Performance Evaluation for IEEE 802.11e Wireless Local Area Network System

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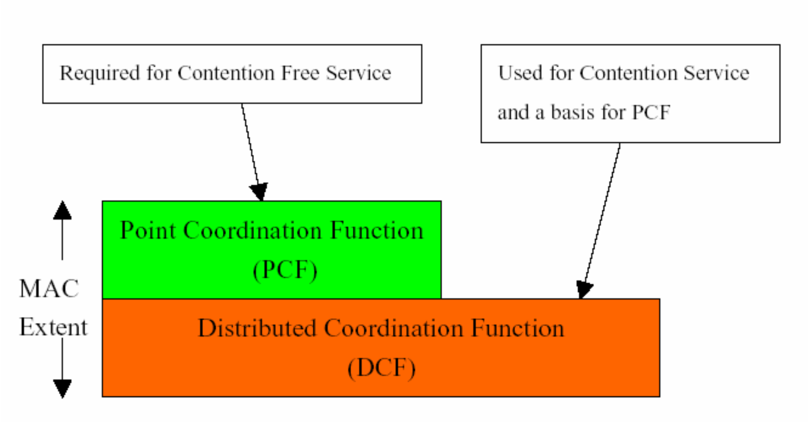
Outline

- Introduction
- Mechanisms in Draft IEEE 802.11e
- Simulation Scenario
- Simulation Results
- Conclusions and Future Work

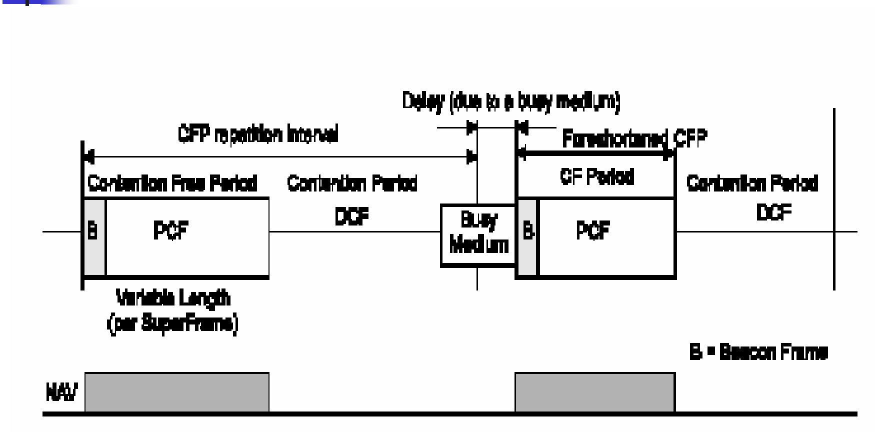
A Brief of IEEE 802.11 standard

- The IEEE 802.11 MAC protocol supports two access methods: DCF (Distributed Coordination Function) and PCF (Point Coordination Function).
- The compulsory DCF access method adopts CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) mechanism to provide services for asynchronous data transmission.
- The optional PCF access method incorporates a polling coordinator that locates at the AP (Access Point), and is proposed for real-time traffic.

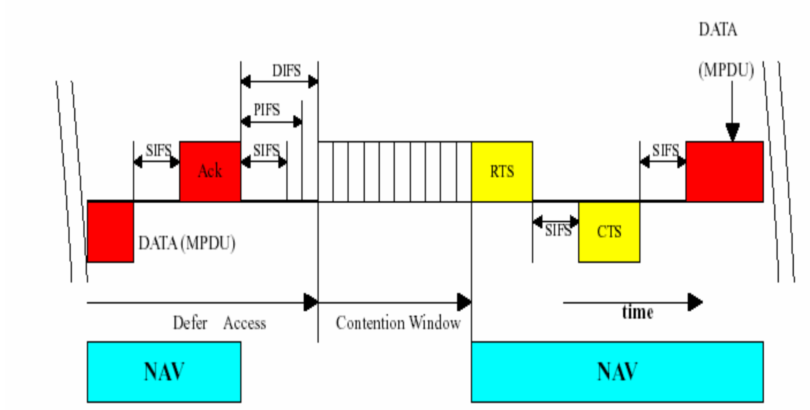
A Brief of IEEE 802.11 standard



A Brief of IEEE 802.11 standard



A Brief of IEEE 802.11 standard



A Brief of IEEE 802.11e standard

- Recently, research efforts over wireless LAN are gradually migrated to provision of Quality of Service (QoS) for real-time multimedia services.
- In its draft, IEEE 802.11e includes the Enhanced DCF access method (EDCF), the Hybrid Coordination Function (HCF), the Direct Link Protocol (DLP), and the Burst ACK Mechanism.
- In this thesis, we will focus on the performance evaluation of the EDCF, Burst ACK mechanism, and power management in an ad hoc network.

Mechanisms of IEEE 802.11e

Enhanced Distributed Coordination Function

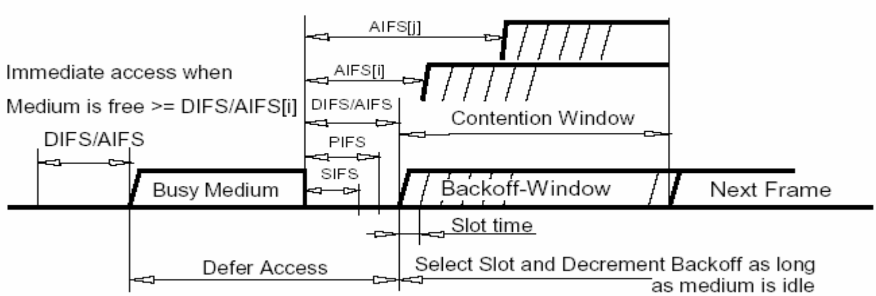
- The Enhanced Distributed Coordination Function (EDCF) mechanism of draft IEEE 802.11e is the basis of the Hybrid Coordination Function (HCF).
- According to the draft, each QoS station (QSTA) may maintain its packets using multiple queues, each of which belongs to different Access Category (AC) and hence has different User Priority (UP).

Enhanced Distributed Coordination Function

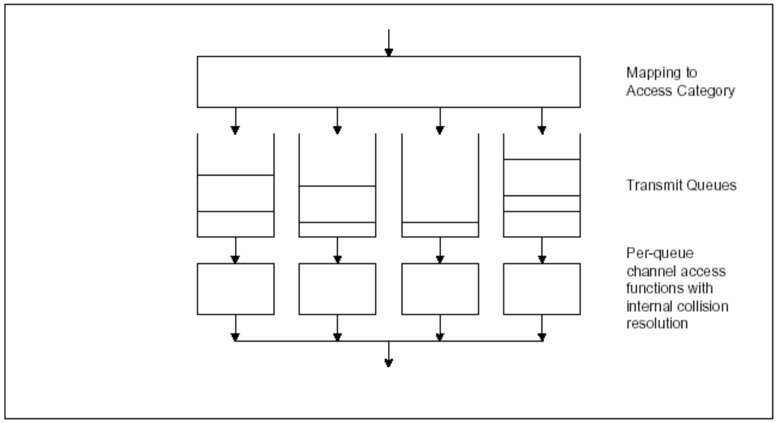
- The Access Category (AC) is parameterized by AC-specific parameters such as CW_{max} , CW_{min} and Arbitration Interframe Space (AIFS).

