IEEE P802.11
Wireless Access Method and Physical Layer Specification

DATE: January 10, 1992

TITLE: **EFFICIENCY FACTORS IN DESIGN OF ACCESS METHOD**

AUTHOR: Chandos A. Rypinski,
Chief Technical Officer
LACE, Inc.
921 Transport Way
Petaluma, California 94954 USA

Telephone: 707 765 9627
Facsimile: 707 762 5328

INTRODUCTION

Handshake and positive acknowledgement are probably essential in radio systems, but the added messages needed decrease the amount of channel time available for payload. Fields added to the header structure for more detailed protocol function also have a cost.

The significance of propagation time increases as the data rate becomes higher and as the number of messages per data transfer increases. This is also an efficiency consideration.

The proportion of overhead for small payloads is much greater, and a limit on payload size is necessary to limit worst case access delay for connection-type services.

It is believed necessary to have an objective approach to these tradeoffs to use as a guide in making a number of dimensional and functional decisions. Results obtained and presented in IEEE P802.11/91-19 are presented again, but now the emphasis is on the tradeoff considerations and methodology used, where in the previous presentation they were given as the characteristics of the particular access method.

There is a substantial difference between the definitions of efficiency as used here, and in previous analysis of other access methods--most notably CSMA/CD. In this case, payload is the transferred data unit excluding header with synchronization fields, PAD to fill out messages to a minimum length and trailer with CRC field. If this is not done, the relative efficiency calculated for short and long messages is much less different than the reality.

Table of Contents Page

FIGURES

EFFICIENCY FACTORS IN DESIGN OF ACCESS METHOD

INTRODUCTION

Handshake and positive acknowledgement are probably essential in radio systems, but the added messages needed decrease the amount of channel time available for payload. Fields added to the header structure for more detailed protocol function also have a cost.

The significance of propagation time increases as the data rate becomes higher and as the number of messages per data transfer increases. This is also an efficiency consideration.

The proportion of overhead for small payloads is much greater, and a limit on payload size is necessary to limit worst case access delay for connection-type services.

It is believed necessary to have an objective approach to these tradeoffs to use as a guide in making a number of dimensional and functional decisions. Results obtained and presented in IEEE P802.11/91-19 are presented again, but now the emphasis is on the tradeoff considerations and methodology used, where in the previous presentation they were given as the characteristics of the particular access method.

There is a substantial difference between the definitions of efficiency as used here, and in previous analysis of other access methods--most notably CSMA/CD. In this case, payload is the transferred data unit excluding header with synchronization fields, PAD to fill out messages to a minimum length and trailer with CRC field. If this is not done, the relative efficiency calculated for short and long messages is much less different than the reality.

ASSUMPTIONS

Ordinary assumptions are no losses from bit-errors in the medium, contention or interference from contiguous like-type systems. However important these points are, the first effort to evaluate an access method must separate these causes of capacity loss.

Saturated Traffic Demand

The key assumption is that the traffic demand equals or exceeds capacity. This assumption was used by McKenny and Bausbacher[1] who said: "The heavy-traffic assumption allows queuing effects and user actions to be ignored, since each node will always have at least one packet ready to be transmitted." This property is not available in many access methods. For the assumption to be valid, the messages in queue must be transmittable as soon as the medium becomes available with contention resolved.

The result of this approach is the volume of traffic that is carryable at saturation in isochronous services or the peak in LAN--now called "peak capacity." If the offered traffic exceeds capacity, there is increasing access delay as the size of the queues build-up. In practice, peaks only exist briefly in properly proportioned systems.

In this situation, the capacity does not consider access delay. Delay may be calculated with the Erlang C formula if all users wait until served and are served in order-of-arrival in queue. The probability of waiting more than one holding time (average duration of one messagesequence) is very small for systems loaded to 90% of peak capacity. This is a reason for limiting the length of transfers, also.

---

[1] McKenny, Bausbacher; "Physical and Link-Layer Modeling of Packet-Radio Packet Radio Performance," IEEE JSAC, Vol.9, Jan 91

Allotter Function

The sequence in which the channel is used is determined by a sub-protocol within the MAC function (elsewhere referred to as a "scheduler"). This function needs to know what traffic is waiting, and also its dimensions and priority. A medium in which a single Station can block availability for a long period cannot provide a means for the allotter to receive timely information on the needs of Stations. This information is not normally available in earlier CSMA/CD protocol and it is less than what it could be in Token Ring.

