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# Simulation of IEEE 802.11(e) QoS Networks Using Nctuns

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## Abstract

In a multi-service IP network, it is a key challenge to provide Quality of Service (QoS) to end-user applications while effectively using network resources.This paper describes Significant differences between 802.11 and 80.11e and Simulates 802.11e using NCTUns, an innovative network simulator and emulator for wireless and mobile networks. Effects of various radio resource management and quality of service (QoS) schemes on higher-layer protocols and real-world applications can be easily studied using NCTUns.

## I Introduction

Radio resource management and quality of service (QoS) schemes are important for next-generation wireless and mobile networks. With them, scarce wireless bandwidth can be more efficiently utilized and applications demanding a certain level of QoS (e.g., voice over IP) can be adequately supported. Several radio resource management and QoS schemes are being proposed for next-generation wireless and mobile networks such as IEEE 802.16 WiMax networks and IEEE 802.11 WiFi networks with IEEE 802.11e QoS supports. Evaluating the performance of these schemes in various conditions can help researchers discover their design flaws and performance limitation.

In a network, providing QoS guarantees for an application (e.g., VoIP) should be end-to-end and up to the application layer. The effect of a radio resource management or a QoS scheme on network-layer routing protocols (e.g., IP), transport-layer protocols (e.g., TCP/UDP), and application-layer protocols (e.g., HTTP) should all be considered. Performance analysis of these schemes at a lower layer such as the MAC layer cannot reflect the real performance of these applications. To obtain more realistic end-to-end application-layer performance, the processing and the interactions among these layers and real-world applications need to be investigated.

Network simulators are valuable tools for researchers to design, test, diagnose, and evaluate network protocols under various network conditions. Conducting simulations is more economical, flexible, and safer than performing real experiments[1].

II IEEE 802.11 (802.11) WLAN standard is being accepted widely and rapidly for many different environments today. Main characteristics of the 802.11 networks are their simplicity and robustness against failures due to the distributed approach. Using the ISM band at 2.4 GHz, the 802.11b version provides data rates of up to 11 Mbit/s at the wireless medium. Now, the new 802.11a version can achieve data rates of up to 54 Mbit/s at the wireless medium using the OFDM modulation technique in the unlicensed 5 GHz band. Today, 802.11 WLAN can be considered as a wireless version of Ethernet, which supports best-effort service. However, the interest in wireless networks supporting QoS has recently grown. Accordingly, the 802.11 Working Group established an activity to enhance the current 802.11 MAC protocol to support applications with QoS requirements. Such a network could open a variety of opportunities for new multimedia applications on mobile/portable devices.

**LEGACY 802.11** Here we briefly summarize the 802.11 MAC protocol and discuss its limitations in QoS support. We consider an infrastructure Basic Service Set (BSS) of IEEE 802.11 WLAN, which is composed of an Access Point (AP) and a number of stations associated with the AP. The AP connects its stations with the infrastructure[2].

**Distributed Coordination Function** The basic 802.11 MAC protocol is the Distributed Coordination Function (DCF) that works as listen before-talk scheme, based on the Carrier Sense Multiple Access (CSMA). Stations deliver MAC Service Data Units (MSDUs) of arbitrary lengths (up to 2304 bytes), after detecting that there is no other transmission in progress on the wireless medium. However, if two stations detect the channel as free at the same time, a collision occurs. The 802.11 defines a Collision Avoidance (CA) mechanism to reduce the probability of such collisions. As part of CA, before starting a transmission a station performs a backoff procedure. It has to keep sensing the channel for an additional random time after detecting the channel as being idle for a minimum duration called DCF Interframe Space (DIFS), which is 34 microsecond for 802.11a. Only if the channel remains idle for this additional random time period, the station is allowed to initiate the transmission. The duration of this random time is determined as a multiple of a slot time (9 µs in 802.11a). Each station maintains a so-called Contention Window (CW), which is used to determine the number of slot times a station has to wait before transmission. For each successful reception of a frame, the receiving station immediately acknowledges the frame reception by sending an acknowledgement frame (ACK). The CW size increases when a transmission fails, i.e., the transmitted data frame has not been acknowledged. After any unsuccessful transmission attempt, another backoff is performed with a doubled size of the CW. This reduces the collision probability in case there are multiple stations attempting to access the channel. The stations that deferred from channel access during the channel busy period do not select a new random backoff time, but continue to count down the time of the deferred backoff in progress after sensing a channel as being idle again. In this manner, stations, that deferred from channel access because their random backoff time was larger than the backoff time of other stations, are given a higher priority when they resume the transmission attempt. After each successful transmission, another random backoff is performed by the transmission-completing station, even if there is no other pending MSDU to be delivered. This is called “post-backoff”, as this backoff is done after, not before, a transmission.

