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EVALUATION OF INTRA-FLOW CONTENTION IN MANET

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ABSTRACT

In mobile ad hoc networks (MANET) with contention-based MAC, the nodes along a path of transmission contend for access the medium in a distributed manner, this leads to intra-flow contention that cause degradation in the network performance. The precision for determining the intra-flow contention helps any contention-based admission control to make correct decisions to admit or reject any new flows, and in turn improves the performance of the network. However, the calculation of the intra-flow contention is challenging, because the nodes only know their neighbors that are located within the transmission range, but do not aware about those are located between the edge of the carrier sense range and the transmission range, or those are located within interference range of the receiver. This paper analysis the intra-flow contention and evaluates the existing methods in the literature for calculating the contention count. The analysis shows that, the current methods still have limitation in term of the covered area for calculating the intra-flow contention, they also have considerable overhead and delay that cause impact on the throughput in MANETs.

Keywords: *MANET, Intra-flow Contention, Contention-based MAC 802.11, Wireless Radio Ranges*

1. INTRODUCTION

Mobile Ad-hoc Network (MANET) [1] consists of wireless nodes that communicate with each other through a common wireless medium without requiring any centralized management. MANETs are infrastructure-less where the nodes configure and organize themselves without any manual prevention. The most commonly accepted technology of MANETs is 802.11 because it does not require synchronized channel. 802.11 [2] standard works in industrial, scientific and medical (ISM) band at 2.4 GHz or in the unlicensed 5 GHz band. 802.11 technologies use Carrier Senses Multiple Accesses (CSMA) for accessing the channel. The channel is shared between nodes are located within interference range. Due to limitations in terms of transmission range and bandwidth in MANET, the nodes cooperate to forward each other's packets through the networks. So, the nodes along a path of transmission could be located within the interference range of each other, which leads to contention between those nodes to access the medium, this contention is called intra-flow contention. In other side, the nodes in a flow may encounter contention from nodes of other flows that are located within the same interference range, this is called inter-flow contention. These contentions between nodes in MANET may cause severe congestion and limit the performance of the network. So, admission control considers those contentions is needed to overcome this problem and improves the network performance. However, the estimation of the contention count for any admission control protocol is challenging, due to difficulty to determine all nodes that are located within carrier-sensing range. In this journal, we analyze the intra-flow contention and evaluate different methods reported in the literature for calculating the contention count.

2. RELATED WORK

The quality of service for Ad hoc On-Demand Distance Vector (QoS-AODV) routing protocol [3] considers the intra-flow contention within transmission range (one hop). So according to this protocol, in a path of more than 3 nodes, the source have a contention count of 2, they represent the node itself and the neighbor node within the transmission range. The intermediate nodes have contention count equal to 3 represent the node itself and both of the upstream and downstream nodes in the path of transmission, the destination node has contention count equal to 1 represents the upstream node .

The Adaptive admission control (AAC) [4] as shown in Figure 1 uses two phases to calculate the contention count, it uses the hops count provided by request and reply routing control packets. The authors found that, the hop count (h_{rrep}) of the route reply packets and the hop count (h_{rreq}) of the route request packets inform the node's rank on the routing path. According to that, the contention count can be calculated using the following Equation.

$$CC(i) = \min(h_{rreq}, h_{max})_i + \min(h_{rrep}, h_{max})_i + M \quad (1)$$

$M = 0$ if the destination node is inside the interfering range, $M = 1$ otherwise, h_{max} is the maximum hop count between a node on the path and nodes within carrier-sense range.

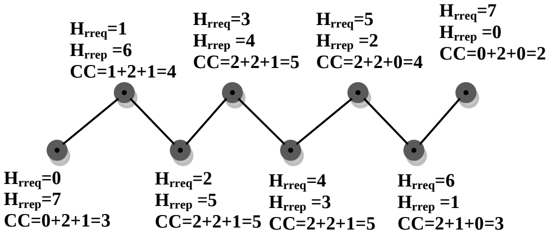

Figure 1.Two Phases For Calculating The Intra-Flow Contention Count By AAC With $H_{max}=2$.

