IEEE 802.11
802 LAN Access Method for Wireless Physical Medium

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TITLE: ACCESS PROTOCOL FOR IVD WIRELESS LAN

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GENERAL DESCRIPTION

The basis of the protocol is a single channel binary data link used alternately by the fixed common control network and a number of fixed or moving STATIONs. All protocol elements are data messages which do not depend in any way on special properties of the physical medium apart from requiring rapid switching between ON and OFF states.

There are many ACCESS-POINTS in the fixed network each of which serves one or a small number of the total number of user STATIONs in an indefinitely large network. Also for very small systems, the ACCESS-POINT function can be included in one of the STATIONs when all STATIONs are sufficiently close so that each is within range of all of the others.

The scope and intentions of this access protocol are as follows:

1) to cover use on wire, radio or optical mediums.
2) to be suitable for indefinitely large systems carpeting a large area, or to be usable as an independent small system with many like type systems on all sides.
3) to limit energy density radiated when all of the simultaneous radiation is summed for interference effect on other spectrum users.
4) to attain complete use of channel time under peak load conditions.
5) to avoid STATION logic dependent on system configuration and public network interface protocols.
6) to make all STATION logics identical independent of the size, scale or traffic capacity of the system in which they are used.
7) to make a local distribution system independent of backbone and interconnected network technology.

REVISION RECORD

RELEASE 1	DEC. 28	11AP0CQ
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ADDITIONS:

PAGE 1	Column 1 - # 7)
PAGE 4	Column 1, Paragraph 4 - (Note:...)
	Column 2, Paragraph 4 & Paragraph 6
PAGE 5	"Resolution of Contention on REQUESTS" - 7 paragraphs
	Column 2 - "Polling Type Contention Resolution" (New Heading)
PAGE 6	Column 1 - "Sorting Type Contention Resolution"- 3 paragraphs
	Column 2 - Paragraph 6 (new)
PAGE 7	"Asymmetry of REQUEST-GRANT Procedure" - 4 paragraphs
PAGE 9	Column 2 - Paragraph 4 (new)
PAGE 11	"BACKBONE INTERCONNECTION CONSIDERATIONS" - 2 paragraphs
	"THE DEFAULT ACCESS MANAGER" - 3 paragraphs
	"Operation of the Minimal System" - 7 paragraphs
	"The Expanded Minimal System" - 3 paragraphs
PAGE 13	Column 1, Paragraph 3 - "The proposed..."
	Column 2, Paragraph 4 - "...an all PACKET/SEND data frames".
PAGE 16	"CONCLUSIONS" - 7 paragraphs
PAGE 17	"TABLE VI" -"Line Rate in MBits/Sec", "Level A" changed from 2,4 to 1,4, "Level B" changed from 4,8 to 4,16
	"Inter-Message Delay μSec", "Level B" changed from 4,12,20 to 2,4
	"Reuse Factor", "Default" changed from 10 to 16
	Added last row "DEFAULT ACCESS MANAGER"

DELETIONS:

PAGE 13	Column 1, Paragraph 2 - "offers a near universal capability"
	Column 1, Paragraph 4 - "A common-equipment Public Network Gateway server would be 802.6 on one side and 802.11 on the other. The concern now is identifying which of"
PAGE 13	Column 1, Paragraph 4 - "It is further assumed that a directory relating global and local addresses will be part of this server."
	Column 2, Heading - "Cell Relay"
	Column 2, Paragraph after "(Contributor's definition)". "This point is distinguishing..."

ACCESS PROTOCOL FOR IVD WIRELESS LAN

Table of Contents **Page**

Table of Contents (cont'd) **Page**

Tables

Figures

Attachments

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TECHNOLOGY FEATURES REQUIRED AND ASSUMED

The access protocol is part of a system plan in which the characteristics of all of the parts depends upon the others. Some of the technology features are implemented in the access protocol. Each part of the system has special features which increase the performance and range of functions and decrease the cost of the entire system. The most important points are described in the following sections.

Single RF Channel Operation

For one ACCESS-POINT, transmission and reception occur alternately (time-division duplex). This simplifies the radio and avoids the need for a two band spectrum assignment.

This mode takes advantage of the rapid radio off-on-off transition provided by the modulation method implementation elsewhere described.

> If the outbound-inbound traffic ratio is asymmetrical, the medium is still used efficiently only with single channel operation.
>
> Only single channel operation allows adaptive, direct peer-to-peer communication when STATIONs are close enough to each other to be used that way.

Radio and UTTP Line Signal

The line signal is chosen to be suitable for UTTP transmission, radio baseband modulation and for fast acquisition of bit-clock from turn-on. The medium is pure binary except for recognition of signal present/absent states. There is no use of medium dependent frame delimiters.

The ACCESS-POINT radio need not contain logic--it is an up/down-converter for the UTTP line signal.

Consequences of Radio Medium

Since the ACCESS-POINT is a simplex radio transmitter-receiver, it is commonplace for a transmitter to be heard by several receivers.

For the case of STATION-to-ACCESS-POINT, this is an advantage that can be turned into path diversity. For the case of ACCESS-POINT-to-STATION, it is a nuisance requiring the STATION to filter traffic heard for the subset which is addressed or relevant to that STATION.

There are some details discussed under central control which are peculiar to a medium with indefinite separation of users.

FEATURES OF THE ACCESS PROTOCOL

This access protocol is different from other 802 protocols in a number of ways mostly as a result of fitting to the particular conditions of use. The extents of an access group are smaller, and the probability of one packet being correctly received on the first try are much smaller. The repetition mechanism must be in the physical layer to bring the performance up to the accuracy levels of other 802 physical layers.

By integrating acknowledgement and the repetition process into the access algorithm, the amount of time required for this function is greatly decreased when it is used.

An essential limitation is provided on the length of time one station can use the radio channel implying segmentation of packets. There are two major reasons for limiting payloads to 288 octets or less:

Under peak conditions, the channel can be shared by two or more users at reduced throughput rate.

For priority packets for virtual circuits, the peak delay before transmission is both determinable and adequately low.

Packet payload size is as long as it needs to be from 1 to 288 octets without segmentation and up to 9,216 octets segmented.

No air-time is used to pad messages out to predetermined boundaries.

Interfaces delivering payloads in predetermined bundles sizes, e. g. 802.6 "cells", can be served with compatible payload (cell) relay avoiding complex buffering and delay from adaptation.

Short addressing is used extensively, and global addressing is supported. The simpler systems need not use air-time for global addressing except when needed.

CENTRAL CONTROL AND ASYNCHRONOUS ACCESS

The widely-used CSMA/CD access method is not capable of using a medium much over 20% of the time. When it is pushed to its limits, there is a possibility of "avalanche" breakdown. The newest 10BaseT systems depend on active hub with station-per-port interfaces, and it is here that contention is resolved--not in the station logic (except for multi-drop on one port).

Big gains can be made by using a deterministic access protocol where use of air-time can approach 100% without "shouting" contests.

<u>The right time to start a second use of the shared medium is immediately after a first use is concluded</u>--and that is the purpose of asynchronous logic. Among shared mediums, radio is particularly diminished by unnecessary "dead" time.

A further property of radio is that there is inevitable interaction between contiguous illuminators. It is not possible to use one radio ACCESS-POINT independently of those around it. This kind of logic is easily handled in common equipment, and unlikely to be effective or efficient distributed over the stations. Only at a common point is it possible to assemble and use essential facts about the system:

1) which STATIONs are available, and
2) capable of directly communicating with each other.
3) what outside priority traffic is waiting for transmission that could take precedence.
4) what is the local address corresponding to a global address in either 6 octet LAN or E.164 BCD format, and vice versa.

The entity providing central control functions is now named the "ACCESS MANAGER" of which there may be different kinds for simple and complex systems. In the simplest case, it might be 10K of additional code activated at one of a small group of stations.

An ACCESS MANAGER would be a part of a campus environment along with the provision for host computer and public network access.

The protocol to be described is believed to satisfy requirements from the simplest to the largest complex types of systems.

Central Control, Request/Grant Inband Message Access Control

STATIONs may transmit only when enabled by received message. Following a centrally-originated *INVITATION*, STATIONs may initiate *REQUEST* messages containing most of the LAN Header information. The centrally-located ACCESS MANAGER originates a *GRANT* message which confirms correct reception of this information, and so the packet, when subsequently transmitted only needs a short identification header.

It is possible that the addressed STATION will be sufficiently close that it can hear the originating message without a relay step. The ACK from the ACCESS-POINT is delayed sufficiently for the ACK to be sent from the destination STATION and recognized.

Because non-interfering ACCESS-POINTs can be used simultaneously, it is probable that a number of such access' are being processed simultaneously. Moreover, messages passing between non-interfering ACCESS-POINTs do not need to wait for inward transmission to end before starting outward.

Central Control and Addressing

STATIONs have a long global address, a short local address and may have a long E.164 telephone address. A directory function in the ACCESS MANAGER enables all traffic within the system to use short addressing. Nonetheless, long addressing for both DA and SA may be used for known externally addressed or originated traffic.

When the *REQUEST* from a STATION contains a long destination address and there is a *GRANT*, that packet or segment is completely defined by the short *Source Address* thereafter. This procedure significantly reduces overhead.

Traffic originating outside the system will be received and forwarded with long DA and SA.

Automatic Repetition (ARQ) of Errored Packets

The advantages of ARQ are that it introduces no decrease in throughput except when it is needed, and it better compensates the temporary outage characteristic of the radio medium than would a full-time FEC.

Error-free (determined by CRC) packets originating at STATIONs are ACKnowledged by receiving ACCESS-POINTs. There is an automatic resend of the packet/segment limited to three attempts (two retries).

Virtual circuit packets may be allowed only one retry or none at all, and then dropped.

STATIONs are permitted to send *NACK* if they are addressed but the packet fails CRC.

ACCESS-POINT Address and Moving STATIONs

Each ACCESS-POINT is assigned a 4-bit identifier (API) which is broadcast in each *INVITATION-TO-REQUEST/REGISTER* message. (Note: 12 bits may be a better choice.) Each STATION will know which ACCESS-POINT is being received or used and whether the current identifier is the same or different than the identified ACCESS-POINT last used.

Signal-level Reporting From ACCESS-POINTs

The received signal level is reported back to the ACCESS MANAGER concurrently with reception. This level is used by the ACCESS-MANAGER to decide which of several ACCESS-POINTs receiving the signal should be used for the next message exchange.

Requirements on ACCESS MANAGER

The ACCESS MANAGER depends upon Source Address in the received message because it cannot rely on the port-of-appearance for this information. Users register with the ACCESS MANAGER when they appear as active STATIONs in the system. Registration allows the ACCESS MANAGER to make a logical decision on which ACCESS-POINT to use for transmission to that STATION, and to update the directory of STATIONs for which traffic can be accepted.