There is one situation when a station is not required to perform the random backoff before starting data transmission. An MSDU arriving at the station from the higher layer may be transmitted immediately without waiting any time, if the last post-backoff has been finished already, i.e., the queue was empty, and additionally the channel has been idle for a minimum duration of DIFS. All the following MSDUs after this MSDU have to be transmitted after random backoff, until the transmission queue is empty again. To limit the probability of long frames colliding and being transmitted more than once, data frames may also be fragmented. Via fragmentation a large MSDU can be divided into several smaller data frames, i.e., fragments, which can then be transmitted sequentially as individually acknowledged data frames. The benefit of fragmentation is, in case of failed transmission, that the error is detected earlier and there is less data to retransmit. The obvious drawback is the increased overhead. To reduce the hidden station problem inherent in CSMA, 802.11 defines a Request-to-Send/Clear-to-Send (RTS/CTS) mechanism, which can be used optionally. Before transmitting data frames, a station has the option to transmit a short RTS frame, followed by the CTS transmission by the receiving station. The RTS and CTS frames include the information of how long it does take to transmit the next data frame, i.e., the first fragment, and the corresponding ACK response. Thus, other stations close to the transmitting station and hidden stations close to the receiving station will not start any transmissions; their timer called Network Allocation Vector, NAV, is set. RTS/CTS helps to protect long data frames against hidden stations. With fragmentation, multiple ACKs are transmitted, whereas with RTS/CTS the MSDU can be efficiently transmitted in a single data frame. Between two consecutive frames in the sequence of RTS, CTS, data, and ACK frames, a Short Interframe Space (SIFS), which is 16 us for 802.11a, gives transceivers time to turn around. See Fig. 1 for an example of the DCF. It is important to note that SIFS is shorter than DIFS, which gives CTS responds and ACKs always the highest priority for access to the wireless medium[4].

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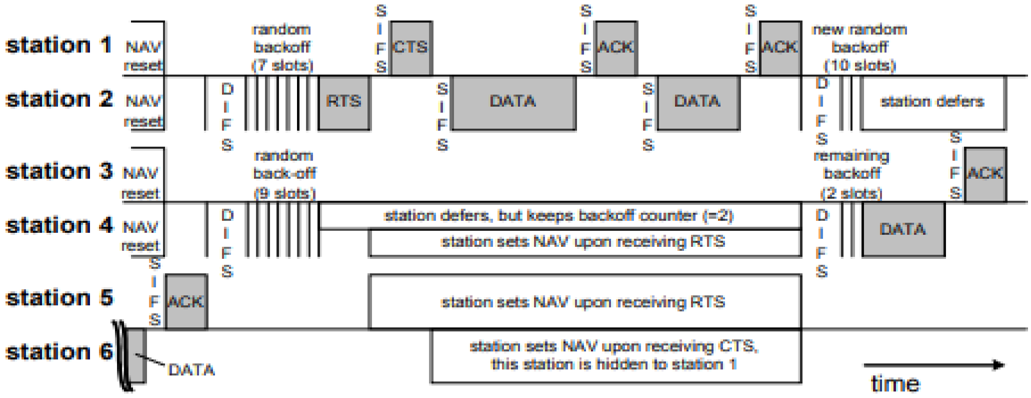



Fig. 1: Timing of the 802.11 DCF. In this example, station 6 cannot detect the RTS frame of the transmitting station 2, but the CTS frame of station 1.

**Limited QoS support with Point Coordination Function To support time-bounded services**, the IEEE 802.11 standard defines the Point Coordination Function (PCF) to let stations have priority access to the wireless medium, coordinated by a station called Point Coordinator (PC). The PCF has higher priority than the DCF, because it may start transmissions after a shorter duration than DIFS; this time space is called PCF Interframe Space (PIFS), which is 25 µs for 802.11a and longer than SIFS, i.e., the shortest inter-frame-space. Time is always divided into repeated periods, called super frames. With PCF, a Contention Free Period (CFP) and a Contention Period (CP) alternate over time, in which a CFP and the following CP form a super frame. During the CFP, the PCF is used for accessing the medium, while the DCF is used during the CP. It is mandatory that a super frame includes a CP of a minimum length that allows at least one MSDU Delivery under DCF. A super frame starts with a so-called beacon frame, regardless if PCF is active or not. The beacon frame is a management frame that maintains the synchronization of the local timers in the stations and delivers protocol related parameters. The PC, which is typically colocated with the AP, generates beacon frames at regular beacon frame intervals, thus every station knows when the next beacon frame will arrive; this time is called target beacon transition time (TBTT) and is announced in every beacon frame. Note that the beacon frame is required in pure DCF even if there is only contending traffic. There is no contention between stations; rather, stations are polled. See Fig. 2 for a typical sequence during CFP. The PC polls a station asking for a pending frame. Because the PC itself has pending data for this station, it uses a combined date and poll frame by piggybacking the CF-Poll frame on the data frame. Upon being polled, along with data, the polled station acknowledges the successful reception. If the PC received no response from a polled station after waiting for PIFS, it polls the next station, or ends the CFP. Thus no idle period longer than PIFS occurs during CFP. The PC continues with polling other stations until the CFP expires. A specific control frame, called CF-End, is transmitted by the PC as the last frame within the CFP to signal the end of the CFP[5].

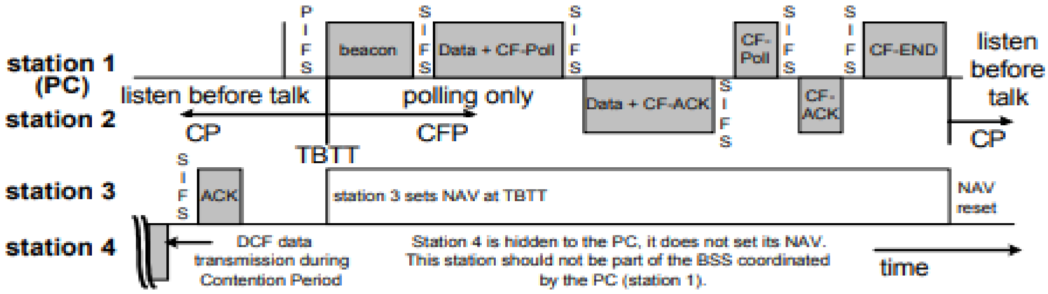



Fig. 2: Example for the PCF operation. Station 1 is the PC polling station 2. Station 3 detects the beacon frame and sets the NAV for the whole CFP. Station 4 is hidden to station 1 and does not detect the beacon frame; it continues to operate in DCF.