In single phase admission (SPAC) scheme [5] the contention count is calculated in one phase during the request phase as shown in Figure 2, the calculation of the contention count in each node is done as follows. The node determines its own contention count firstly by using the following Equation [5].

$$CC(i) = h + d + 1 \quad (2)$$

$$\text{Where } h = \begin{cases} \text{Hops count} & \text{if hops count} <=2 \\ 2 & \text{if hops count} >2 \end{cases}$$

$$\text{And } d = \begin{cases} 0 & \text{If the destination within the transmission range of node} \\ 1 & \text{Else} \end{cases}$$

When the node completes its contention count calculation, it then goes to calculate the contention count of its previous node as follows. The contention count of the previous node equals to the contention count of the current node if the hops count is smaller than or equal to 2, and it equals to the contention count of the node plus one if the hop count is greater than 2.

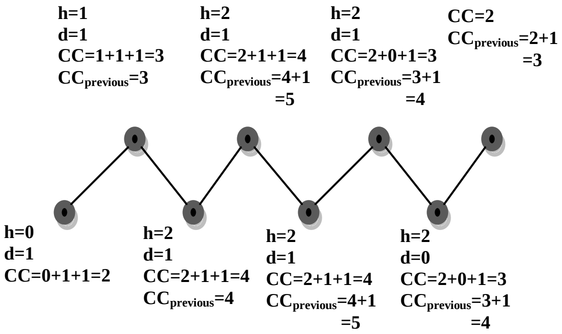

Figure 2.One Phase For Calculating The Intra-Flow Contention Count In SPAC

The Contention-aware Admission Control Protocol (CACP) [6] calculates the contention count using two phases that are used for the route discovery by reactive routing protocols. In the request phase each node collects the identities of neighbors within its transmission range. In the reply phase, each node on the path broadcasts a message carries the full route of a flow to their neighbor nodes within carrier-sensing range, it uses CACP-Power approach, which uses power for transmitting this message higher than that is used to send the data, this is for ensuring that all nodes within the carrier sense range receive the message. Or it uses CACP-Multihop approach, by broadcast the message within two hops range for attempting to cover all neighbors within the carrier-sensing range. At the end of this phase, each node on the path will probably be aware about its neighbor nodes within carrier-sensing range, thus it can easily calculate its contention count by using the following Equation.

$$CC(i) = (CSN(i) \cap NONP - d) + 1 \quad (3)$$

Where $CSN(i)$ is the carrier sense's neighbors of node i, $NONP$ is the number of nodes on the path and d is the destination.

Two approaches were proposed by Sanzgiri et al. [7] to calculate the contention count, In these approaches the nodes monitor the duration of the received signal and record it. The first one uses Pre-Reply Probe (RRP) which is in the reply phase, it uses one phase only for calculating the contention count. In the routing discovery, Specifically when the destination receives the route (RREQ) it produces a Pre-Reply Probe Message, which has a unique transmission period. The destination transmits the message in the reverse path to the sender. Each node on the path senses the duration of the message and record it in a table called carrier-sensing table. At the end of this phase each node on the path will know all its neighbor nodes within carrier-sensing range which lies on that path. The second approach uses Route Request Tail (RRT) by two phases for calculating. Instead of using a new message as in the previous approach, a tail is appended to the RREQ packets, a unique size is assigned randomly for each tail by each node. During the route discovery the sender attaches a unique long tail to the request, as well the size of that tail, and then broadcast it to the next hop, all the nodes within the carrier sense range set down the period of RREQ packet. Upon receiving the RREQ packet, the intermediate node eliminates the tail which is appended by the previous node and append its own tail to the RREQ with the new packet size to define itself and broadcast the packet, the nodes within the carrier sense range record the new period of RREQ packet. Note that a list of different packet sizes is collected in the RREQ packet in this approach. When the RREQ reach the destination, it produces route reply(RREP) packet and appends the accumulated packet sizes of the RREQ packet to the RREP packet and unicasts it to the next hop on the reverse path, each node receives the RREP packets matches the sizes recorded in its table with that included in the RREP packets to get its true contention count.

