Journal of Southeast University (English Edition) Vol. 31, No. 1, pp. 5 − 11 Mar. 2015 ISSN 1003—7985

A distributed on-demand bandwidth-constrained multicast routing protocol for wireless ad hoc networks

Yu Yanping Ni Lingling Zheng Yuanyan

(School of Information and Electronic Engineering, Zhejiang Gongshang University, Hangzhou 310018, China)

Abstract: To meet the bandwidth requirement for the multicasting data flow in ad hoc networks, a distributed on-demand bandwidth-constrained multicast routing (BCMR) protocol for wireless ad hoc networks is proposed. With this protocol, the resource reservation table of each node will record the bandwidth requirements of data flows, which access itself, its neighbor nodes and hidden nodes, and every node calculates the remaining available bandwidth by deducting the bandwidth reserved in the resource reservation table from the total available bandwidth of the node. Moreover, the BCMR searches in a distributed manner for the paths with the shortest delay conditioned by the bandwidth constraint. Simulation results demonstrate the good performance of BCMR in terms of packet delivery reliability and the delay. BCMR can meet the requirements of real time communication and can be used in the multicast applications with low mobility in wireless ad hoc networks.

Key words: wireless ad hoc networks; multicast routing; bandwidth satisfaction; on-demand multicast routing; distributed multicast routing; QoS multicast routing

doi: 10.3969/j. issn. 1003 − 7985. 2015. 01. 002

It is usually necessary to design QoS multicast routing algorithms to implement multicast applications in which packets are forwarded from a source to a group of receivers with QoS support[1-2]. Bandwidth is considered as the primary QoS parameter in most QoS routing protocols. Some of QoS routing protocol in wireless ad hoc networks is involved in bandwidth calculation (BWC)[3-5].

Early work focused on multicast routing without supporting QoS, for instance, MAODV[6] and ODMRP[7]. Some examples of QoS multicast in ad hoc networks are MCEDAR[8], M-CAMP[9], BDP[10]. However, the QoS multicast protocols mentioned above are not able to provide even soft QoS support, not to mention strict QoS support. Therefore, two bandwidth-violation problems, i. e., the hidden route problem (HRP) and the hidden multicast route problem (HMRP), identified in the bandwidth-satisfied multicast tree (BSMT), may seriously affect the performance of the QoS multicast[11]. In Ref. [11], the authors proposed a method to estimate residual bandwidth before multicast routing calculation. In the mean time, a bandwidth-satisfied shortest multicast tree from a server to its clients is determined concurrently. One of the drawbacks of this algorithm is that it needs to collect the information of the entire network in order to determine the bandwidth-satisfied multicast routes, which goes against the distributed nature of ad hoc networks. Another drawback is that only the shortest paths which are formed by minimum number of forwarders are determined. Although minimum forwarders usually lead to a minimum delay, it does not always remain true.

In this paper, the influence of the neighbor nodes and hidden nodes is considered while we investigate QoS multicast routing. A distributed on-demand bandwidth constrained multicast routing protocol in wireless ad hoc networks is proposed, considering the influence of neighbor nodes and hidden nodes. B, $2B$, $3B$ and $4B$ are the possible values of the bandwidth needed to be reserved for a flow requiring bandwidth B. A node will determine how much bandwidth should be reserved according to whether it is a source node, a forwarding node, a leaf node or a neighbor node. The resource reservation table will record the bandwidth requirement of the data flows which access its neighbor nodes and hidden nodes as well; and every node calculates the remaining available bandwidth by deducting the bandwidth reserved in the resource reservation table from the total available bandwidth of the node. Moreover, BCMR searches in a distributed manner for the paths with the shortest delay conditioned by the bandwidth constraint. It is a distributed on-demand multicast routing protocol based on local information, and is suitable for the self-organized wireless ad hoc networks.

1 The Operation of BCMR

Suppose that the MAC protocol is IEEE 802. 11 DCF. The wireless channel is bi-directional. Multicast sessions can only be initiated and terminated by the source node. The data is only sent by the source node to the destinations nodes.