A suitable allotter function is a necessary part of this or any other 802.11 candidate protocol. It is now assumed possible, but it is not described beyond what has been presented in previous contributions.

Propagation Delay

This parameter is now defined as the time interval between the end of a transmitted message and the beginning of the response transmission at the receiving point. This interval is made up of free space and interposed metallic media transit time, but it could be increased by insufficiently fast processing time at a receiving point.

The processing of a received message can begin, in the worst case, at the start of the trailer and the result is not needed sooner than the end of the preamble in the header of the response message. This is at least four octets more than the propagation delay.

The default choice is 4 μseconds or 1200 meters in free space or about 400 to 600 meters in telephone twisted pair. The propagation delay is added to the duration of each message in computations.

Data Transfer Size (Payload)

Two dimensions for payload are used. One is 48 octets which is thought to be larger than most of the short messages actually encountered, and the other is 288 octets which is an arbitrary choice for the largest size of one transfer. The difference is sufficient to show the role of payload size on capacity loss from overhead. The protocol proposed allows any size of payload up to a defined maximum.

Message Structure

The message structure was expanded between 802.9/90-19 and -95 as reported in -80 adding channel, power and system identification fields the total of which is two octets. The performance shown in the figures is slightly higher than if these fields were present, but this does not make a material difference for the present purpose.

Data Rates

1, 4 and 16 Mbs are the physical medium signaling rates used for calculations.

Traffic Mix

Station originate messages use more time than Access-point originate because of handshake. Worst case or "WC" is all Station originate, and "MIX" is 50/50%.

EFFECT OF LOST MESSAGES

In this protocol, missed messages are tried again. An approximation of this effect is that the retries create proportional additional traffic. With retry capacity used, equal to 10% of transported capacity, a capacity of 99% would be required to get 90% through successfully.

USE OF CHANNEL TIME

Channel time is used for overhead, payload and propagation time. As a starting reference, the breakdown for 4 and 16 Mb/s signaling rate is shown in figures 1 and 2 on a following page for 48 octet payloads and 4 μsec propagation delay. Important values from the two figures are as follows:

48 octet mix--4 μsec	CHANNEL TIME USED	
	4 MB/S	16 MB/S
PAYLOAD:	46.0 %	35.4 %
PROPAGATION TIME:	11.1 %	31.6 %

It is immediately evident that the bite for propagation delay is much larger and more significant for a high rate and a short message size.

Effect of Varying Propagation Delay

Other values of propagation time of 2 and 6 microseconds with 16 Mb/s signaling are shown on a following page as Figures 3 and 4. The tabulated result is as follows:

48 octet mix--16 Mb/s	CHANNEL TIME USED	
	2 μSEC	6 μSEC
PAYLOAD:	46.0 %	33.2 %
PROPAGATION TIME:	19.2 %	41.5 %

Efficiency As A Function of Propagation Delay

Efficiency is now defined as the ratio of payload octets carried to the channel time used in octets to carry them. This is a much more restrictive definition than is commonly used.

For reference, the result is shown for a traffic mix with either 48 or 288 octet payloads in the following Figures 5 and 6. The range of propagation delays is 3 to 12 μsec as shown.

It is evident that propagation delay is much more of a factor with the 48 octet payloads than with 288 octets.

Efficiency As A Function of Channel Rate, Payload Size and Traffic Mix

In Figure 7, a different combination of input variables is shown. Several channel signaling rates from 1 to 24 Mb/s are shown as a variable parameter. The faster rates carry more, but are less efficient primarily because constant propagation time is assumed.

If propagation time were scaled with rate so that halving the rate doubled the propagation delay (and the maximum path distance), then all rates would have the same efficiency.

The difference between MIX and WC traffic makes a noticeable difference, but it is not much. For that reason, this variable has not been shown in the other contexts.

