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Call Admission Control in Wireless Ad-hoc Networks with Multiple Channels and Radios

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Abstract

In this paper, an Ad-hoc Routing Protocol that works in wireless Ad-hoc communication networks with multiple radios and multiple channels and that controls call admission based on bandwidth measurement is proposed. Unlike the conventional Ad-hoc node with a single radio using a single channel, an Ad-hoc node of the protocol proposed, the MCQosR(Multiple Channel Quality of Service Routing), has multiple radios and uses multiple channels, which allows full duplex transmission between wireless Ad-hoc nodes, and reduces intra interference on the route. Also, a fixed channel only for reception at each node enables the estimation of the available bandwidth, which is used to control the call admission for QoS provision. The performance of the MCQosR was verified by simulation.

Key Words : Wireless Ad-hoc Network, Multiple Radios and Channels, Available Bandwidth Estimation, Call Admission Control, Quality of Service

1. Introduction

In wireless Ad-hoc communication networks based on CSMA/CA(Carrier Sense Multiple Access with Collision Avoidance), control packets such as RTS(Request To Send), CTS(Clear To Send) and ACK(ACKnowledgement), and data packets are carried on a single channel, which results in a reduction of available bandwidth of the wireless link because of half duplex transmission and intra route interference[1]. For provision of multimedia service that requires QoS(Quality of Service) control, the reduction of available bandwidth becomes a more difficult problem to deal with. In this paper, the use of multiple radios and multiple channels to solve the bandwidth reduction and the QoS provision problem of conventional single channel wireless Ad-hoc communication networks is presented.

Wireless LAN(Local Area Network) based on CSMA/CA, such as 802.11, defines the multiple channels that are used for adjacent access points. The use of a different channel at each node in multi-hop Ad-hoc networks can increase available bandwidth by decreasing the intra route interference. However, the use of a different channel at each node results in deafness or

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multi-channel hidden terminal problems, and makes the connectivity of a flooding-based Ad-hoc network difficult to maintain. To overcome these difficulties, periodic use of a common channel can be used, but the implementation is complex[2].

Also, the use of multiple channels with a single radio as a network interface does not use the full capacity of the wireless link because of a half duplex transmission. Recent technologies provide cheap radios and the use of multiple radios at each Ad-hoc node has become possible. Bahl et al[3]. has proposed an approach where a node is equipped with multiple radios and different channels are assigned to each radio. This approach is able to increase the performance, but is not cost effective.

To reduce the cost of multiple radio use and increase the merit of multiple channel use, an approach that uses less radios than the number of channels has been researched, and the static or dynamic use of channels at each radio is here proposed. Using 12 channels and 2 radios, Raniwala et al[4]. has provided results on channel assignment and routing in a static mesh network. In their work, traffic was assumed to be from or to a specific gateway, and 2 radios at each node were used to send traffic, one for the to-gateway and the other for the from-gateway. This approach increases throughput 7 times more than that of the single-radio single-channel method.

For the purpose of QoS provision, the traffic in a network must be managed. But in a 802.11 wireless LAN with contention-based MAC (Medium Access Control) layer, it is difficult to assign bandwidths to a specific traffic flow. AS opposed to a wired network where traffic can be controlled and the required bandwidth is assigned to a specific flow, CAC(Call Admission Control) is used to provide QoS, which guarantees the bandwidth assigned to an already accepted flow by restricting new traffic flow into a network[5]. When a new flow requests to be served, the flow must provide the bandwidth required. The network accepts the flow if it can assign the requested bandwidth, or rejects if not. In this way, only the traffic which can be handled by a network is accepted and the assigned bandwidth can be guaranteed.

In this paper, a new approach is proposed in which multiple radios are used with multiple channels at each Ad-hoc node to resolve the bandwidth problem. Furthermore, the use of a fixed receive-only channel at a fixed radio of each node makes it possible to measure the available bandwidth of a wireless link, as well as making it possible to offer a call admission control, which will eventually provide a bandwidth-guaranteed QoS. The proposed routing protocol is called a MCQosR(Multi-radio and -Channel Qos Routing Protocol).

In Section 2, the way in which multiple radios and multiple channels are to be used in MCQosR is presented. The way to measure and estimate the available bandwidth of a wireless link is proposed in Section 3 while the CAC based on this available bandwidth estimation during the routing process, which excludes intra route interference, is presented in Section 4. In Section 5, the approach proposed in this paper is verified through a simulation. Section 6 concludes the paper by presenting the future work that is planned in this area.