The relevant terminology is as follows. There are five

Received 2014-09-30.

Biography: Yu Yanping (1965—), female, doctor, professor, yuyanping @ zjgsu. edu. cn.

Foundation item: The Natural Science Foundation of Zhejiang Province (No. Y1090232).

Citation: Yu Yanping, Ni Lingling, Zheng Yuanyan. A distributed on-demand bandwidth-constrained multicast routing protocol for wireless ad hoc networks[J]. Journal of Southeast University (English Edition), 2015, 31(1): 5 − 11. [doi: 10.3969/j. issn. 1003 − 7985. 2015. 01. 002]

types of packets, named RREQ, RREP, RRES, RREL, SES-END. RREQ is used when a node initiates a session. RREP is used as a response to the reception of a RREQ for a destination node. RRES is used to reserve resources especially for neighbor nodes. RREL is sent when the reserved resource needs to be released. SES-END is used when a source node intends to terminate a session.

1.1 Bandwidth calculation

Bandwidth calculation has to be done before making a routing decision in BCMR.

1.1.1 Available bandwidth calculation

The available bandwidth of a node is the result of subtracting all of the reserved bandwidth from the total bandwidth of a node.

All transmissions going on one-hop neighbors will affect the local channel of the current node. However, not all transmissions going on two-hop neighbors will affect the local channel. Taking Fig. 1 as an instance, node *B* is out of the transmission coverage range of node *A*. When node *B* transmits information to a node that is located in the shadow area, the interference to the transmission of node *A* occurs. Thus, in many cases, when node *A* are transmitting or receiving, only one-hop neighbors of node *A* is necessary to reserve bandwidth. When node *A* has a session with node *C* which is located in the shadow area covered by both node *A* and node *B*, the one-hop neighbors of node *C* need to reserve resources as well. Fig. 1 (a) and (b) illustrate two scenarios. Assume that the maximum bandwidth of a node is 7 units.

In Fig. 1(a), there is no flow going through node *C*. The flow over link *A*-*E* will proceed when the bandwidth requirement of 5 units is met. Then node *C* needs to reserve 5 units of bandwidth for the above mentioned session. It is unnecessary to notify the one-hop neighbors of node *C* to reserve a bandwidth for this session. Thereafter, node *B* and node *D* establish a session with a requirement of 3 units of bandwidth. Node *C* needs to reserve 3 units of bandwidth for node *B* and likewise it is unnecessary to notify one-hop neighbors of node *C* to reserve bandwidth. In such cases, the possible negative value of available bandwidth of node *C* might occur. However, this situation does not affect the session proceeding between *A*-*E* and *B*-*D* as long as there is no session going through node *C*.

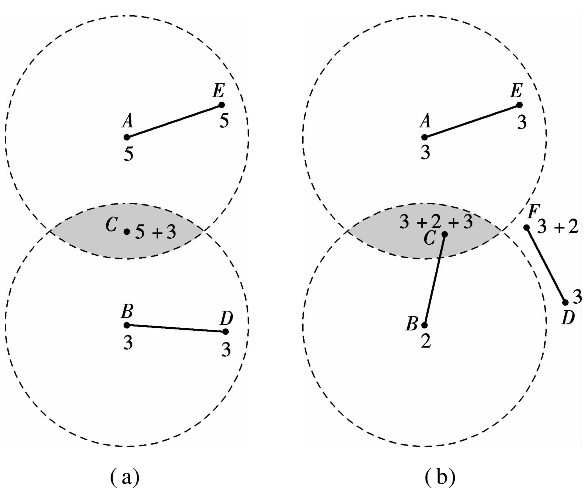

Fig. 1 Illustration of bandwidth calculation between neighbor nodes. (a) No flow going through node *C*; (b) A flow going through node *C*