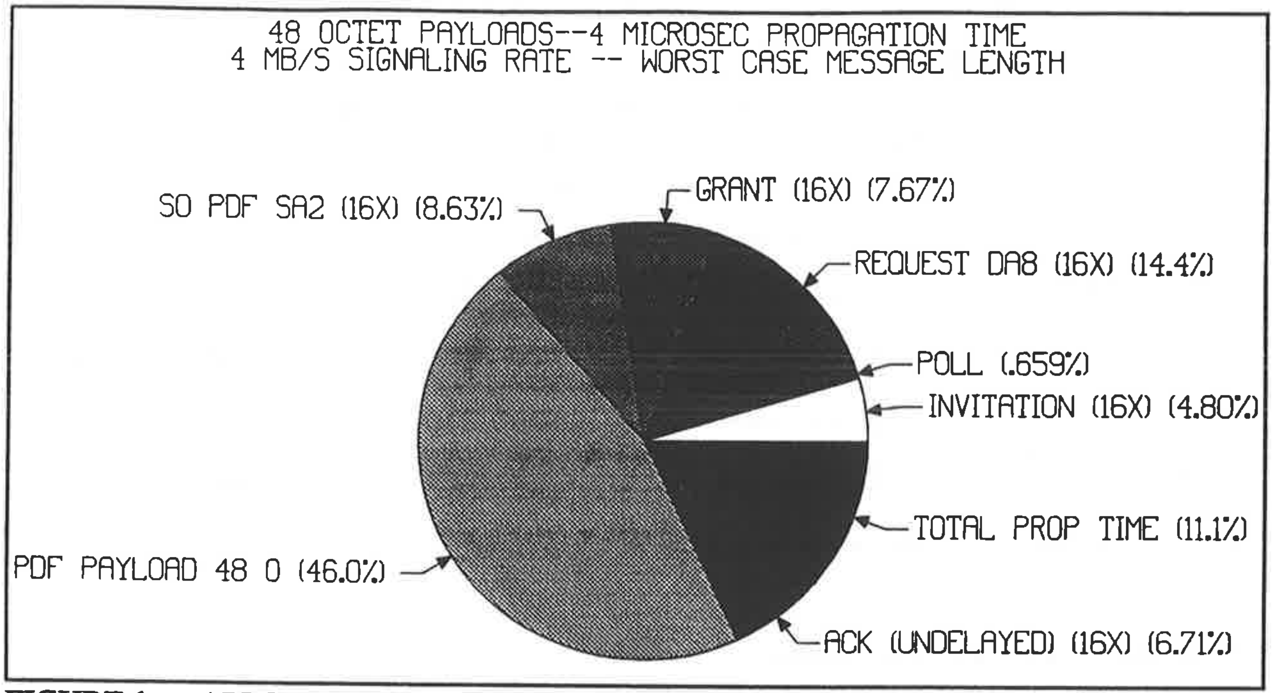

FIGURE 1 APPORTIONMENT OF CHANNEL TIME USAGE

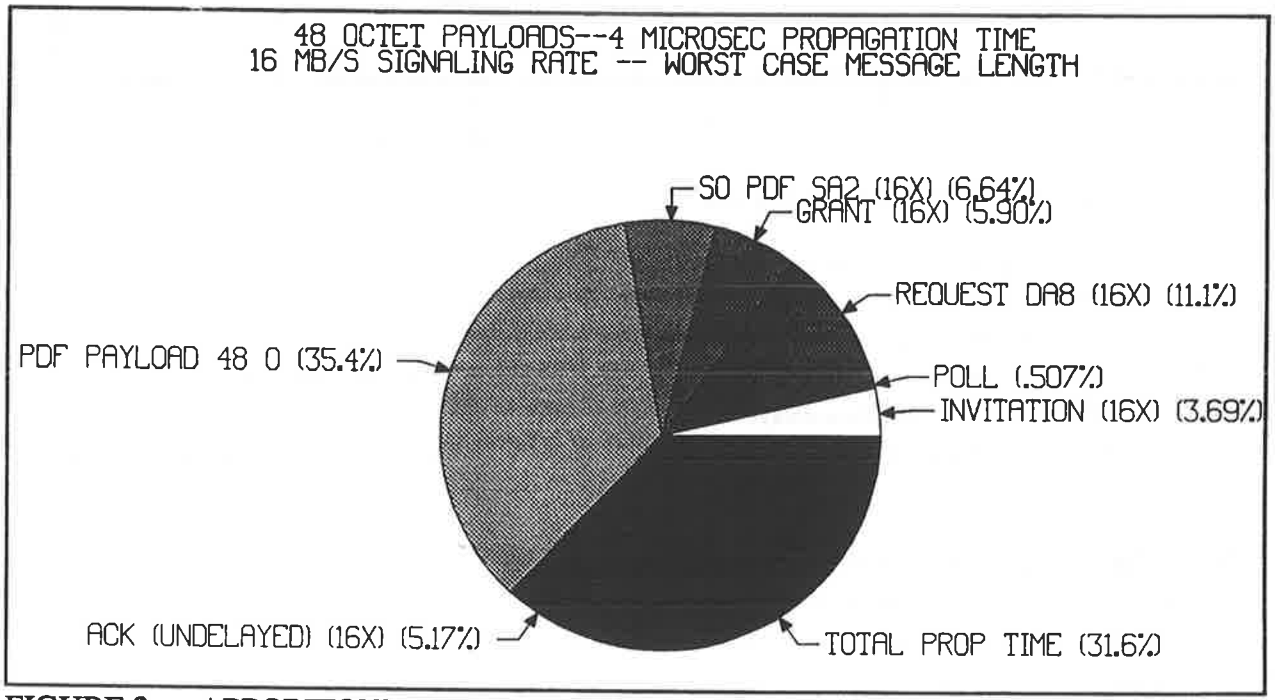