2. Use of multiple radios and channels

From previous research, the ways in which multiple radios and channels are used can be divided into two classes. In one way, such as the

DCA(Dynamic Channel Assignment)[6], radios (/channels) are used for common control and transmit/receive. In the other way, such as the MCR(Multi-Channel Routing)[7], radios(/channels) are used for receive-only and transmit-only. For the former, channels can be used without the problem of deafness, and for the latter, complex channel assignment can be eliminated.

It is difficult to measure the available bandwidth of a wireless link in a dynamic channel assignment. Because the CAC, which is based on the measurement of available bandwidth, was used in this study, one radio with a fixed channel only for reception at each Ad-hoc node was needed. Therefore, a receive-only radio was used with a fixed channel at each node, which eliminated the complexity of dynamic channel assignment, and made it easy to measure the available bandwidth. Also, a common control radio with a fixed channel was used at all nodes, which provides connectivity between nodes in Ad-hoc wireless networks.

2.1 An Ad-hoc node with M Radios using N channels

This study used CSMA/CA as a MAC layer protocol, where an RTS/CTS packet is used for the reservation of the wireless link and the ACK packet is used to confirm the successful transmission of data. Also it was assumed that each Ad-hoc node had $M(\geq 3)$ Radios and used an $N(\geq 4)$ channel , including a common control radio(/channel). In this case, the radio was assumed to be a transceiver while the network interface card also has a transceiver. In this paper, the channels at each node were used differently according to their function. These were the CoC (common Control only Channel), RoCs(Receive only Channels), and ToCs(Transmit only Channels).

The CoC is a fixed channel for all Ad-hoc nodes in a network, and is used for broadcast messages such as periodic hello messages for network connectivity and control packets for routing. A fixed radio with a CoC is called a CoR(common Control only Radio). Each Ad-hoc node has fixed RoCs, where possible, different from the RoCs of surrounding nodes. RoCs are fixed to RoRs (Receive only Radios) and used for layer 3 data reception. A node can have more than one RoCs depending on the number of available channels except that of the CoC. A node can change its RoCs, but should not change the RoCs in use if possible. When a node must transmit data, it uses ToRs(Transmit only Radios). ToCs are the channels used by the ToRs(Transmit only Radio), and can be any available channel except their own CoC and RoCs. A transmitting node that wants to send data can do so after it changes its own ToC to the RoC of the receiving node. As opposed to RoR, a ToR changes its ToC according to the RoC of the receiving node. If there are many radios, the number of RoRs and ToRs can be determined by the amount of sending or receiving traffic. If there is an equal amount of sending and receiving traffic at a node, the number of RoR and ToR can be $\lceil (M-1)/2 \rceil$ and $\lceil (M-1)/2 \rceil$, respectively.

Throughout the rest of this paper, a node is assumed to have 3 radios, each of which is used as CoR, RoR and ToR, and to have 4 interference-free channels, one for the CoC, one for the RoC, and the other 2 for the ToC.

2.2 RoC assignment to an RoR

One node has a fixed channel for an RoC, and this RoC must be different from the RoCs of the surrounding nodes, if possible. A node and a 1-hop neighbor node share an equal amount of channels with the RoCs from available channels excepting the CoC.

(1) Initialization of RoC: If a new node is added to an Ad-hoc network, the node randomly chooses a channel from all available channels. After getting a Hello message from the surrounding nodes, the node selects a channel which is not in use by the surrounding nodes as an RoC, and change its own RoC to the selected one. If the number of nodes using the same channel as the RoC is equal, the channel with more available bandwidth is selected. If its own RoC changes, the node informs its 1-hop neighbors of the changed RoC using a Hello message.

When a new node, shown as a small circle at the center of Fig. 1, is added in an Ad-hoc network, the initialization of the RoC is shown as in Fig. 1. A circle surrounding a new node represents the transmission range, and the large dotted circle represents the interference range. The number inside the small circle is the number of the channel used as the RoC. There are 3 channels which can be used as an RoC, and they are numbered 1, 2, and 3. The new node selects channel 2 as the RoC because the 2 1-hop neighbors are using channel 1 and 3.