In Fig. 1(b), consider the case that the two-hop neighbors do not reserve bandwidth. There is a flow between nodes *B* and *C* consuming 2 units of bandwidth. Node *A* and node *F* will reserve 2 units of bandwidth for the aforementioned flow between node *B* and node *C*. Then there is a session request between nodes *A* and *E* which requires 3 units of bandwidth. If node *A* and node *E* has enough bandwidth for this session, the session is allowed to start. As a one-hop neighbor of node *A*, node *C* needs to reserve 3 units bandwidth. Then, there is another session request between node *F* and node *D* requiring 3 units of bandwidth. For node *F* and node *D*, the available bandwidth is enough to support this session. However, as a one-hop neighbor of node *F*, node *C* also needs to reserve a bandwidth of 3 units. The summation of the bandwidth which needs to be reserved of node *C* is 8 units which certainly exceeds its total available bandwidth. The admission of the session between node *F* and node *D* will influence the previously admitted session. To avoid this situation of inadequate bandwidth, when node *A* itself needs to admit a session just after node *B*(two-hop neighbor of node *A*) has a session with node *C* in the shadow area, node *F*(one of the two-hop neighbor of node *A*) needs to reserve bandwidth as well. Then the session between node *F* and node *D* cannot proceed because the available bandwidth of node *F* is not enough.

1.1.2 Calculation of the required bandwidth of a node

The consumed bandwidth of a node for a flow with bandwidth requirement depends on the position of the node[11]. Suppose that HOPs denotes the number of previous two-hop neighbors and next two-hop neighbors on the route. The relationship between the consumed bandwidth of a node on the route (denoted as B_c) and the requested bandwidth of a flow (denoted as B_r) is as follows:

If a node is a forwarding node

If(HOPs = 1)	$B_c = B_r$
Else if(HOPs = 2)	$B_c = 2B_r$
Else if(HOPs = 3)	$B_c = 3B_r$
Else	$B_c = 4B_r$

Else if a node is a one-hop and two-hop neighbor node

$$B_c = B_r$$

1.2 Detail description of BCMR

As an on-demand multicast routing protocol, BCMR disseminates RREQs throughout a network only when there is data in a source node needed to multicast to a group. For each node, there is a routing table to record the route for every group and a resource reservation table to record the amount of reserving bandwidth and its corresponding reservation status for each flow. Four possible reservation statuses are "explored", "registered", "neighbor", and "two-hop". Here, "explored" indicates that the resource has been reserved after receiving a RREQ. "registered" indicates the reservation status of a forwarding node or a source node right after it receives a corresponding RREP. "neighbor" indicates the reservation status of a neighbor node of a flow right after it receives a RRES. "two-hop" indicates the reservation status of a two-hop neighbor node after it receives a RRES, which needs to be determined according to different scenarios.

How nodes in a network cooperate with each other to complete multicast routing in BCMR will be explained next.

1.2.1 Route discovery

1) A source node sending a RREQ

The source node which has data to disseminate to a group checks whether its own available bandwidth meets the requirement of a flow, i. e. $B_a > B_c$. If satisfied, the source node broadcasts a RREQ to establish a multicast forwarding structure for the destined group. Then, reserve resources, set the resources reserving the status of the node for this flow as "explored", and set corresponding reserving time. Recalculate the available bandwidth of the source node by $B_a = B_a - B_c$. If not satisfied, the source node will not send a RREQ.

2) When an intermediate node receives a RREQ

Upon an intermediate node receiving a RREQ, the node first determines whether it has received a RREQ containing the same source node IP address and RREQ ID. If such a RREQ has been received, the node discards the RREQ.

The case that the RREQ is not discarded is explained as follows. First, the node determines the consumed bandwidth B_c based on the position of a node. Then B_a is compared to B_c and the node discards the received RREQ if B_a is less than B_c. Otherwise, the node reserves the bandwidth of B_c, sets the reserving status as "explored" and the reserving time, and updates the value of B_a. Next determine whether the HOPs is smaller than the hop threshold. If so, broadcast the RREQ just received. Otherwise, stop broadcasting the RREQ. If the node does not receive any RREP or RRES before reserving timeout, it releases the reserved bandwidth.