3. THE CONTENTION-BASED MAC 802.11

In 802.11 standards [2][8] the basic access method is the Distributed Coordination Function (DCF). DCF is based on a mechanism called Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). CSMA is a Contention-based priority scheme where a node listens to the channel before the transmission to determine whether another node else within its carrier sense range is transmitting or not. If the channel is idle for a time equal DIFS then a random backoff value is chosen between [0, CW_{min} -1], where CW_{min} is the minimum contention window. Then the backoff reduces by value equal slot time, then the medium is sensed, if it becomes busy the backoff stops, and it returns when the medium becomes idle for a time equal DIFS, the node starts it's transmitting when the backoff reaches to zero. The contention window is set to CW_{min} after each successful transmission, and it is doubled up to the maximum contention (CW_{max})when the transmission fails due to collisions with other transmissions at the receiver, or due to noise, attenuation etc.

4. THE THREE RANGES RELATED TO A WIRELESS RADIO

As shown in Figure 3 the wireless radio in MANET has three ranges [9]. The first one is the node's transmission range (TR) (e.g *A's* transmission range), where the node could transmit data successfully to any node is located in its transmission range, but with ensuring the following, there is no interference with the transmissions of other nodes. The nodes *B* and *D* are located within *A's* transmission range are called TR-neighbors. The radius of this range can be calculated by the following Equation:

$$TR = \sqrt[4]{\frac{P_t\, G_t\, G_r\, h_t^2\, h_r^2}{P_{minr}}} \qquad (4)$$

Where P_{minr} is the minimum receiving power that could be decoded by the receiver.

The second one is the node's carrier sense range (CSR) (e.g. *A's* carrier sense range). The transmission of any node is located within this range can be sensed by the node has this range. The nodes that are located within this range are called CSR-neighbors. The radius of this range depends on two factors, the antenna sensitivity of the node and the required area to overcome the interference. This range defines the level of the radio ruse by the MANET, where small carrier sense ranges lead to high level of radio ruse and vice versa. The nodes are located within this range and outside the transmission range (e.g. nodes *E* and *F*) are called hidden terminals of a node, and can reach them by multi-hop or high power. The radius of this range can be calculated by the following Equation:

$$CSR = \sqrt[4]{\frac{P_t\, G_t\, G_r\, h_t^2\, h_r^2}{P_{mins}}} \qquad (5)$$

Where P_{mins} is the minimum sensitivity that gives the required area that is supposed to overcome the interference. Ns2 that is used by the most of the researches assumes that CSR is 2.2 times TR [9].

The last one is the node's interference range (IR) (e.g. *B's* interference range), the concurrent transmissions of nodes located within this range could interfere each other at the receiving node. The nodes that are located within this range are called IR-neighbors. For example *A* cannot sense the transmission of node *C* which is located in the interference range of *B*, because node C is located outside the carrier-sensing range of node *A*. So the transmission of node *A* to *B* could interfere with the transmission of node *C* to another node at node B.

The radius of this range is not fixed and depends on the distance between the sender and the receiver, it can be calculated by the following Equation [10].

$$IR = 1.78 * L \qquad (6)$$

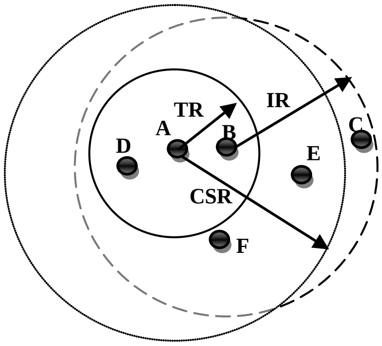

Figure 3. The three radio ranges of node in MANET

Where L is the distance between the sender and the receiver, it can be measured with Global Position System [11] or using the power of the received packets.