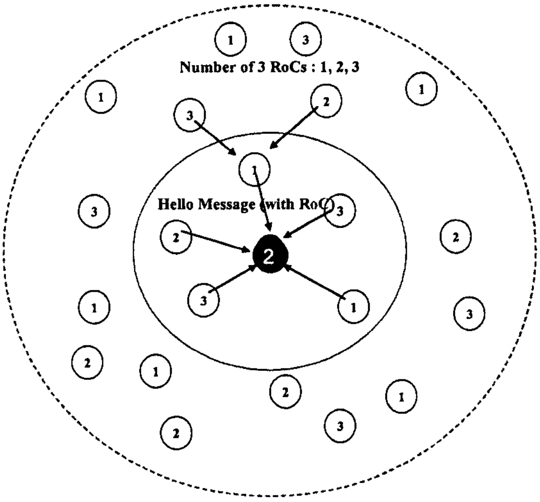


Fig. 1. RoC of an Ad-hoc Node

(2) Change of RoC: If nodes using the same channel as their own RoC become great in number, a given node will change its RoC to the channel least used by its 1-hop neighbors, and informs its 1-hop neighbor nodes of the change of its RoC using a Hello message.

The change of RoC can be done only when there is no route including the node in use, and a temporal change of RoC due to temporal node movement should be suppressed. Also, prior to or following the movement of the node, the neighbor nodes can change their RoC, and the neighbors of neighbor nodes could also change their RoCs. This is called a ripple effect. This ripple effect should be suppressed.

3. Available bandwidth estimation of a wireless link by measurement

The available bandwidth(aBw, available Bandwidth) of the wireless link between Ad-hoc neighbor nodes can be determined by the available bandwidth for transmission(TaBw, Transmittable Bandwidth) of the sending node and the available bandwidth for the reception(RaBw, Receivable Bandwidth) of a receiving node, as shown in Fig. 2. Here, the available bandwidth can be estimated by measuring the idle time of a link. Idle time refers to the duration of time in which the channel of the link is not self-activated or activated by other nodes[8].

At a node using multiple channels, the RaBw of the RoC used by the RoR is estimated by measuring the idle time of the RoR. The RaBw of the RoR, the RaBw(RoR), is equal to the RaBw of the RoC, RaBw(RoC). The estimation of the TaBw of the ToCs, the TaBw(ToCs), then has a problem since the ToR changes ToC according to the RoC of the receiving node. It is not necessary to know the TaBw(ToCs) because the ToR needs only the transmittable bandwidth of the ToR, which is not concerned with which channel is used for transmission. The idle time of the ToR is measured and the TaBw of the ToR, the TaBw(ToR), is then estimated. The abbreviation of the available bandwidth of a node, the radio and the channel as well as the relationship between them is shown in Table 1.

Table 1. Abbreviation and relationship of available bandwidth

RaBw = RaBw(node)	= RaBw(RoR)	= RaBw(RoC)
TaBw = TaBw(node)	TaBw(ToR)	TaBw(ToC)
aBw = aBw(node)	aBw(ToR)	aBw(ToC)

The 1-hop neighbors of a given node give information about their RaBw(RoC) by broadcasting a Hello message with the RaBw(RoC) as shown in Fig. 2. A node arranges the RaBw(RoC) received according to the RoC, and the minimum RaBw of an RoC is used as the available transmittable bandwidth of the channel.

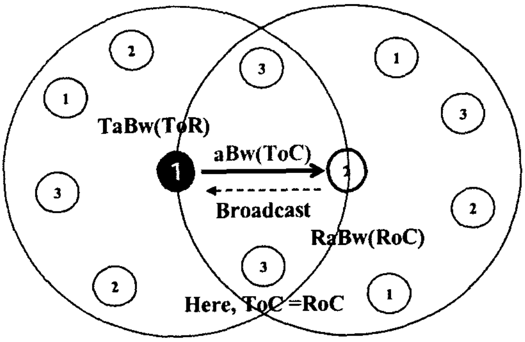


Fig. 2. Available Bandwidth of wireless link

3.1 Estimation and broadcast of available bandwidth at a node

In an Ad-hoc network, a node measures the idle time of an RoR with the period(T), and estimates the RaBw(RoC) and TaBw(ToR) using Equation 1 from the raw link capacity(Bw, Bandwidth of a link). Equation 1 is defined as below.

