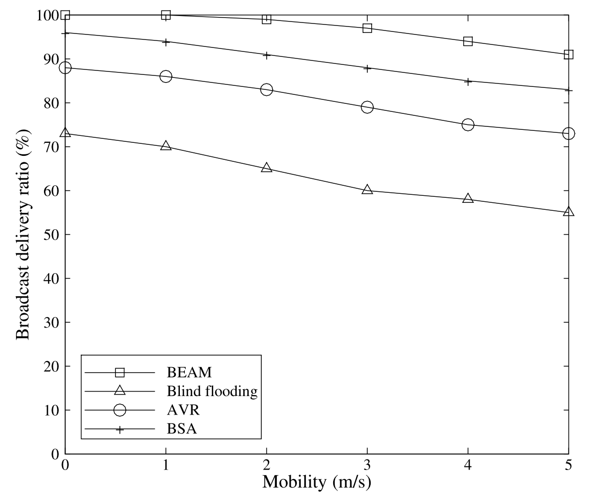

Fig. 16 The broadcast delivery ratio of BEAM, BF, AVR, and BSA where MaxRetry = 3 and number of nodes = 50 in walking environment.

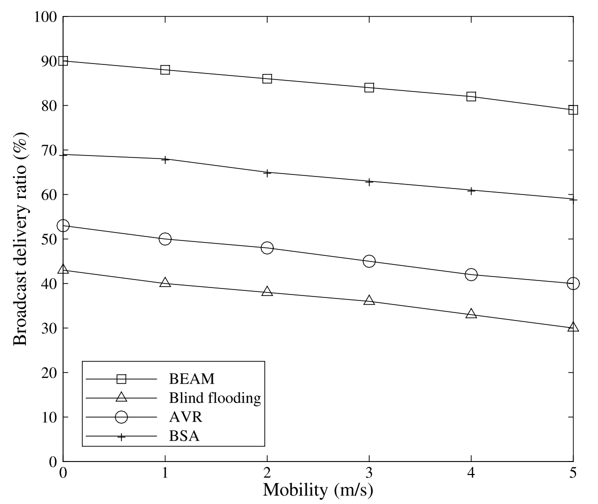

Fig. 17 The broadcast delivery ratio of BEAM, BF, AVR, and BSA where MaxRetry = 3 and number of nodes = 100 in walking environment.

ration is designed to draw the diameter of the network topology for more hops and to investigate the effect of broadcast delivery ratio on long flooding range. Different numbers of nodes (10, 50, and 100) are randomly placed in this area with different mobilities (from 0 to 5 m/s), respectively. The data arrival rate of unicast and broadcast per each node are 1 pps and 2 pps, respectively.

From Fig. 15, we can see that BEAM still performs 100% delivery ratio in 5 m/s speed but BF, AVR and BSA decreases in different degrees since 3 m/s. This is because that due to mobility the problem of hidden terminal will become more seriously and interrupts other ongoing transmissions. However, BEAM can suppress hidden terminals' transmission effectively and thus gets higher delivery ratios. These results also imply that BEAM can deliver broadcast data efficiently even in longer diameter network topology. When the number of nodes increases, see Fig. 16 and Fig. 17, the performances of all schemes degrade. BEAM still gains above 80% broadcast delivery ratio as the number of nodes is 100 and the moving speed is 5 m/s. This result shows that the performance of BEAM outperforms other schemes in large network size.

