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C-DAM: CONTENTION BASED DISTRIBUTED RESERVATION PROTOCOL ALLOCATION ALGORITHM FOR WIMEDIA MEDIUM ACCESS CONTROL

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Abstract

WiMedia Medium Access Control (MAC) provides high rate data transfer for wireless networking thereby enables construction of high speed home networks. It facilitates data communication between the nodes through two modes namely: i) Distributed Reservation Protocol (DRP) for isochronous traffic and ii) Prioritized Contention Access (PCA) for asynchronous traffic. PCA mode enables medium access using CSMA/CA similar to IEEE 802.11e. In the presence of DRP, the throughput of PCA saturates when there is an increase in the number of devices accessing PCA channel. Researchers suggest that the better utilization of medium resolves many issues in an effective way. To demonstrate the effective utilization of the medium, Contention Based Distributed Reservation Protocol Allocation Algorithm for WiMedia Medium Access Control is proposed for reserving Medium Access Slots under DRP in the presence of PCA. The proposed algorithm provides a better medium access, reduces energy consumption and enhances the throughput when compared to the existing methodologies.

Keywords: WiMedia MAC, Distributed reservation protocol, Prioritized contention access, Medium access slot allocation algorithm, Quality of service.

1. Introduction

WiMedia Alliance provides a fully distributed MAC to the maximum of 480Mb/s with very low power consumption. It plays a vital role in constructing networks which includes video streaming, health care applications, surveillance systems, radar imaging, multimedia sensor, asset management etc. Most of these applications require efficient channel access method to withstand uncom-

Nomenclatures

DRP_DEVICE_LIST	List of devices already registered
DRP_FULL	True, if no free MAS are available under DRP
DRP.request	Explicit DRP reservation request
DRP.response	Denotes reply for the request
$pcaTimer_{DstAddr}$	Timer initialized for first time access or DRP_FULL

Greek Symbols

μ	Value of 10^{-6}

Abbreviations

AIFS	Arbitrary Inter-Frame Space
BP	Beacon Period
C-DAM	Contention Based DRP Allocation Algorithm for WiMedia MAC
CSMA	Carrier Sense Medium Access
DRP	Distributed Reservation Protocol
EDCA	Enhanced distributed channel access
MAC	Medium Access Control
MAS	Medium Access Slot
PCA	Prioritized Contention Access
QoE	Quality of Experience
QoS	Quality of Service
SIFS	Short Inter-Frame Space

promising Quality of Service requirements like minimizing the delay, packet drop, and enrich the throughput.

The WiMedia MAC provides two mode of access, (i) Using reservation based methodology - Distributed Reservation Protocol (DRP) and (ii) Using random access methodology - Prioritized Contention Access (PCA). Both of these adhere to slotted access through Medium Access Slots (MASs). Each slot is having a duration of 256μs guarded by Short Inter Frame Space (SIFS) whereas zones are separated by guard time (10μs).

Once synchronized, DRP enables the communicating devices to register the required bandwidth by identifying free slots through Control Frame - by making an explicit request or Beacon frames - by processing the Information Element contained in it(Implicit registration). Once the device completes the registration using DRP, includes one or more MAS slot with respect to reservation limitations then it may start to use it [1]. Using DRP, the device could save the energy spent, including backoffs while trying to access the medium [2]. Since the competing device may not be aware of the availability of the requested slot, it may fail to gain the medium access. Therefore, the entire effort put forth in accessing the medium is lost either in terms of power or processing time. Hence considering the nature of the network, there is a possibility of losing its chance due to congestion. The intention behind this proposal is nodes are prioritized considering its waiting time using a timer from the beginning.

WiMedia MAC also supports contention based access through PCA, using CSMA, one of the widely used channel access method in the wireless networking. If the medium is found idle, then the device waits for Arbitrary Inter Frame Space

(AIFS). After AIFS, the medium is found to be idle then the frame transaction starts otherwise the device initiates backoff procedure.