There are problems with the PCF that led to the current activities to enhance the protocol. Among many others, those include the unpredictable beacon delays and unknown transmission durations of the polled stations. At TBTT, a PC schedules the beacon as the next frame to be transmitted, and the beacon can be transmitted when the medium has been determined to be idle for at least PIFS. Depending on the wireless medium at this point of time, i.e., whether it is idle or busy around the TBTT, a delay of the beacon frame may occur. The time the beacon frame is delayed, i.e., the duration it is sent after the TBTT, delays the transmission of time-bounded MSDUs that have to be delivered in CFP. From the legacy 802.11 standard, stations can start their transmissions even if the MSDU Delivery cannot finish before the upcoming TBTT . This may severely affect the QoS as this introduces unpredictable time delays in each CFP. Beacon frame delays of around 4.9 ms are possible in 802.11a in the worst case.

There is another problem with the PCF, the unknown transmission time of polled stations. A station that has been polled by the PC is allowed to send a single frame that may be fragmented and of arbitrary length, up to the maximum of 2304 bytes (2312 bytes with encryption). Further, different modulation and coding schemes are specified in 802.11a, thus the duration of the MSDU Delivery that happens after polling is not under the control of the PC. This destroys any attempt to provide QoS to other stations that are polled during the rest of the CFP. A hidden station that misses the previous beacon frames and does not have any knowledge about the TBTT does not stop its operation based on DCF. It is likely that it transmits interfering frames during CFP. In general, a station sets the NAV at TBTT irrespective of the reception of a beacon frame. However, if it did not receive any of the beacon frames before, it does not set the NAV at TBTT.

## QOS SUPPORT MECHANISMS OF 802.11E

To support QoS, there are priority schemes , IEEE 802.11 Task Group E currently defines enhancements to the above-described 802.11 MAC, called 802.11e, which introduces EDCF and HCF. Stations, which operate under 802.11e, are called enhanced stations, and an enhanced station, which may optionally work as the centralized controller for all other stations within the same QBSS, is called the Hybrid Coordinator (HC). A QBSS is a BSS, which includes an 802.11e-compliant HC and stations. The HC will typically reside within an 802.11e AP. In the following, we mean 802.11e-compliant enhanced stations by stations. With 802.11e, there may still be the two phases of operation within the super frames, i.e., a CP and a CFP, which alternate over time continuously. The EDCF is used in the CP only, while the HCF is used in both phases, which makes this new coordination function hybrid.

**Enhanced Distributed Coordination Function** The EDCF in 802.11e is the basis for the HCF. The QoS support is realized with the introduction of Traffic Categories (TCs). MSDUs are now delivered through multiple backoff instances within one station, each backoff instance parameterized with TC-specific parameters. In the CP, each TC within the stations contends for a TXOP and independently starts a backoff after detecting the channel being idle for an Arbitration Interframe Space (AIFS); the AIFS is at least DIFS, and can be enlarged individually for each TC. After waiting for AIFS, each backoff sets a counter to a random number drawn from the interval [1,CW+1]. The minimum size (CWmin[TC]) of the CW is another parameter dependent on the TC. Priority over legacy stations is provided by setting CWmin[TC] < 15

As in legacy DCF, when the medium is determined busy before the counter reaches zero, the backoff has to wait for the medium being idle for AIFS again, before continuing to count down the counter. A big difference from the legacy DCF is that when the medium is determined as being idle for the period of AIFS, the backoff counter is reduced by one beginning the last slot interval of the AIFS period. Note that with the legacy DCF, the backoff counter is reduced by one beginning the first slot interval after the DIFS period. After any unsuccessful transmission attempt a new CW is calculated with the help of the persistence factor PF[TC] and another uniformly distributed backoff counter out of this new, enlarged CW is drawn, to reduce the probability of a new collision. Whereas in legacy 802.11 CW is always doubled after any unsuccessful transmission (equivalent to PF=2), 802.11e uses the PF to increase the CW different for each TC:

$$newCW\ [TC] >= ((oldCW[TC]+1)*PF)-1$$

The CW never exceeds the parameter CWmax[TC], which is the maximum possible value for CW

A single station may implement up to eight transmission queues realized as virtual stations inside a station, with QoS parameters that determine their priorities. If the counters of two or more parallel TCs in a single station reach zero at the same time, a scheduler inside the station avoids the virtual collision. The scheduler grants the TXOP to the TC with highest priority, out of the TCs that virtually collided within the station, as illustrated in Fig. 5. There is then still a possibility that the transmitted frame collides at the wireless medium with a frame transmitted by other stations.

