Physical Layer Effects on MAC Layer Performance of IEEE 802.11 a and b WLAN on the Martian Surface

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Abstract—The MAC layer performance of IEEE 802.11a and b WLAN standards on the Martian surface is studied. The Gusev Crater region and the Meridiani Planum (Hematite) region are chosen as example sites based on the mission science and mission success criteria. The radio frequency (RF) multipath environment is obtained using digital elevation maps (DEMs) from the Mars Global Surveyor mission, taking into account the atmosphere and other factors on the Martian surface. Two methods are presented to incorporate the physical layer effects on the Martian surface into the OPNET modeler. Simple network configurations are considered. Three performance metrics are used: energy per successful bit, throughput per unit load and average delay. The effects of packet size, data rates, retry limits are studied and the use of RAKE receivers for 802.11b is considered. It is observed that the transmission parameters must be carefully selected in order to have acceptable performance levels. Larger packet sizes improve energy efficiency but increase delay and reduce throughput. For 802.11a, the 12 Mbps rate is found to provide acceptable results. For 802.11b, the 11 Mbps rate provides good results when a RAKE receiver is employed. Overall, the performance of 802.11a is found to be better than the performance of 802.11b.

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1. INTRODUCTION

Future Mars exploration missions may involve setting up of proximity wireless networks on the Martian surface for collecting data from different locations. These networks have to be reliable, robust and power efficient. Instead of developing and testing such networks from scratch, a cost effective approach would be to adapt existing technology with appropriate modifications. Towards this objective, this paper investigates the medium access control (MAC) layer performance of two well known wireless local area network (WLAN) standards IEEE 802.11a and IEEE802.11b on the Martian surface.

In previous work [1], the physical layer performance of the IEEE 802.11a and b WLANs on the Martian surface has been extensively studied. In particular, using the received power and multipath results from [2],[3], simulations have been carried out for different data rates on several sites on the Martian surface. Physical layer results in terms of bit error rate (BER) and packet error rate (PER) have been obtained. The effect of antenna height and transmit power has also been investigated. It has been observed in this work that successful communication is possible within a few hundred meters of the transmit antenna when the transmit power is more than 1 mW and the antenna heights are fixed at about 1.5 m above the ground. Further, it has been observed that while the packet error rate performance of 802.11b is more adversely affected by the multipath effects than 802.11a, significant improvement in performance is obtained by using a RAKE receiver for 802.11b.

This paper continues the previous work of [1] by presenting the effects of the physical layer on the MAC layer performance of both IEEE 802.11a and b. MAC layer statistics such as the energy per successful bit, mean throughput per unit load and mean delay have been obtained for ad–hoc networks set up at two different sites on the Martian surface. It is observed that multipath adversely affects the MAC throughput as well as the mean packet delay due to significant number of retransmissions.

This paper is organized as follows. In Section 2, we provide an overview of the 802.11 MAC layer specifications. The basic access mechanism and the general 802.11 MAC frame format are described in this section. In Section 3, our simulation methodology is described. Section 4 presents the MAC simulation results such as the energy per successful bit, throughput per unit load and delay at different sites for various scenarios.

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A discussion on the interpretations of the simulation results is presented in Section 5. Finally, Section 6 presents the conclusions of our study.

2. IEEE 802.11 WLAN MAC

In this section, we present a brief overview of the MAC layer specifications of the IEEE 802.11 standard [4], [5]. The physical layer details, as relevant to this paper, can be found in the standards [4], [6] or in our earlier work [1]. The 802.11 MAC supports two modes of operation: the contention based distributed coordination function (DCF) and the contention free point coordination function (PCF). In this section, however, only the default DCF mode is discussed. The MAC layer is common for both 802.11 a and b standards.

The DCF mode of operation is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) together with binary exponential backoff. A wireless station, which wants to transmit, senses the medium (physically and virtually). Due to the inability of every wireless station to communicate directly with every other wireless station in the network, a virtual carrier sensing mechanism is implemented in IEEE 802.11 MAC through the use of a network allocation vector (NAV) in addition to the physical carrier sense.