The ACCESS MANAGER has the possibility of using more than one ACCESS-POINT for simultaneous transmissions to more than one STATION. The selection of a second active ACCESS-POINT that is non-interfering with a presently active ACCESS-POINT or points must be based on a further detailed algorithm.

The ACCESS MANAGER has packet routing capability sufficient to receive a packet from an ACCESS-POINT, and then to repeat that packet on the appropriate ACCESS-POINT (if not on the receiving port, with one octet of delay) or on a path to an outside destination.

NARRATIVE DESCRIPTION

The use of messages to control of the use of all ACCESS-POINTs is first described by function, and later by format using diagrams.

The messages and the field definitions within them are later defined and shown in Tables III and IV and in ATTACHMENT A, Figures 1 and 2.

ACCESS-POINT Idle State

When in Idle State, each ACCESS-POINT transmits short messages which are *INVITATION-TO-REQUEST/REGISTER* used for either purpose.

All connected ACCESS-POINTs are divided into groups of 16 in which the four LSB identification are non-interfering when used simultaneously. In a pattern of STATIONs on a square grid, there is then a minimum spacing of three inhibited cells between simultaneously active ACCESS-POINTs. The *INVITATION* messages are transmitted on each of the 16 ACCESS-POINT use groups consecutively. (The relation between contiguous groups of 16 is important in high capacity systems, and will be treated in further detail in a later contribution.)

Registration Messages

The *INVITATION* messages contain identity numbers for the transmitting ACCESS-POINT (API). Registered STATIONs know that they are hearing or not hearing the ACCESS-POINT at which they are currently registered. Assuming that the STATION knows or deduces that it is unregistered, the STATION responds after any valid *INVITATION* message with a *REGISTER* message.

Upon receipt of a *REGISTER* message, the ACCESS MANAGER decides which ACCESS-POINT received that message with the best signal, makes an assignment, and sends a *RACK* message on the assigned ACCESS-POINT. Short address could be assigned upon registration.

This process serves STATIONs coming into the system from outside or from turn-ON. It does not matter if the STATION moves to the coverage of another ACCESS-POINT before attempting the first message.

Request and Grant Messages

When a registered STATION wants to send a packet, the STATION listens for an *INVITATION-TO-REQUEST/REGISTER* message from the ACCESS-POINT at which the STATION is registered. At the end of the *INVITATION* message, the STATION immediately sends a *REQUEST* message containing the DA, SA, SID and LEN packet header fields.

This is a CSMA process with the possibility of collision made small by the frequency of opportunities to *REQUEST* and the division of the traffic so that there are no more than a few active users per ACCESS-POINT.

If there is no contention on the *REQUEST*, or if there is contention but a *REQUEST* message was still received successfully, the ACCESS MANAGER will send a *GRANT* message via the ACCESS-POINT on which the STATION was received with the highest signal level.

Normally, the *GRANT* is immediate on the channel of registration. Sometimes the *GRANT* will not be sent, and the requesting STATION must wait until a new *INVITATION* message is received before repeating the *REQUEST* procedure.

The *GRANT* message contains a CRC-8 field on the content of the *REQUEST* message so the STATION knows it is received correctly, and does not need to resend this information in the packet header. Otherwise, a new *REQUEST* is made.

There are two forms of *REQUEST* messages corresponding to long and short addressing as indicated in the TYP field.

Resolution of Contention on *REQUESTS*

This problem is different depending on whether the contention possibilities are limited to 8 stations (as in the multi-drop ISDN S interface) or a hundred or more that might be present in a long-reach-low-rate system.

CSMA, as proposed above, on the first try is preferable if contention is rare. This can be the case when the duty cycle of any one ACCESS-POINT is low--under 10%.

When the contending REQUESTs are from STATIONs served on the same ACCESS POINT, it is still possible that they will be resolved without further added function.

Since the stronger radio signal masks the weaker, access may be granted in an order based on proximity rather than order-of-arrival into queue. The "work-off" rate for few STATIONS and short packets is so rapid, that "fairness" is unimportant in this limited circumstance.

It is also possible that both REQUEST messages may be received as contending on their home ACCESS POINT but one or the other may dominate on a second and third ACCESS POINT. It is quite possible, in the radio system, for alternate paths to make unresolvable contention much less likely.

Nonetheless, there should be a back-up form of contention resolution to define worst-case access delay, and to obtain satisfactory operation in more defined mediums without coverage overlap.

The polling type contention recovery mode is suitable for systems with a small number of station per access point, and is described first.

The sorting method of contention recovery is suitable for perhaps 250 stations per access point, and is described next.

Polling Type Contention Resolution

When the ACCESS MANAGER senses contention at a particular ACCESS-POINT, a poll of STATIONs registered at that ACCESS-POINT is initiated. Since the number of registrants might average four, and is rarely over eight, this does not consume much time.

If this process does not work, the STATION may *REGISTER* again or wait for his poll message whichever happens first.

When a correct *REQUEST* message is received, the ACCESS MANAGER responds with a *GRANT* message on the appropriate ACCESS-POINT.

Sorting Type Contention Resolution
(described for discussion purposes only)

This algorithm may be considered where there is a possibility of contention from a large number of stations sharing a common ACCESS POINT. The principle of operation is a binary sort starting with the LSB of the short address in steps requiring a message exchange.

The sorting requires that the ACCESS POINT send a POLL message with special form in which some of the address bits are specified and others are don't care. This is done by splitting the SA-2 into two fields of four and twelve bits. The first field specifies the boundary between the specified and don't care bit positions and the second field specifies defined bit values up to 12 bits. The enabled STATIONs respond with a repeated REQUEST message.

One step requires a POLL and a REQUEST (DA-8) interval plus propagation. It is calculated (using values from Table III shown later): 7 + 17 octets + 8 μsec = 200 μsec @ 1 Mbit/s. The number of steps required depends upon the number of bits to be compared before a difference is discovered. For example: a sort to one-out-of-64 would require six steps or 6 x 200 = 1200 μsec @ 1 Mbits/s. This time includes the successful REQUEST message, and it could be up to 36 octets shorter with all REQUEST (DA-2) messages.

STATION Packet Send

The STATION starts sending the *PACKET DATA FRAME* containing the payload data immediately upon conclusion of the *GRANT* message. The packet header only needs to contain the SA-2 field to identify the transmission since the long or short DA, SA and LEN were passed in the *REQUEST*.

ACK/NACK for STATION-originate Packets

Upon reception of the complete *PACKET DATA FRAME* (in some cases after a delay as described below), the ACCESS MANAGER sends the *ACK* message containing SA, or it sends a *NACK-REPEAT* message which is almost identical to a second *GRANT* message to initiate a repeat of the packet.

A STATION sends *ACK* immediately upon receipt of an addressed message.

Peer-to-Peer Direct Message and ACK

The system plan permits but does not assume direct STATION-to-STATION communication. When an addressed STATION receives a message from another STATION, the *ACK* message is transmitted immediately. The ACCESS-POINT also receives the undelayed STATION *ACK*, and then can discard its copy of the message and its intention to send a delayed *ACK*. If the ACCESS MANAGER does not hear the immediate *ACK*, it transmits a delayed *ACK*.

The amount of delay must be the length of an *ACK* message plus a propagation time, or 6 octets plus 4 μseconds.

Since the ACCESS MANAGER will know whether there is a possibility of direct peer-to-peer communication, it is probable that better implementations will provide the Access Manager *ACK* delay selectively. An approximate logic would be to provide the delay only for packets between stations registered on the same or immediately contiguous ACCESS-POINTs.

Because of this function, it is necessary for a station to process *REQUEST* and *STATION* send format messages.

ACCESS-POINT Packet Send

The ACCESS MANAGER can use the medium at any time by halting the sending of *INVITATION* messages. If there is waiting priority traffic via any controlled ACCESS-POINT in a group, it is sent after the current *INVITATION, REQUEST, GRANT, PACKET SEND AND ACK* cycle is completed. Waiting non-priority traffic is sent after the inward cycle for that ACCESS-POINT. this precedence is unimportant except when the system is heavily loaded.

From the registration procedure (and reinforced by the polling procedure to be described below), the ACCESS MANAGER knows that the STATION is available or not.

The ACCESS MANAGER sends a different (from the STATION originated) format *PACKET DATA FRAME* to the STATION which has the complete header including short or long DA, SA and LEN fields. The STATION must be ready to receive packets at any time after registering.

Upon receipt of a valid *PACKET DATA FRAME*, the STATION sends an *ACK* message. Without the *ACK* message, the ACCESS MANAGER may resend up to three tries.

Asymmetry of *REQUEST-GRANT* Procedure

The upward *REQUEST-GRANT* procedure is essential to keeping *STATION* logic simple and avoiding contention. It would be possible to use the same *REQUEST-GRANT* procedure in both directions rather than only upward traffic.

802 philosophy is that a *STATION* is always ready. A message is always sent--ready or not. It is for higher layers to provide a method of knowing whether *STATION*s are there. Since 802 generally does not allow *STATION*s to refuse a message, this would be a point of incompatibility.

If *STATION*s could say "wait," a further buffering and indeterminate delay factor would be introduced in the network implementation. The amount of storage required in this protocol is only that to do repeat send on no *ACK*. Otherwise messages "fall on the floor" after a completed delivery attempt.

A symmetrical protocol is not used, because there is no functional value in downward *REQUEST-GRANT*, and it would cost air-time.

Polling

The function of polling is a background task to determine the status of registered STATIONs and to determine that STATIONs have moved or shut-down without notifying the ACCESS MANAGER. The *POLL* message is an addressed message that must be answered with an *ACK* message.

The *POLL* message for one station is sent after every 16th *INVITATION* message in a sequence.

De-register Message

In response to an *INVITATION* message, a STATION should send a *DE-REGISTER* message upon shut-down or leaving the system. The polling function will eventually find this out if the message is not sent.

The opportunity for this function occurs with the same frequency as the poll described above.

SIMULTANEOUS USE OF ACCESS-POINTS

The reuse strategy so far described assumes that within contiguous 16 AP identifier patterns, simultaneous use is restricted to corresponding numbers. In fact, the 3, 5 or 7 of the most distant cells of each contiguous pattern may be used simultaneously.

Since the traffic demand in contiguous groups of 16 will not stay in step with a pattern, there is an opportunity for development of ingenious algorithms to minimize use blockage in surrounding cells from message activity in one cell.

PACKET SIZE AND SEGMENTATION

The proposed maximum payload size of 288 octets corresponds to 384 kb/s transfer rate with a sample bundle every 6 milliseconds. It is also a good maximum size for packets or segments of packets when it is desired to interleave the traffic of many users at less than the medium rate rather than give the medium entirely to one user until complete transmission of any length of packet.