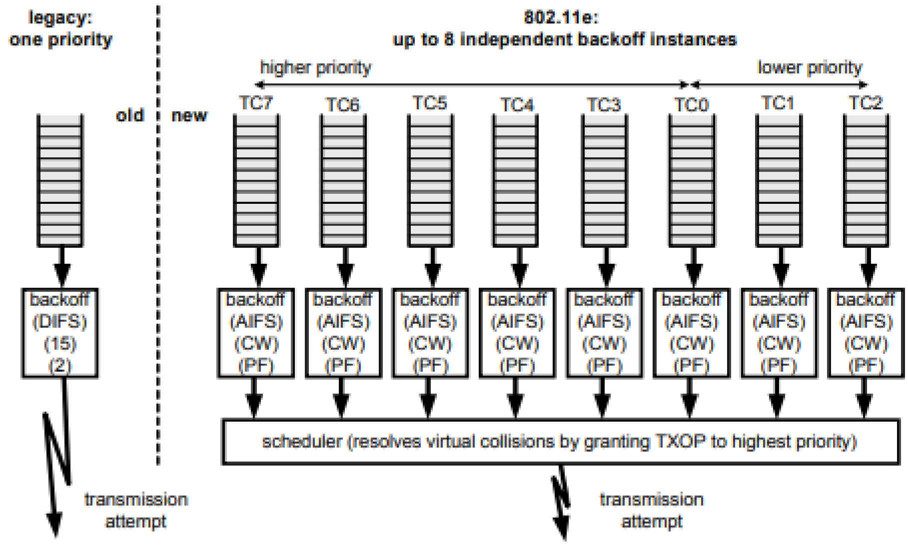



Fig. 5: Virtual backoff of eight traffic categories: (1) left one: legacy DCF, close to EDCF with AIFS=34us, CWmin=15, PF=2; (2) right one: EDCF with AIFS[TC]>=34us, CWmin[TC]=0-255, PF[TC]=1-16.

One crucial feature of 802.11e MAC is the Transmission Opportunity (TXOP). A TXOP is defined as an interval of time when a station has the right to initiate transmissions, defined by a starting time and a maximum duration. TXOPs are allocated via contention (EDCF-TXOP) or granted through HCF (polled-TXOP). The duration of an EDCF-TXOP is limited by a QBSSwide TXOP limit distributed in beacon frames, while the duration of a polled TXOP is specified by the duration field inside the poll frame. However, although the poll frame is a new frame as part of the upcoming 802.11e, also the legacy stations set their NAVs upon receiving this frame. More details about polled TXOP follow in the next subsection. The prioritized channel access is realized with the QoS parameters per TC, which include AIFS[TC], CWmin[TC], and PF[TC]. CWmax[TC] is optional. Discussions are ongoing to introduce a priority dependent EDCF-TXOP[TC]. The QoS parameters can be adapted over time by the HC, and will be announced periodically via the beacon frames. Protocol-related parameters are included in the beacon frame, which is transmitted at the beginning of each superframe[6].

Hybrid Coordination Function The HCF extends the EDCF access rules. The HC may allocate TXOPs to itself to initiate MSDU Deliveries whenever it wants, however, only after detecting the channel as being idle for PIFS, which is shorter than DIFS. To give the HC priority over the EDCF, AIFS must be longer than PIFS and can therefore not have a value smaller than DIFS. During CP, each TXOP begins either when the medium is determined to be available under the EDCF rules, i.e., after AIFS plus backoff time, or when the station receives a special poll frame, the QoS CF-Poll, from the HC. The QoS CF-Poll from the HC can be sent after a PIFS idle period without any backoff. Therefore the HC can issue polled TXOPs in the CP using its prioritized medium access. During the CFP, the starting time and maximum duration of each TXOP is specified by the HC, again using the QoS CF-Poll frames. Stations will not attempt to get medium access on its own during the CFP, so only the HC can grant TXOPs by sending QoS CF-Poll frames. The CFP ends after the time announced in the beacon frame or by a CF-End frame from the HC. See Fig. 6 for an example of an 802.11e superframe. As part of 802.11e, an additional random access protocol that allows fast collision resolution is defined. The HC polls stations for MSDU Delivery. For this, the HC requires information that has to be updated by the polled stations from time to time. Controlled contention is a way for the HC to learn which station needs to be polled, at which times, and for which duration. The controlled contention mechanism allows stations to request the allocation of polled TXOPs by sending resource requests, without contending with other (E)DCF traffic. Each instance of controlled contention occurs during the controlled contention interval, which is started when the HC sends a specific control frame. This control frame forces legacy stations to set their NAV until the end of the controlled contention interval, thus they remain silent during the controlled contention interval. The control frame defines a number of controlled contention opportunities (i.e., short intervals separated by SIFS) and a filtering mask containing the TCs in which resource requests may be placed. Each station with queued traffic for a TC matching the filtering mask chooses one opportunity interval and transmits a resource request frame containing the requested TC and TXOP duration, or the queue size of the requested TC. For fast collision resolution, the HC acknowledges the reception of request by generating a control frame with a feedback field so that the requesting stations can detect collisions during controlled contention[7].