NAV is included in every transmitted frame to indicate to a listening station the amount of time after which the wireless medium will become available. A listening station avoids a frame transmission by examining the NAV value even when it detects that the medium is idle through a physical carrier sense. If it finds the medium idle for a DIFS amount of time, it begins its transmission. If, however, the station finds the medium busy during the DIFS interval, it defers its transmission by a random amount of time (in slots) as determined by binary exponential backoff algorithm and increments the appropriate retry counter. During each backoff slot the medium is sensed for activity. If the medium is idle for the duration of a particular backoff slot, the backoff algorithm decrements the backoff time by a slot time. If the medium is busy at any time during a backoff slot, the backoff timer is not decremented for that slot. Backoff procedure resumes only when the medium has been sensed to be idle for DIFS amount of time. A frame is transmitted whenever the backoff timer reaches zero. In case an ACK is not received, i.e. transmission is unsuccessful, the contention window size is doubled and the backoff procedure is started all over again.

Bytes: 2	2	6	6	6	2	0-2304	4
Frame Control	Duration /ID	Address 1	Address 2	Address 3	Sequence Control	Frame Body	FCS

MAC Header

Figure 1. General MAC frame format

The general 802.11 MAC frame format is shown in Fig. 1. It consists of three parts: the 24 byte MAC header, the variable length (maximum 2304 bytes) frame body and the 4 byte frame check sequence (FCS). The MAC header consists of frame control, duration/ID, sequence control and address fields. The frame control field indicates whether a frame is a data, control or management frame and also provides fragmentation, retry, power management and privacy information. The duration/ID field indicates the time the channel will be allocated for successful transmission of MAC frame. Also, in some control frames, it contains association or connection identifier. The MAC header contains upto four address fields which include addresses of source, destination, transmitting and receiving stations. However we ignore the fourth address field which is used for the distribution of wireless distribution system (WDS) frames which are rarely used. The sequence control field contains information for fragmentation and reassembly as well as a sequence number to number frames between given transmitter and receiver. The frame body contains information specific to particular data or management frames. The FCS is a 32–bit CCITT–CRC protecting the MAC header and frame body. An empty MAC frame, i.e., a MAC frame with no data is 28 bytes long.

As given in [7], for 802.11a, the time required to transmit an l–byte packet is

$$\begin{aligned} T_{data}(l,m) &= tPLCPPreamble + tPLCP\_SIG \\ &+ \left\lceil \frac{30.75 + l}{BpS(m)} \right\rceil tSymbol \\ &= 20\mu s + \left\lceil \frac{30.75 + l}{BpS(m)} \right\rceil 4\mu s \end{aligned}$$

where

$tPLCPPreamble$ = PLCP preamble duration = $16\mu s$
$tPLCP\_SIG$ = PLCP signal field duration = $4\mu s$
$tSymbol$ = OFDM symbol interval = $4\mu s$
$BpS(m)$ = Bytes per symbol for 802.11a PHY mode *m* as obtained from Table 2

For 802.11b, the time required to transmit an l–byte packet is

$$\begin{aligned} T_{data}(l) &= tPLCPPreamble + tPLCPHeader \\ &+ \frac{8(l + 28)}{DataRate} \\ &= 192\mu s + \frac{8(l + 28)}{DataRate} \end{aligned}$$

where

$tPLCPPreamble$ = PLCP preamble duration = $144\mu s$
$tPLCPHeader$ = PLCP header duration = $48\mu s$
$DataRate$ = 1, 2, 5.5 or 11 Mbps

3. Simulation Methodology

The physical layer simulation software has been developed in MATLAB using the mWLAN toolbox from CommAccess

Technologies [8]. This software requires multipath channel coefficient values on the Martian surface in order to simulate the transmission and reception of 802.11a and b data packets. These coefficients are obtained using the ICS Telecom software from ATDI [9]. Digital Elevation Map (DEM) files are converted to ATDI's format for the Martian sites (11m/pixel resolution), and are loaded into the software to generate the multipath coefficients.