TaBw(ToR) and RaBw(RoC)
= Bw * (1idle_time/measured_time,T) * (1/Weight_Factor) (1)

Here, weight factor (α) is greater than or equal to one, and includes the time due to the 802.11 overhead characteristics such as DIFS(DCF InterFrame Space), SIFS(Short InterFrame Space), and control packets. The node informs its neighbors of the estimated RaBw(RoC) by broadcasting a Hello message.

3.2 Receivable bandwidth of a receiving node

A sending node determines the RaBw(RoC) according to the channel from the RaBw(RoC)s of the 1-hop neighboring nodes by using Equation 2. Here, its own RoC is excluded.

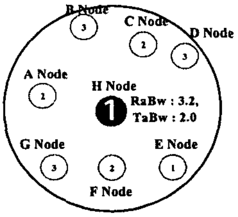
RaBw(RoC) = Min{RaBw(RoC)s} (2)

3.3 Transmittable bandwidth of a wireless link according to channel

A sending node determines the aBw(ToC) from the TaBw(ToR) of the sending node itself and the RaBw(RoC)s of the 1-hop neighbors by using Equation 3 as shown below. Here, the ToC of the sending node is equal to the RoC of the receiving node.

$$aBw(ToC) = Min\{RaBw(RoC),\ TaBw(ToR)\},$$
$$aBw = Max\{aBw(ToC)s\} \qquad (3)$$

In Fig. 3(a), there are 7 1-hop neighbors(A, B, C, D, E, F, G) within the transmission range of Node H. Node H can determine the transmittable bandwidth depending on the channels as follows. Each node measures and estimates the RaBw(RoC) and TaBw(ToR). The neighbors of Node H inform Node H of the RaBw(RoC) by broadcasting a Hello message. Node H stores the information as shown in Fig. 3(b), and determines the receivable bandwidth of the neighbor nodes according to channel 2 and 3 and excluding its own receiving channel, channel 1. For channel 2, any neighbor node can receive data at Min{2.1, 3.2, 0.9}= 0.9[Mbps]. For channel 3, any neighbor node can receive data at Min{2.5, 4.1, 4.8}= 2.5[Mbps]. To determine the transmittable bandwidth according to channel, the sending Node H compares the RaBw(RoC) with the TaBw(ToR). Finally, Node H can determine that it can transmit on channel2 with Min{0.9, 2.0} = 0.9[Mbps], and on channel 3 with Min{2.5, 2.0} = 2.0[Mbps]. The aBw(node H), the maximum transmittable bandwidth of Node H, is Max{0.9, 2.0} = 2.0[Mbps].



(a) Ad-hoc Node H

Neighbor Node	RoC (1,2,3)	RaBw Max. 5.4
A	2	2.1
B	3	2.5
C	2	3.2
D	3	4.1
E	1	1.0
F	2	0.9
G	3	4.8

(b) Data Structure of Node H

Fig. 3. Data Structure of an Ad-hoc node

4. Call Admission Control and Ad-hoc Routing

In Ad-hoc networks, the routing protocol uses control packets, RREQ for route requests and RREP for route replies. An RREQ packet includes information of a new call. A source node broadcasts the RREQ packet, and the packet is delivered by intermediate nodes until it reaches its destination. The destination node receiving the RREQ replies to the source node by sending an RREP packet to give notification that the route is founded.

In this study, to perform a call admission control, 2 fields were added in the RREQ packet, the bandwidth requested by a new call, the rBw (requested Bandwidth), and the RoC of the preceding nod e of the node sending the RREQ, pre-RoC(preceding node's RoC). These 2 items were used for making decisions of the 2 call admission requirements performed in this routing protocol. The transmittable bandwidth requirement (CA1, Call Admission requirement 1) means that the node receiving the RREQ compares the rBW and aBw, and drops the RREQ if the rBw is greater than aBw. The route intra interference exclusion requirement(CA2, Call Admission requirement 2) means that the node receiving the RREQ drops the RREQ if CA2 is not satisfied using the pre-RoC. The CA1 for the node receiving tRREQ is defined as Equation 4 while CA2 is defined below.

Transmittable bandwidth requirement (CA1)
$$: aBw > rBw \qquad (4)$$

4.1 Route intra interference exclusion requirement

In multi-hop Ad-hoc networks, the transmittable bandwidth of the wireless link is not used fully because of the route intra interference[9]. In this study, the route intra interference requirement was applied during the routing process, making it possible to fully use the capacity of the wireless link.