FIGURE 2 APPORTIONMENT OF CHANNEL TIME USAGE

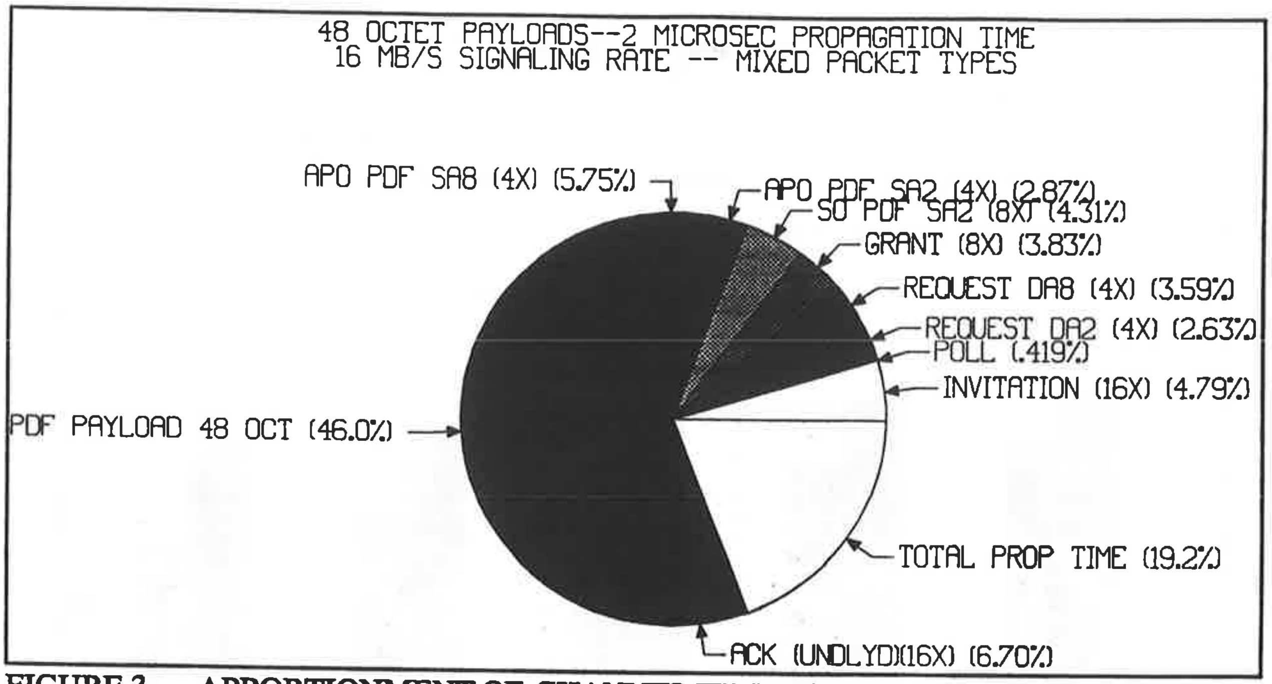

FIGURE 3 APPORTIONMENT OF CHANNEL TIME USAGE

