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Performance Analysis of Extended AODV with IEEE802.11e HCCA to Support QoS in Hybrid Network

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Abstract

The integration of the fixed wired network and wireless mobile ad hoc network can be used to eliminate dead zones in the wireless network, and can also be used to extend the coverage of wireless networks. The integration of wired and wireless networks also known as hybrid networks, is gaining popularity due to its usefulness and practical use. Real time applications in hybrid network need some suitable quality of service. The quality thresholds are imposed on parameters like delay, jitter, packet loss and throughput. This paper utilizes the Extended AODV routing protocol for communication between MANET and fixed wired network and IEEE 802.11e MAC function HCF Controlled Channel Access (HCCA) to support quality of service in hybrid network. The performance of extended AODV, with HCCA (IEEE 802.11e) and without HCCA (IEEE802.11) is compared using simulation for real time voice over IP traffic. The extensive set of simulations shows that extended AODV with HCCA provides the drastic reduction in jitter compare to without HCCA.

Keywords: *quality of service, MANET, HCCA, extended AODV, hybrid network*

1. Introduction

A variety of approaches have been proposed to provide wireless internet access to mobile ad hoc networks (MANETs). Since the integration of wired and wireless networks is gaining popularity due to its usefulness and practical use. The interconnection of fixed wired network with MANET is achieved by introducing an Internet Gateway that provides the link to external hosts. Thus, a gateway acts as a bridge between a MANET and the Internet and all communication between the two networks must pass through gateway. This paper used the modified version of AODV routing protocol which is known as extended AODV, to route packets not only within a mobile ad hoc network, but also to a fixed wired network [1]. Although, the Internet Engineering Task Force (IETF) has proposed several routing protocols for MANETs, such as Ad hoc On-Demand Distance Vector (AODV) [2], Dynamic Source Routing (DSR) [3], Optimized Link State Routing Protocol (OLSR) [4]. However, all these protocols were designed for communication within an autonomous MANET. These routing protocols are not suitable for integration of MANET and fixed wired network or hybrid network.

If Quality of service (QoS) is provided to the hybrid network, then it is more advantageous to real time applications [5]. The Quality of service (QoS) [6] of wireless Internet access that could be offered to MANET nodes in hybrid network strongly depends on the selection of MAC schemes. The IEEE 802.11 [7], the WLAN legacy standard cannot provide QoS support for multimedia applications. Thus, considerable research efforts have been carried out to enhance QoS support for IEEE 802.11 [8]. Among them, IEEE 802.11e [9, 10] is the upcoming QoS enhanced standard proposed by the IEEE working group. In 802.11e a new MAC layer function called the hybrid coordination function (HCF) that deals with both contention-based and contention-free access mechanisms and provides prioritized and parameterized QoS. In particular two new MAC functions are added to the pre-existing ones: the Enhanced Distributed Channel Access (EDCA) [11] and the HCF controlled Channel Access (HCCA) [12]. EDCA improves the mandatory and contention-based Distributed Coordination Function (DCF) by introducing traffic prioritization. HCCA enhances the optimal Point

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Coordination Function (PCF) polling scheme with a parameterized traffic classification [13]. This paper analyses the performance of Extended AODV with 802.11e HCCA to support in Integration of MANET with fixed wired networks [14]. The simulation is carried out by using NS2 (2.29) for real time voice over IP traffic. The simulation results prove that extended AODV with IEEE802.11e HCCA is beneficial for real time application.

The rest of the paper is organized as follows: In section 1.1 the routing protocol extended AODV is described. In section 1.2 the IEEE802.11e MAC protocol illustrated. In section 2 simulation scenario with parmeters values are explained. Section 3 provides the performance merics used for proposed simulation scenario. Section 4 is detailed description of simulation results. Section 5 presents conclusion of paper.

1.1. Extended AODV

Extended AODV routing protocol, which is also known as AODV+, extends the widely used Ad hoc On-Demand Distance Vector (AODV) routing protocol to route packets between the wireless ad hoc network and the wired Internet, through a gateway [1, 14].