- During a contention period (CP), each AC within a station contends for a Transmission Opportunity (TXOP) by independently starting its own backoff mechanism after detecting and assuring channel idle for an AIFS time.

Enhanced Distributed Coordination Function



Enhanced Distributed Coordination Function



Reference Implementation Model of IEEE 802.11e.

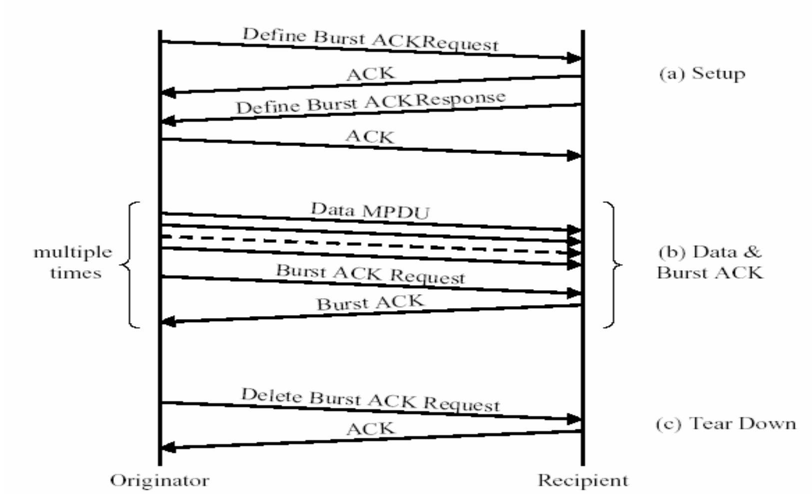
Enhanced Distributed Coordination Function

User Priority (IEEE 802.11D Priority)	IEEE 802.11D Designation	Access Category	Designation (Informative)
0	BE	0	Best Effort
1	BK	0	Best Effort
2	—	0	Best Effort
3	EE	1	Video Probe
4	CL	2	Video
5	VI	2	Video
6	VO	3	Voice
7	NC	3	Voice

Burst Acknowledgement Mechanism

- The Burst Acknowledgement mechanism allows a burst of QoS data packets to be transmitted consecutively, only separated by an SIFS (short Interframe Space) period.
- The mechanism improves the channel efficiency by aggregating several ACK frames into one Burst ACK frame.
- It consists of three stages:
  1. Setup;
  2. Data and Burst ACK;
  3. Tear Down.

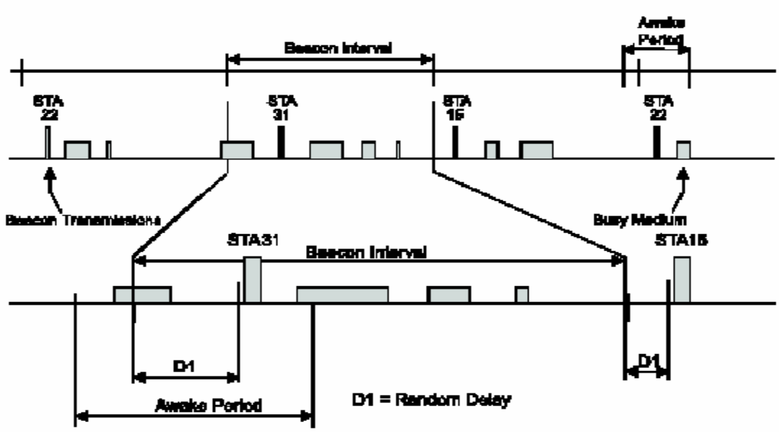
Burst Acknowledgement Mechanism



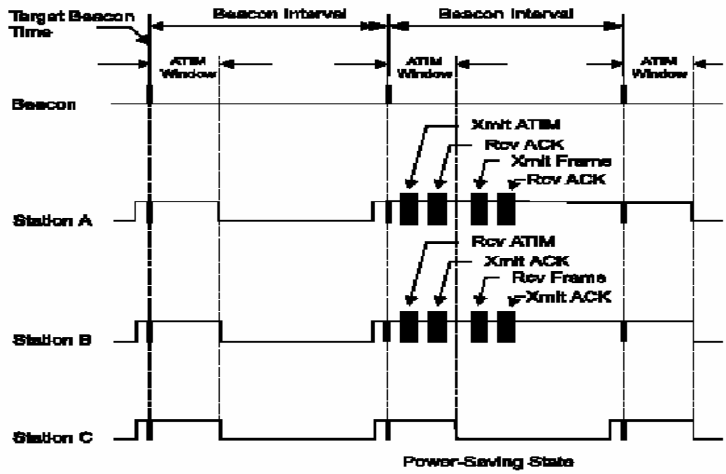
Power-Save Stations in an Ad Hoc network

- Power consumption is a significant issue for mobile devices like PDA or notebooks.
- After the ATIM window, power-saving stations, except the sender of beacon or ATIM frame or the receiver of ATIM frame, enter doze state to save power.

Power-Save Stations in an Ad Hoc network



Power-Save Stations in an Ad Hoc network



Simulation Scenario
Scenario of the Burst ACK Mechanism

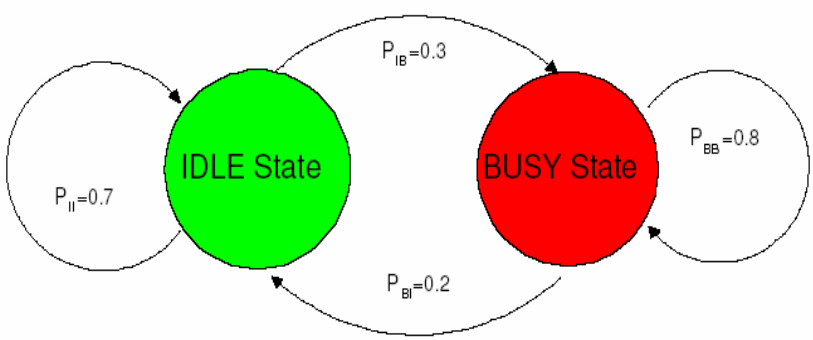


Figure 3.1: The Markov-Modulated Poisson Process.

Scenario of the Burst ACK Mechanism

- In our system, we use the Markov-Modulated Poisson Process (MMPP) to simulate the arrival traffic of each station.
- The MMPP has two states: idle state and busy state. In idle state, no packets are generated, namely, the arrival data rate is exactly zero. In busy state, packets arrive the queue according to a Poisson distribution with mean data arrival rate λ = 300 packet/second.

