Wireless LAN Access Points as Queuing Systems: Performance Analysis and Service Time

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ABSTRACT

We present a queuing model of wireless LAN (WLAN) access points (APs) for IEEE 802.11b. We use experimentation to obtain our analytic models. The model can be used to analyze and compare the performance of different WLAN APs. We focus on the delay introduced by an AP. The major observations are that the delay to serve a packet travelling from the wireless medium to the wired medium (on the uplink) is less than the delay to serve a packet with same payload but travelling from the wired medium to the wireless medium (on the downlink). A key result is an analytic solution showing that the average service time of a packet is a strictly increasing function of payload.

Categories and Subject Descriptors

C.4 [**Performance of Systems**]: *Measurement techniques, Modeling techniques, performance attributes.*

General Terms

Performance, Design, and Experimentation.

Keywords

WLAN, AP, IEEE 802.11b, queuing system, service time.

1. INTRODUCTION

Since the approval of the IEEE 802.11b [1] by the IEEE in 1999, the demand for WLAN equipment and networks has witnessed a rapid growth. Today most WLANs use WLAN APs to connect multiple users to a wired backbone network [2]. To provide suitable service, an understanding of the behavior of WLAN APs is essential. The first step is to define the system of interest [3]. Based on our initial experiments, we model the WLAN AP as a queuing system. We are not aware of any study that has looked at the WLAN AP as a point of reference to be modeled as a queuing system. The advantages of our model are manifold; ranging from the ability to compare the performance of different APs, to the simple parameterization of service time. The key result is an analytic model for the average service time of a packet travelling through the WLAN AP in terms of payload.

2. QUEUING MODEL

In our investigation, we seek to model the delay processing in the WLAN AP. A set of assumptions were made. We isolate the AP and define two events: *arrival* and *departure* (figure 1). The parameters of interest are the arrival time and the departure time.

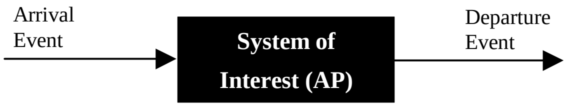

Figure 1. System of interest isolated, logical model

Since the number of packets inside the system changes when a packet arrives or when a packet departs, i.e. at separate points in time, then the system is a discrete-event system [4]. The system (figure 1) considers any packet entering the AP, whether coming from the Ethernet side or the WLAN side, as an arriving packet. Similarly, any packet leaving the AP, whether it leaves to the Ethernet medium or to the WLAN medium, is considered a departing packet. The arrival and departure times recorded from experiments have shown that the system can be modeled as a single server system with one FIFS queue (figure 2). We, then, add one more event: *entering the server* (figure 3), and we define the two system states: waiting and service [5]. The waiting time and the service time of packet P_i are denoted by W_i *and* S_i, respectively, where *i* is a positive integer representing the logical *identification* of the packet with respect to its time of arrival. We define the total delay of a packet, as the *response time* (R_i), to be the time difference between the departure time and the arrival time of a packet, hence $R_i = W_i + S_i$.

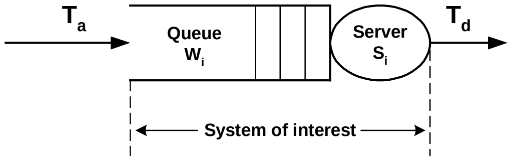

Figure 2. Detailed view of the model; T_a and T_d are the arrival and departure time of the packet, respectively. W_i and S_i are the waiting time and the service time of packet P_i respectively

There is, however, a physical constraint that prevents direct measurement of W_i and S_i, because we can only easily measure the

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arrival and the departure times of a packet. To solve this problem, we designed an algorithm that is described in section 3.

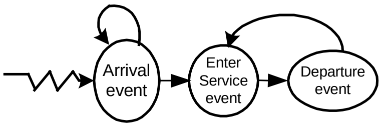

Figure 3. Event graph of AP system with *enter-service* event

3. TEST DESIGN AND ANALYSIS

We send UDP packets to avoid any bits traveling backwards, and we increase the UDP payload by 32 bytes in each experiment. The maximum UDP payload we use is 1472 bytes, because sizes beyond the MTU result in fragmentation [6]. We designed the SSTP (Simple Service Time Producer; figure 4) algorithm to calculate the values of internal-event states: W_i and S_i.