TABLE I -- MESSAGE AND FUNCTIONAL DEFINITIONS

802.11 MAC PACKET or SEGMENT

For STATION-originated payload data unit length up to 288 octets, the 802.11 MAC packet is in two parts: The header is contained in the *REQUEST* message, and the remaining part of the message in the *PACKET DATA FRAME*. The packet data frame uses *SHORT ADDRESS* SA-2 for identification.

For payload data unit length exceeding 288 octets, two or more *PACKET DATA FRAMEs*, called *SEGMENTs*, are used and identified by *SHORT ADDRESS*.

For ACCESS-POINT-originated messages, the header and packet body are combined in the first *PACKET DATA FRAME* using either *SHORT OR LONG ADDRESSing*. The same rules are used for following *SEGMENTs* of payloads exceeding 288 octets as for oppositely directed messages.

VIRTUAL CIRCUIT

A CONNECTION is realized by setting up a long segmented packet stream. The bandwidth depends upon the size and frequency with which maximum length segments are transmitted.

Packets used for virtual circuits are marked and treated as priority packets. Priority packets are transmitted at the first available opportunity relative to non-priority packets. In the presence of multiple priority packets, an approximation of order-of-arrival queuing is used. The priority marking is in the SID field.

The preferred algorithm for the ACCESS MANAGER is for it to issue *GRANT* automatically after the first request until 192 segments of 48 (or other combinations totaling 9,216) octets have been transmitted (1.152 seconds of samples at 6 millisecond intervals for 64 kb/s voice). Thereafter, the originating STATION must place a new *REQUEST*.

PROPAGATION TIME

This interval is defined as the propagation time between ACCESS MANAGER and STATION including the effects of both air and wire. There are other delay effects in the apparatus which are measured in absolute time rather than octets, and which can be included in this factor.

The default assumption for worst case delay is 4 μseconds which corresponds to 400 meters of cable and 400 meters of air in series. The velocity in cable may be as low as half of that in air (air = 300 meters/μsecond).

For the higher data rates, smaller allowances for propagation time may be necessary and used.

DATA VALID DELAY

This is the interval between the first incidence of radio signal at the receiver input and the existence of valid clock, data and framing at the receiver data output. The time allowed is 1-bit for reaction time, 15-bits for clock acquisition and 7-bits for the Start Delimiter (3 octets – 1-bit).

SIGNAL RECOGNITION TIME

Absence of signal is a recognized condition after *INVITATION, POLL, DATA FRAME* messages when *REQUEST* or *ACK* is expected but not always received.

Signal is recognized as present after three octets when valid clock is received.

Signal is recognized as absent after eight octets and no valid clock is received.

MEDIUM SIGNALING RATE

This is the raw transmission bit-rate in the medium now defined to be one of the following:

1, 2, 4, 8, 16, 24 Mbits/sec

CLUSTER SIZE

This is the number of ACCESS-POINTS in a group that are each activated sequentially insofar as *INVITATION* messages are concerned.

TABLE II -- LISTING AND DEFINITION OF FIELDS USED

SHORT GLOSSARY

AP	=	ACCESS-POINT
ACK	=	ACKNOWLEDGMENT
NACK	=	NOT ACKNOWLEDGED
RACK	=	REGISTRATION ACK
SO	=	STATION ORIGINATE
APO	=	ACCESS-POINT ORIGINATE

FIELD ABBREVIATIONS AND DEFINITION

PRE = *Preamble*

Every transmission starts with 15 bits of predefined bit pattern to enable the receiving modem to acquire bit clock.

SD = *Start Frame Delimiter*

This is the first field following PRE, and it is a 7 bit normal Barker character.

DIR = *Directional Field*

This is a 1 bit field following SD indicating that the transmission originates either at a STATION or at an ACCESS POINT.

ED = *End Frame Delimiter*

This is the last field of a transmission, and it is an inverted 7-bit Barker character.

CRC-N = *Cyclic Redundancy Check*

CRC characters are used to indicate probable accuracy of the preceding checked bit sequence. 4-bit CRC is used for small numbers of bits in a header, 8-bit for full headers and 16-bit for complete messages (segments). This use of CRC is independent of the end-to-end 32 bit CRC for payload integrity in complete 802 PDUs.

DA = *Destination Address* (2/8 octets)

The *Destination Address* is 2 octets (short) for packets to STATIONS and for local use, or 8 octets (long) for external destination global address in *REQUEST* messages. The type of long address is marked in the first 4-bits as defined in 802.6. The marking of SA or DA is in the TYP field.

For the 48-bit 802 format, these formats are as defined in 802 particularly referring to definitions of the first bit, source routing and broadcast address markers.

For the 60-bit format CCITT E.164 and 802.6 definitions are used.

SA = *Source Address* (2/8 octets)

The long SA is used for registration with the format defined for the long DA. After registration, short SA fields are used, except for externally addressed messages which uses the long SA.

LEN = *Payload Data Unit* Length in Octets

This length may have any value between 1 and 288, however certain specific values may become more probable or locally preferred. The value 48 would be associated with ATM compatibility, and 192 with ISDN.

The LEN field is the primary means for determining the end of the current message. The ED field is an alternative means backed by time, count-out and the content of the SID field.

The LEN on segments is redundant until the last segment where the remaining number of octets is indicated.

API = *ACCESS-POINT Identifier*

ACCESS-POINT identifiers are 4-bits enabling division into 16 groups. This sorting is used exclusively for marking in messages to STATIONs. Within the ACCESS MANAGER logic, the API is 12-bits of which the message portion is the least significant 4-bits.

TYP = *Type of Message*

This 4-bit field designates the message type with a separate set for AP originate and STATION originate as marked by the DIR bit. A directory of message types is given in a following section.

SID = *Service Identifier*

The first 2-bits of this 4-bit field is priority marking (differentiating packet data from isochronous virtual connections). The last 2-bits mark first, continuing and last segments of segmented or virtual connection packets or no segmentation in 802.6 format.

PLDU = *Payload Data Unit*

This is the data payload within a data frame. The PLDU may include all or parts of another frame structure such as an ATM Cell or an X.25 packet as long as that substructure is not processed by the 802.11 MAC.

TABLE III – MESSAGE TYPE LISTING WITH CONTENT AND SIZE

DIR/TYP	MESSAGE NAME	ORIGINATION POINT	FIELDS USED (PLUS PRE, SD, DIR, ED)	LENGTH OCTETS
001	*PACKET/SEGMENT DATA FRAME–SA2*	APO	API,TYP,SID,LEN,DA2,SA2,PLDU,CRC-16	PLDU+12
003	*PACKET/SEGMENT DATA FRAME–SA8*	APO	API,TYP,SID,LEN,DA2,SA8,PLDU,CRC-16	PLDU+18
005	*INVITATION TO REQUEST/REGISTER*	APO	API,TYP	5
007	*POLL*	APO	API,TYP,DA2	7
009	*NACK*	APO	API,TYP,DA2	7
011	*ACK OR RACK*	APO	API,TYP,DA2	7
013	*NACK-REPEAT*	APO	API,TYP,DA2	7
015	*GRANT*	APO	API,TYP,DA2,CRC-4 IN REQUEST	8
102	*REGISTER*	SO	TYP,CRC4,SA8	13
104	*DE-REGISTER*	SO	TYP,CRC4,SA8	13
106	*REQUEST-DA2*	SO	TYP,SID,DA2,SA2,LEN,CRC-4	11
108	*REQUEST-DA8*	SO	TYP,SID,DA8,SA8,LEN,CRC-4	17
110	*ACK*	SO	TYP,CRC-4,SA2	7
112	*NACK*	SO	TYP,CRC-4=0000,SA2	7
114	*PACKET/SEGMENT DATA FRAME*	SO	TYP,SID,SA2,PLDU,CRC-16	PLDU+9

TABLE IV – MESSAGE TYPE LISTING WITH TRANSMISSION TIME VS. LINE RATE

DIR & TYP	MESSAGE NAME	ORIGINATION POINT	LENGTH OCTETS	MESSAGE LENGTH IN μSECOND		
				1 MB/S	4 MB/S	16 MB/S
001	*PACKET/SEGMENT DATA FRAME-SA2*	APO	PLDU+12	PLDU+96	PLDU+24	PLDU+6
003	*PACKET/SEGMENT DATA FRAME-SA8*	APO	PLDU+24	PLDU+19	PLDU+48	PLDU+12
005	*INVITATION-TO-REQUEST/REGISTER*	APO	5	40	10	2.5
007	*POLL*	APO	7	56	14	3.5
009	*NACK*	APO	7	56	14	3.5
011	*ACK OR RACK*	APO	7	56	14	3.5
013	*NACK-REPEAT*	APO	7	56	14	3.5
015	*GRANT*	APO	8	64	16	4
102	*REGISTER*	SO	11	104	26	6.5
104	*DE-REGISTER*	SO	11	104	26	6.5
106	*REQUEST-DA2*	SO	11	88	22	5.5
108	*REQUEST-DA8*	SO	15	136	34	8.5
110	*ACK*	SO	7	56	14	3.5
112	*NACK*	SO	7	56	14	3.5
114	*PACKET/SEGMENT DATA FRAME*	SO	PLDU+9	PLDU+72	PLDU+18	PLDU+4.5

BACKBONE INTERCONNECTION CONSIDERATIONS

This access protocol is completely independent of backbone implementation as viewed at the user STATION air-interface. There are some configurations and topologies which are more favorable than others from a cost and complexity view-point. These may be considered in some detail to show the feasibility of the overall system in which the air-interface is a part.

The preferred protocol between wiring closets and a common equipment room is the very same protocol on a "star" wired plan. There is then no protocol conversion for other than actual interconnection needs.

THE DEFAULT ACCESS MANAGER

A "default" ACCESS MANAGER is defined, and it would be a required part of all conformant MACs. Its function would be sufficient for a small number of STATIONs to interoperate without dependence on fixed or common equipment. The protocol supported would be the necessary, LAN only subset of that previously described.

It is anticipated that minimal systems will use the lower signaling rates, but there is no limitation in the protocol that is rate dependent.

The system operation is described as a method of defining the necessary functions.

Operation of the Minimal System

A minimal wireless system might be three PCs close enough together so each can communicate with all others. The default ACCESS MANAGER in the MAC can then be used as now described.

The first station to power-on hears no *POLL or INVITATION* messages, and concludes that default ACCESS MANAGER should be activated.

The second station to power-on hears the *INVITATION* message and responds with *REGISTRATION* and obtains *RACK*. The same thing happens for the next few stations that power-on.

The first station keeps a directory of registered addresses and can use *POLL* of the list if contention is present. There would be an open *INVITATION* at fixed time intervals--possibly 100 milliseconds. By definition, the capacity of the default ACCESS MANAGER is limited to small numbers.