Scenario of the Burst ACK Mechanism

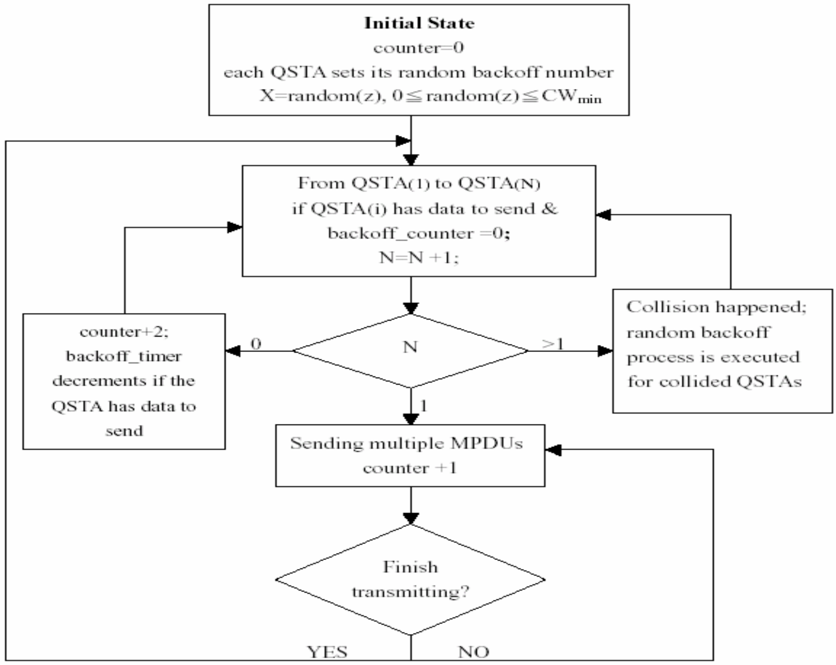
- Two scenarios are considered in our simulation of the Burst ACK Mechanism. The first one considers no RTS/CTS exchange, while the second one includes the RTS/CTS exchange. In addition, only ac hoc topology is investigated in our research.
- In our ad hoc network system, all the QSTAs are assumed to be in the same QBSS, and are within the radio range of all the other QSTAs; so the hidden node problem is excluded.
- Furthermore, all the QSTAs are operated in awake mode, namely no power-saving QSTAs reside in the QBSS.

Scenario of the Burst ACK Mechanism

Data Rate (Mbps)	10
A SIFS Time (us)	10
A DIFS Time (us)	50
A Slot Time (us)	20
CW_{min} (slots)	7
CW values in between (slots)	15, 31, 63, 127
CW_{max} (slots)	255
Packet Size (byte)	1000
Number of QSTAs	2~30
TX Queue Size (Kbyte or 1000 bytes)	16~32768
Burst Length (packets)	1~16

Scenario of the Burst ACK Mechanism

- In total, 200,000 packets of length 1000 bytes are sent during the entire simulation.
- The channel is presumed to be error-free; hence, there is no packet loss or packet error due to interference or multipath effect.
- For simplicity, the receiving queue of each QSTA is supposed infinite in length, and the transmission time of ACK frames is assumed negligible, if being compared to the transmission time of data frames.
- Also neglected in our performance calculation is the set stage during which the originator and the recipient exchanged Define Burst ACK frames to handshake the system setting.



Scenario of the Enhance Distributed Coordination Function (EDCF)

- In our EDCF simulation, we restrict our consideration to a situation in which each QSTA only consists of one AC (i.e., only has one priority). We then evaluate the system performance of an ad hoc wireless LAN with QSTAs having different priorities.

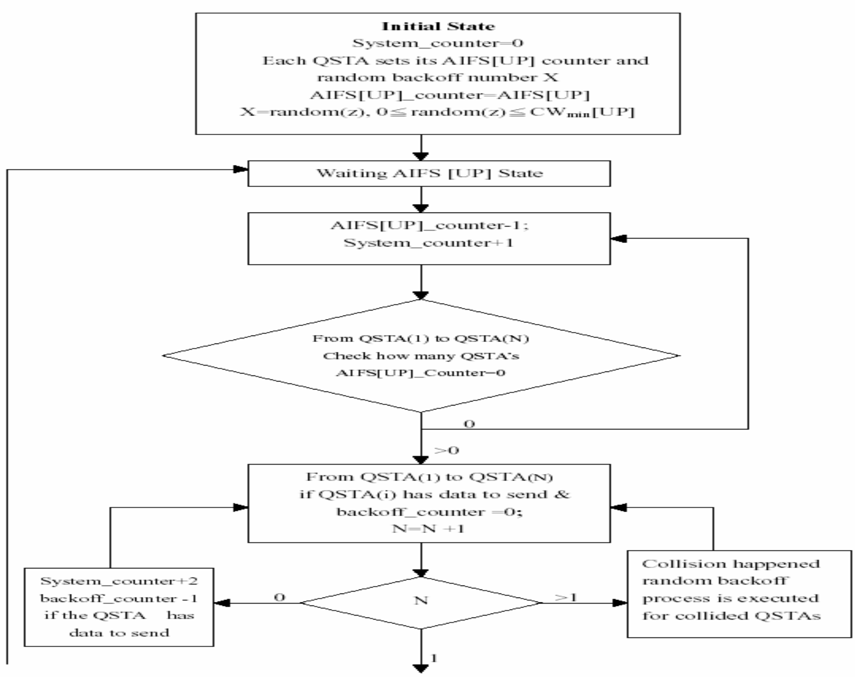
- Each QSTA sends out one packet whenever it wins the contention. (In this simulation, we consider no Burst ACK Mechanism for simplicity.)

Scenario of the Enhance Distributed Coordination Function (EDCF)

- Data rate, SIFS, DIFS, slot time and packet size, are the same as those used in Burst ACK Mechanism Simulation.(ps. Page 21)
- The TX queue size is set to be 1,024 Kbytes, and RX queue size is assumed infinite.

Table 3.2: The CW values (in slot times) of QSTAs.

Priority	AIFS (us)	CW_{min}	CW used inbetween				CW_{max}
0	50	7	15	31	63	127	255
1	70	9	19	39	79	159	319
2	90	11	23	47	95	191	383
3	110	13	27	55	111	223	447



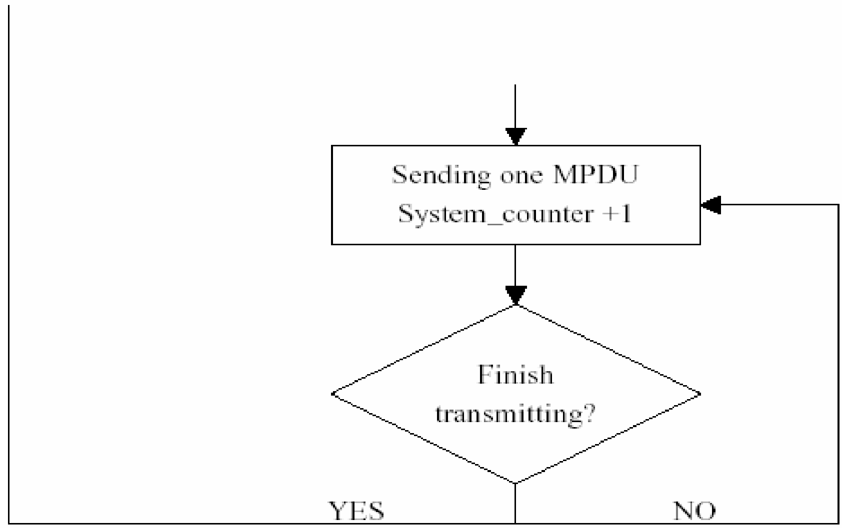
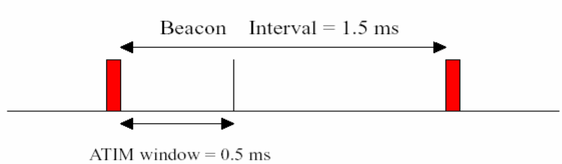


Figure 3.3: The Simulation Flow Chart of the EDCF.