For MAC protocol based on CSMA/CA using RTS/CTS, the route, as shown in Fig. 4, shows 3 different characteristics depending on the use of channels and radios. It was assumed that there was no interference from neighbor nodes not on the route. RoC(node) means the RoC of a node.

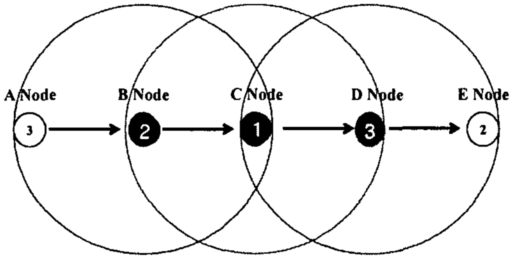


Fig. 4. Route Intra Interference

Case 1. A radio and RoC(B)=RoC(C)=RoC(D) (single radio and single channel): For Node C, receiving data from Node B and sending data to Node D, there are 4 node operations regarding half duplex transmissions: when Node B receives data from Node A, when Node C receives data from Node B and sends data to Node D, and when Node D sends data to Node E. Therefore, the bandwidth which can be used by Node C is 1/4 of the link capacity.

Case 2. A radio and RoC(B)≠RoC(C), RoC(C)≠RoC(D), RoC(B)≠RoC(D)(single radio and multiple channel): When Node C receives data from Node B and sends data to Node D, Node C can send data to Node D using a different channel from the channel used by Node B receiving data from Node A, while Node C can receive data from Node B using a different channel from the channel used by Node D sending data to Node E. Therefore, the bandwidth used by Node C is 1/2 of the link capacity.

Case 3. Single receive-only radio and RoC(B)≠RoC(C), RoC(C)≠RoC(D), RoC(B)≠RoC(D) (multiple radios and multiple channels): Node C can receive and send data independently of Node B's data reception and Node D's data transmission. Node C uses the full capacity of the wireless link.

From Case 3, it was found that a node on a route needs to use a different channel from the channels of the previous and next node on the route, and that the channels of the previous and next node must be different from each other to exclude route intra interference. The 3 consecutive nodes on a route, B, C, and D in Fig. 4, must therefore satisfy the following equation, Equation 5.

Route intra interference exclusion Requirement (CA2):

$$\mathrm{RoC}(B) \neq \mathrm{RoC}(C),\ \mathrm{RoC}(C) \neq \mathrm{RoC}(D),\ \mathrm{RoC}(B) \neq \mathrm{RoC}(D) \qquad (5)$$

4.2 Call Admission Control

During the routing process, the node receiving the RREQ decides whether the call admission requirement 1 and 2 is satisfied or not. If any one of the requirements is not satisfied, the RREQ is dropped and a new call request is rejected. In Fig. 5, the call admission control operation is performed on Node C receiving an RREQ. Node C decides whether the CA2 is satisfied or not, using the RoCs of Nodes A and B, and decides whether the CA1 is satisfied or not by comparing the rBw and aBw(ToR) estimated from the Node D RaBw.

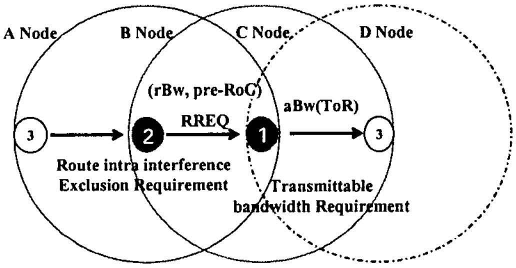


Fig. 5. Requirement of Call Admission

A source node requesting a new call calculates the required bandwidth of a new call, the rBw, using Equation 6. Here, the new call generates R packets per second where the packet size is L[Byte].

$$\text{rBw[bps]} = R * L * 8 * \text{Weight Factor} \quad (6)$$

Here, the weight factor (β) is greater than or equal to 1 with the same meaning of Equation 1. The source node checks the CA1, and, if the aBw is greater than the rBw, includes the rBw and pre-RoC with its RoC in the RREQ. It then broadcasts the RREQ using the CoC. Otherwise, the new call drops at the source node.