The first station does not perform a relay function. The system is dependent on the peer-to-peer direct communication mode only.

The first station assumes (but not necessarily correctly) that all registered stations are in radio range. If a fourth station powers-on and cannot hear the first, then there will be a second ACCESS MANAGER operating. Some stations might hear both. This is not too bad if the traffic demand is a small fraction of capacity.

If the third station hears *INVITATION* messages from two different sources, they may be distinguishable by the API field (but not certainly) enabling the station to stay with his first registration point. If the third station responds with *REQUEST* to the wrong *INVITATION*, *GRANT* will not be received. There is the possibility that the STATION will re-register every time the alternate *INVITATION* message is received. Some logic detail will be needed to keep this process from being too frequent.

With some possibility of lost messages and with the default ACCESS MANAGER active, multiple stations can coexist if all systems are lightly loaded.

The Expanded Minimal System

The primary difference in a second level system is that it is planned and setup. One station is designated as having an active ACCESS MANAGER, and uses a favorable antenna-radio location (ACCESS POINT) so that coverage of all other intended stations is secured. It is possible for this STATION to be semi-permanently installed when all other STATIONs are transients.

The default ACCESS MANAGER is configured active in the designated STATION. Modules may be added to that station to support:

1) a relay-repeat function, and
2) outside access to a modem (voice-band) type PSTN interface.

The relay repeat function is necessary to cover the case where peer-to-peer propagation paths are unsatisfactory.

CONNECTION-TYPE SERVICES

It is sometimes presumed that isochronous traffic (including voice telephony) cannot be carried efficiently by an asynchronous medium. Since the definition of ATM (asynchronous transfer mode of B-ISDN), the functionality of packetized connections and cell relay are accepted. The bearer may or may not be slotted in relation to a 125 μsecond frame. The real requirement for the local distribution physical medium is that isochronous payloads be delivered at exactly the same rate and sequence that they are received from the source. The source alone has responsibility for rate.

The equivalent of one direction of a 64 Kb/s voice path is one packet of 48 octets every 6 milliseconds (167 packets/second). If this protocol were used entirely for B-channels (64 Kbits/s isochronous channels), the efficiency would be about 50% (relative to time slotted-channels). A 4 Mbit/s medium would carry about 16 such duplex channels.

For normal TDM point-to-point multiplex, two 2.048 Mbits/s channels would carry 30 B-channels.

If a more clever voice coding were used so that silence was not carried as 48 octets, but as a compressed code, there could be a 2-to-1 increase in the relative capacity of the packetized speech system.

Buffer Elasticity Considerations

It may be assumed that the isochronous data source at the public network interface delivers a perfectly timed data stream, and that rate must propagate to and through the station equipment. For transmission through the 802.11 LAN, the samples are bundled and sent at irregular intervals, however the average rate out is the same as in.

If the physical medium delivers all bundles to the station interface with a 3.0 ± 2.9 millisecond delay from receipt, there will not be a problem of two bundles arriving in the wrong order or simultaneously or any other obstacle to accurate restoration of the input stream.

For other implementation reasons, the actual tolerance must be less than this level, possibly 4.0 ± 1.5 millisec.

There is no need for the 802.11 access protocol to take any notice of the 125 μsecond periodicity of isochronous information. A priority for such information means that no access to non-priority traffic need be granted until the isochronous is passed. This is readily accomplished as long as the isochronous traffic with included overhead is a minor fraction of the capacity of the medium.

A 16 Mbits/s medium used 25% for isochronous B-channels would carry 16 such duplex channels simultaneously and non-blocking. Assuming a system limited to this loading, the access delay for a bundle would be between 0 and the worst case (the time required for 15 STATIONS each to pass 288 octet long-address packets). It will later be shown that this interval is 3 milliseconds, and this is a variability within the reach of FIFO buffering at the output port.

It is interesting to note that the worst case access delay does not depend on the number of non-blocking (simultaneous) B-channels provided (within limits) as it does on the ratio of the size of the maximum frame length to that required for the isochronous transmission. The delay could be halved, approximately by reducing the 288 octet payload size limit to 144 octets.

C-channel Capacity

The maximum packet size was chosen to allow efficient handling of at least one or two 384 Kbits/s C-channels (H0) in the traffic mix when the B-channels are used as demand-assigned trunks.

With cell-based technology, demand-assigned circuit bandwidth can be provided with simple control as compared with slotted techniques. This is a required service function in the near future.

The 802.6 MAC Connectionless Service Protocol Data Unit -- (Attachment B)

Some measure of compatibility with public network interfaces must be realizable. The proposed protocol can be interfaced equally to frame or cell type network interfaces. In the time frame in which the 802.11 Standard might come into use, it can be expected that SMDS and 802.6 will be available. Other interfaces such as PRI will remain available, but with extended possibilities for packet data and wider bandwidth. All of these may be tariffed on data transferred rather than circuit time used.

The ATM Cell definition is shown in ATTACHMENT B copied from the recently approved 802.6 Standard (Draft 16). The degree of compatibility proposed for 802.11 is cell-relay interworking for payload but not for overhead frame structure.

The overhead functions in 802.6 are now identified which must be accommodated in 802.11.

TABLE V
802.6 CARRY-OVER FIELDS to 802.11

MAC Service Data Unit	[1 right]
64-bit address field structure	[2 left]
Segment type	[10 left]
Derived MAC Protocol Data Unit	[11]

In particular, the VCI [13 left] virtual circuit identifier is beyond the scope of 802.11. This compatibility can be undertaken once only in a common PSTN Gateway.

It is possible that some of the DMPDU header and trailer fields [10] will not be passed through.

All of this interworking is a proper subject for further discussion.

The 2-bit *Segment Type* field is placed in the SID field since the normal content of the SID is passed on the *REQUEST* and all PACKET/SEND data frames.

The proper goal for 802.11 is the capability to relay the 802.6 ATM cells as received with minimal delay. Since these cells can arrive from a 150 mbits/s line at rates exceeding once-per-millisecond for a 384 kb/s virtual circuit, it may be necessary for the server to buffer these out into larger bundles for 802.11 handling.

Cell relay implies that received segments are relayed through common equipment with less delay than the interval between cells or possibly six milliseconds (Contributor's definition).

Complexity Added for IVD

Little has been added to the access protocol to accommodate 802.6 or isochronous compatibility. The main consequence is enabling a long address of 8 octets rather than 6. The SID field is partly needed to distinguish connection-oriented services, but it is needed in any case.

If it is accepted that extension via the public network is a necessary compatibility, these differences may be inevitable.

Some of the added complexity is not due to voice-data integration, but rather to the adjustments necessary to fit this system into others that are around it.

Voice Bandwidth Compression

All of the recently proposed digital cellular telephone systems incorporate some form of speech coding to reduce the transmission capacity required to 16 kbits/s or less. In general, this additional processing uses time, consumes power and adds cost. Most important, it prevents transmission continuity through the public network for non-voice.

Speech compression can be used, but it is not presently necessary or desirable for this to be undertaken by 802.11.

EFFECTIVENESS OF CHANNEL TIME USE

"Efficiency" as it is now used is the ratio of the time used for payload transmission to that used for all of the transmission and message functions over a cycle in which every station in a 16-cluster has an opportunity to (and may) pass traffic. Two kinds of traffic loading are imagined: worst case with all-station-originate messages called "maximum" or "wc", and the other a mix of station originate and short address messages called "mixed." Two message lengths are considered carrying payloads of 48 and 288 octets.

These variables are considered in some detail in ATTACHMENT C which includes a sample of the spread sheet from which conclusions have been derived. Some summary Figures are presented following.

In ATTACHMENT C, efficiency is presented for various signal rates, for both WC and Mixed message types and with various propagation times.

Efficiency vs. Signal Rate and Message Type

Figure 1 below shows the relatively high efficiency obtained with a full sequence of 16 passed long and short messages, various signaling rates and both message type mixes.

The efficiency at low signaling rate shows overhead loss, and the further decline in efficiency at higher signaling rates shows the effects of the 4 μsecond propagation time (larger with higher signaling rate).

Channel Time Usage

In Figures 2 and 3 on the following page, the use of channel time in a complete sequence of 16 messages passed is shown for 48 octet payloads. At the 4 Mbits/s rate, the loss from propagation time is moderate, but increases greatly at the 16 Mbits/s rate.

These Figures show the importance of minimizing the maximum distance between STATION and logical control for high signaling rates.