Scenario of the power-saving stations in an ad hoc network

- Consider an ad hoc network that is composed of power-saving stations.
- Slot time, SIFS, DIFS, packet size, data rate, data arrival rate, TX queue size and RX queue size, are all the same as those in the EDCF scenario.(ps. Page 25)
- The Beacon Interval and ATIM window are assumed 1.5 milliseconds and 0.5 milliseconds in IEEE 802.11b ad hoc network, respectively.

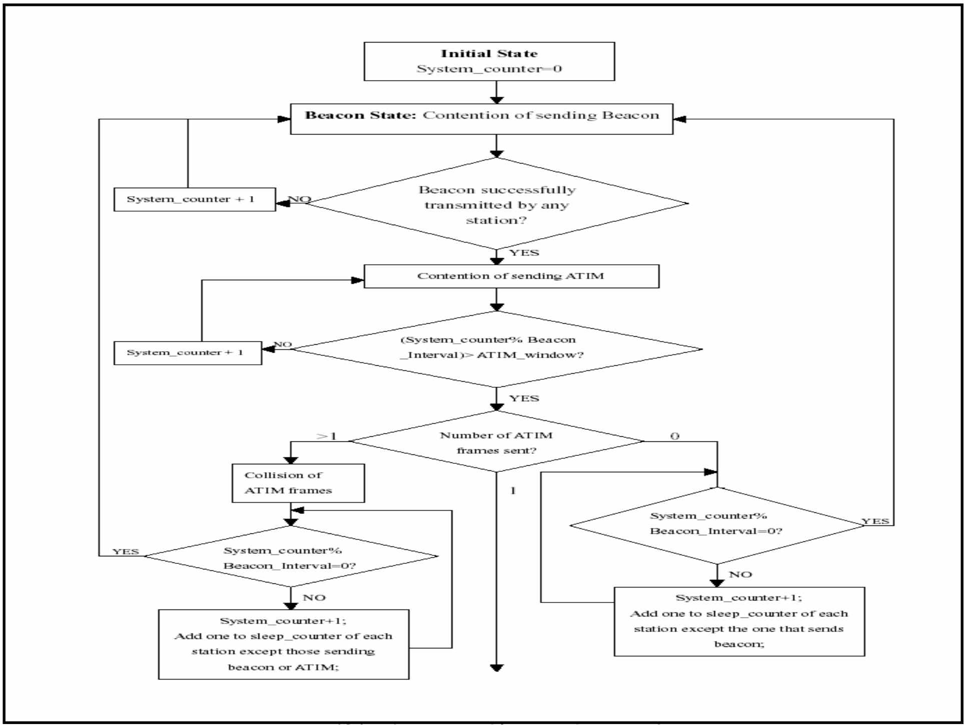


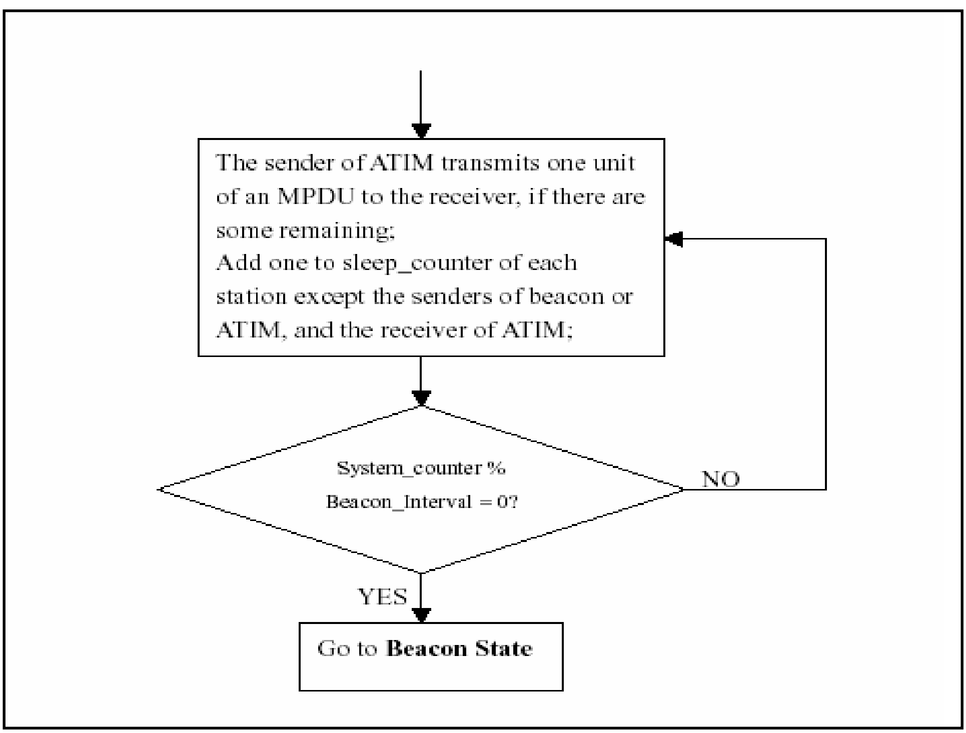
Scenario of the power-saving stations in an ad hoc network

- The $CW_{min,ATIM}$ and $CW_{max,ATIM}$ used in the backoff procedure in transmitting ATIM frames are set to 15 and 63 slot times, respectively.
- Besides, the $CW_{min,data}$ and $CW_{max,data}$ for the transmission of data frames are set to 7 and 255 slot times, respectively.