The MAC layer performance is studied using OPNET [10] modules. OPNET is a discrete event simulator and is highly suited for performing MAC layer simulations. However, OPNET does not provide any detail physical layer platform to incorporate the Martian multipath environment. We propose two solutions: (1) OPNET directly calls MATLAB functions that simulate the physical layer behavior for each individual data packet. So the MATLAB functions run in conjunction with the OPNET modules, thus providing cosimulation results. (2) In the second approach, the physical layer behavior is first studied using the MATLAB functions, and probabilistic models are developed. These probabilistic parameters are then passed on to OPNET. Thus cosimulation of OPNET and MATLAB is avoided.

The OPNET Wireless Module includes a standard IEEE 802.11 MAC simulation model. In this model, the decision whether a packet is good or bad is made based on the received power. The packet is considered to be valid if the received power is above a user-defined threshold. However, if the received power is below the threshold, the packet is marked bad and is considered as noise. To see the effect of Martian terrain on the 802.11 MAC layer, modifications are made to the standard OPNET 802.11 MAC simulation Model. The standard OPNET method to compute a packet's received power based on the free space propagation model is not used. Instead, in our first cosimulation approach, a packet's source and destination addresses are passed from OPNET to the MATLAB physical layer simulation module. Based on these addresses, an appropriate Martian power delay profile (PDP) is selected and a physical layer simulation is carried out in MATLAB for that PDP. It is ensured that the data rate, packet size and transmit power used in the MATLAB physical layer simulation are the same as defined in the OPNET 802.11 MAC simulation model. If the packet is successfully received at the physical layer (all the bits in the packet are received correctly), the received power is set above the threshold, otherwise it is set below the threshold. This received power value is sent back to OPNET and the packet is then treated accordingly by the OPNET 802.11 MAC simulation model. This approach is highly beneficial as we do not need to make any assumptions for the physical layer.

Although the cosimulation approach reflects reality more closely, the long simulation run time sometimes becomes unacceptable. Especially when high packet arrival rates (1000 packets per second) are considered cosimulation time requirements become prohibitive. Thus, the second approach becomes important and is used in our paper. In this approach, we first obtain a physical layer PER estimate using the MATLAB simulation modules for the given transmitter and receiver locations on the Martian surface. The MAC layer simulations are then carried out in OPNET based on this PER. Each data packet is randomly regarded as a successful or as an unsuccessful packet depending on the PER value. This approach drastically cuts down on the simulation time. The delay/throughput results obtained using our two approaches are shown Figures 2 and 3 for 802.11a and b respectively. In case of 802.11a, perfect agreement has been observed throughout the simulation period. In the case of 802.11b, there is difference during the initial transition period due to random initializations. However, the steady state values of the two approaches agree very well. We note that our paper investigates the steady state values.

In our study, several MAC layer performance metrics are considered: (1) delay, (2) throughput per unit load, and (2) energy per successful bit. The delay is defined as the average time taken by a packet to be successfully delivered from a transmitter to the desired receiver. It includes the time spent during retransmission of a packet. The throughput in bits/sec is defined as the average number of bits successfully received per second by the MAC layer and delivered to the higher layer. The load is defined as the average number of bits delivered per second by the higher layer to the MAC layer. Finally, energy per successful data bit is defined as ratio of the the total number of data bits successfully delivered to the total energy spent. The total energy spent includes the energy spent during successful transmission of a packet plus the energy spent during any retransmission attempts of the packet. All the physical and MAC layer overheads are taken into account to calculate the energy of a packet.