Finally, we extend the mobility model to vehicular environment (from 10 to 20 m/s). We use the working space 1000 m × 1000 m to compare with the walking model shown in Fig. 13. In Fig. 18 and Fig. 19, all simulation parameters are same with walking model except moving speeds. We can see that broadcast delivery ratios of all schemes lower down when mobility increases. There are two reasons to result in this outcome. The first one is that high mobility will lead mobile nodes to leave their previous place where they broadcast a data packet to its neighbors. This implies that the network topology is changed due to mobility and broadcast retransmission is not effective. The another one is that the transmission would be likely interrupted by other mobile nodes or interrupts other nodes' transmissions due to mobil-

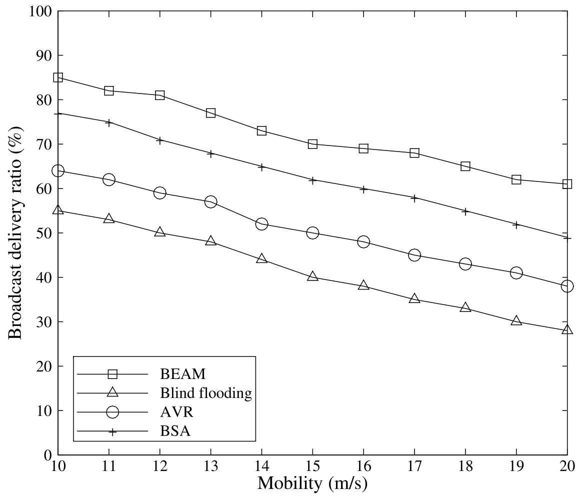

Fig. 18 The broadcast delivery ratio of BEAM, BF, AVR, and BSA where MaxRetry = 3 and number of nodes = 50 in vehicular environment.

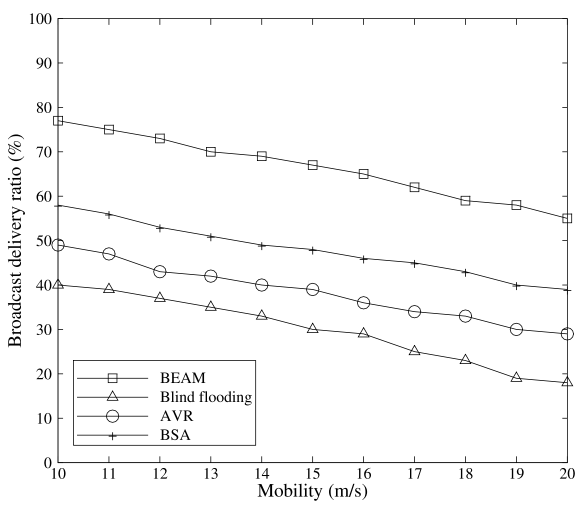

Fig. 19 The broadcast delivery ratio of BEAM, BF, AVR, and BSA where MaxRetry = 3 and number of nodes = 100 in vehicular environment.

ity. Although BEAM has BNAV to restrain other nodes to transmit data packets, it still cannot overcome high mobility well. This problem encourages us to investigate further.

5. Conclusions

In this work, we propose a broadcast transmission scheme named broadcast engagement acknowledgment mechanism (BEAM) for reliable broadcast transmission in mobile ad hoc networks. This work is achieved by enforcing the neighboring nodes to confirm their receipts of the broadcast frame accordingly. BEAM not only achieves high flooding (broadcast) delivery ratio but is fully compatible with IEEE 802.11 MAC protocol. BEAM could enhance the broadcast fraction of the IEEE 802.11 to 100% even in heavy traffic load. Besides, BEAM is a data link layer protocol rather than a network layer protocol and thus reduced a lot of control overheads in achieving reliability. Simulation results show that BEAM combined with network layer broadcast scheme could approach higher broadcast delivery ratio as well as reduce bandwidth consumption efficiently. Regardless of environment, BEAM has higher broadcast delivery ratio and reduces the problem of hidden terminal occurrence effectively. Moreover, the problem of reliability on broadcast transmission caused by mobility is one potential future focal point of researches in MANETs.

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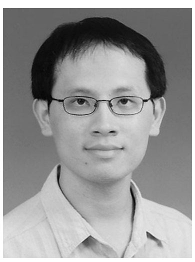

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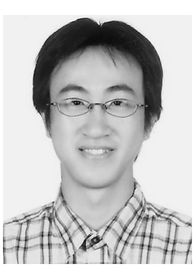

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