3) When a destination receives a RREQ

A member of the multicast group is termed as a destination node. When a destination node receives the first RREQ with the specific source IP address and packet ID, the available bandwidth of the destination node B_a is compared to the consumed bandwidth for this specific flow B_c, and the RREQ is discarded if B_a is less than B_c. Otherwise, the node adds an entry to the routing table, reserves the bandwidth, sets the reservation status of the corresponding entry as "registered" and its corresponding reserving time, and updates the available bandwidth. If the HOP is under the hop threshold, the node broadcasts the RREQ in the same manner as its upstream node did, since a destination node can also be a forwarding node for other destinations. Then the destination node responds the received RREQ by unicasting a RREP.

If there is some entry in the resource reservation table whose status is "neighbor", the node sends a RRES to their neighbors for every such entry.

1.2.2 Route reply

1) When a forwarding node receives a RREP

An intermediate node receiving a RREP can determine whether itself is a forwarding node (a node on the multicast forward structure) or a neighbor node (a node which is a neighbor of a node on the multicast forwarding structure) from the previous node address in the RREP. There are several situations that need to be considered.

If the current forwarding node is the common upstream forwarding node of two destination nodes, which can be determined from the resource reservation table where an entry with status "registered" for a different destination of the same multicast group already exists, only a new routing entry needs to be added to the routing table.

If there are entries which show that resources have been reserved for different destinations in the same multicast group with status "neighbor" or "two-hop", check the available bandwidth by comparing it to the consumed bandwidth of a flow. If $B_a > B_c$, the current forwarding node updates the value of the reserved bandwidth, adds a routing entry in the routing table and forwards the received RREP. Otherwise, it RREL to the next downstream node. The RREL will be forwarded along the route through which RREP is received and the reserved bandwidth will be released until this RREL reaches a destination node.

If there are entries showing that resources have been reserved for the same multicast group with status "explored", which means that the current node has only received the corresponding RREQ; it will add a new entry to the routing table, change the reserving status to "registered", set the reserving time to infinity, update B_a, fill the last hop address into RREP, and forward the RREP. If there is some other entry whose status is "neighbor" in addition to the abovementioned entry, the node sends a RRES to notify its neighbor nodes the reserving information with status "neighbor".

2) When a neighbor node receives a RREP

When a neighbor node receives a RREP, it will determine whether it has reserved resources for some other destinations in the same group. If this is the case, it means that this newly coming RREP is from a different destination, and the resource reservation request is from a different route. When RREQ is received by this node, the bandwidth reserved is only enough for one route. As a result, the bandwidth reservation with status "neighbor" has to be updated and B_a needs to be recalculated at this time.

3) When a source node receives a RREP

If the source node receives a RREP, it adds a new routing entry to the routing table, sets the resource reservation status to "registered" and forwards the RREP to its one-hop neighbor. Then it determines whether it has received RREPs from all the destinations of the group. If this is the case, it will start to send DATA packets which carry the source node address, sequence ID, and multicast group address over the established multicast forwarding structure. Timeout and retry mechanisms are adopted for the source node.

1.2.3 Neighbor nodes processing resource reservation

When any node receives a RRES, it will proceed differently according to the reservation status in the resource reservation table. If it has not reserved any resources for the same destination in the same multicast group as shown in RRES, which means that it has not received any RREQ from the same group, it sets the resource reserving status to "two-hop", sets reserving time to infinity and updates B_a. If it has reserved resources, it will proceed according to the reserving status. If the reserving status is "two-hop", the reserved bandwidth of corresponding entry is compared to B_c and the greater one is used to update the corresponding reserving entry. Otherwise, the current node is a forwarding node or a destination node, no processing is necessary.

Fig. 2 illustrates this scenario. Here node *E* and node *H* are destination nodes. Suppose that node *E* and node *H* have received the same RREQ and node *F* and node *G* have already received the RREP from node *H* when node *C* receives the RREP from node *E*. Then node *F* and *G* are not only the forwarding nodes of the group but also the one-hop neighbor nodes of route *A-B-C-D-E*. Node *J* needs to reserve resources for the flow over route *A-B-C-D-E*. So both node *F* and node *G* need to send a RRES to notify two-hop neighbor node *J* to reserve the resources.