Table 1. Data file after analysis of measured parameters

Packet #	T_a	T_d	Response time	Waiting time	Service time
P_1	T_1	T'_1	R_1	W_1	S_1
:	:	:	:	:	:
P_{i-1}	T_{i-1}	T'_{i-1}	R_{i-1}	W_{i-1}	S_{i-1}
P_i	T_i	T'_i	R_i	W_i	S_i
:	:	:	:	:	:
P_n	T_n	T'_n	R_n	W_n	S_n

Measured data set

```
1  For i = 1 to n
2    Do $R_i = T'_i - T_i$
3      If i = 1 or $T_i \geq T'_{i-1}$
4        then $W_i = 0$
5          $S_i = R_i$
6      else if $T_i < T'_{i-1}$
7        Then $W_i = T'_{i-1} - T_i$
8          $S_i = T'_i - T'_{i-1}$
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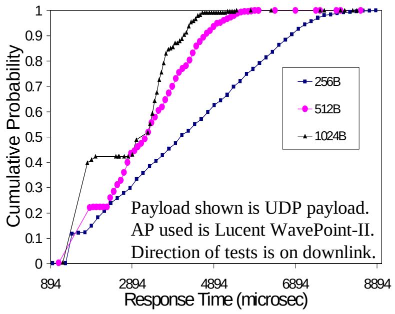
Figure 4. SSTP algorithm calculates response time (R_i, line 2), waiting time before entering service (W_i, lines 4 and 7), and service time (S_i, lines 5 and 8) for each packet P_i

4. RESULTS

4.1 Response Time

The cumulative probability of the response time shows a piece-wise linear increase with one cutoff point, and it increases with increasing payload for the same utilized bandwidth (figure 5).



Payload shown is UDP payload.
AP used is Lucent WavePoint-II.
Direction of tests is on downlink.

Figure 5. CPF of response time is larger for larger payloads utilizing the same bandwidth

4.2 Directional Delay

For the same AP, the uplink service time is less than the downlink service time for packets with identical payloads (table 2).

Table 2. Comparison of 2 Lucent APs. AP1 is WavePOINT-II. AP2 is AP-2000 [7]. Uplink has less service time than downlink

IP Payload (Bytes)	AP1 Average Service Time (µs)		AP2 Average Service Time (µs)	
	Downlink	Uplink	Downlink	Uplink
40	894	152	999	171
138	962	257	1140	274
264	1087	395	1374	419
520	1323	668	1820	733
1480	2089	1705	3399	1876

Downlink and uplink average service times show that server of AP1 is faster than that of AP2

4.3 Service Time Analytic Solution

The discrete-event system allows us to look at the service time values as terms of a sequence. Our analysis showed that the average service time, S_n, can be modeled as presented in equation (1). Since we use a 32B increment in the payload, then the UDP payload is always divisible by 32B, hence, n is a positive integer.

$$S_n = S_o + (n-1).r \qquad (1)$$

where, S_o and r are different for different APs,

n = (IP_Payload$_{\text{[in bytes]}}$ - 8B$_{\text{[UDP header]}}$) /32B
S_n = service time (µs) for packet with IP payload of (32.n+8)B
S_o = service time (µs) for packet with 40B IP payload
r = incremental difference in µs (calculated from linear regression of average service times of different payloads).

5. WORK IN PROGRESS

We use our model to study the QoS of layered MPEG-4, MPEG-2, MPEG-1, and H.261 streaming applications over WLANs.

6. CONCLUSION

The main purpose was to reveal a mathematical model for wireless LAN access points: a single server, single queue, FIFS system. An interesting result is that the uplink service time is relatively much smaller than the downlink service time. Using our model and test design, one can get an analytic solution of the average service time, which is a linear function of payload.

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