5. ANALYSIS THE INTRA-FLOW CONTENTION IN MANET

The precision for estimating of the intra-flow contention plays role to make proper decisions by any contention-based admission control implemented in MANET, so this parameter must be estimated accurately. In this section this phenomena are analyzed to get the true contention count numbers for each node. We use two scenarios for our analysis.

5.1 Scenario 1: the nodes on the path of transmission arranged in a chain

Figure 4 illustrates a scenario of chain of nodes, where the competed nodes for each node on the path positioned at a distance of one to two hops.

Based on the three ranges mentioned in section 4 and Figure 3, when node *A* has a packet to transmit, it uses the access mechanism which already mentioned to send the packet to *B*.

After receiving the packet by node *B* successfully both *A* and *B* will contend to access the channel, assume that *B* wins to send its packet to node *C*. Then *A* and *C* will contend to send their packets, assume that the backoff counter of both *A* and *C* reaches to zero at the same time and result in that both of them send their packets, *A's* packet will overlap with the transmission of *C*.

When the node *D* has a packet comes from *A* through *B* and *C*. *D* can send that packet, *A* also could send a packet (because *D* is hidden terminal form *A*), *A's* packet then will overlap with the transmission of *D* at *B*, but the *D's* packet will receive successfully to *E*.

According to the scenario, the contention count for node *A* is 4 and not 3 as was calculated by existing methods. So *B* may be also has contention count equal 5 and *C* has 6. It has to be noted that, the node which is added to the contention count of a node due to the interference depend on the distance between the sender and the receiver *L*. The distribution of the intra-flow contention count along the flow for the scenario is depicted in Figure 5.

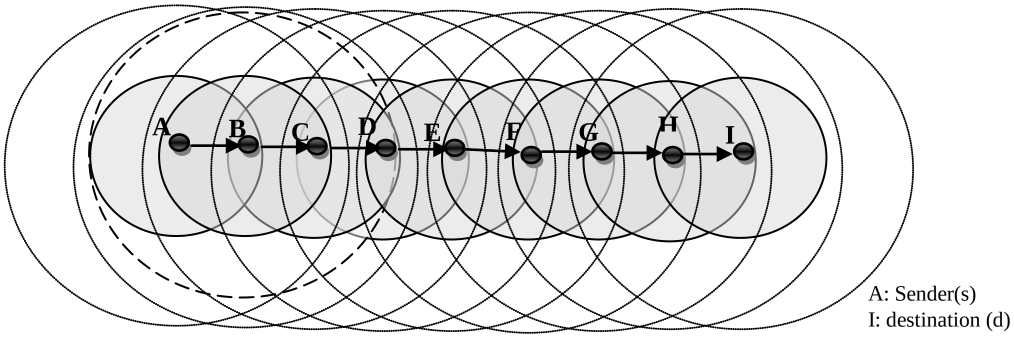

Figure 4. Scenarios 1 Where The Carrier Sense Neighbors Positioned At A Distance Of Two Hops.

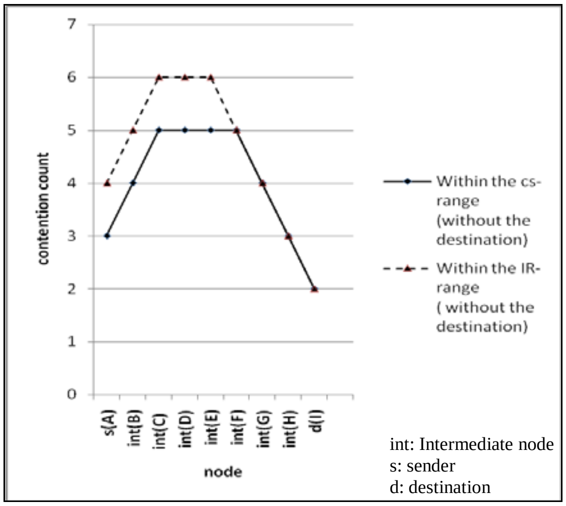

Figure 5. The Distribution Of The Intra-Flow Contention Along The Flow According To Scenario1