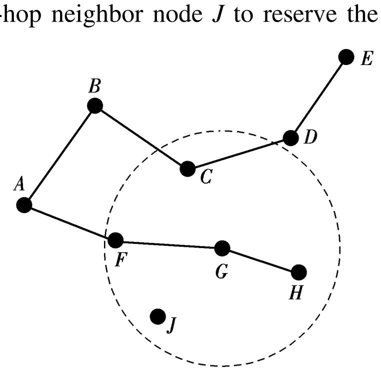

Fig. 2 Illustration of resources reservation

After comparing B_c contained in both RRESs, node *J* reserves the greater one.

1.2.4 Resource release

1) When a forwarding node receives a RREL

When a forwarding node receives a RREL, it simply forwards the RREL to the immediate next node, deletes the corresponding routing entries, and releases the reserved resources. When a destination node receives a RREL, it will forward the RREL, and release reserved resources. For any forwarding node receiving a RREL, if there are any entries in the reservation table whose reserving status is "neighbor", it will release the corresponding reserved resources and send a RREL to all neighbors according to every entry with status "neighbor" to release the corresponding reserved resources.

2) When a neighbor node receives a RREL

After the neighbor node receives a RREL, it releases the corresponding reserved resources and transfers RREL to its neighbors (two-hop neighbors) to release the reserved resources.

3) When two-hop neighbors receive a RREL

When a two-hop node receives a RREL, the only task that it needs to do is to release the reserved resources for the flow.

1.2.5 When any node receives a DATA packet

If a node that receives a data packet is a forwarding node or a destination node, it will simply forward the data packets according to the routing table to reach the destinations of the group. Any other node that receives a data packet will simply discard it.

1.2.6 Route releasing

1) A source node sending a SES-END

When a source node intends to terminate a session, it will initiate the process to end the session after waiting for some time so that other nodes complete transmitting the data packets that have been sent out. First, it will send a SES-END to its neighbor nodes, and then delete the corresponding routing entries in the routing table and release the reserved resources.

2) When a non-source node receives a SES-END

The destination nodes, the forwarding nodes, the one-hop neighbors and the two-hop neighbor nodes reserve the resources for flows with status "registered", "neighbor", "two-hop", respectively, until receiving a SES-END from the source node of the specific group.

If a node other than the source node receives a SES-END for the corresponding group, it first checks whether there is a corresponding entry in the resource reservation table. If not, it discards the SES-END. Otherwise, it will proceed according to the next hop address field in the SES-END and reserving status. If itself is the node indicated in the next-hop field in the SES-END, it updates the next hop address in the SES-END according to the routing table, deletes the corresponding routing entries, releases the corresponding reserved resources, and forwards the SES-END to the next hop (or next hops). If itself is not the next hop node indicated in the SES-END, it just releases the reserved resources and forwards the SES-END with its next-hop fields empty. If the next hop field is empty in the received SES-END and the reserved status is "two-hop", the only thing for the current node to do is release the reserved resources, without forwarding SES-END. The rest nodes received SES-END just simply discard the SES-END.

2 Performance Evaluation of BCMR

2.1 Simulation scenarios

This section presents the performances of BCMR by the simulation. We compared the performances of BCMR and MAODV. The reason for selecting MAODV as a reference is that the essential mechanism under BCMR is very similar to that of MAODV.

In the simulation, wireless networks were set up with 50, 80, 100 nodes which were randomly and uniformly distributed over an area of 1 000 m × 1 000 m. The wireless transmission range of each node is 250 m. IEEE 802.11 DCF with link bandwidth of 11 Mbit/s was selected as the MAC layer protocol. The packet size is 512 bytes, and the source node sends CBR flows with a rate of 5 packet/s. Each group has a multicast group source node and three destination nodes.