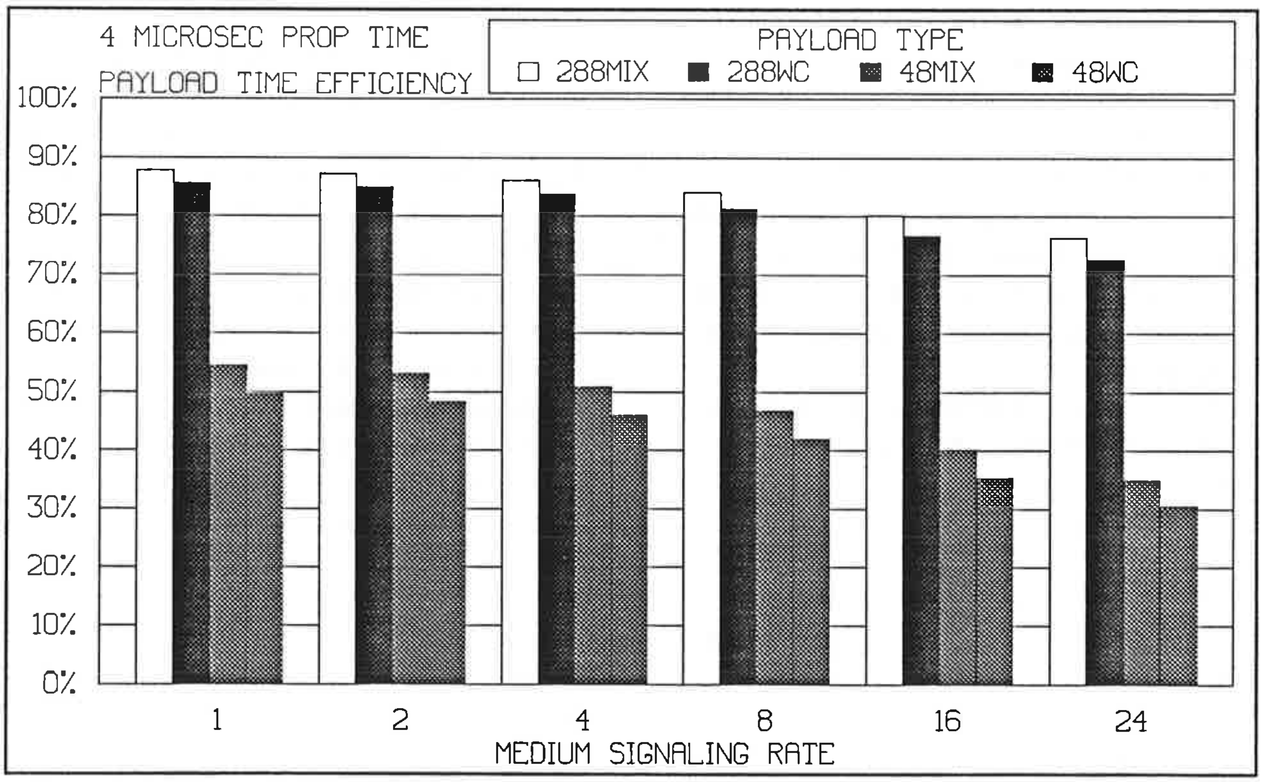


FIGURE 1 EFFICIENCY VS. SIGNALING RATE

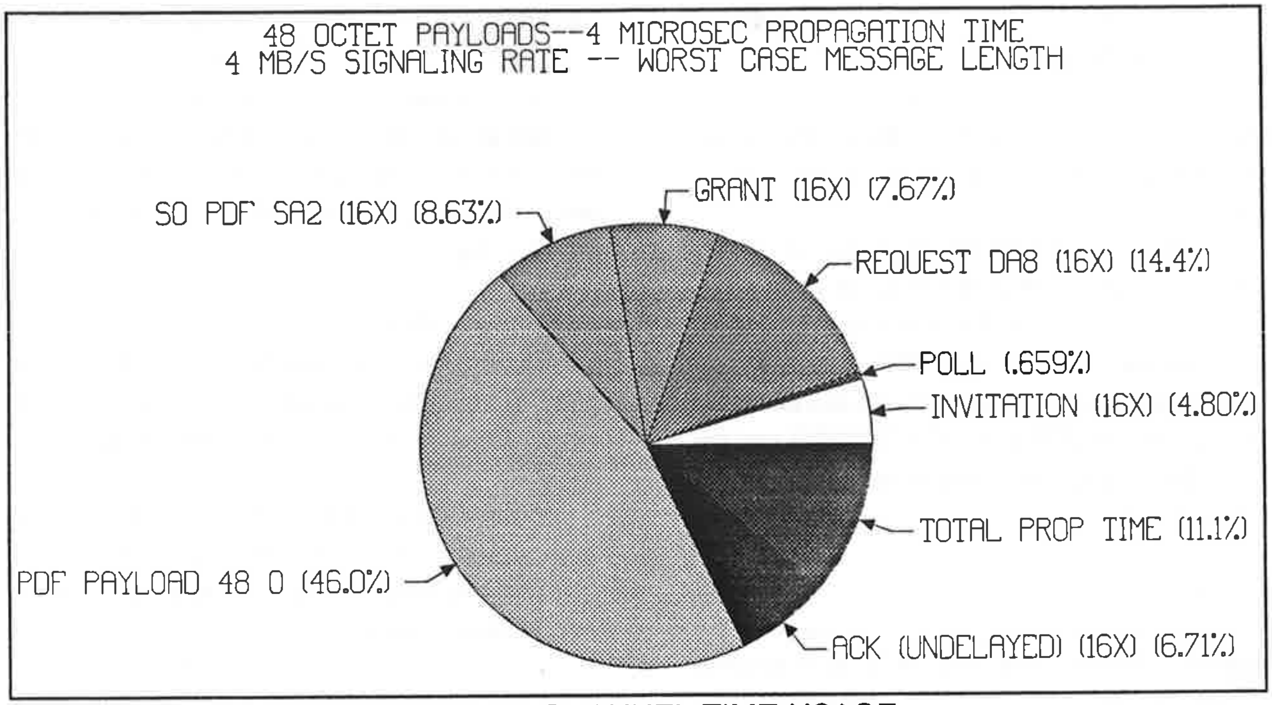


FIGURE 2 APPORTIONMENT OF CHANNEL TIME USAGE

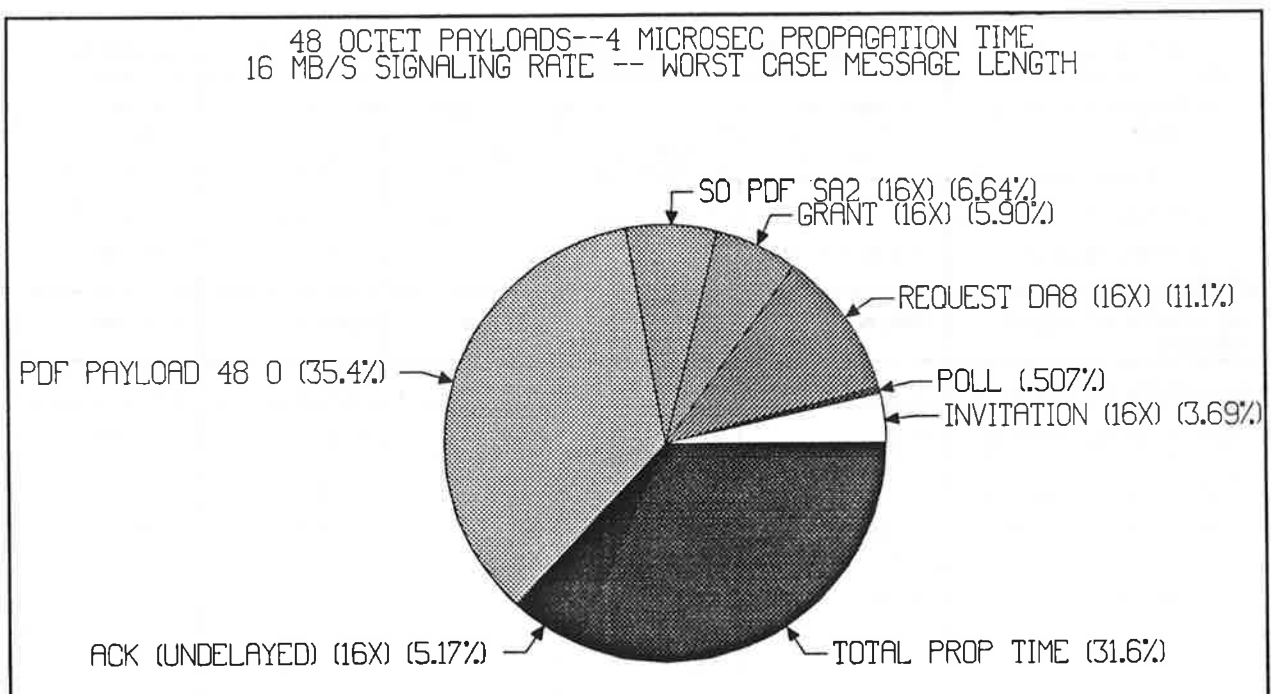


FIGURE 3 APPORTIONMENT OF CHANNEL TIME USAGE

CONFIGURABLE OPTIONS

There are a number of parameters which might be configurable. Table VI is an initial effort to identify these parameters and list the possibilities. A subset of these are default values and available values required in conforming equipment.

Level A conformance is assumed to be minimum cost working at the lower data rates, and Level B is higher performance and data rates. The common ground is at 4 Mbits/s.

The setting of these parameters can affect the ACCESS MANAGER, the ACCESS-POINT and the STATION or any combination as shown in the right column.

Line Rate

This parameter affects all major parts of the system. Initially, this rate is a configuration parameter set at a single value throughout one system; however the rate could eventually become adaptive at the STATION and configurable at the ACCESS MANAGER.

Delay Intervals

The intermessage delay is configurable to provide for longer distances through radio and wire than can be accommodated with the default.

Not all systems will have a peer-to-peer direct requirement. The delay introduced with the length of one *ACK* message should not be compulsory.

Lengths and Retries

There is some saving in configuring out the ATM compatible long address in systems for which 802.6 public network compatibility is not required.

If the ACCESS MANAGER misses a packet, it is a tradeoff on how many retries are appropriate.

The maximum size segment is also a configurable tradeoff.

TABLE VI – CONFIGURABLE PARAMETERS WITH CONFORMANCE-REQUIRED VALUES

PARAMETER NAME & DESCRIPTION	PERMITTED & POSSIBLE VALUES	REQUIRED FOR CONFORMANCE			SCOPE OF EFFECT
		DEFAULT	LEVEL A	LEVEL B	
LINE RATE IN MBITS/SEC:	1, 2, 4, 8, 16, 24	4	1, 4	4, 16	STN, A-P, AM
INTER-MESSAGE DELAY μSEC:	1, 2, 3, 4, 8, 12	4	4, 12	2, 4	STN, AM
PEER/PEER ACK DELAY OCTETS:	OFF, 8, 10, 12	10	OFF, 10	OFF, 10	STN, AM
MSG RETRIES N TIMES:	1, 2, 3, 4, 5	2	1, 2, 3	1, 2, 3	AM
LONG ADDRESS LENGTH:	6, 8	6	6	6, 8	STN, AM
REUSE FACTOR:	9, 10, 12, 16	16	10, 16	10, 16	AM
MAX SEGMENT PAYLOAD LENGTH:	48, 64, 128, 192, 288, 384	288	288	48, 192, 288	STN, AM
MAX PACKET LENGTH:	2,304, 4,608, 9,216	9,216	9,216	9,216	STN, AM
DEFAULT ACCESS MANAGER	ON, OFF	OFF	OFF, ON	OFF, ON	STN

CONCLUSIONS

1. It is possible to use a single protocol for:
   - A. Radio, optical and wire mediums, and
   - B. Minimum, medium and high function STATIONs, and
   - C. Short and medium distance, and
   - D. Systems with a few to many hundreds of STATIONs, and
   - E. LAN and connection-type services;

   provided that provision is made for:
   - F. some configurable options, and
   - G. a medium independent interface to allow a few different types of phy.

2. An entirely asynchronous protocol can be evolved on the principle that the next step begins when the current step is completed; and that a high time utilization can be obtained in this way.

3. Adaptively used peer-to-peer communication can be provided without absolute dependence on its existence.

4. All necessary functions can be obtained from a library of less than 16 different message types--half upward, half downward.

5. Propagation time is a very critical parameter for high signaling rates, and it limits the distance between station and control point. For 16 Mbits/s, 4 μsec may be an upper limit.