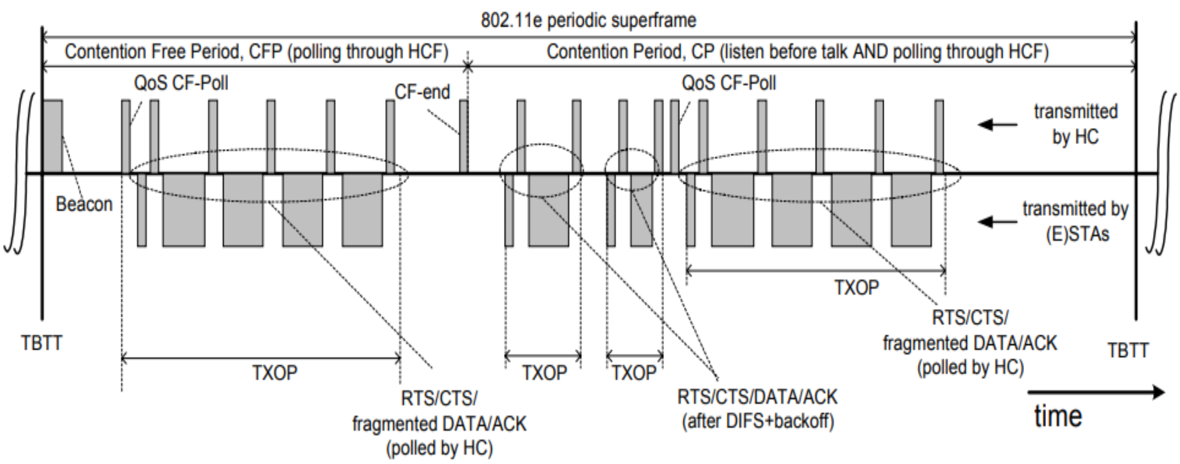
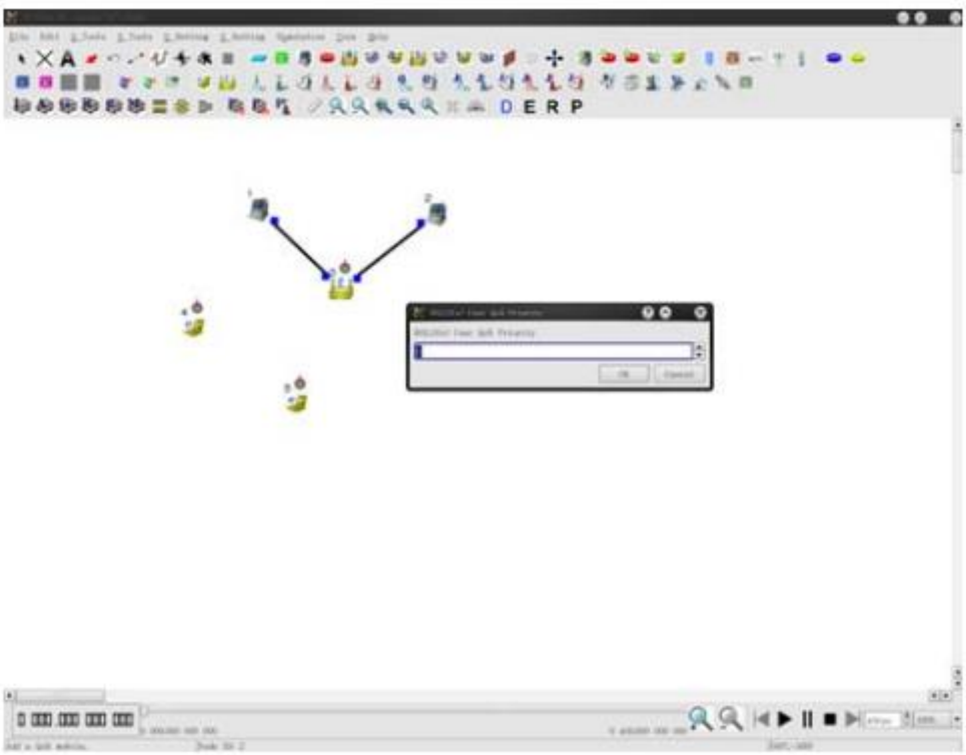



Fig. 6: A typical 802.11e superframe. The concept relies on TXOPs. Polled-TXOPs may be located in CP and CFP.

## Simulation Methodology

The IEEE 802.11(e) mechanism is used in an infrastructure mode WLAN. To simulate an IEEE 802.11(e) WLAN network in NCTUns, the IEEE 802.11(e) access point and the IEEE 802.11(e) mobile node should be used.

Insert 802.11(e) Mobile Nodes: When placing an 802.11(e) mobile node on the working area of the topology editor, a user is asked to input the user QoS priority for that mobile node. This declares each mobile node's medium access priority during the contention period.




*The user QoS priority needs to be set before an 802.11(e) mobile node can be placed on the working area of the topology editor.*

If a user want to quickly place many 802.11(e) mobile nodes, he (she) can use the Menu -> N_Tools -> 802.11(e) Wireless Network -> Insert 802.11(e) Mobile Nodes command. In the insertion dialog box, a user can choose how many access points should be inserted and which positioning style (random or an array style) should be used. If a user wants to change the protocol stack of all inserted mobile nodes, he (she) can also do the change here.