To evaluate the performance of BCMR, three metrics in terms of packet delivery ratio, routing control overhead, average maximum end to end delay are defined as follows. Packet delivery ratio is defined as the ratio of the number of data packets successfully received by all of the destination nodes to the number of data packets that all the destination nodes should receive. The number of data packets that all the destination nodes should receive is the product of the number of data packets sent out by the source and the number of destination nodes. The control overhead is expressed as the average number of control packets to successfully deliver each data packet. Control packets include RREQ, RREP, RRES, RREL, SES-END and so on. Average maximum end to end delay is defined as average maximum delay from a source to each destination. MAODV and BCMR are simulated under 100 different scenarios with different seeds each time and the results are averaged over these scenarios.

2.2 Simulation results

Fig. 3 presents the packet delivery ratio of networks with the network size of 50, 80, 100 nodes, respectively. These results show that there is a great improvement in terms of packet delivery ratio of networks using BCMR compared to MAODV. Meanwhile, the packet delivery ratio of BCMR almost remains stable when the group number changes. In contrast, the packet delivery ratio of MAODV drops as the number of multicast groups increases. This is because if the remaining available bandwidth of a node is less than the consumed bandwidth for a new flow in BCMR, it will not allow new data flows to access it, which guarantees the packet delivery ratio which has been accessed before. In contrast, a node can access new flows without checking whether the available bandwidth can satisfy the consumed bandwidth in MAODV, which causes severe collisions in networks and leads to the evident decrease in the packet delivery ratio.

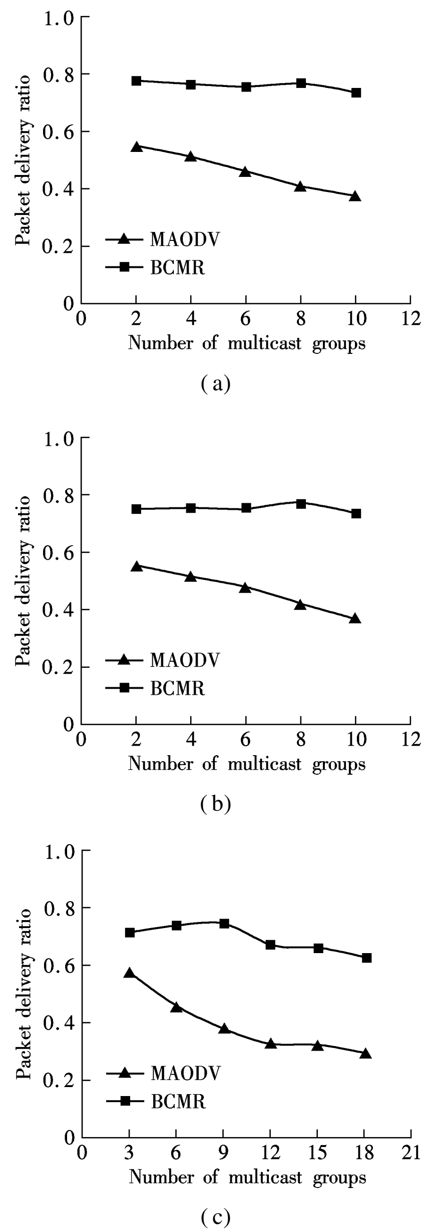

Fig. 3 The packet delivery ratio of networks. (a) With size of 50 nodes; (b) With size of 80 nodes; (c) With size of 100 nodes

Fig. 4 presents the routing control overhead of networks with size of 50, 80, 100 nodes, respectively. It can be seen from the figures that the routing control overhead of BCMR is comparatively much higher than that of MAODV and the routing control overhead of BCMR grows with the increase in the number of group. This is because the bandwidth reservation needs to be considered in BCMR. If the available bandwidth of node cannot meet the requirements, part of the reserved bandwidth of the upstream nodes needs to be released by sending RREL. Also, during the route request phase, a node will send RRES to their corresponding neighbor nodes and two-hop neighbor nodes, which also causes additional overhead.