The intermediate Ad-hoc node receiving the RREQ checks whether the CA1 and CA2 is satisfied or not. For CA2, the intermediate node compares its RoC with the RoC of the node sending the RREQ and the pre-RoC in the RREQ. If the 3 RoCs are not different from each other, the RREQ is dropped. The intermediate node also checks whether the aBw(ToC), excluding the RoC of the node sending the RREQ and its own RoC, is greater than the rBw in the RREQ. If all of the aBw(ToC)s is less than the rBw, the RREQ is dropped, and the new call request is rejected. If the CA1 and the CA2 are satisfied, the immediate node changes the pre-RoC in the RREQ with the RoC of the node sending the RREQ, and broadcasts on the CoC.

When a destination node receives an RREQ, it checks whether the CA2 is satisfied or not. If CA2 is satisfied, its stores the routing metric and unicasts the RREP to the source node. If a destination node receives more than one RREQ, the destination node compares the metric with the previous one, and if a better metric is found, it then unicasts the RREP to the source node. The routing metric used in this paper is defined in Equation 7. Here, n is the hop count of the established route. The routing metric defined in Equation 7 is from the MCR[7][10]. However, the interference related term was deleted since CA2 was used to exclude the route intra interference during the routing process.

$$\text{MCQosR} = \sum^{n}(\text{ETT}_i + \text{SC}(C_i)),\ \text{SC}(j)$$
$$= \text{Ps}(j) * (\text{channel switching delay}) \quad (7)$$

Here, ETT_i is the expected transmission time of the i^{th}-hop in a route, $\text{SC}(C_i)$ is the channel switching cost of using channel $C_i(=j)$, which is required because the i^{th}-hop node on the route must change its ToC into C_i. The Ps(j) is the probability that a switchable interface is on a different channel when a packet arrives on channel j. The switching delay is the interface switching latency, which can be estimated offline.

5. Simulation

The routing protocol proposed in this paper, the MCQosR, has different effects prior to and fowing network congestion because of the call admission control. Before network congestion occurs, load balancing effects distribute traffic over the network. After the occurrence of network congestion, the QoS guarantees the bandwidth required for an accepted call by rejecting new calls that are greater than network capacity. The effects of using the MCQosR were verified via simulation using Qualnet[11], and were compared with the MCR to illustrate performance improvement.

During the simulation, a node with 2 IEEE 802.11a network interface cards and 5 interference-free channels(36, 48, 64, 149, 161)[7] was used. It was assumed that the channel switching delay was 1ms. It was also assumed that the data transmission rate of the wireless link was 12[Mbps], transmission range was 150[m], and interference range was 300[m].

5.1 Transmission bandwidth of wireless link

To confirm the transmission bandwidth of the wireless link, a chain topology was used where nodes were linearly aligned and fixed. A single call was then generated, path length was increased hop by hop and throughput was measured. As shown in Fig. 6, there was a static throughput and 70[%] wireless link capacity even though the hop count increased. Because a different channel was used at each node on the route, the route intra interference was eliminated, allowing the static throughput to be achieved even though the hop count was increased.

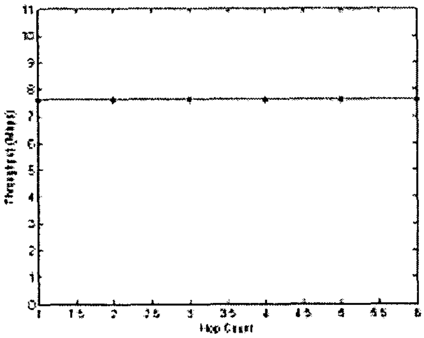


Fig. 6. Available Bandwidth of wireless link

5.2 Throughput and Delay after congestion

Due to the CAC operation of the MCQosR, the calls accepted can access the bandwidth required by rejecting new calls which overflow the network capacity. The throughput and end to end delay is therefore maintained throughout the call duration.

For the simulation, 100 nodes were placed in a lattice structure, and a 1[Mbps] CBR call was generated every second until network congestion occurred. The throughput and end to end delay was measured and compared with that of the MCR. The total simulation time was 60 seconds and the duration of the CBR call was also 60 seconds.

Fig. 7 shows that network congestion occurred when 17 calls were generated for the MCQosR and MCR. The simulation results showed that new calls were accepted even during network congestion, and the throughput dropped for the MCR. New calls were rejected when network congestion occurred and the throughput was steadily maintained for the MCQosR.