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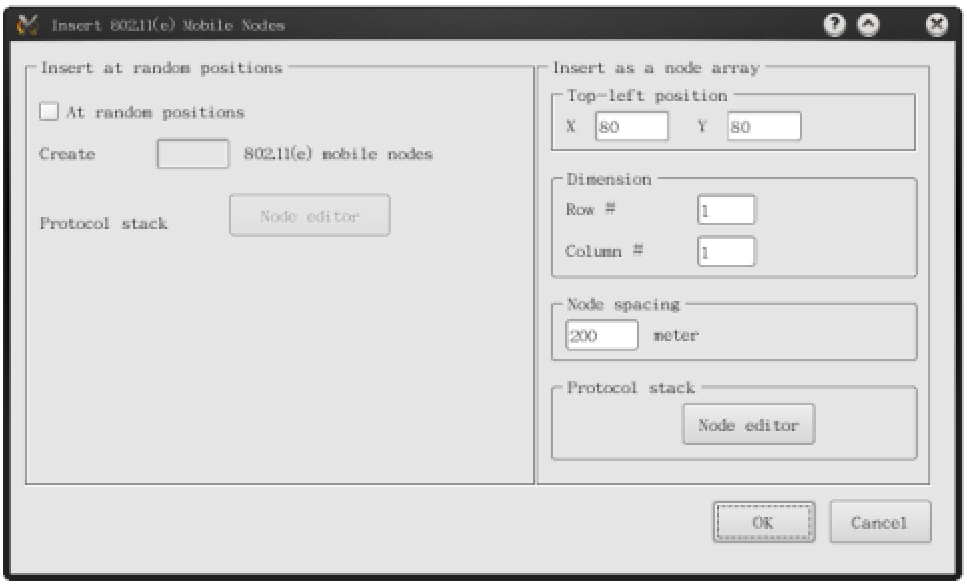
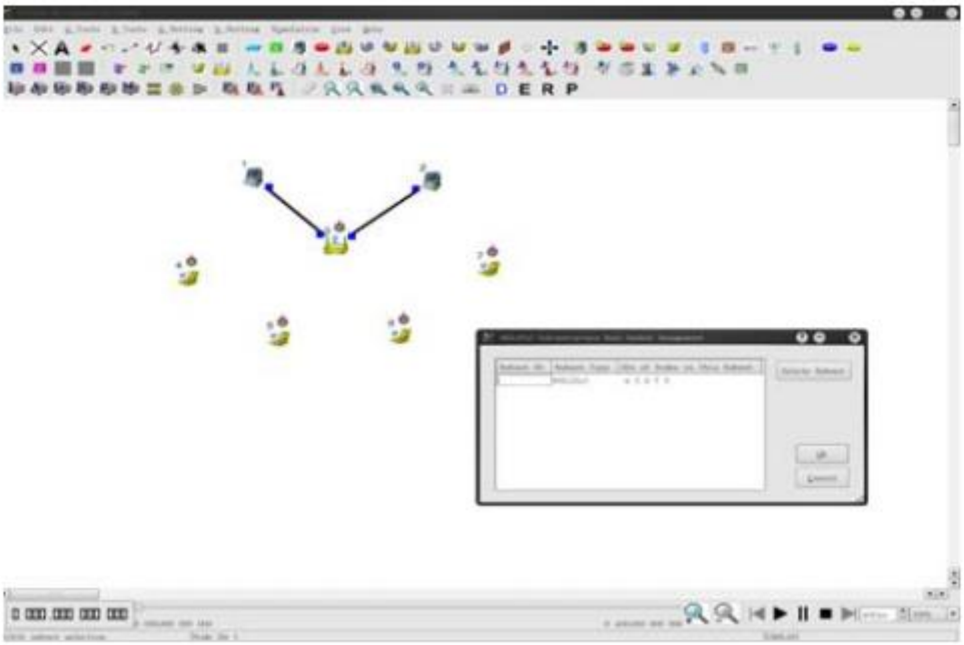
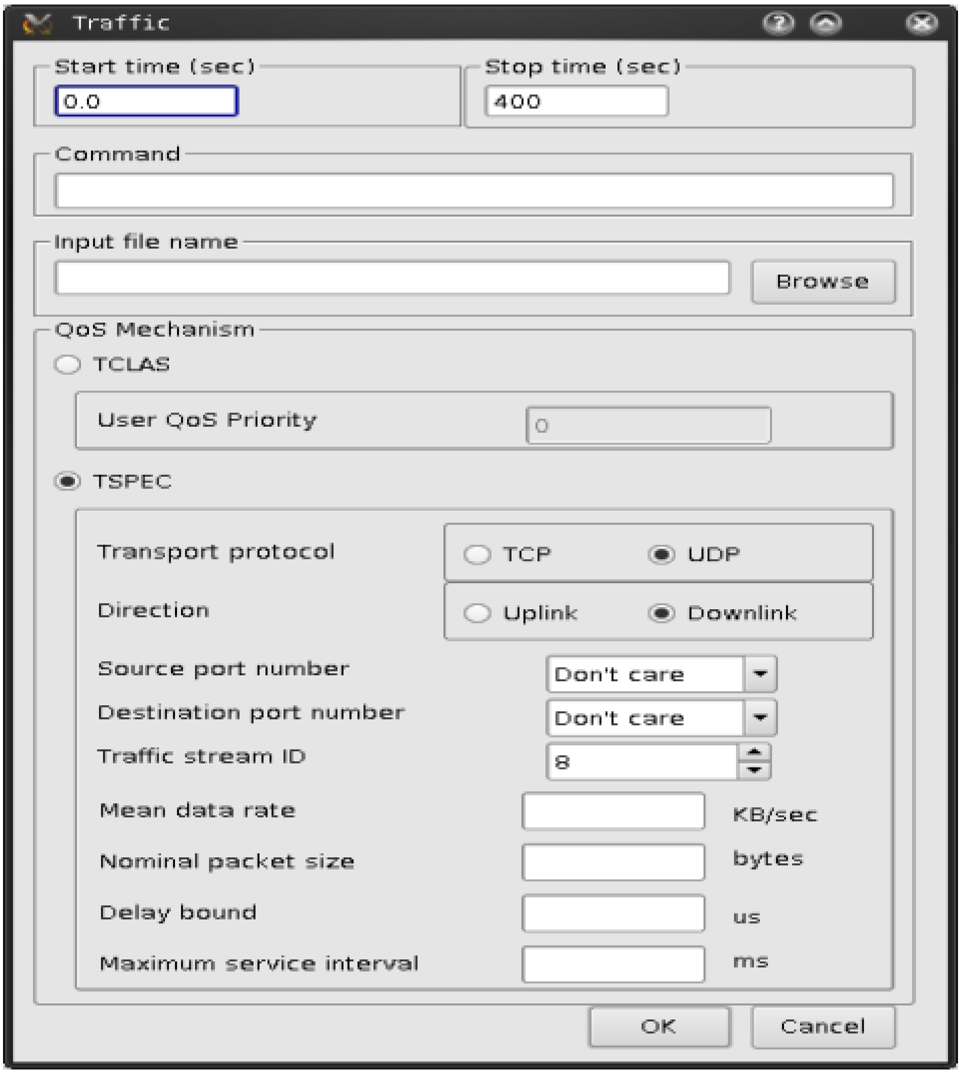



*Insert multiple 802.11(e) mobile nodes at the same time to save time and effort*

After inserting 802.11(e) mobile nodes, a user must use the "Form wireless subnet" ( ) tool to select all such nodes and the 802.11(e) access point to group them together to form a wireless subnet. Specifying this relationship enables the GUI program to automatically assign IP and MAC addresses to all of these nodes, saving much time and effort of the user. The formed 802.11(e) wireless subnets can be viewed and managed by executing the Menu -> N_Tools -> 802.11(e) Wireless Network -> Manage 802.11(e) Infrastructure Mode Subnets command. The following figure shows the dialog box of this command.