When a mobile node wish to communicate with a fixed wired node as a destination; the mobile node needs to begin route discovery process if it does not find a route towards fixed wired node in its routing table. Route discovery process is initiated by broadcasting RREQ message as in conventional AODV routing protocol. When a RREQ message is received by an intermediate mobile node, an intermediate mobile node send a RREP back to the originator of the RREQ if it has route towards the wired destination. But in that case, the source would think that the destination is a mobile node that can be reached via the intermediate node. It is important that the source knows that the destination is a fixed node and not a mobile node, because these are sometimes processed differently. But in extended AODV, this problem has been solved by preventing the intermediate node to send a RREP back to the originator of the RREQ if the destination is a wired node. Instead, the intermediate node updates its routing table and rebroadcasts the received RREQ message. To determine whether the destination is a wired node or not, an intermediate node consults its routing table. If the next hop address of the destination is a default route (see Table 1), the destination is a wired node. Otherwise, the destination is a mobile node or a gateway. Since neither the fixed node nor the mobile nodes in the MANET can reply to the RREQ, it is rebroadcasted until its TTL value reaches zero. When the timer of the RREQ expires, a new RREQ message is broadcasted with a larger TTL value. However, since the fixed node cannot receive the RREQ message (no matter how large the TTL value is) the source will never receive the RREP message it is waiting for. After a network-wide search without any RREP, the wireless station assumes that the destination is a wired station and sends its data packets to the gateway, which in turn forwards them to the destination. As an alternative approach to waiting for a network-wide search, the gateway could respond to incoming RREQs on behalf of wired stations on the Internet.

Table 1. The Routing Table of Mobile Node

Destination Address	Next Hop Address
Fixed node	Default
Default	Gateway
Gateway	IMN

1.2. IEEE 802.11e MAC Protocol

The IEEE 802.11e compensates for the lack of QoS and real-time support of the IEEE 802.11b standard by introducing two new functions: the Enhanced Distributed Channel Access (EDCA) and the HCF Controlled Channel Access (HCCA) [15]. EDCA is a distributed scheme so it can be used in both infrastructure and ad hoc networks. However, it cannot provide any Quality of Service (QoS) guarantees; only service differentiation. On the other hand, HCCA can provide QoS guarantees through resource reservation but it is a centralized and more complex scheme, which is useful in infrastructure networks only. The controlled channel access referred to as HCF controlled channel access (HCCA). The controlled channel access is a polling-based scheme enhanced from point coordination function (PCF) of 802.11. The HCCA mechanism uses a QoS-aware centralized coordinator [16, 17] called hybrid coordinator (HC), and operates under some rules that are different from the point coordinator (PC) of the PCF.

The IEEE 802.11e standard can deliver multimedia streams with respect of their QoS and real-time (i.e. timing constraints expressed in terms of flows deadlines) requirements [18, 19].

1.3. IEEE 802.11e HCCA

HCCA has been proposed in IEEE 802.11e to provide parameterized QoS support in the centralized polling mechanism of PCF (Point Coordination Function) [20, 21]. EDCA is basically an improved mechanism for DCF, and HCCA is basically an improved mechanism for PCF. One main new feature of HCF is the concept of transmission opportunity (TXOP) [22], which refers to a time duration during which a Quality of Service Station (QSTA) is allowed to transmit a burst of data frames. These bounded time intervals were introduced to solve the problem with unknown transmission times of polled stations in PCF. HCCA TXOP is calculated according to TSPEC (Traffic Specification) sent by each QSTA, then use the CF-Poll frame to transmit to each QSTA. Transmission different traffic classes called traffic streams (TSs) are introduced in HCCA. TSPEC (Traffic Specification) is added information element in IEEE 802.11e standard. The QoS request frame includes a Traffic Specification (TSPEC) element (see Table 2) that brings the information to notify the requirements of the traffic stream (TS) [23 ,24]. This simple scheduler uses the mandatory set of TSPEC parameters to generate a schedule. A TSPEC describes the QoS characteristics of a traffic stream (TS) by specifying parameters such as Mean Data Rate, Service Interval (SI), Delay Bound, Nominal SDU size etc. Each TS can either be uni-directional or bi-directional (or both of them), corresponds to a specific service level identified by the values of the Traffic Specification (TSPEC) protocol parameters. In order to control the delay, the maximum value of a TXOP is bounded by a value called TXOPLimit, which is determined by the Quality of Service Access Point (QAP). A QSTA can transmit multiple frames within its TXOP allocation. A QSTA never allowed exceeding the TXOP limit imposed by the QAP, including interframe spaces and acknowledgements. This new feature also tends to provide time-based fairness between QSTAs. The Service Interval (SI), which is the time interval between two successive polls of the node, and the transmission opportunity (TXOP) which is the node transmission duration, based on the mean application data rates of its TSs.

Table 2. TSPEC Element Fields

TS Info	Nominal MSDU Size	Max. MSDU Size	Min. Service Interval	Max. Service Interval	Inactivity Interval
Mean Data Rate	Peak Data Rate	Max. Burst Size	Delay Bound	Min. Physical Rate	Surplus Bandwidth Allowance

2. Simulation Setup

The network simulator ns-2 (version 2.29) is used to evaluate the performance of extended AODV with IEEE 802.11e (with HCCA) and IEEE 802.11 (without HCCA) [25], for the integration of MANET and fixed wired network. The main reason for using ns-2.29 is that the extended AODV and IEEE 802.11e HCCA both are compatible with this version.