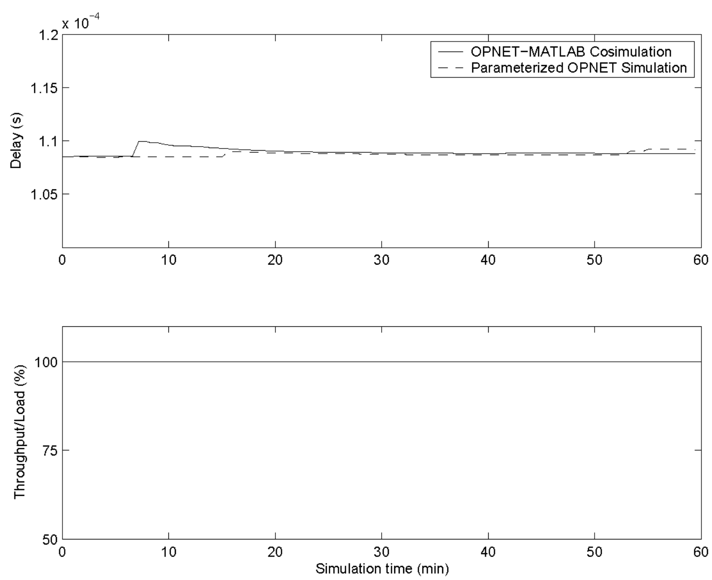

Figure 2. Validation of cosimulation for 802.11a–12 Mbps–Hematite4 Site1–Packet size=100 bytes–Number of retries=7

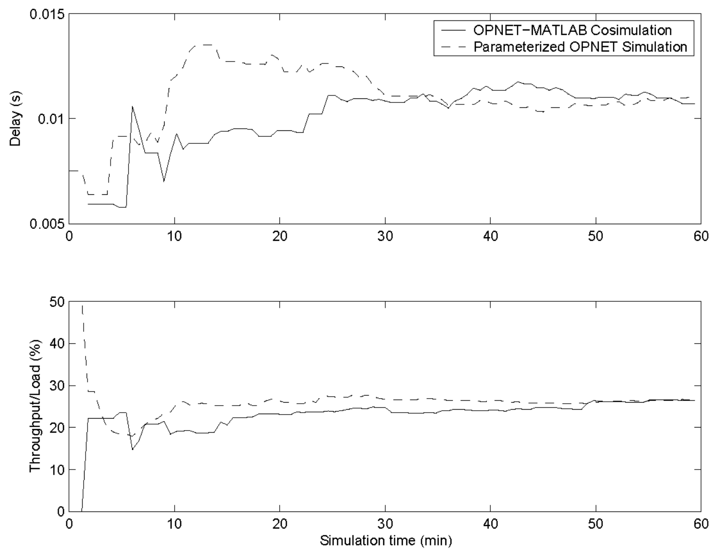

Figure 3. Validation of cosimulation for 802.11b–11 Mbps–Hematite4 Site1–Packet size=100 bytes–Number of retries=7

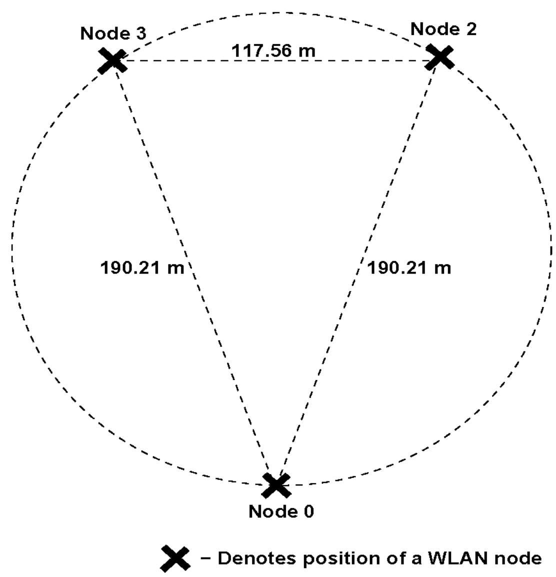

Figure 4. Position of nodes for MAC Layer Simulations

The IEEE802.11b protocol is studied with and without the use of a RAKE receiver. The RAKE receiver passes the signal through a delay line [11]. The delayed versions are then matched with the spreading sequences and then combined by weighting with the corresponding estimated multipath components. Each delayed version is called a finger of the RAKE. In our results, as high as 100 fingers (depending on the multipath scenario) have been used.