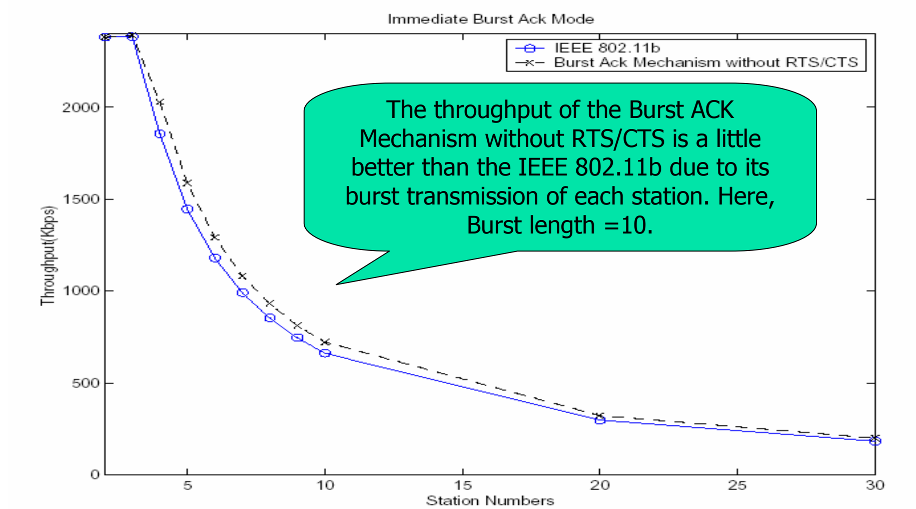
Scenario of the power-saving stations in an ad hoc network

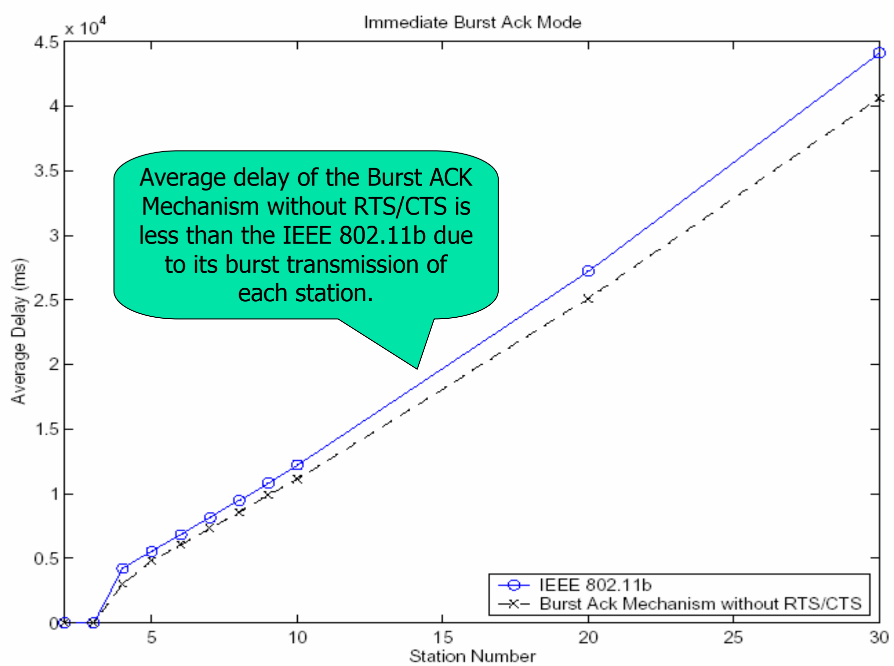
- For the burst length of two packets, the Beacon Interval is 2.5 milliseconds.
- When the burst length increases to three packets, the Beacon Interval is 3.5 milliseconds.
- The ATIM window, however, remains the same as 0.5 milliseconds, independent of the burst length taken.


Initial State
System_counter=0
Beacon State: Contention of sending Beacon
Beacon successfully transmitted by any station?
System_counter + 1
NO
YES
Contention of sending ATIM
(System_counter% Beacon _Interval)> ATIM_window?
System_counter + 1
NO
YES
Number of ATIM frames sent?
>1
0
1
Collision of ATIM frames
System_counter% Beacon_Interval=0?
YES
NO
System_counter+1; Add one to sleep_counter of each station except those sending beacon or ATIM;
System_counter% Beacon_Interval=0?
YES
NO
System_counter+1; Add one to sleep_counter of each station except the one that sends beacon;


The sender of ATIM transmits one unit of an MPDU to the receiver, if there are some remaining;
Add one to sleep_counter of each station except the senders of beacon or ATIM, and the receiver of ATIM;
System_counter % Beacon_Interval = 0?
NO
YES
Go to Beacon State

Simulation Results





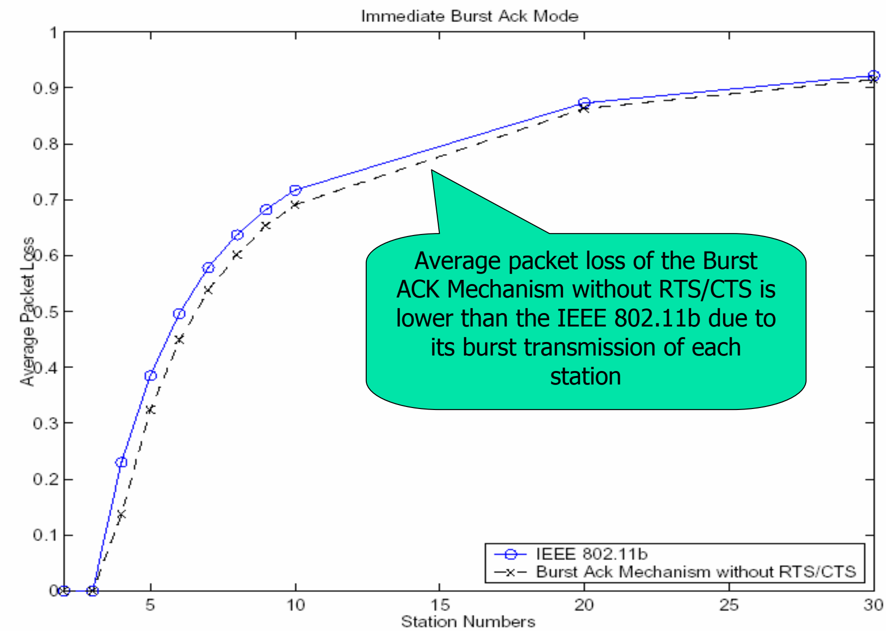


Figure 4.3: The packet loss rate versus the number of QSTAs.

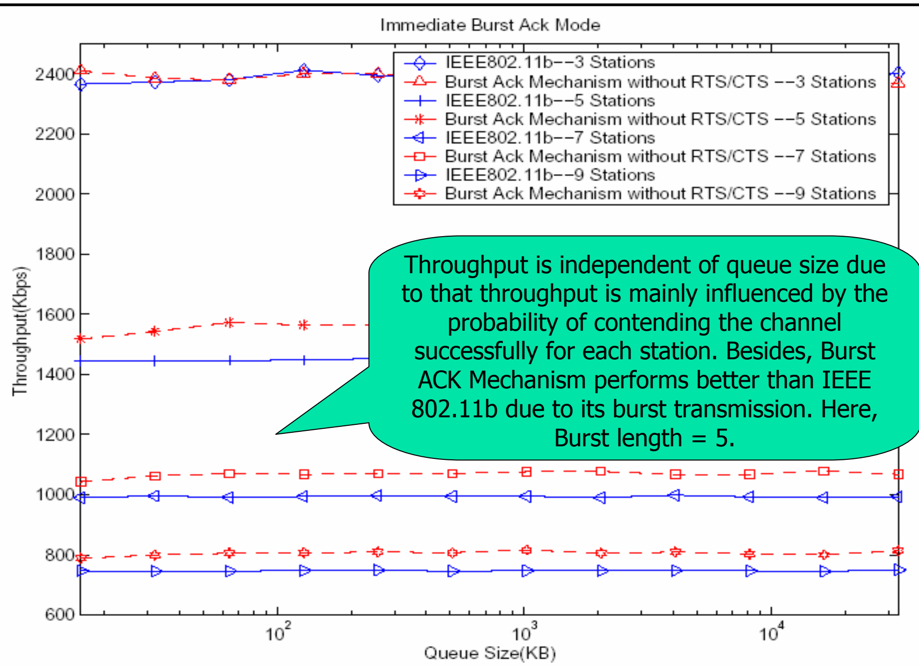


Figure 4.4: The system throughput versus the TX queue size.