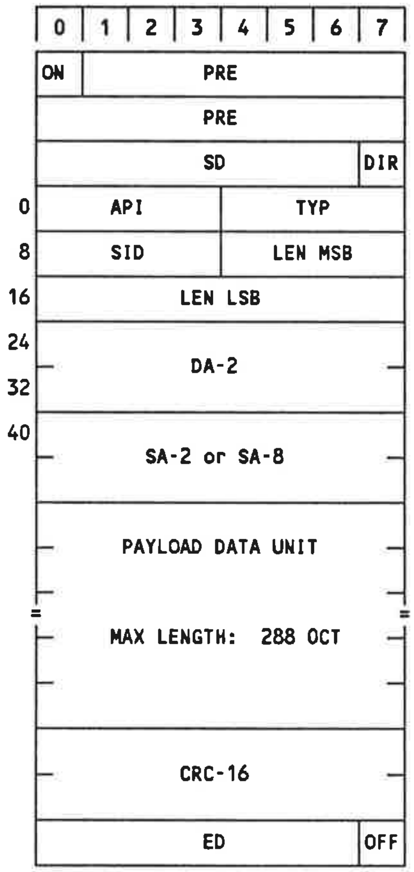
6. The selection of maximum message length for time efficiency is controlled by tolerable peak access delay. A good compromise is in the range of 144-288 octets.

7. For wireless systems, major improvements in utilization can be obtained from reducing the number of contiguous coverages which cannot be used simultaneously.

ATTACHMENT A – Figure 1
FORMAT OF MESSAGES USED – APO (ACCESS-POINT ORIGINATE)

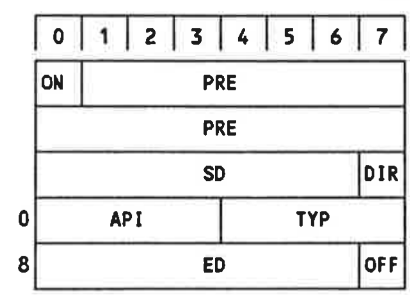
PACKET/SEGMENT DATA FRAME (APO) TYP = 001
PACKET/SEGMENT DATA FRAME (APO) TYP = 002

(SHORT SOURCE ADDRESS SHOWN--
LONG SOURCE ADDRESS SIMILAR)

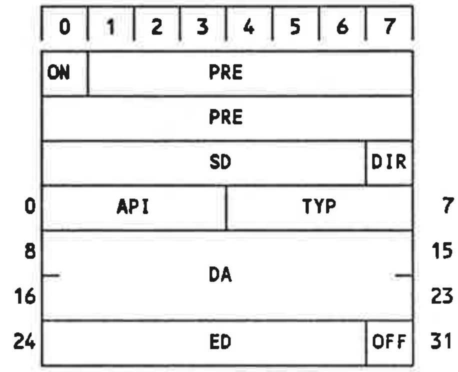


CRC-16: API, TYP, SDI, LEN, PLDU

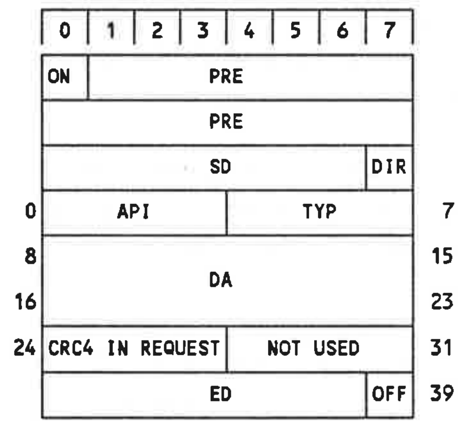
INVITATION-TO-REQUEST/REGISTER (APO)
TYP = 005



POLL (APO) TYP = 007
NACK (APO) TYP = 009
ACK OR RACK (APO) TYP = 011
NACK-REPEAT (APO) TYP = 013

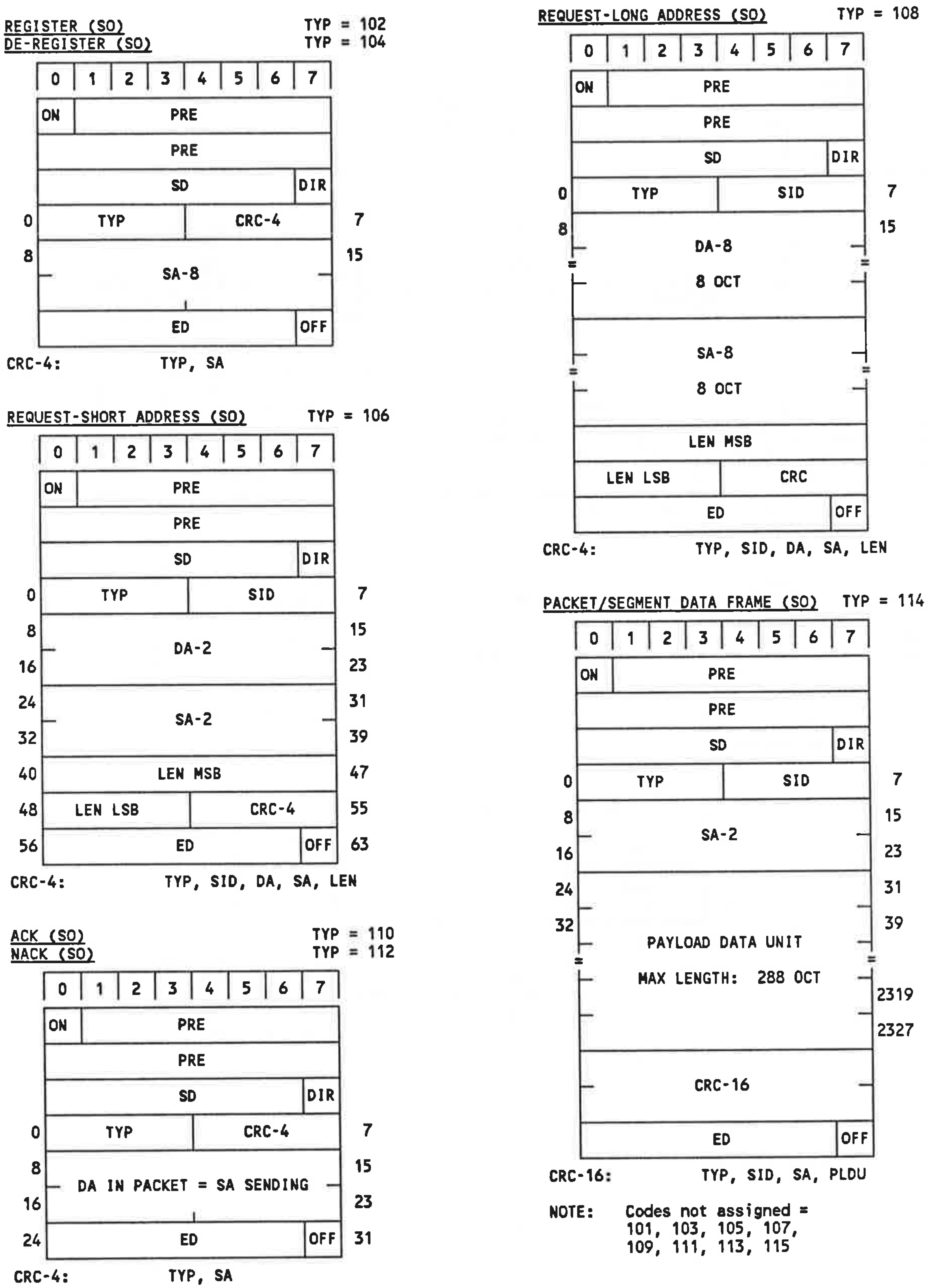


GRANT (APO) TYP = 015



NOTE: Codes not assigned =
000, 002, 004, 006,
008, 010, 012, 014

ATTACHMENT A – Figure 2
FORMAT OF MESSAGES USED – SO (STATION ORIGINATE)