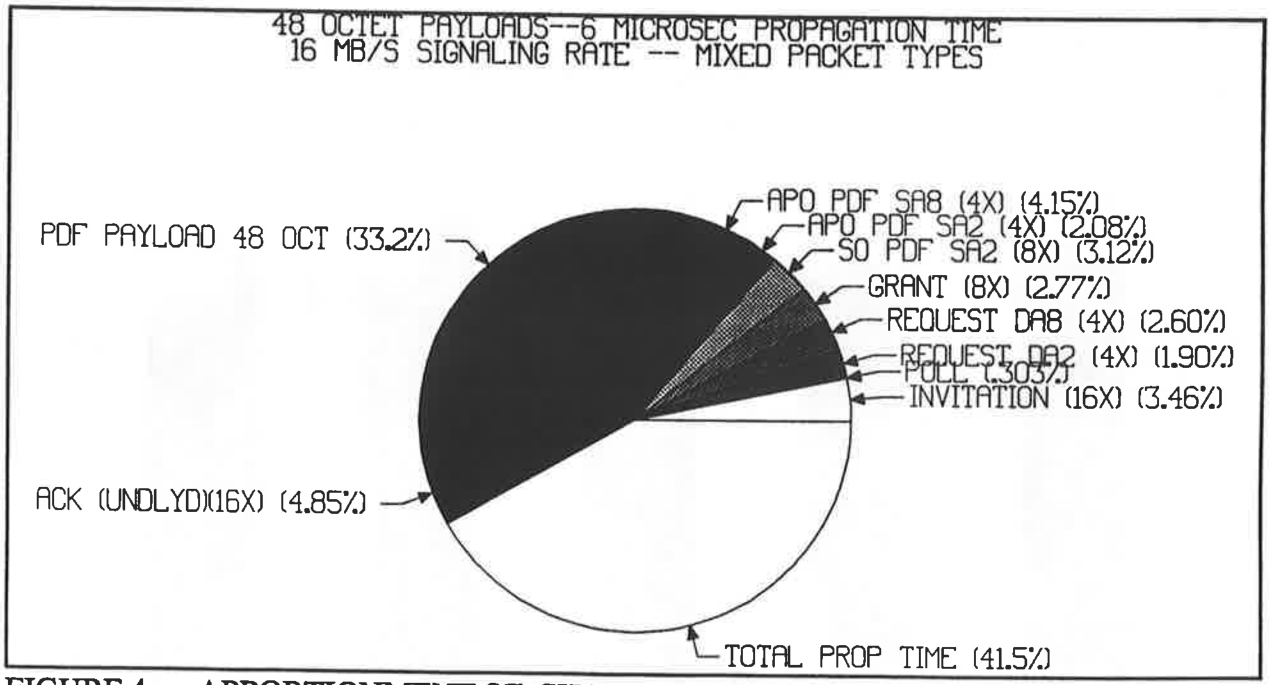

FIGURE 4 APPORTIONMENT OF CHANNEL TIME USAGE

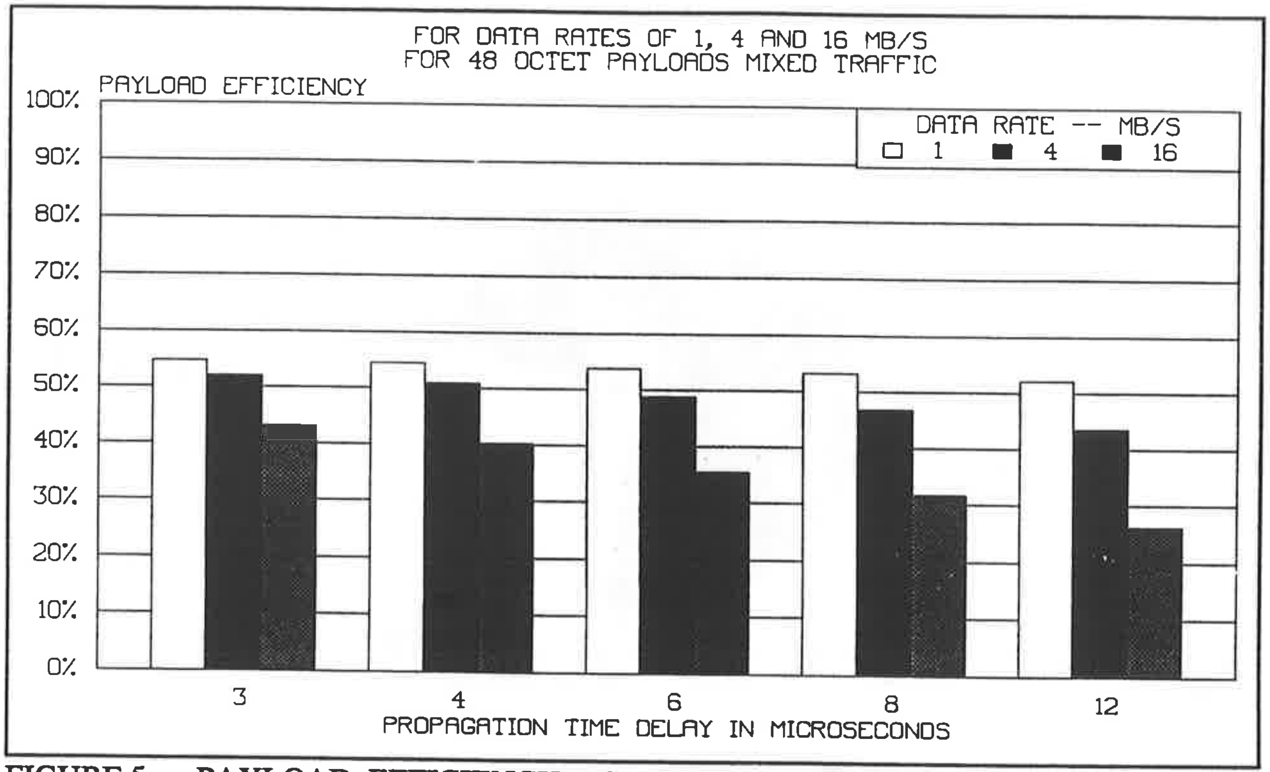