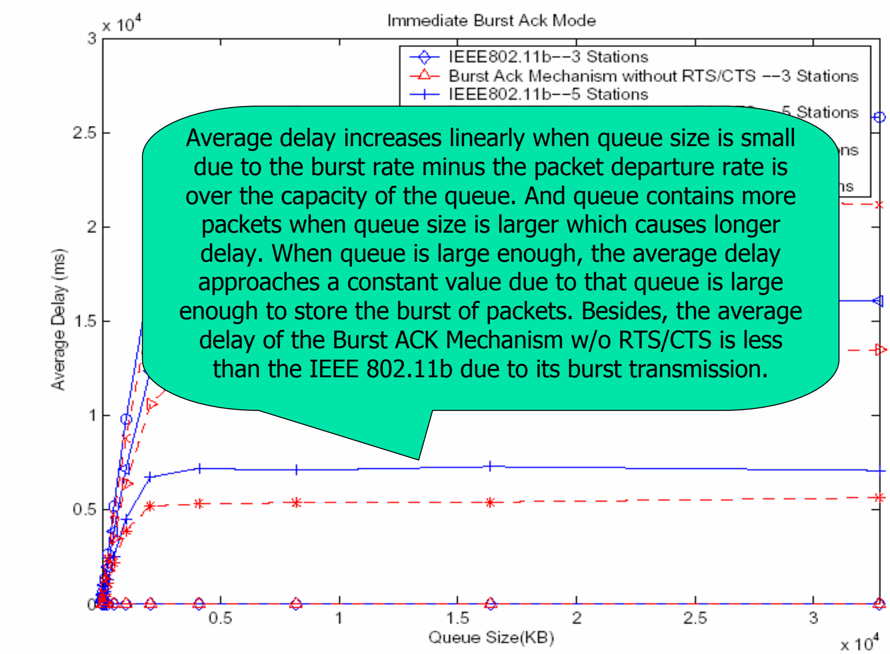


Figure 4.5: The average queueing delay versus the TX queue size.

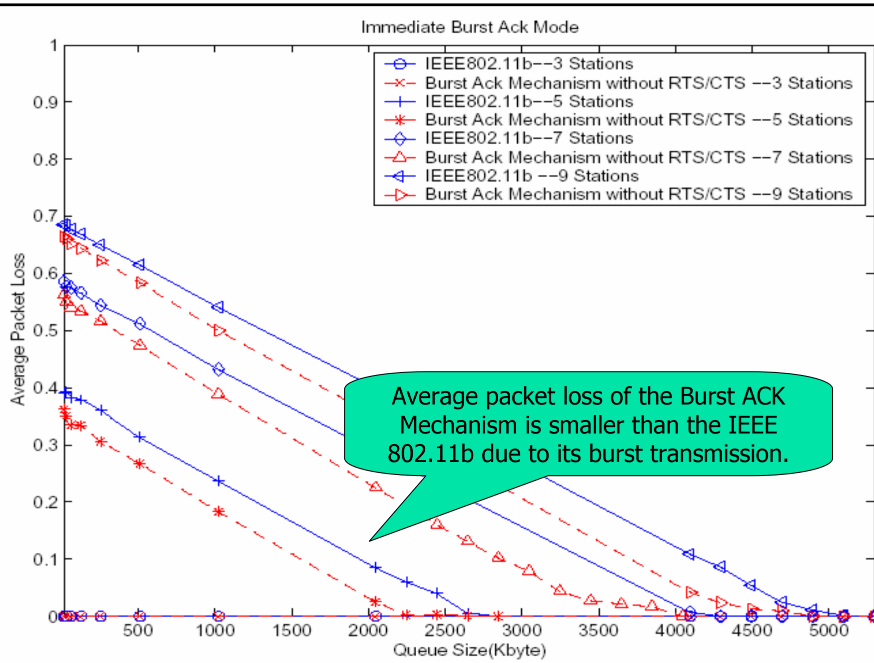


Figure 4.6: The packet loss rate versus the TX queue size.

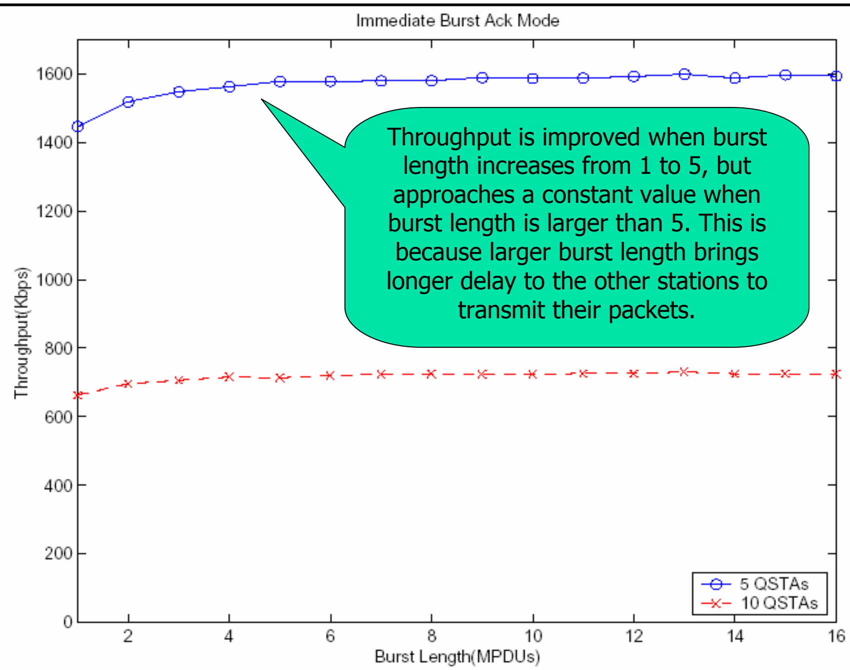


Figure 4.7: The system throughput versus the burst length.