Mode	Modulation	Code Rate	Data Rate	BpS
1	BPSK	1/2	6 Mbps	3
2	BPSK	3/4	9 Mbps	4.5
3	QPSK	1/2	12 Mbps	6
4	QPSK	3/4	18 Mbps	9
5	16-QAM	1/2	24 Mbps	12
6	16-QAM	3/4	36 Mbps	18
7	64-QAM	2/3	48 Mbps	24
8	64-QAM	3/4	54 Mbps	27

Table 2. IEEE 802.11a data rates

4. PERFORMANCE AT DIFFERENT SITES

We perform our study at two sites: Hematite4 Site1 and Gusev1 Site1. The reasons for selecting the Gusev and Hematite sites are described in [1]. A 3-node *ad-hoc* network is considered at each location. The three nodes are placed on a circle as shown in Fig. 4. The location of the center of the circle for each site is given in Table 4. Although not shown in this paper, an increase in the number of nodes from 3 to 5 is found to have no significant effect particularly at low packet arrival rates.

Site	*Mars Latitude*	*Mars Longitude*
Gusev1 - Site 1	$14^\circ\ 47'\ 39.35''$ S	$176^\circ\ 1'\ 29.18''$ E
Hematite4 - Site 1	$2^\circ\ 11'\ 0.69''$ S	$-5^\circ\ 53'\ 5.16''$ E

Table 1. Sites for WLAN Performance Study.

In all our numerical results, we use 1mW transmit power and the antenna heights are fixed at 1.5 m above the ground. As we will see, the delay spread plays a vital role on the performance. For the locations chosen in Hematite4 Site1, maximum rms delay spread is observed to be 0.13 μs for 802.11a and 0.19 μs for 802.11b. Similarly, the maximum of the maximum delay spread (considering all the nodes) is found to be 6.2 μs for 802.11a and 12.26 μs for 802.11b. For the locations in Gusev1 Site1, maximum rms delay spread is observed to be 2.7 μs for 802.11a and 6.37 μs for 802.11b. The maximum of the maximum delay spread is observed to be 47.2 μs for both 802.11a and 802.11b. Thus Gusev1 Site1 delay spread results in this case are much worse than the Hematite results. The effects of packet size, data rates, packet arrival rates and retry limits are studied.

Effect of Retry Limits and Packet Arrival Rates

The effects of retry limit and packet arrival rates on delay, throughput per unit load and energy per successful bit are studied in Figs. 5 and 6. The retry limit is the maximum number of attempts that a particular node can make for sending a packet. In the case of 802.11a, we observe that the performance is almost independent of the retry limit chosen. This is because the received signal is very good and almost 100% throughput per unit load is achieved. Most of the packets have been successfully transmitted in the first attempt and other retry values are hardly tried. This is not the case with

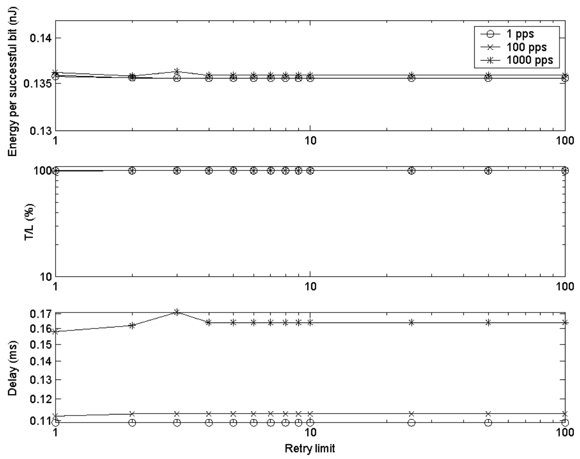

Figure 5. Effect of retry limit and packet arrival rate on 802.11a for Hematite4 Site1. The data rate is 12 Mbps and the packet size is 100 bytes

802.11b without RAKE. Significant number of packets are lost due to poor physical layer behavior. A very high retry limit can make the delay unacceptably high although throughput increases. More retry values can improve throughput per unit load, but the energy per successful bit starts increasing after a certain value. For an energy constrained scenario, as in the case of the Martian surface, this value needs to be small. Hence, a reasonably small value, such as 8 for example, may be a good choice in this case.