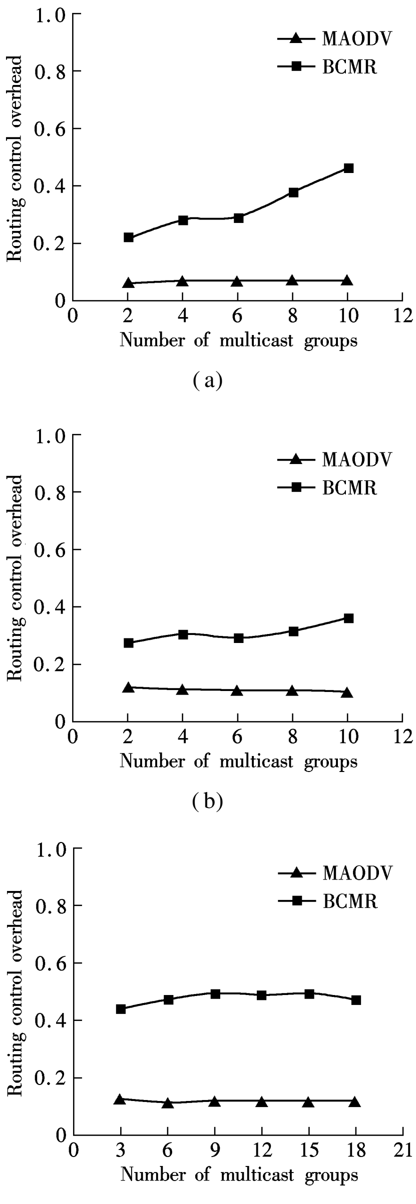

Fig. 4 The routing control overhead of networks. (a) With size of 50 nodes; (b) With size of 80 nodes; (c) With size of 100 nodes

Fig. 5 shows the average maximum end-to-end delay of networks with size of 50, 80, 100 nodes, respectively. The results show that there is a great improvement in terms of the average maximum end-to-end delay of networks using BCMR compared to MAODV. Meanwhile, the average maximum end-to-end delay of BCMR always remains at an acceptable value for real-time communications. The reason is that the bandwidth is guaranteed for those with an already admitted session while it declines a newly coming session if the bandwidth cannot meet the requirements. If the resources are satisfied, less collision will occur and thus, less delay may be caused.

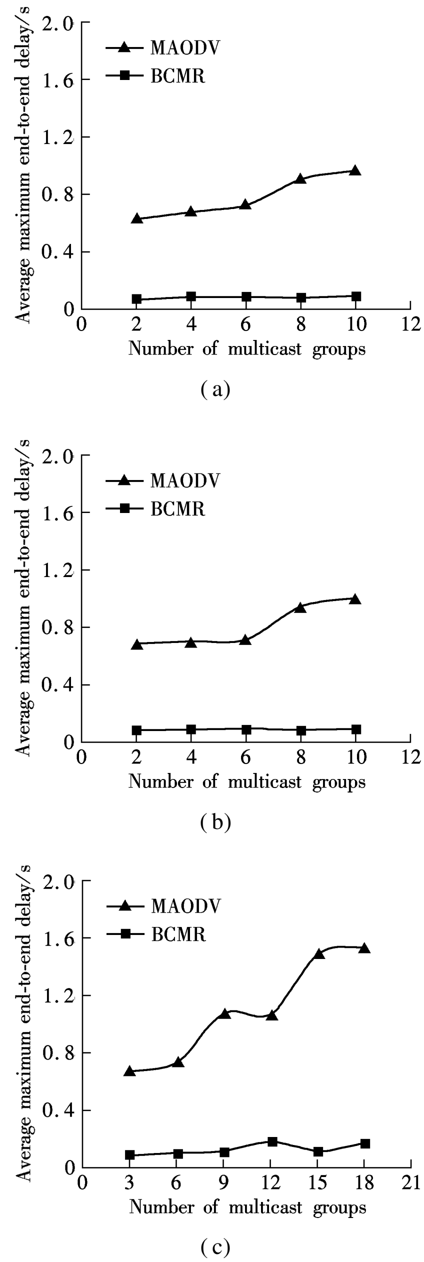

Fig. 5 The average maximum end-to-end delay of networks. (a) With size of 50 nodes; (b) With size of 80 nodes; (c) With size of 100 nodes

3 Conclusion

BCMR is an on-demand multicast routing protocol. The main contribution of this paper is that a node will not only reserve the bandwidth for the sessions going through itself but also reserve the bandwidth for the neighbor nodes and the hidden nodes. In this way, sufficient bandwidth is reserved for the sessions that are successfully established, so that less collision will occur, thus causing less delay. In conclusion, BCMR is a protocol that has good performance in terms of packet delivery ratio and end-to-end delay which are the two primarily important QoS parameters.