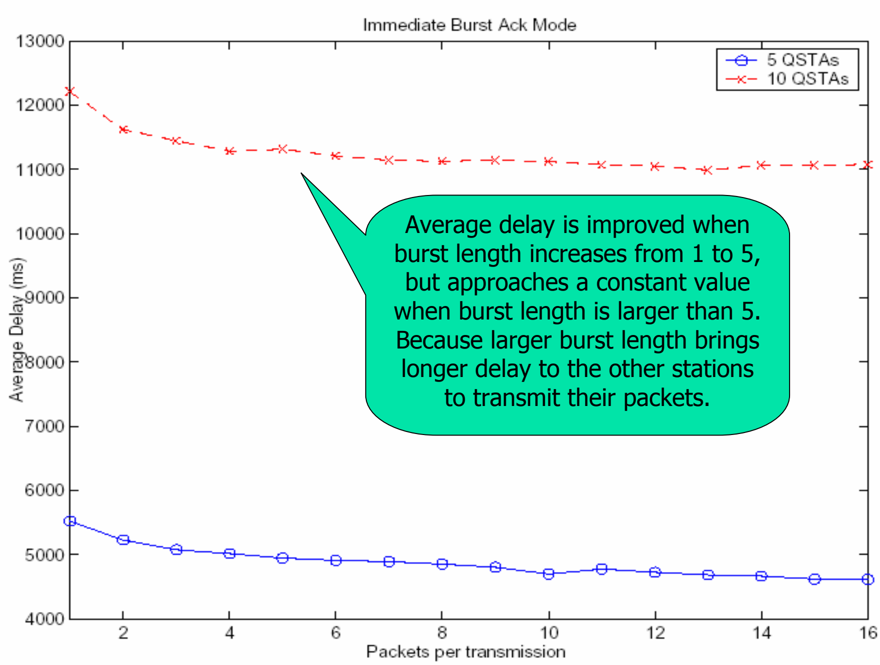


Figure 4.8: The average queueing delay versus the burst length.

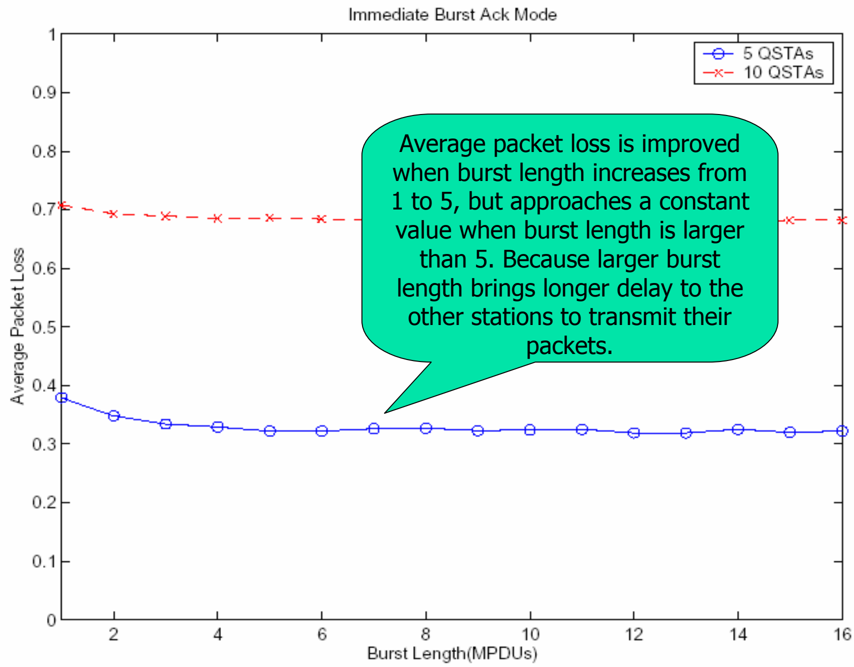


Figure 4.9: The packet loss rate versus the burst length.

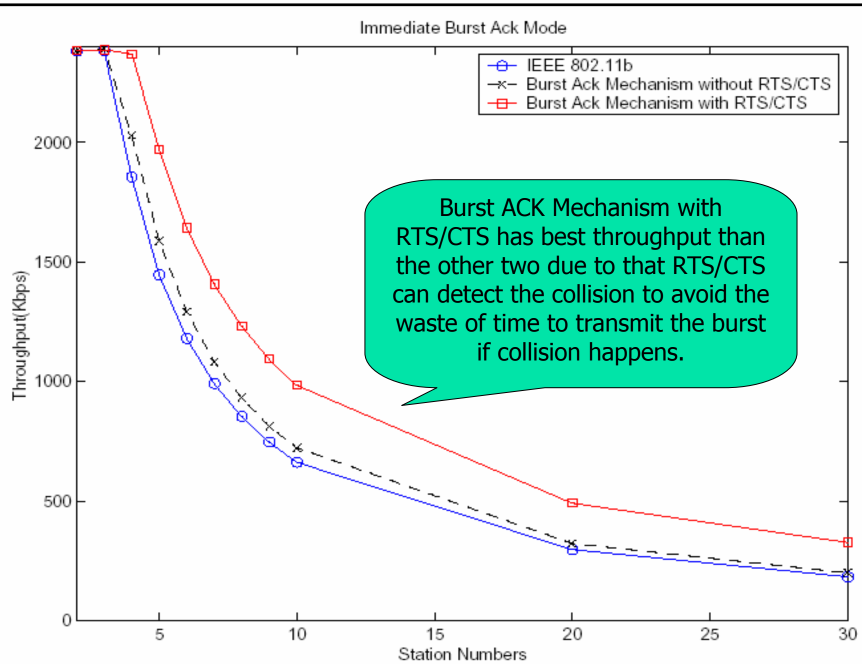


Figure 4.10: The system throughput versus the the number of QSTAs.

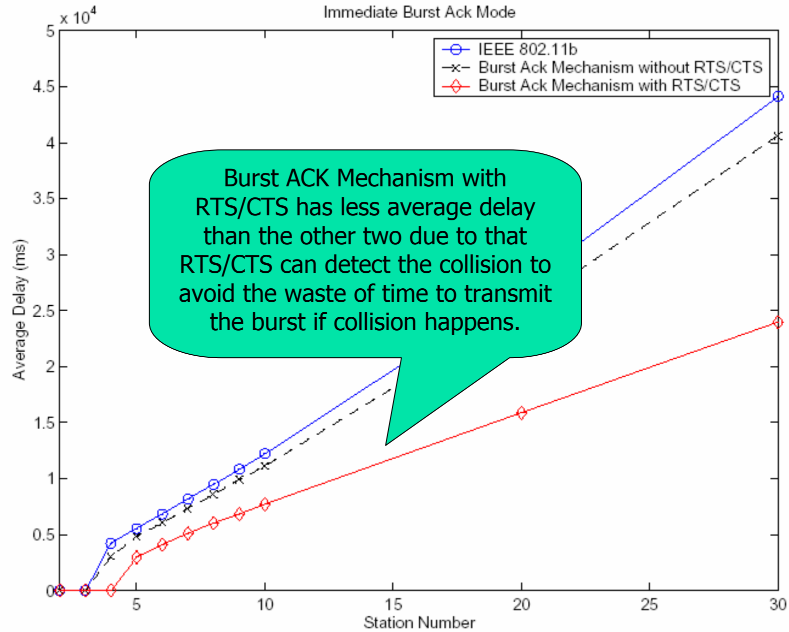


Figure 4.11: The average queueing delay versus the the number of QSTAs.