The packet arrival rates too seem to affect 802.11b more than 802.11a. In the case of 802.11a, only the delay seems to be significantly affected when the packet arrival rate increases from 1 pps to 1000 pps. This is because collisions become high. In the case of 802.11b, higher packet arrival rates significantly degrades the performance.

The effects of retry limits are also studied via Tables 3 and 4 for Hematite4Site1 and Gusev1Site1. Since Gusev1 site delay spread is worse than Hematite4 site for the particular transmitter receiver locations used in our study, we observe poor performance at Gusev1 site for both 802.11a and 802.11b. In the case of the Hematite4 site, the performance of 802.11a is practically independent of retry limit. However, in the case of the Gusev1 site, throughput per unit load improves with increase in the retry limit. The delay, on the other hand, can become unacceptably large. Due to the use of the RAKE receiver, the performance of 802.11b improves significantly over those shown in Figs 5 and 6. However, the delay still remains very high for larger retry limits. It appears that 802.11a is performing better in almost all cases.

Effects of Packet Size

Tables 5 and 6 show the effects of different packet sizes for the Hematite and Gusev sites respectively. With an increase in the packet size, the energy wastage due to the overhead

Retry limit	Energy per successful bit (nJ)		Mean throughput per unit load		Delay (ms)	
	802.11a	802.11b	802.11a	802.11b	802.11a	802.11b
1	0.136	0.503	99.67	87.16	0.158	223.2
2	0.136	0.463	99.99	98.36	0.162	2.81×10^3
3	0.136	0.474	100.00	99.58	0.171	6.27×10^3
4	0.136	0.472	100.00	99.33	0.164	7.51×10^3
5	0.136	0.475	100.00	99.98	0.164	7.25×10^3
6	0.136	0.469	100.00	100.00	0.164	6.67×10^3
7	0.136	0.471	100.00	100.00	0.164	7.74×10^3
8	0.136	0.463	100.00	100.00	0.164	3.67×10^3
9	0.136	0.467	100.00	99.47	0.164	6.17×10^3
10	0.136	0.476	100.00	99.99	0.164	1.00×10^4

Table 3. Comparison of MAC layer statistics for 802.11a and 802.11b (RAKE) for Hematite4 Site1. The data rates are 12 Mbps and 11 Mbps for 802.11a and b respectively. The packet size is 100 bytes, and the packet arrival rate is 1000 packets per second.

Retry limit	Energy per successful bit (nJ)		Mean throughput per unit load		Delay (ms)	
	802.11a	802.11b	802.11a	802.11b	802.11a	802.11b
1	0.530	1.176	45.60	52.01	0.16	378.80
2	0.467	1.062	69.89	75.52	0.59	1.1×10^4
3	0.476	1.083	82.85	87.17	77.00	3.0×10^4
4	0.506	1.159	89.65	90.24	3.5×10^3	6.5×10^4
5	0.531	0.687	93.06	93.05	1.1×10^4	2.6×10^5
6	0.544	1.258	96.69	88.41	2.0×10^4	3.5×10^5
7	0.560	1.289	97.19	82.70	3.9×10^4	4.1×10^5
8	0.581	1.434	98.52	65.42	5.7×10^4	7.7×10^5
9	0.598	1.377	98.53	74.24	7.2×10^4	6.8×10^5
10	0.612	1.394	98.22	73.56	1.0×10^5	7.3×10^5

Table 4. Comparison of MAC layer statistics for 802.11a and 802.11b (RAKE) at Gusev1 Site1. The data rates are 12 Mbps and 11 Mbps for 802.11a and b respectively. The packet size is 100 bytes, and the packet arrival rate is 1000 packets per second.