ATTACHMENT B -- 802.6 CELL FORMAT

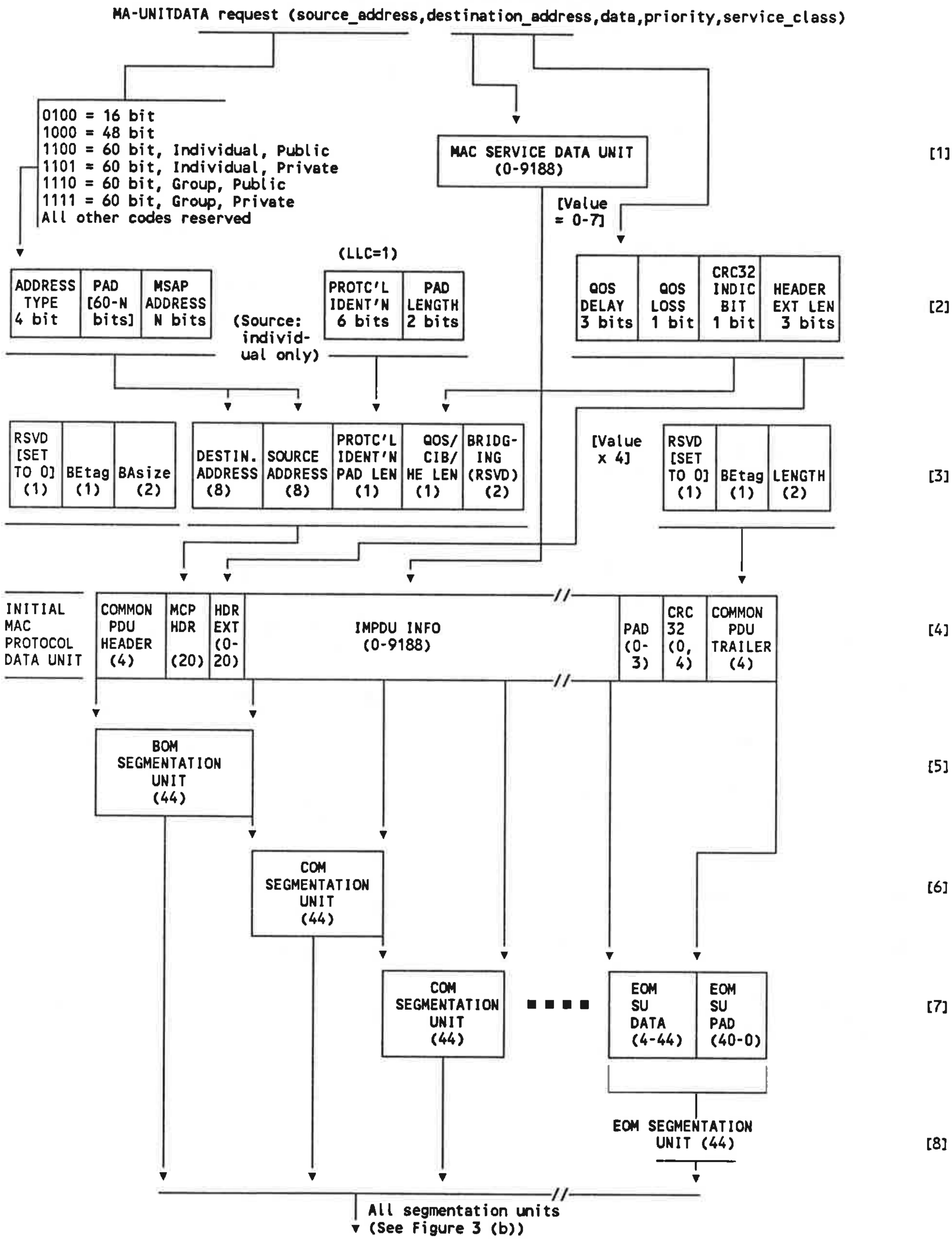


Figure 1a MAC Connectionless Service Protocol Data Unit Hierarchy

ATTACHMENT B – 802.6 CELL FORMAT

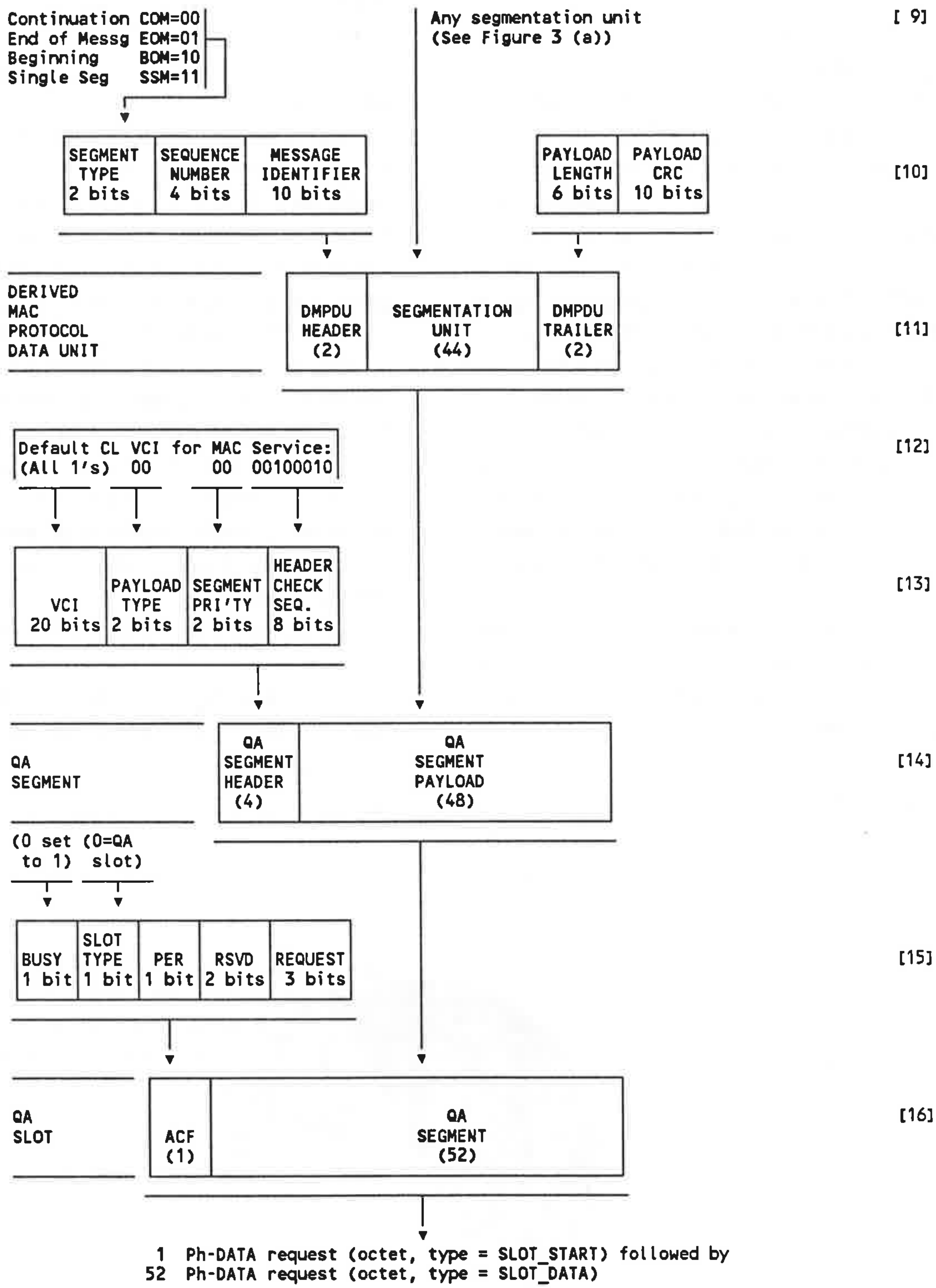


Figure 1b MAC Connectionless Service Protocol Data Unit Hierarchy (cont.)

ATTACHMENT C -- EVALUATION OF EFFICIENCY VS. PROPAGATION TIME

EVALUATION METHOD

A spread sheet was created as shown in Figure 8(a) and 8(b).

In (a), propagation time T and the other basic time intervals are entered or calculated from the definitions. Next, a Table of message types is formed. At this point, all functions are dimensioned in μseconds as a function of medium data rate. The time required for a *REGISTRATION* and the time required for a system cycle with zero activity are calculated.

In (b), two similar tables are calculated for worst case message length and for an ordinary mix of station originate and terminate and for short and long address. The result of these tables is the ratio of payload to channel time consumed for a full cycle of message transmissions containing payloads of either 48 or 288 octets.

The calculation assumes independently-accessed packets rather than continued segments causing some understatement of realizable efficiency for big files and virtual circuits. This choice is necessary for calculation of worst-case access delay for virtual circuits.

RESULTS

Figure 1 below shows the relative use of time for the various message functions for a propagation time of 4 μseconds and a signaling rate of 16 Mbits/s. Figures 2 and 3 on the following page are for 3 and 6 μseconds. In these the propagation time is 32.1, 26.2 and 41.5% of the air time for the three time intervals.

Figures 4 and 5 show efficiency in the use of channel time vs. propagation time for payloads of 288 octets and in 6 and 7 for 48 octets.

The 288 octet payload slightly understates the efficiency attainable for large file transfers, and the 48 octet payload understates the efficiency obtainable handling 64 kbits/s virtual circuits in 6 millisecond bundles.

The efficiency for short packets is lower at the 1 and 4 Mbits/s rates and much lower at 16 Mbits/s. Reducing the propagation time is very important to minimizing the increase in loss at high data rates.