5.2 Scenario 2: the nodes on the path of transmission arranged like a spiral

Figure 6 illustrates scenario 2 where the flow starts at node *A* and end at the node I in a way like a spiral. We can see that, the CSR-neighbors of some nodes are not only within number of hops as in the previous scenario, but they can be found in different places along the path, e.g. the CSR-neighbors of node *A* are *B*, *C*, *E*, *F* and *H*. Note that also the CSR-neighbors of node H are *A*, *E*, *F* and *G*.

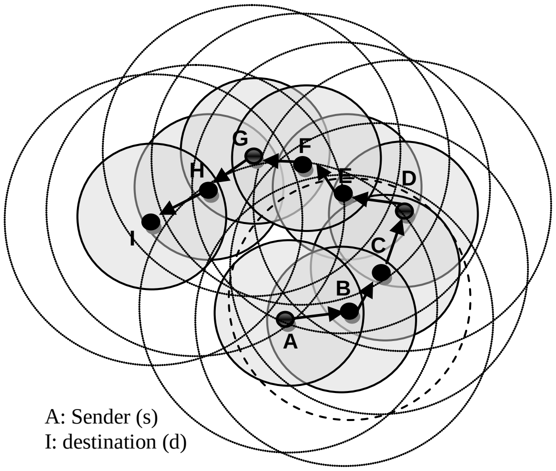

Figure 6. Scenario 2 Like Spiral. In This Scenario, The CSR-Neighbors Of Node Can Be Existed In Different Places On The Path. E.G The CSR-Neighbors Of Node A Are The Nodes B, C, E, F And H.

Table 1 shows the CSR-neighbors and the contention count within carrier sense range. It also shows the IR-neighbors that are located within the interference range of the receiving node, they are calculated based on Equation 6. The contention count within these ranges at each node in the path is calculated as follows. The number of neighbor nodes without the destination plus 1.The scenario shows that, the nodes within carrier-sensing range of a node not always positioned within consecutive hops of a path, but also could be placed within separated places of that path. Note that on the path of flow from *A* to *I*, the node F located within the carrier sense range of node *A* but *D* does not. The distribution of contention count along the path in this scenario is illustrated in Figure 7.

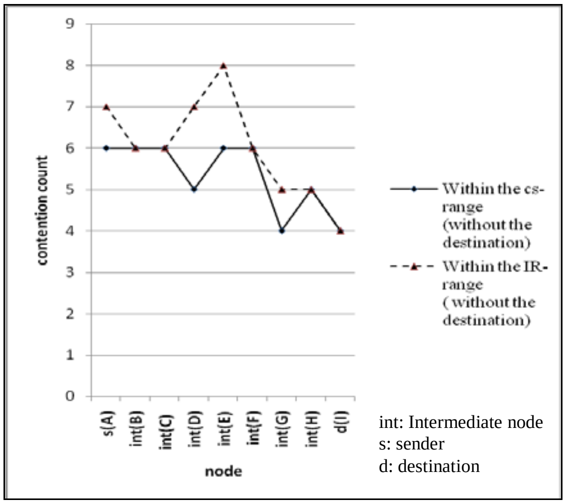

Figure 7. The Distribution Of The Intra-Flow Contention Along The Flow According To Scenario2

6. ANALYTICAL COMPARISON

Based on scenario 1 and scenario 2 that were mentioned in the previous section, AODV-QoS, AAC and SPAC make their calculations for the contention count assuming that the nodes are positioned in a path like in scenario 1. Indeed, AAC's QoS and SPAC calculate the contention count for that scenario accurately (within the carrier sense range) comparing with AODV-QoS which use one hop only for its calculation of contention count. However, both of the techniques do not cover all the nodes that are located within the interference range of a node in a path like in scenario 2 which is illustrated in Figure 6, even if they extend their calculation to more hops