Packet size (bytes)	Energy per successful bit (nJ)		Mean throughput per unit load		Delay (ms)	
	802.11a	802.11b	802.11a	802.11b	802.11a	802.11b
10	0.6026	2.9801	100.00	99.99	0.079	1.34×10^3
100	0.1359	0.4752	100.00	99.98	0.164	7.25×10^3
200	0.1110	0.3165	100.00	99.96	0.282	8.47×10^3
500	0.0973	0.2516	100.00	99.01	65.9×10^4	2.89×10^4
1000	0.0922	0.2411	100.00	98.19	1.78×10^3	1.52×10^5

Table 5. Effect of packet size on MAC layer statistics for 802.11b (RAKE) and 802.11a at Hematite4 Site1. The data rates for 802.11a and b are 12 Mbps and 11 Mbps respectively. The packet arrival rate is 1000 packets per second, and the number of retrie limits is 5.

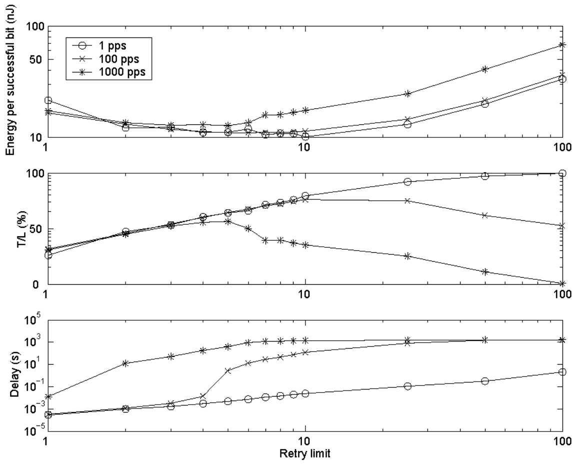

Figure 6. Effect of retry limit and packet arrival rate on 802.11b for Hematite4 Site1. The data rate is 11 Mbps and the packet size is 100 bytes. The receiver does not use RAKE.

Packet size (byte)	Energy per successful bit (nJ)		Mean throughput per unit load		Delay (s)	
	802.11a	802.11b	802.11a	802.11b	802.11a	802.11b
10	2.0112	9.0068	96.82	92.79	4.53	143.12
100	0.5310	0.6866	93.06	93.05	10.50	256.99
200	0.3840	2.3203	95.68	35.26	6.27	793.50
500	0.3931	1.8317	90.69	28.95	24.90	637.57
1000	0.3815	1.6944	87.73	29.99	61.70	840.45

Table 6. Effect of packet size on MAC layer statistics for 802.11a and 802.11b (RAKE) at Gusev1 Site1. The data rates are 12 Mbps and 11 Mbps for 802.11a and b respectively. The packet arrival rate is 1000 packets per second, and the number of retrie limits is 5.

Data rate (Mbps)	Energy per successful bit (nJ)	Mean throughput per unit load	Delay (ms)
6	0.2467	100.00	0.322
9	0.1783	100.00	0.230
12	0.1359	100.00	0.164
18	0.1059	100.00	0.146
24	0.0832	100.00	0.110
36	0.0954	99.98	0.365
48	0.2958	74.60	8.92×10^3
54	0.3777	62.67	1.535×10^4

Table 7. Comparison of MAC layer statistics for different data rates for 802.11a. The site is Hematite4 Site1. The packet size is 100 bytes, and 1000 packets per second is considered. The number of retrie limits is fixed at 5

Data rate Mbps	Energy per successful bit (nJ)		Mean throughput per unit load		Delay (ms)	
	No RAKE	RAKE	No RAKE	RAKE	No RAKE	RAKE
1	10.06	1.57	38.37	100	2.8×10^6	1.4×10^3
2	8.91	0.90	36.09	100	2.1×10^6	7.4×10^3
5.5	5.50	0.48	36.59	99.99	1.5×10^6	2.1×10^3
11	12.73	0.48	13.42	99.98	3.9×10^5	7.3×10^3