The current research interest in networking concentrates on multimedia communications. These communications requires higher bandwidth, low packet loss, low delay, etc., Even though PCA is relatively slow compared to DRP, it is effective in a smaller network. As the size of the network grows, the efficiency of PCA is decreased. Generally the contention based protocols were not designed to provide Quality of Service(QoS). The motivation behind this work is to maximize the throughput, minimize latency and power consumption, hereby trying to ensure a better utilization of resources to reduce the waiting time. So the objectives of the C-DAM are

- To design and develop a method to provide adaptive throughput in WiMedia communication.
- To analyse and propose an efficient channel utilization approach to support in QoS.
- To enable DRP allocation through the PCA mode.

2. Related Work

A node can be prioritized based on the nature of the data it transmits [3] for provisioning medium access because the real time data is highly delay sensitive, so PCA provides different types of Access Categories in order to handle the data [1]. Several works [4-6] related to contention based access for real time traffic were done, but the issues related to the allocation of freed up slots were unaddressed. When there is a possibility of reuse, the effective utilization of the slots and prioritization of the nodes through PCA is highly recommended. Few researchers [4, 5] proposed hybrid mode of accessing medium, in which if enough bandwidth is not allocated through DRP then PCA is chosen for buffering and transmitting the data. In order to provide contention free service to support high data rate as well as appreciable quality of service it is preferable to use DRP rather than PCA [7, 8].

Resource scheduling algorithms [2] like subframe-fit, isozone-fit reservations and multiple piconet (scatternet) were also proposed. Significant improvements in the performance were shown by DRP compared to PCA [8, 2] including reuse of the channel. Energy consumption can be reduced by an appropriate algorithmic approach [6; Table 1].

The least prioritized PCA stream of traffic incurs minimum throughput and maximum delay during more data traffic and therefore some bandwidth can be allocated for PCA traffic [9-11]. Researchers extended a relay based method for accessing WiMedia network using DRP approach [12]. This paper in addition uses an Information Element to reserve bandwidth for accessing the medium. Through this it has shown a significant increase in throughput of the network. Hence in this paper we proposed a procedure to enable MAS reservation for availing contention free slots.

In later sections of this paper, we discussed the solution proposed using DRP allocation when devices access the medium for a long period compared to other nodes. These nodes were prioritized when reallocating the slots which were freed up most recently rather than providing the chance to the newly attempting node. We also analysed the effectiveness of the proposed algorithm and its influence in throughput and latency factors with respect to traditional approaches.

Table 1. Research advancement in PCA mode of Access for WiMedia MAC.

Year	Author(s)	Issues addressed
2008	K. –H. Liu, Xinhua Ling, Xuemin Shen, Mark, Jon W [13]	Effect of AIFS need to be enlarged when the traffic load is high or bursty.
2009	Ruby.R, Jianping Pan [4]	Using PCA protocol, under heavy traffic, low priority data is affected compared to high data traffic. Frame service time in the presence of DRP is beneficial.
2010	Zhang. R, Ruby.R, Jianping Pan, Lin Cai [5]	PCA protocol may lead have significant collision
2011	Chang. H.C, Saewoong Bahk, [7]	MAS allocation using different policies. In which shared resource allocation results better throughput.
2012	Rosier H, Sambale K [8]	Channel access using DRP based reservation gain reuse when compared to PCA.
2013	Muhammad Alam, Shahid Mumtaz, Firooz B. Saghezchi, Ayman Radwan, and Jonathan Rodriguez [2]	Flexibility in reservation increase QoS and QoE.
2007	D.T.C. Wong, F.P.S. Chin, M.R. Shajan and Y.H. Chew [9]	Throughput of hard DRP is higher than the soft DRP.

3. Problem Description

WiMedia provides time division based access, called superframe using beacon enabled devices. Figure 1 signifies the structure of superframe and the various modes of access of WiMedia MAC, the superframe duration is 65536μs. DRP is a distributed reservation based access method for transmitting isochronous traffic. PCA provides CSMA/CA based access method to transmit asynchronous traffic similar to IEEE 802.11e EDCA. The synchronization among the devices in a superframe is based on beacon frames.

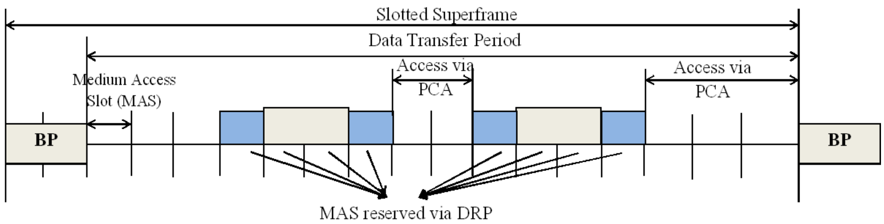

Fig. 1. Structure of a superframe.