Table 1. The Contention Count Of Nodes In The Path According To Scenario 2

Node	CSR-neighbors without the destination	Contention count	IR-Neighbors Without the destination	Contention count
A	B, C, E, F and H	6	B, C, D, E, F and H	7
B	A, C, D, E and F	6	A, C, D, E and F	6
C	A, B, D, E and F	6	A, B, D, E and F	6
D	B, C, E and F	5	A,B, C, E, F and G	7
E	B, C, D, F and G	6	A, B, C, D, E, G and H	8
F	C, D, E, G and H	6	C, D, E, G and H	6
G	E, F and H	4	A, E, F and H	5
H	A, E, F and G	5	A, E, F and G	5
I	F, G and H	4	F, G and H	4

Some nodes on the path couldn't have a CSR-neighbor in the near hop (e.g. in the third hop), but has CSR-neighbors located in the far hops (e.g. on the fourth hop). For example, as in Figure 6 node *D* which is located in the third hop of node *A* is not neighbor for *A*, but *E* which is located in the fourth hop is neighbor for *A*. Actually this can happen in various forms similar to that is illustrated scenario 2. The advantage of SPAC over AAC's QoS and CACP–multipath on that, the calculations by SPAC completely are done in one phase, in the request phase, this leads to early decision to accept or reject the new flow. The overhead introduced by SPAC and AAC's QoS are low. However it is considerable in CACP–multipath. CACP-power, PRP and RRT calculate the contention count and cover all the nodes within the carrier sense range, but don't cover all the nodes within interference range. They can calculate the intra-flow contention count accurately (within the carrier sense range) for both scenario 1 and scenario 2. The drawback of CACP-power, the high power which is used to send the messages during the reply phase to complete the calculation of contention count, it increases the collisions with the transmissions of other nodes, also could consume the power of nodes. Both of RRP and RRT can calculate the intra-flow contention count accurately as CACP-power but still have a drawback in their ability to measure the duration of the messages precisely, which are used to calculate the contention count, RRT has considerable overhead comparing with RRP. In this paper the analysis shows that, there are limitations in the current methods in term of the covered area for calculating the intra-flow contention, some methods cover nodes within transmission range only and some other cover nodes within carrier sense range. However, There are other nodes are not be considered by the current methods, e.g. The nodes that are between the carrier sense range edge and the interference range. In, AAC's QoS, CACP–multipath, CACP-power, PRP and RRT, each node has to wait to get information from the reply phase to complete its calculation for contention count, these results in increasing admission time and overhead. SPAC is delayed by one hop to complete its calculation for contention count. The power which is used by CACP-power cause much more interference and consumes the power, all of these limitations and drawbacks cause impact in the throughput in MANETs.

7. CONCLUSION AND FUTURE WORK

In this paper, we analysed the intra-flow contention on MANET. We also presented and evaluated the existing methods for calculating the intra-flow contention. Two scenarios were used for the analysis and the evaluation. AAC, SPAC and CACP-multihop protocols calculate the contention count for a path as in scenario 1 within the carrier sense range accurately, but they get difficult to cover all nodes that are located within the interference range of a node in a path likes in scenario 2. CACP-power, RRP and RRT calculate the contention count accurately for both scenarios but with considerable overhead and sacrifice on power of nodes (CACP-power). All of the existing methods do not take into account all nodes that cause interference, especially those nodes that are located between the carrier sense range edge and the interference range. Presently, we are performing simulations by NS2, to show the impact of intra-flow and inter-flow contentions on the throughput in MANETs, we also are implementing a new throughput based admission control protocol, it depends in mechanisms aiming to reduce the effects of intra-flow and inter-flow contention on the throughput in MANETs.

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