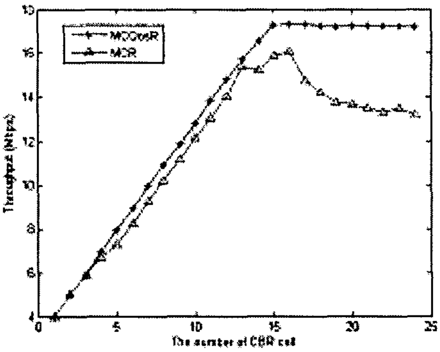


Fig. 7. Congestion and Throughput

The results of the end-to-end delay are shown in Fig. 8. The circumstances for the simulation were identical with the throughput simulation in

Fig. 7. For the MCR, there was a rapid change of the end to end delay after congestion occurred and this phenomenon confirmed the change of throughput change in Fig. 7. For the MCQosR, there was no rapid change of the end to end delay like the MCR, after congestion occurred.

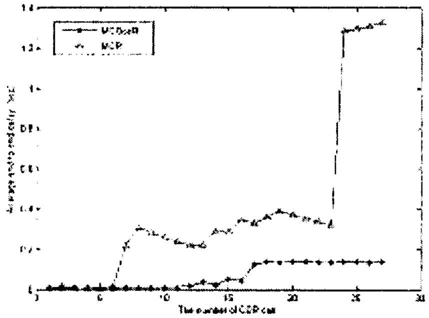


Fig. 8. Congestion and Delay

5.3 Load balancing before congestion

Before congestion occurred, the MCQosR was able to distribute traffic throughout the network because the nodes less used tend to be involved in the establishment of a new route. To verify the load balancing effect, the number of active nodes in a network was measured. The situation for this simulation was the same as the simulation for throughput. In Fig. 9, it can be seen that more nodes were active in the MCQosR than in the MCR.

According to the simulation, even by excluding the route intra interference, the full capacity of the wireless link cannot be utilized because there was still route extra interference and an overhead of Hello messages. The bandwidth assigned cannot be guaranteed because of the contention-based MAC protocol. To improve the performance of the MCQosR, it is necessary that control packets such as hello messages and routing packets are separated from data packets by using a separate radio and channel for common control, and that the service level of IEEE 802.11e is used for more guaranteed service.

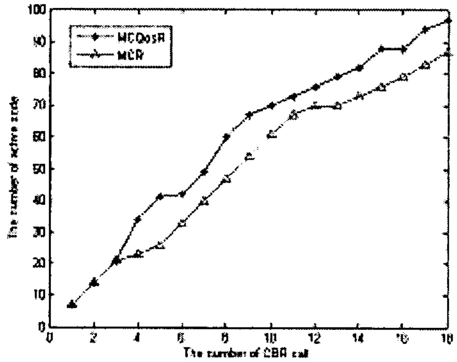


Fig. 9. Active Nodes before congestion

6. Conclusion

In wireless Ad-hoc networks based on CSMA/CA, the use of a single radio and single channel reduces the available bandwidth of a wireless link due to route intra interference, while the use of contention based MAC protocol makes it difficult to estimate and guarantee the available bandwidth, and therefore the QoS provision becomes more difficult. In this study, a routing protocol was proposed that can increase the available bandwidth of a wireless link by the use of multiple radios and multiple channels, and that can provide QoS by admission control based on available bandwidth measurements and an estimation of a wireless link.

In the MCQosR, one node has a fixed radio and a fixed channel dedicated to data reception, which makes it possible to exclude route intra interference and measure the available bandwidth of the wireless link. During the routing process of the MCQosR, nodes on the route are adjusted to use a different channel for data receiving, which excludes route intra interference and increases the transmittable bandwidth. A call admission control, which rejects new calls requiring more bandwidth that can be supported by a network, is performed to guarantee the bandwidth of accepted calls, based on bandwidth measurements of the wireless link and the requested bandwidth of the new call.

Because of the CAC operation, the MCQosR allows load balancing before network congestion occurs, and also ensures QoS provision after network congestion occurs. Before the network congests, the length of the route and the active nodes increase, but traffic is distributed over the network, which prevents traffic concentration in a specific spot. After the network becomes congested, new calls are rejected and the bandwidth of calls already accepted is guaranteed. These effects were verified via a simulation. More study on the movement of the Ad-hoc node, which will bring route broken and reduce the guaranteed bandwidth. Traffic control at the MAC layer using IEEE 802.11e is also required.

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Biography

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