Configure Application with QoS Parameters When a user specifies an application to be run on an 802.11(e) mobile node, the 802.11(e) QoS parameters demanded by this application should be specified. A user can click the Add button under the Application tab and then he (she) will see the QoS demand parameter configuration part at the bottom of the popped-up dialog box, which is shown below. The meanings of these parameters are defined in the 802.11(e) specification. A user needs to read the related 802.11(e) documents or specifications to understand the purposes of these parameters.



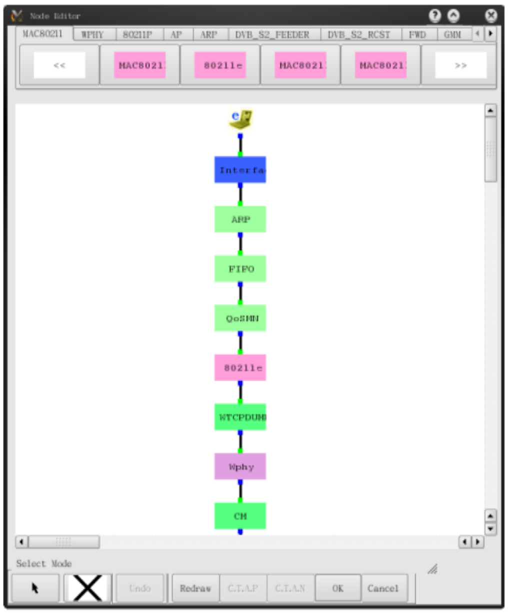

*Specify 802.11(e) QoS parameters when adding an application*

For example, suppose that a user wants to achieve a guaranteed 200 KB/sec UDP traffic flow from an 802.11(e) mobile node to the 802.11(e) access point and he (she) uses the "ttcp -t -u -s -p 8000 1.0.1.1" command to launch a greedy UDP traffic generator on that mobile node to send packets to another node with IP address 1.0.1.1. For this particular case, the user needs to choose the "TSPEC" (Traffic SPECification) option. In addition, the "Transport protocol" has to be set to UDP, the "Direction" has to be set to Uplink, the

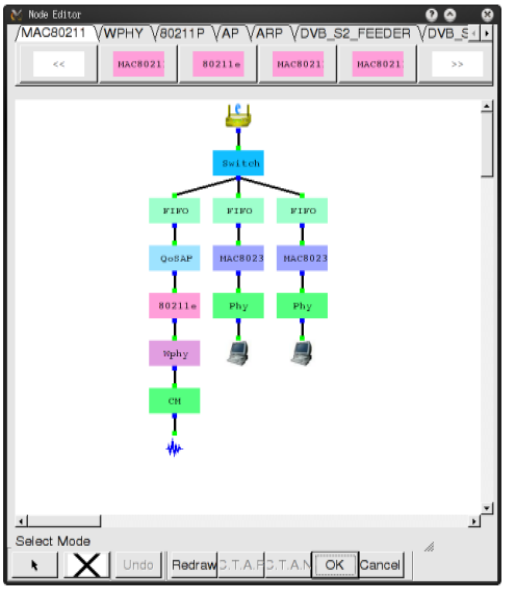
"Source port number" has to be set to "Don't care," the "Destination port number" has to be set to 8000, the "Traffic stream ID" has to be set to one of the values ranging from 8 to 15, the "Mean data rate" has to be set to 200 KB/sec, and the "Nominal packet size" has to be set to1024 bytes because the greedy UDP traffic generator sends packets with 1,024-byte data payload. Here, the "Delay bound" represents the maximum period of time from the arrival of a MSDU (Mac Service Data Unit) at the local MAC layer to the completion of the MSDU's transmission. The "Maximum service interval" is the maximum interval between the starts of two successive polling periods. According to the specification, if both of the "Delay bound" and the "Maximum service interval" are specified, only the latter will be used. If the user wants the access point to poll the mobile node every 20 ms, the "Maximum service interval" should be set to 20 ms and the "Delay bound" can be left empty.

IEEE 802.11(e) Protocol Stac

The following figures show the protocol stacks of the 802.11(e) mobile node and the 802.11(e) access point. The QoSMN and 80211e modules used inside the 802.11(e) mobile node do not need special parameter settings. Similarly, the QoSAP and 802.11e modules used inside the 802.11(e) access point do not need special parameter settings[8]



An 802.11(e) mobile node's protocol stack.




An 802.11(e) access point's protocol stack.

## Results and Discussion

In this section we present the simulations conducted to evaluate 802.11e Qos. The simulations are conducted in NCTUns network simulator.

Performance Evaluation Metrics The performance is evaluated based on the four metrics specified below:

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1. Throughput: The number of bits correctly transferred from source to destination. The throughput is represented in Kbps.

2. End-to-end delay: The time taken between inserting a packet in the sender's queue and the reception of this packet by the receiver. The end-to-end delay is represented in milliseconds (ms).

3. Jitter: The difference of the latency of the current packet and previous packet. The jitter is represented in milliseconds (ms).