Table 8. Comparison of MAC layer statistics for different data rates for 802.11b at Hematite4 Site1. The packet size is 100 bytes. The packet arrival rate is 1000 packets per second, and the number of retrie limits is fixed at 5.

bits decreases. Hence energy per successful bit decreases. However, throughput per unit load can decrease due to the loss of many data bits in a big lost packet. The delay also increases since retransmission of large data packets may take much longer time. Hence an appropriate packet size selection is very important.

Data rate (Mbps)	Energy per successful bit (nJ)	Mean throughput per unit load	Delay (s)
6	0.9660	93.14	18.20
9	0.6546	94.82	10.60
12	0.5310	93.06	10.50
18	0.4720	89.95	12.80
24	0.3855	89.28	14.90
36	0.3855	80.73	15.00
48	0.3328	61.24	21.90
54	1.5246	19.33	20.50

Table 9. Comparison of MAC layer statistics for different data rates for 802.11a at Gusev1 Site1. The packet size 100 bytes, and the packet arrival rate is 1000 packets per second. The number of retries is 5.

Effects of Data Rates

The effects of data rates are shown in Tables 9 and 10 . In the case of 802.11a, 12 Mbps rate appears to be a good compromise in terms of the performance metrics studied in this work. Higher data rates appear to decrease throughput per unit load and increases average delay. In the case of 802.11b, the use of a RAKE receiver is found to improve throughput many times, particularly for higher data rates. The RAKE also decreases the average delay significantly. In terms of energy per successful bit, the 11 Mbs rate is found to be the most efficient when RAKE is used. In the absence of RAKE structure this rate is one of the worst performer.

5. DISCUSSION

The simulation results show that selection of appropriate parameters is critical for the successful MAC performance on the Martian surface due to severe delay spreads. The results observed show that 802.11a, in general, is performing better

Data rate (Mbps)	Energy per successful bit (nJ)		Mean throughput per unit load		Delay (s)	
	No RAKE	RAKE	No RAKE	RAKE	No RAKE	RAKE
1	11.7567	1.7185	38.61	99.20	590.00	27.00
2	21.1784	1.2509	15.14	98.95	521.00	27.90
5.5	25.2782	1.3404	8.17	95.53	515.00	108.00
11	53.4446	0.6859	2.83	93.05	845.11	256.99

Table 10. Comparison of MAC layer statistics for different data rates for 802.11b at Gusev1 Site1. The packet size is 100 bytes, and the packet arrival rate is 1000 packets per second. The number of retries is 5.

than 802.11b. The reason is that 802.11a is designed to handle delay spread up to 0.8 μs. Hence if the delay spread is not too severe, it perfoms quite well. There are many transmission parameters that need to be considered. We consider only the packet size, data rate and the retry limit in the MAC protocol. Larger packet sizes improve energy efficiency but increases delay and reduces throughput. Similarly, large retry limits increase throughput but can severely affect average delay and energy efficiency since severe multipaths may force the protocol to keep trying the transmission of the same packet.

6. Conclusions

We have presented two methods to incorporate the physical layer effects on the Martian surface into the OPNET modeler for studying the MAC layer performance of 802.11a and b WLANs. Simple network configurations are considered. Three performance metrics are used: energy per successful bit, throughput per unit load and average delay. We study the effects of packet size, data rates, retry limits and the use of RAKE receivers for 802.11b. It is observed that the transmission parameters must be carefully selected in order to have acceptable performance levels. Larger packet sizes improve energy efficiency but increase delay and reduce throughput. For 802.11a, the 12 Mbps rate is found to give an overall good set of results. For 802.11b, the 11 Mbps rate provides good results when a RAKE receiver is employed. The performance degradation in our study is mainly due to the large delay spreads. Overall, the performance of 802.11a is found to be better than the performance of 802.11b.

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