WiMedia MAC maintains the reservation details are mentioned in DRP Allocation Field. Before transmitting the data, source devices check for the availability of the medium. If the specified destination details are not found in the list, it requests the receiver to allocate the MAS slot for the amount of time it needs to use the channel. If the amount of time requested is not granted for completing the data transfer then it may need to continue in the next Superframe depending upon the mTotalMASLimit [1]. Based on the number of incoming request for a device, it can allocate multiple slots for its neighbours. If the request exceeds the limit, then the device may access through PCA mode.

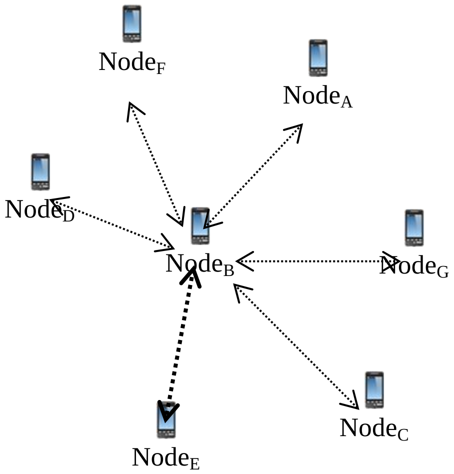

Fig. 2. $Node_B$ is communicating with $Node_E$ via PCA.

Assume that $Node_B$ allocates the slots to its neighbouring node as per reservation limitations Since no more slots are left in DRP, $Node_E$ communicates with $Node_B$ using PCA (Fig. 2). If any one of the node ($Node_C$) releases the allocated slots using Unused DRP reservation Announcement (UDA) control frames and the receiver in turn confirm the release of these reserved slots with Unused DRP Reservation response (UDR) control frames, then $Node_B$ checks for the nodes that is in contact for a longer time period, for eg. $Node_E$. Then the freed slots are allocated to the concern node. Otherwise, the Slot is allocated to the incoming request.

4. C-DAM: Contention Based DRP Allocation Algorithm for WiMedia MAC

Since network consists of finite resources, it may not satisfy the entire resource requirements. In the network to deliver a particular flow of quantitatively specified quality of service, like a bound on delay, it is necessary to set aside certain resources such as a share of bandwidth, link adaption, number of buffers, for the specific flow [5]. In order to maintain the quality of service commitments, the network architecture needs to maintain resource allocation algorithm.

Wireless CSMA networks may starve for resource while the high priority nodes always gain good throughputs compared to other nodes. The starvation may be classified into two categories: i) Equilibrium Starvation, where the link may always be underutilized resulting least throughput and ii) Temporal Starvation, in which resources are not available for a long period of time. So in this work, a solution for the second category by considering a node's past history of link utilization/quality or its future behaviours and prioritized the trust worthy nodes based on temporal information. In C-DAM, the history of the communication is used and whichever the node is transferring data for a longer period is given the highest priority by using a timer called pcaTimer. By considering the reliability of neighbor node a new methodology for registering medium access slots under DRP is suggested for sharing the communication links in an efficient manner.

The resource allocation procedure use a parameter called "hit" to maintain the history of access. Every time the node accesses the neighbor through PCA mode it gains a credit (hit) and gets incremented by 1. The node having more number of credits will be having the highest chance for MAS reservation using DRP. When the slots are released by its neighbouring node, the corresponding device will sort all the Pca_list based on waiting time and then by hit value. In the Pca_list, address having the highest waiting time and hit value will be chosen. An explicit DRP reservation procedure will be initiated for the identified device. If the specified device responds with reason code as either pending or denies then the chance will be given to the device with the next highest hit value otherwise the registration is accomplished. The procedure continues until a device with the highest hit value accepts the reservation. DRP_DEVICE_LIST consists of the set the devices registered using DRP reservation method. If the total number of slots exceeds the mTotalMASLimit then DRP_FULL is set to true otherwise it holds false.