The simulated scenario shown in Figure 1, and scenario parameters are given in Table 3.The considered simulation scenario for hybrid network consist of 18 mobile nodes in MANET domain, a gateway, 3 FTP server and 1-7 real time CBR Sources in fixed wired domain. The topology area is 1000m x 1000m is taken for this simulation scenario. All MANET domain nodes can communicate directly with gateway and its direct transmission range is 250 meters. The simulation ran for 100 seconds and the first 20 seconds are considered as warm up time. The interest is to study the steady state behaviour of the proposed network scenario of Figure 1. To achieve this objective, some tests concludes that the first 20 seconds are the transient state of the network during which the connections are set up, so that the first 20 seconds are ignored in simulations. In order to evaluate the effectiveness of HCCA, this scenario uses real time CBR traffic. The real time CBR traffic is modelled according to VoIP stream based on G.711 voice codec generating 160 bytes every 20 ms, resulting in 64 kbps data rate. This kind of traffic is given higher priority over the other traffic used in the proposed scenario. The another selected application is FTP, which represents a bulk data transfer of large size, sending TCP segments equal to 1024 bytes. FTP is given low priority and this application has always something to send and runs throughout the whole simulation. Therefore, when CBR source begins sending data, then FTP has to stop its transmission that time and give the priority to CBR traffic for transmission.

Figure 1. Simulation Scenario

For simulation, 1 to 7 nodes from wired domain involved in VoIP communication and remaining three servers for FTP. The purpose of selecting the varying number of real time VoIP calls was made to demonstrate and analyzed the ability of IEEE 802.11e HCCA.

The VoIP messages are encapsulated in UDP/IP packets while the FTP messages are encapsulated in TCP/IP packets. At the network layer, the extended AODV is used as ad hoc routing protocol with reactive gateway discovery to access the fixed network or vice versa through gateway. At the MAC and physical layer IEEE 802.11e HCCA or IEEE 802.11 without HCCA are used for the evaluation and comparison purpose. To provide the quality of service (QoS) to the hybrid network, the IEEE 802.11e standard is used for simulation. The MAC layer parameters used in simulation are given in Table 4. The traffic sources are started simultaneously and the simulation results are presented when there is no mobility. This paper simulates a scenario where users sit in a cafe, university campus, conference hall, airport, or railway station and access the Internet using their laptops.

Table 3. Simulation Parameters

Parameter	Value
Topology area	1000m x 1000m
Mobile Nodes	18
Gateway	1
Number of CBR sources	1-7 variable
Number of FTP sources	3
CBR packet size and rate	160 bytes, 64kbps
FTP packet size	1024 bytes
Transmission range	250 m
Simulation Time	100 sec.
Warm up time	20 sec

Table 4. MAC Simulation Parameters

Parameter	Value
SlotTime	20µs
SIFS	10 µs
Preamble Length	144 bit
PLCP Header Length	48 bits
PLCP Data Rate	1 Mbps
Data Rate	11Mbps
Basic Rate	1 Mbps
CWMIN	31
CWMAX	1023
Max SDU Size	2132

3. Performance Metrics

The following metrics are used in simulation for purpose of evaluation and performance comparison of extended AODV with HCCA and without HCCA in hybrid network scenario shown in Figure 1.

Packet Delivery Ratio (PDR) is calculated as the number of data packets received at the destination divided by the number of data packets generated at the source.

Average End –to- End Delay: End –to- End Delay is calculated as the time when a packet is received at the destination minus the time when the packet was generated at the source.

Jitter is calculated as the variance of the end- to- end delay.

Throughput is calculated as the number of data bits received at the destination divided by the time the considered traffic type (VoIP, FTP).

4. Simulation Results

This section presents the results of integration of MANET with internet model scenario which is obtained through simulations. The performance analyzed the benefits of IEEE 802.11e (HCCA) over the IEEE 802.11 without HCCA in the considered simulation scenario.

4.1. Average End to End Delay

The Figure 2 and Figure 3 shows average end- to- end delay plot for IEEE 802.11 and 802.11e HCCA MAC and proves that the average end- to- end delay varies significantly in IEEE 802.11 MAC compared to 802.11e (HCCA) MAC. This is because of the reservation to access the medium in IEEE 802.11e (HCCA) MAC for transmission of traffic stream (TS), based on QoS requirements. The Service Interval (SI) value and Transmission Opportunity (TXOP) are predefined by Quality of service Access Point (QAP) for the real time periodic traffic and contention free medium access for VoIP calls. Therefore, allocation of medium periodically to a specific traffic stream by QAP provides almost constant end-to-end delay as desired. An interesting observation that needs to be focused is the sharp increase of average end- to- end delay as number of CBR sources increases. This is because that few stations are outside the transmission range of both transmitters and receivers. But with increase in CBR sources, average end- to- end delay is very less in the case of IEEE 802.11e (with HCCA) comparing to IEEE 802.11 (without HCCA).