FIGURE 5 PAYLOAD EFFICIENCY VS. PROPAGATION TIME FOR 48 OCTET PAYLOADS MIXED TRAFFIC

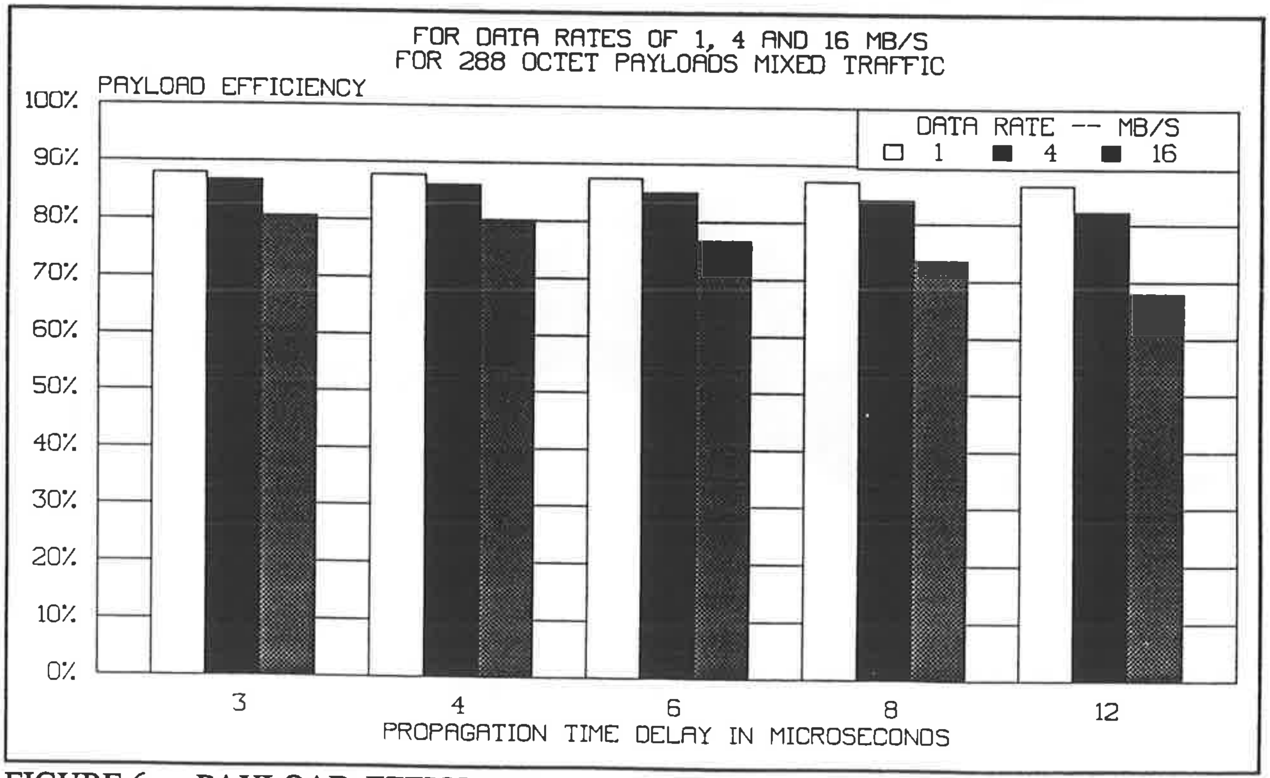

FIGURE 6 PAYLOAD EFFICIENCY