Algorithm for DRP reservation using C-DAM:

```
Source Node:
Input: DRP_DEVICE_LIST,DstAddr,Pca_list[]
Output: DRP_DEVICE_LIST, Pca_list[]
while true do
        Receive data from upper layer
        Check the availability of MAS slot with DRP reservation for the
        DstAddr
        Initialize hit to zero
        if DRP_DEVICE_LIST != DstAddr && DRP_FULL then
                if !pcaTimerDstAddr then
                        initialize pcaTimerDstAddr
                endif
                increment hit by 1
                access the medium through PCA slots
                update Pca_list with self-address
                send Pca_list along with the data
        else
                proceed with DRP based reservation procedure
                continue data transfer using registered slot
        endif
end while
Destination Node:
Input: DRP_DEVICE_LIST,DstAddr,Pca_list[]
```

```
Output: DRP_DEVICE_LIST, Pca_list[]
while true do
        Receive data from lower layer
        Initialize flag to 1
        //Maintain PCA device list
        Pca_list[i].address = srcAddr
        Pca_list[i].waitTime = pcaTimerDstAddr
        Pca_list[i].hit = hit
        Sort Pca_list by waitTime then by hit
        DRP slot released using UDA frames
        Confirm the free slots by receiving UDR frames
        for every address in Pca_list do
                Send the DRP.request to the address
                Receive the DRP.response from the address
                set address to SrcAddr
                if SrcAddr accepts then
                        initiate data transfer in the identified slot
                        break
                else
                        flag = 0
                endif
        endfor
        if flag == 0 then
                identify device with highest hit value
                Send the DRP.request to the corresponding SrcAddr
                Confirm DRP.reservation
                Continue data transfer using registered slot
        else
                // If no such device available
                free up the slots for new request
        endif
end while
```

5. Performance Analysis

OMNeT++ is an open source model for component based architecture, programmed in C++ incorporated into a large single component. Omnet++ has an extensive GUI support, reusable models which can be embedded into any applications. It holds huge number of protocols and agents for working with communication networks. INET is particularly advantageous while designing and validating new set of protocols, or exploring new or exotic scenarios. INET contains models for the Internet protocol stack for both wired and wireless link layer protocols in order to support mobility, MANET protocols, DiffServ, several application models, and many other protocols and components. Several other simulation frameworks take INET as a base, and extend it into specific directions, such as vehicular networks, overlay/peer-to-peer networks, or LTE.

To evaluate the proposed method, we have used OmNet++ version 4.3 and inetmnanet-2.2.

The parameters used for simulation are listed in Table 2 as per specification.

Table 2. Simulation parameters.

Parameters	Values
Number of Node	Varies from 10 to 50
Superframe duration	256 × MAS duration
Payload	4096 bytes
Bandwith	480Mbps
MAS duration	256 μs
Total No. of MAS	256 MASs
mTotalMASLimit	112 MASs
SIFS	12μs
AIFS(0)	28 μs

Since WiMedia supports various access categories (AC), we assume the access category is the same for the communicating nodes. In peer to peer network, any node needs to handle its data traffic by itself and it must identify its chance for accessing the medium by competing other nodes including those having higher priority. Any simplest MAC protocol using contention based access may result lower performance. In PCA mode, when the number of communicating nodes increases the throughput of the system starts decreasing sharply, hence the below mentioned case specifies the degradation of throughput. DRP assures data transfer only when slots are registered. Although packets may be dropped by the application layer, DRP ensures data transmission after the slots were registered. As shown in Fig. 3, the number of nodes increases collision, thereby number of packets to be transmitted is not guaranteed since it purely depends on the factor whether it will be able compete the other nodes or not.

The throughput of the network is inversely proportional to the number of devices accessing the concern Superframe. Using C-DAM, a nearly optimal scheduling method for DRP based slot allocation using PCA mode is proposed. The Nodes may spend time in accessing the medium through CSMA/CA method, so initially there is a high possibility of delay in the overall network throughput. Though the throughput is not similar to that DRP, the proposed algorithm attempts to increase the throughput (Fig. 4) by prioritizing the nodes while reserving the slots. However the nodes may experience the delay since its initial mode of access via PCA and the success is based on the time taken in trying to contact the neighbor.