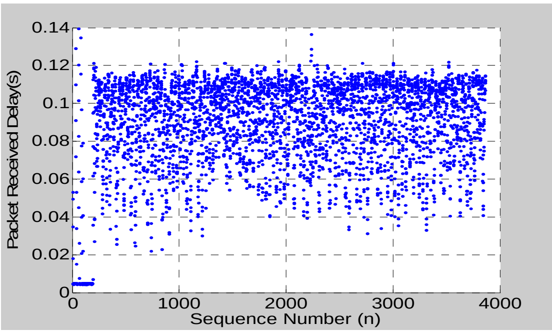

Figure 2. Packet Delay Plot without HCCA

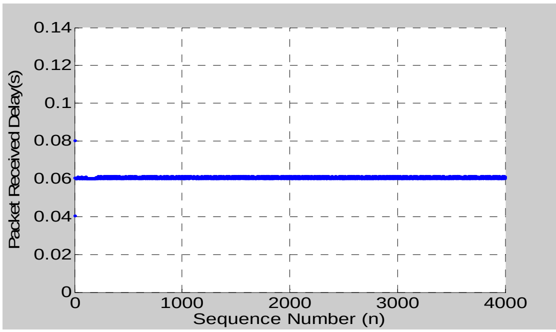

Figure 3. Packet Delay Plot with HCCA

4.2. Jitter

Table 5 is for the comparison of jitter for IEEE 802.11 (i.e. Without HCCA) and 802.11e HCCA MAC, when the number of CBR sources is varying from 1 to 7. This Table 5 shows that as the CBR sources are increasing, the jitter is quite low and almost constant with IEEE 802.11e HCCA MAC compare to the IEEE 802.11 MAC. The result shows that the IEEE 802.11e HCCA is able to provide QoS to high priority traffic even during high traffic load. In contrast to this, the jitter variation pattern is random and quite high with the IEEE 802.11 and does not provide QoS to the hybrid network. Since the jitter is related with end to end delay, therefore, the similar reason is here to get low jitter value with IEEE 802.11e HCCA MAC and is able to provide the QoS to the considered hybrid network scenario.

Table 5. Jitter

	Jitter (10^{-4} s^2)	
No. of CBR	CBR	
Sources	Without HCCA	With HCCA
1	2.7999	0.0016
4	4.9612	0.0035
	4.9688	0.0035
	5.0256	0.0035
	5.0707	0.0015
7	3.1377	0.0034
	3.1872	0.0036
	3.1851	0.0035
	3.2014	0.0036
	3.1919	0.0033
	3.1434	0.0015
	3.3024	0.0036

4.3. Packet Delivery Ratio

Table 6 shows that, the packet delivery ratio decreases with IEEE 802.11 MAC for CBR is used and packet loss become higher as number of CBR sources increases. On the other hand, the packet loss is negligible with IEEE 802.11e MAC (with HCCA) for CBR. It is observed from Table 6 that a very high packet delivery ratio for both with and without HCCA in FTP, as the number of CBR sources increases. This is due to the reliable delivery service provided by TCP. FTP use connection – oriented TCP, which retransmits dropped packets.

Table 6. Packet Delivery Ratio

	Packet delivery ratio %			
No. of CBR	CBR		FTP	
Sources	Without HCCA	With HCCA	Without HCCA	With HCCA
1	96.57	99.93	96.53	96.96
4	91.12	99.92	95.50	96.22
7	86.35	99.89	94.64	95.87

4.4. Throughput

Table 7 is for throughput analysis of the considered simulation scenario. And it is found that the throughput is slightly better with IEEE 802.11e HCCA compare to the IEEE 802.11 (without HCCA). Table 7 proves for the case of throughput without HCCA, as the more number of traffic streams are contending for medium access, the higher the probability of collisions and retransmissions resulting lower throughput. Although, as the traffic streams increases, the throughput is almost consistent and very close to the actual value in case of IEEE 802.11e HCCA.

Table 7. Throughput

	Throughput (kbps)			
No. of CBR	CBR		FTP	
Sources	Without HCCA	With HCCA	Without HCCA	With HCCA
1	61.82	63.97	3154.94	3202.15
4	233.33	255.86	2709.50	2910.82
7	386.96	447.65	2313.11	2619.70

5. Conclusion

This paper evaluates the ability of extended AODV with IEEE 802.11e HCCA and IEEE 802.11 without HCCA to hybrid networks. Simulation results shows that the performance is degraded with increasing number of CBR sources when IEEE 802.11 (without HCCA) is used to the hybrid network scenario, whereas IEEE 802.11e (with HCCA) successfully providing QoS support in terms of low and controlled end-to-end delay and jitter, the required throughput, and negligible packet loss to real time applications.

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