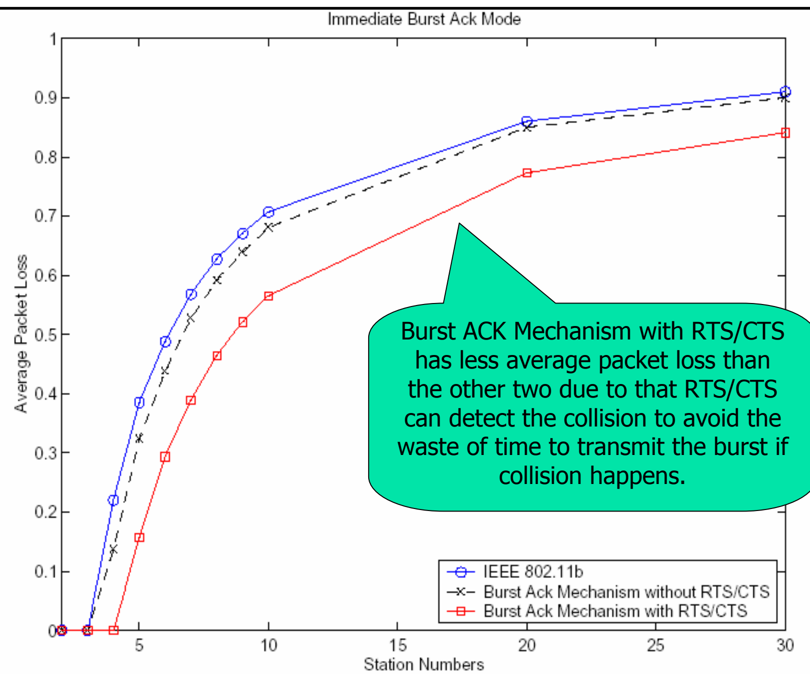


Figure 4.12: The average packet loss versus the number of QSTAs.

Performance of the Enhanced Distributed Coordination Function

Table 4.1: The throughput of the QSTAs with different priorities.

	Average throughput(Kbps)	Normalized to the average throughput of QSTA 7
QSTA 0(priority 0)	2371.723	14.5
QSTA 1(priority 0)	2393.956	14.6
QSTA 2(priority 1)	1395.085	8.5
QSTA 3(priority 1)	1348.988	8.2
QSTA 4(priority 2)	494.848	3.0
QSTA 5(priority 2)	475.923	2.9
QSTA 6(priority 3)	178.300	1.1
QSTA 7(priority 3)	163.611	1.0

Performance of the Enhanced Distributed Coordination Function

Table 4.2: The average queueing delay of the QSTAs with different priorities.

	Average queueing delay(ms)	Normalized to the average queueing delay of QSTA 0
QSTA 0(priority 0)	11.47	1
QSTA 1(priority 0)	11.11	0.97
QSTA 2(priority 1)	6445.08	561.9
QSTA 3(priority 1)	6668.50	581.4
QSTA 4(priority 2)	18384.51	1602.8
QSTA 5(priority 2)	19125.55	1667.4
QSTA 6(priority 3)	51176.59	4461.8
QSTA 7(priority 3)	55727.88	4858.6

Performance of the Enhanced Distributed Coordination Function

Table 4.3: The average packet loss rate of the QSTAs with different priorities.

	Average packet loss rate
QSTA 0(priority 0)	0
QSTA 1(priority 0)	0
QSTA 2(priority 1)	0.40
QSTA 3(priority 1)	0.42
QSTA 4(priority 2)	0.77
QSTA 5(priority 2)	0.78
QSTA 6(priority 3)	0.90
QSTA 7(priority 3)	0.91

Power Economy of Burst ACK Mechanism

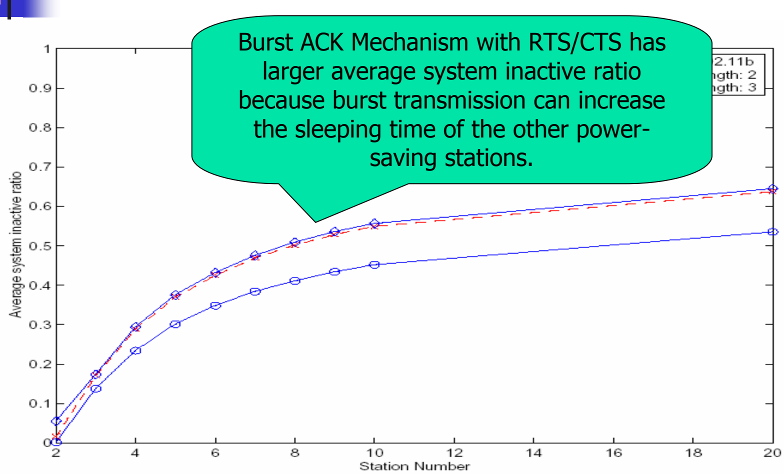


Figure 4.13: Average system inactive ratio versus the number of QSTAs.

Power Economy of Burst ACK Mechanism

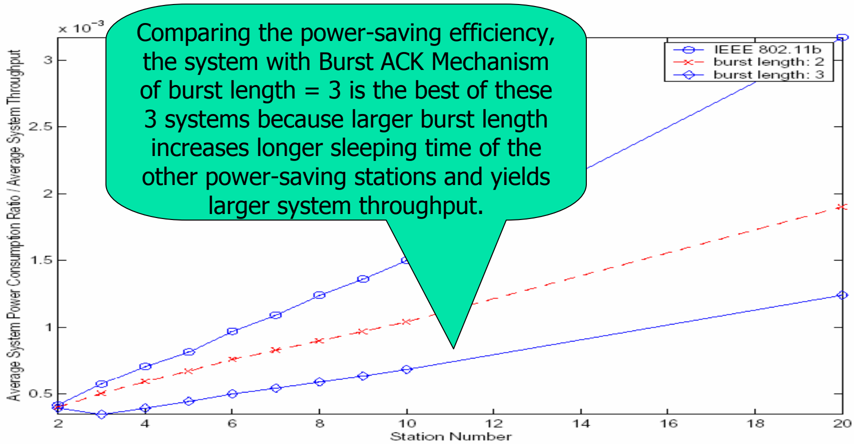


Figure 4.14: Average system power consumption ratio over average system throughput versus the number of QSTAs.

Conclusions

- The immediate Burst ACK Mechanism without RTS/CTS improves the performance of the legacy IEEE 802.11 network in all three performance indices (Throughput, Delay, Packet Loss Rate), although limited.
- A marked improvement can be obtained if RTS/CTS exchange is additionally enabled. This is because that RTS/CTS exchange can detect the collision before the burst transmission starts and avoid the waste of time to transmit the burst of packets.

Conclusions

- The simulations on the EDCF imply that by a proper adjustment of CW_{max}, CW_{min} and AIFS, we may statistically fulfill the needs of services with different QoS requirements.

- The immediate Burst ACK Mechanism with RTS/CTS is more power economic in an ad hoc network.

Future Works

- Since the proposals of the IEEE 802.11e, such as HCF and DLP are also important part of the draft standard, their performance evaluation of them is one possible future work.

- Further, we can examine the performance of various combination of all these proposed mechanisms, and provide more insight suggestions to future standard.