References

[1] Sahasrabuddhe L H, Mukherjee B. Multicast routing algorithms and protocols: a tutorial[J]. *IEEE Network*, 2000, **14**(1): 90 – 102.

[2] Biradar R, Manvi S. Review of multicast routing mechanisms in mobile ad hoc networks[J]. *Journal of Network and Computer Applications*, 2012, **35**(1): 221 – 239.

[3] Dong Y, Makrakis D. Effective bandwidth calculation for QoS routing in IEEE 802.11 DCF ad hoc networks[J]. *Ad Hoc & Sensor Wireless Networks*, 2005, **2**(3): 245 – 280.

[4] Xue Q, Ganz A. Ad hoc QoS on-demand routing (AQOR) in mobile ad hoc networks[J]. *Journal of Parallel and Distributed Computing*, 2003, **63**(2): 154 – 165.

[5] Chen L, Heinzelman W B. QoS-aware routing based on bandwidth estimation for mobile ad hoc networks[J]. *IEEE Journal on Selected Areas in Communications*, 2005, **23**(3): 561 – 572.

[6] Royer E M, Perkins C E. Multicast operation of the ad-hoc on-demand distance vector routing protocol[C]//*Proc of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking*. New York, USA: ACM Press, 1999: 207 – 218.

[7] Lee S J, Gerla M, Chiang C C. On-demand multicast routing protocol[C]//*Proc of IEEE Wireless Communications and Networking Conference*. New York, USA: Institute of Electrical and Electronics Engineers Inc, 1999: 1298 – 1302.

[8] Sinha P, Sivakumar R, Bharghavan V. MCEDAR: multicast core-extraction distributed ad hoc routing[C]//*Proc of IEEE Wireless Communications and Networking Conference*. New York, USA: Institute of Electrical and Electronics Engineers Inc, 1999: 1313 – 1317.

[9] Pagani E, Rossi G P. A framework for the admission control of QoS multicast traffic in mobile ad hoc networks [C]//*Proc of the 4th ACM International Workshop on Wireless Mobile Multimedia*. New York: ACM Press, 2001: 2 – 11.

[10] Biradar R C, Manvi S S. Ring mesh based multicast routing scheme in MANET using bandwidth delay product [J]. *Wireless Personal Communications*, 2012, **66**(1): 117 – 146.

[11] Hu C C, Wu E H K, Chen G H. Bandwidth-satisfied multicast trees in MANETs[J]. *IEEE Transactions on Mobile Computing*, 2008, **7**(6): 712 – 723.

无线自组织网络中带宽约束的分布式按需组播路由协议

余燕平　倪玲玲　郑元琰

(浙江工商大学信息与电子工程学院, 杭州 310018)

摘要:为了满足无线自组织网络中的组播数据流带宽需求,提出了无线 ad hoc 网络中带宽约束的分布式按需组播路由协议. 该协议中,每个节点的资源预留表将记录接入自身、邻居节点和隐蔽节点的数据流的带宽需求,然后从该节点的全部可用带宽中减去资源预留表中预留的带宽,计算出剩余的可用带宽,且 BCMR 在带宽约束的前提下分布式地搜索最短时延路径. 仿真结果表明,BCMR 在分组投递率和时延方面性能较好,能满足实时通信的要求,可用于低移动性的无线 ad hoc 网络组播应用中.

关键词:无线 ad hoc 网络;组播路由;带宽满足;按需组播路由;分布式组播路由;QoS 组播路由

中图分类号:TP393