VS. PROPAGATION TIME FOR 288 OCTET PAYLOADS MIXED TRAFFIC

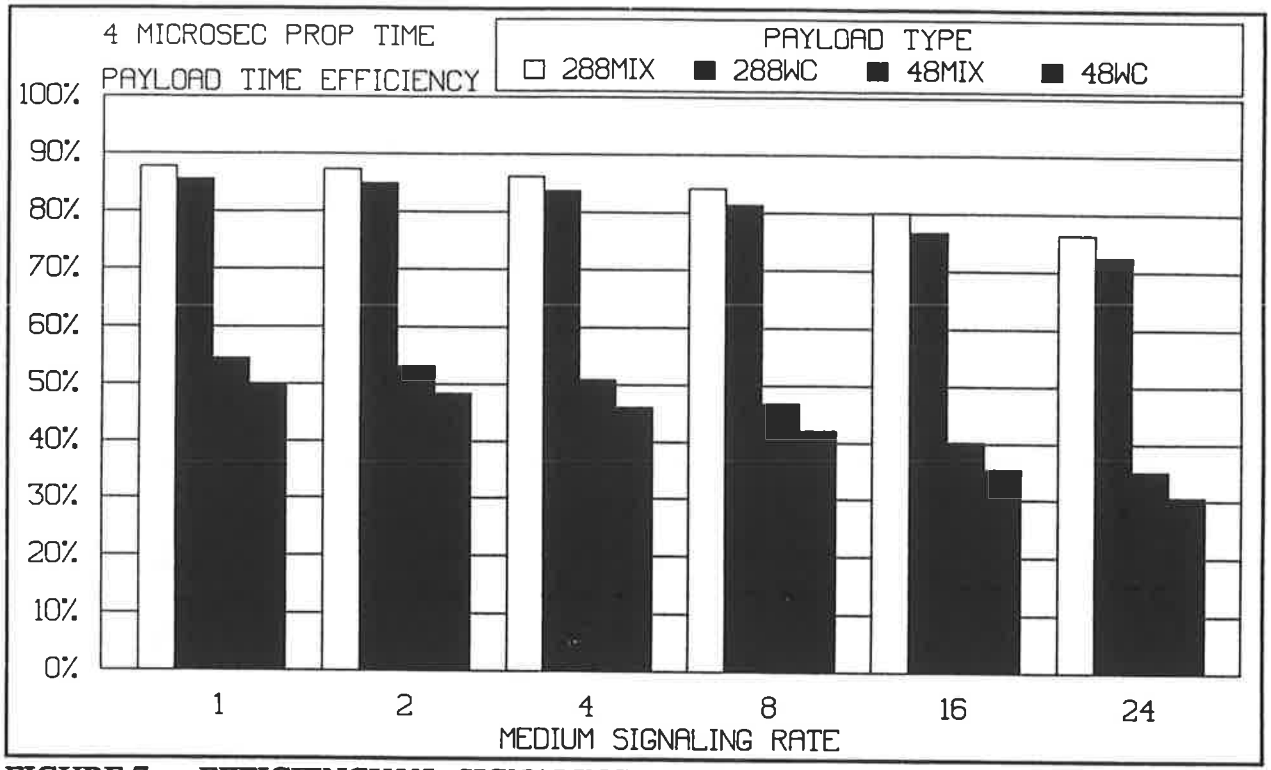

FIGURE 7 EFFICIENCY VS. SIGNALING RATE