4. Fairness: Fairness is measured as the number of admitted flows compared to the number of requests made. The objective of this metric is to identify the fairness of admission control unit among different type of traffic.

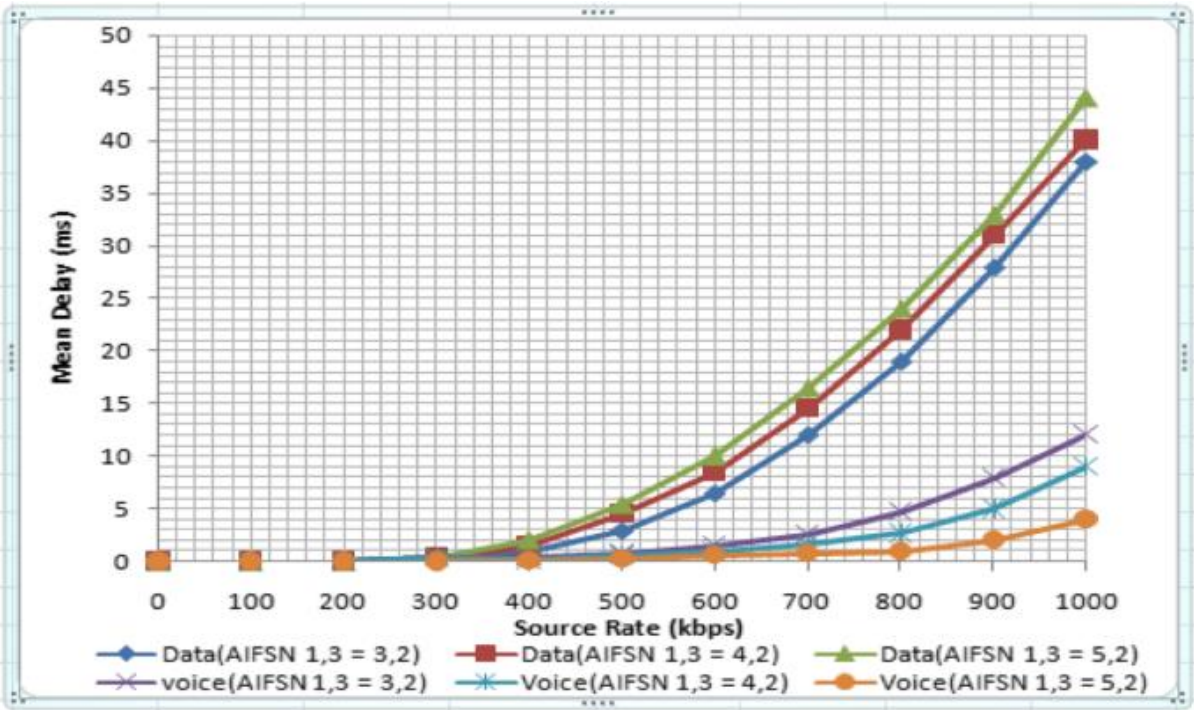


Fig Impact of load on delay

## CONCLUSION

In this paper we discussed comparison of performance 802.11 Wireless LAN and 802.11e wireless LAN with Qos, Methodology of simulation of 802.11e In NCTNs software. Mean delay is measured for 802.11e and plotted as graph.

## REFERENCES

[1] S. V. Saliga, "An introduction to IEEE 802.11 wireless LANs," *2000 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium Digest of Papers (Cat. No.00CH37096)*, 2000, pp. 11-14, doi: 10.1109/RFIC.2000.854406.

[2] IEEE 802.1 lb Draft Supplement to IEEE Std 802.11, Wireless LAN Medium Access Control (M-4 C) and Physical Layer (PHY) Specifications: Higher Speed Physical Layer (PHyl Extension in the 2.4 GHz band, Draft 7.0, July 1999

[3] IEEE 802.1 la Draft Supplement to IEEE Std 802.11, Wireless LANMedium Access Control MAC) and Physical Layer (PHyl specifications: High Speed Physical Layer in the 5 GHz Band, Draft 7.0, July 1999

[4] P. K. Wong, D. Yin and T. T. Lee, "A Markov Model of the 802.11 Distributed Coordination Function: Part II -- Stablility Analysis," *2011 Third International Conference on Communications and Mobile Computing*, 2011, pp. 535-538, doi: 10.1109/CMC.2011.16.

[5] D. D. Vergados and D. J. Vergados, "Synchronization of multiple access points in the IEEE 802.11 point coordination function," *IEEE 60th Vehicular Technology Conference, 2004. VTC2004-Fall. 2004*, 2004, pp. 1073-1077 Vol. 2, doi: 10.1109/VETECF.2004.1400186.

[6] M. Frikha and F. Ghandour, "Quality of service improvement in 802.11e: Conditioned Enhanced Distributed Coordination Function (CEDCF)," *2006 2nd International Conference on Information & Communication Technologies*, 2006, pp. 3228-3232, doi: 10.1109/ICTTA.2006.1684933.

[7] Y. Chen, M. Chuang, F. Tseng and C. Ke, "High Performance Distributed Coordination Function with QoS support in IEEE 802.11e networks," *2011 Australasian Telecommunication Networks and Applications Conference (ATNAC)*, 2011, pp. 1-6, doi: 10.1109/ATNAC.2011.6096656.

[8] Zhifeng Tao and S. Panwar, "An analytical model for the IEEE 802.11e enhanced distributed coordination function," *2004 IEEE International Conference on Communications (IEEE Cat. No.04CH37577)*, 2004, pp. 4111-4117 Vol.7, doi: 10.1109/ICC.2004.1313322.