As a result of the C-DAM, we were able to maximize the throughput when compared to PCA’s performance. But the discussion is limited to the availability of free slots available under DRP i.e. mTotalMASLimit. Various suggestions were made for the betterment of PCA since it prioritizes the data which was not considered under DRP. Hence, researchers have shown simulation studies on energy consumption of slotted CSMA/CA protocol considering the backoff period required when the medium is busy [14]. Researchers consider various metrics like reservation type, packet drop ratio other than backoffs along with slotted CSMA/CA to minimize energy consumption.

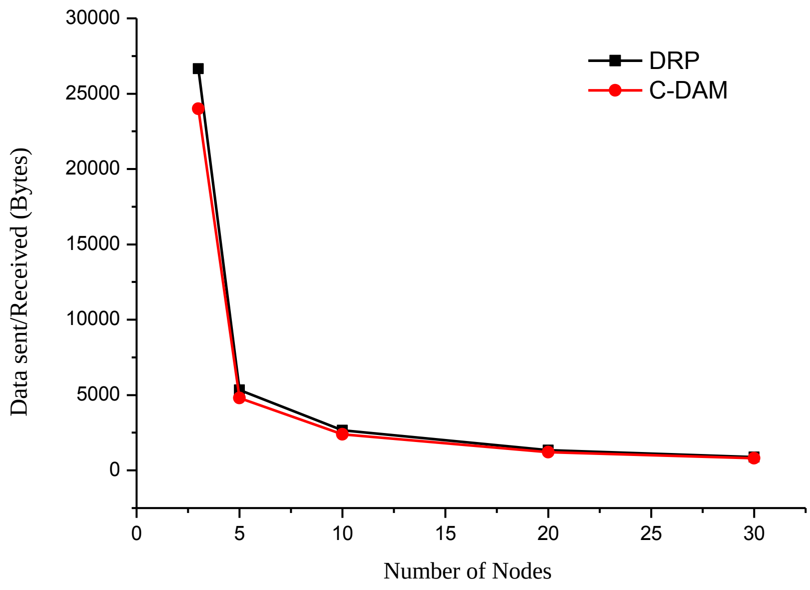

Fig. 3. Node density vs. DRP and C-DAM.

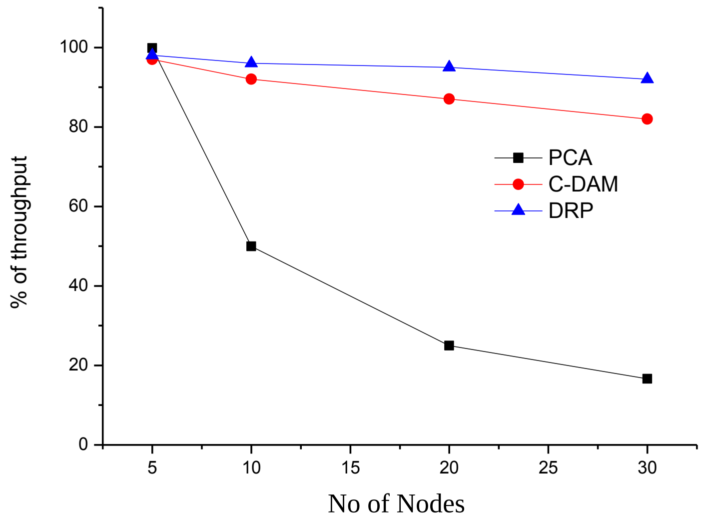

Fig. 4. Comparison of throughout in PCA, DRP, and C-DAM.

6. Conclusion

This paper investigates the degradation of network performance in a congested network. Devices that access their respective slots through the beacon may be non-active. Those devices, which initiate the communication, will start transmitting the first beacon and the alignments may be possible due to the new additions and deletions. So a methodology for enhancing QoS using MAS allocation is proposed which shows the improvement in the channel utilization. By this algorithm a new method of DRP allocation and prioritize the trust worthy neighbours are done. Even though the devices experiences delay, the overall performance of the C-DAM shows an effective utilization of the bandwidth. One of the important factors for energy dissipation is while transmitting/receiving data. Since the devices accessing the medium continuously is prone to lose more energy and also, CSMA method consumes more power, the proposed algorithm helps to reduce the power consumption.

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