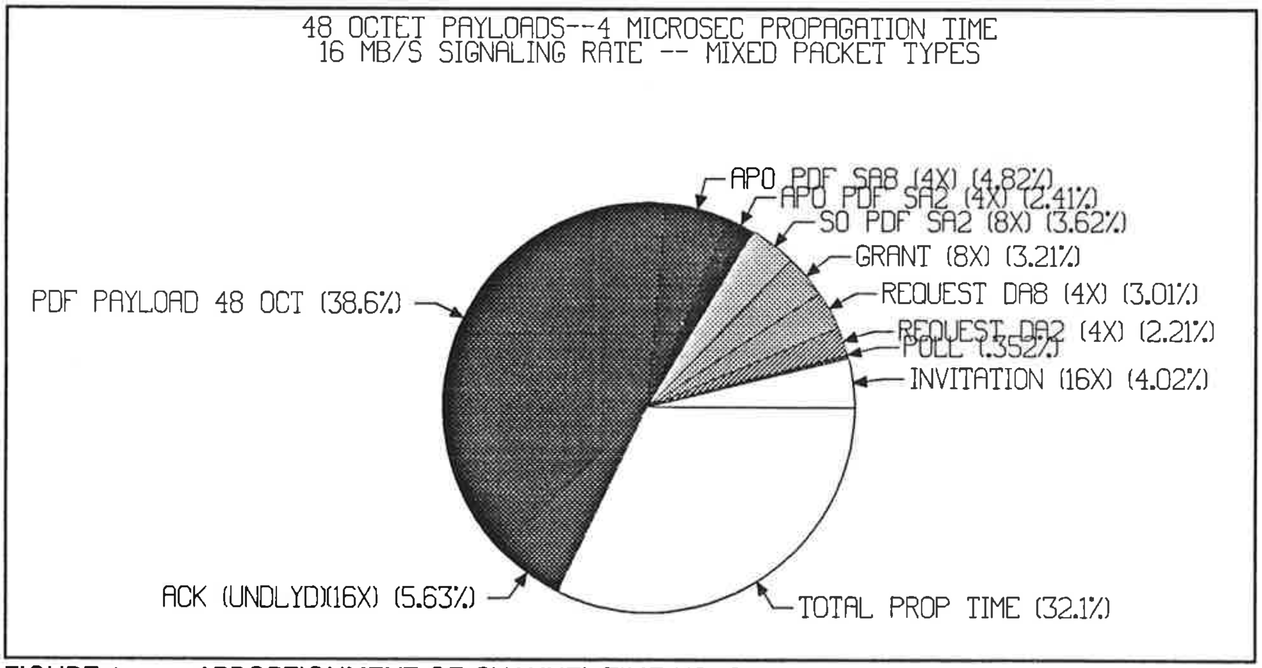


FIGURE 1 APPORTIONMENT OF CHANNEL TIME USAGE

ATTACHMENT C – FIGURES 2 AND 3

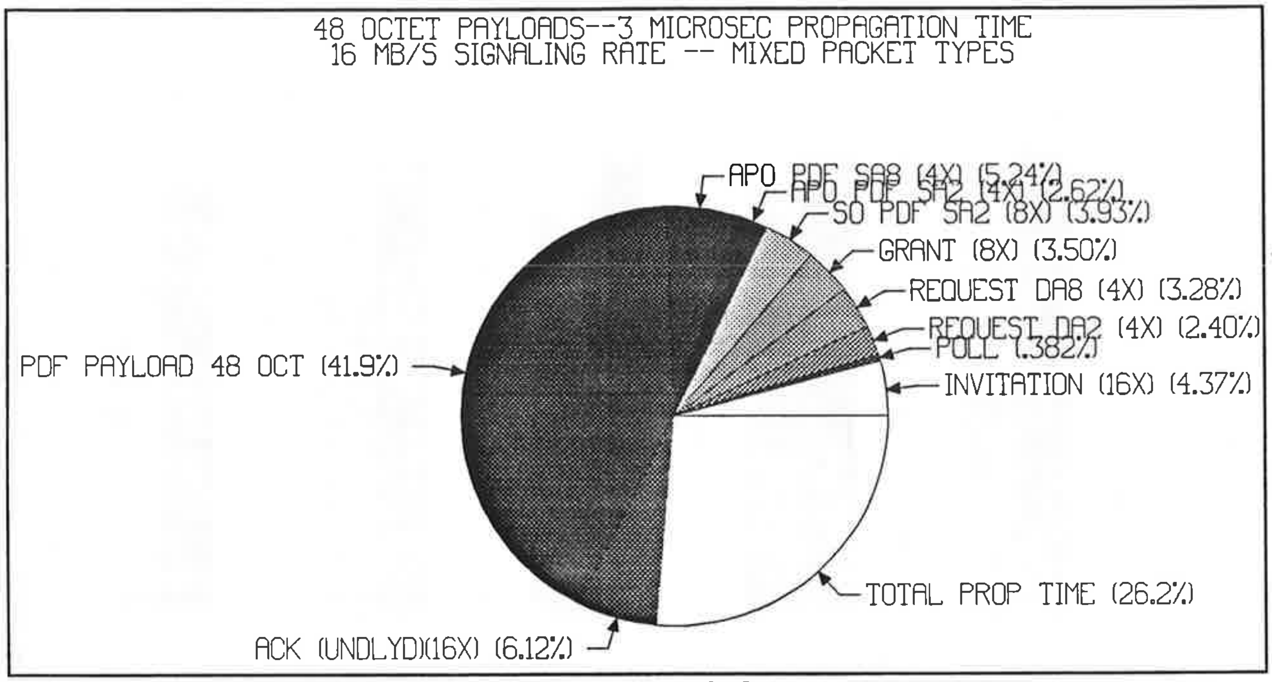


FIGURE 2 APPORTIONMENT OF CHANNEL TIME USAGE

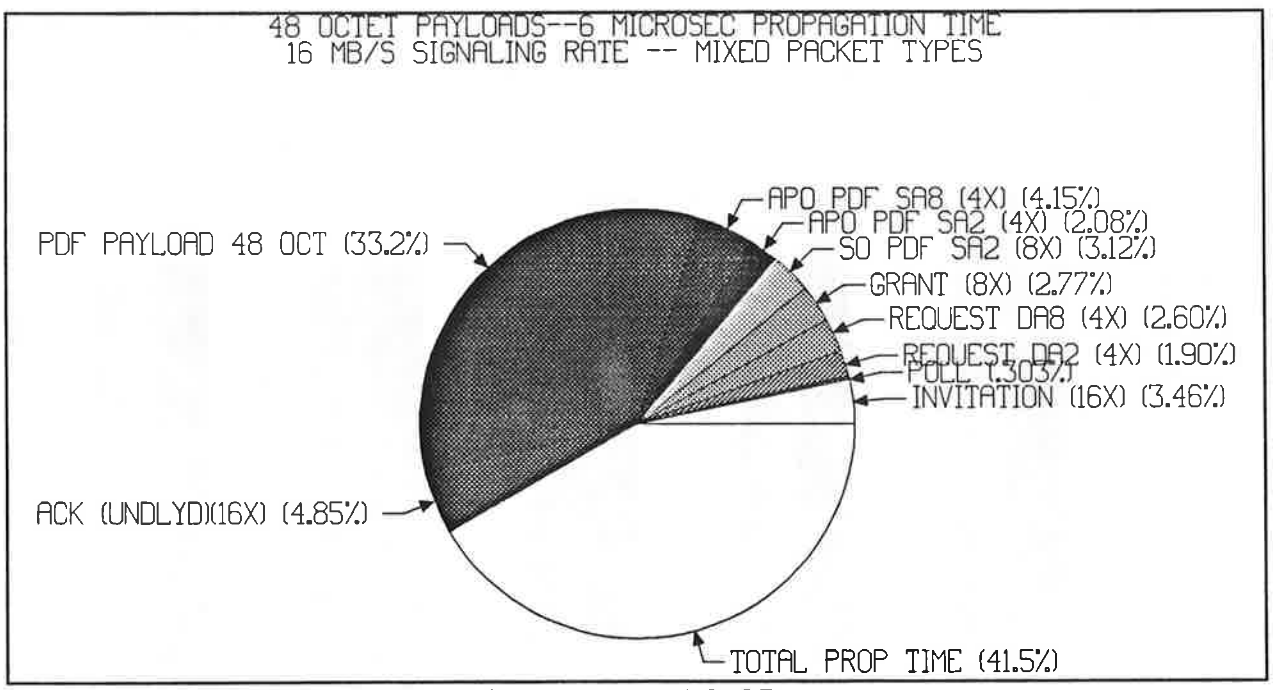


FIGURE 3 APPORTIONMENT OF CHANNEL TIME USAGE

ATTACHMENT C -- FIGURES 4 AND 5

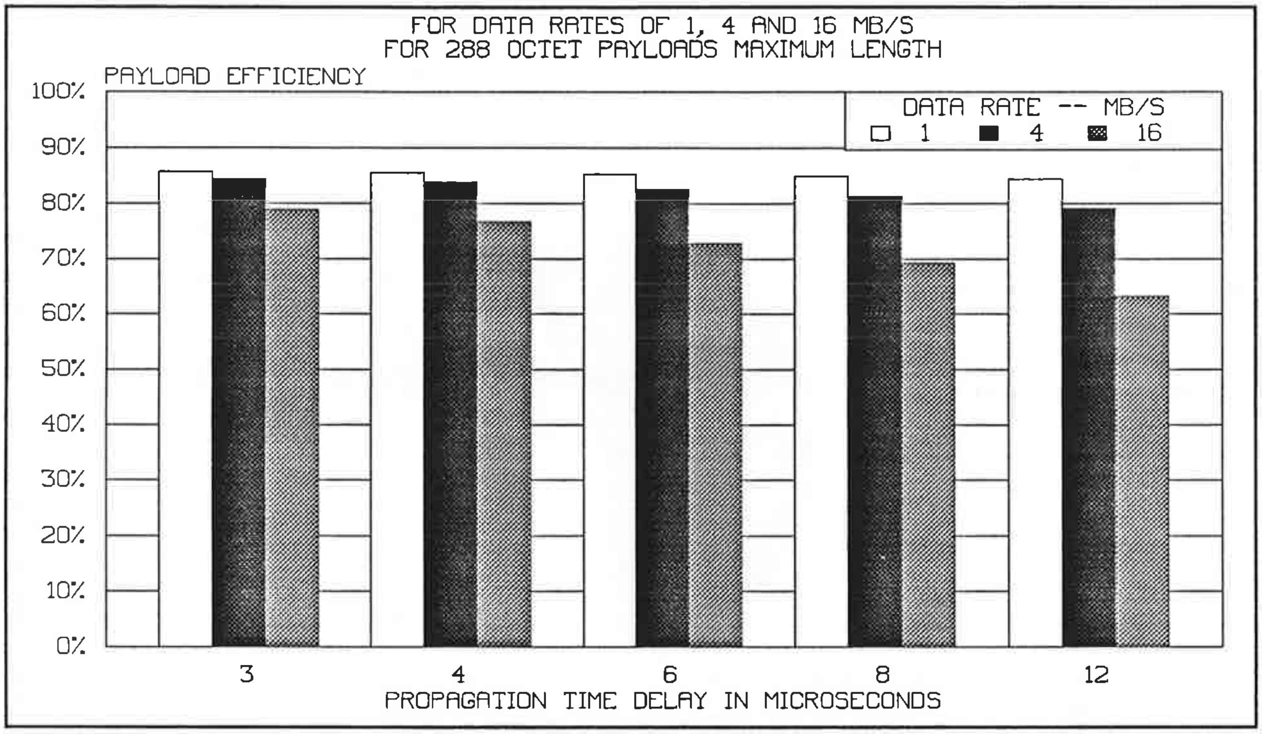


FIGURE 4 PAYLOAD EFFICIENCY VS. PROPAGATION TIME FOR 288 OCTET PAYLOADS MAXIMUM LENGTH

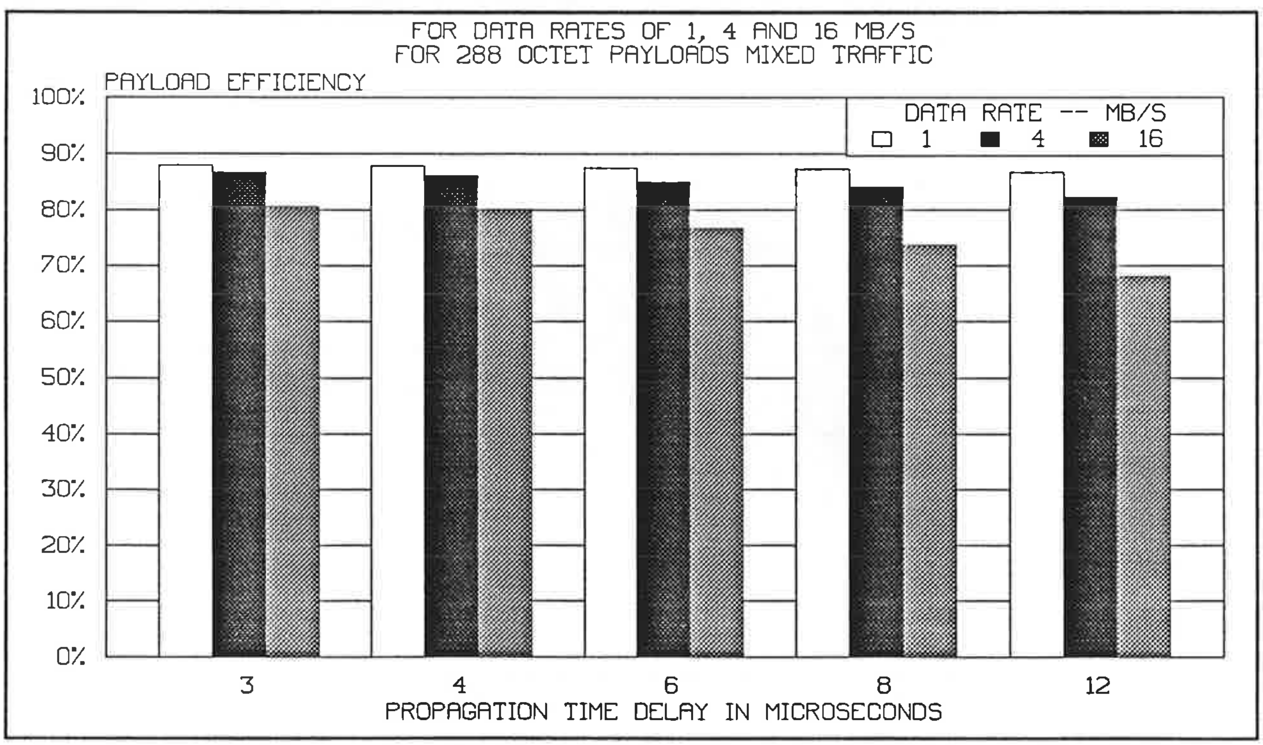


FIGURE 5 PAYLOAD EFFICIENCY VS. PROPAGATION TIME FOR 288 OCTET PAYLOADS MIXED TRAFFIC

ATTACHMENT C -- FIGURES 6 AND 7

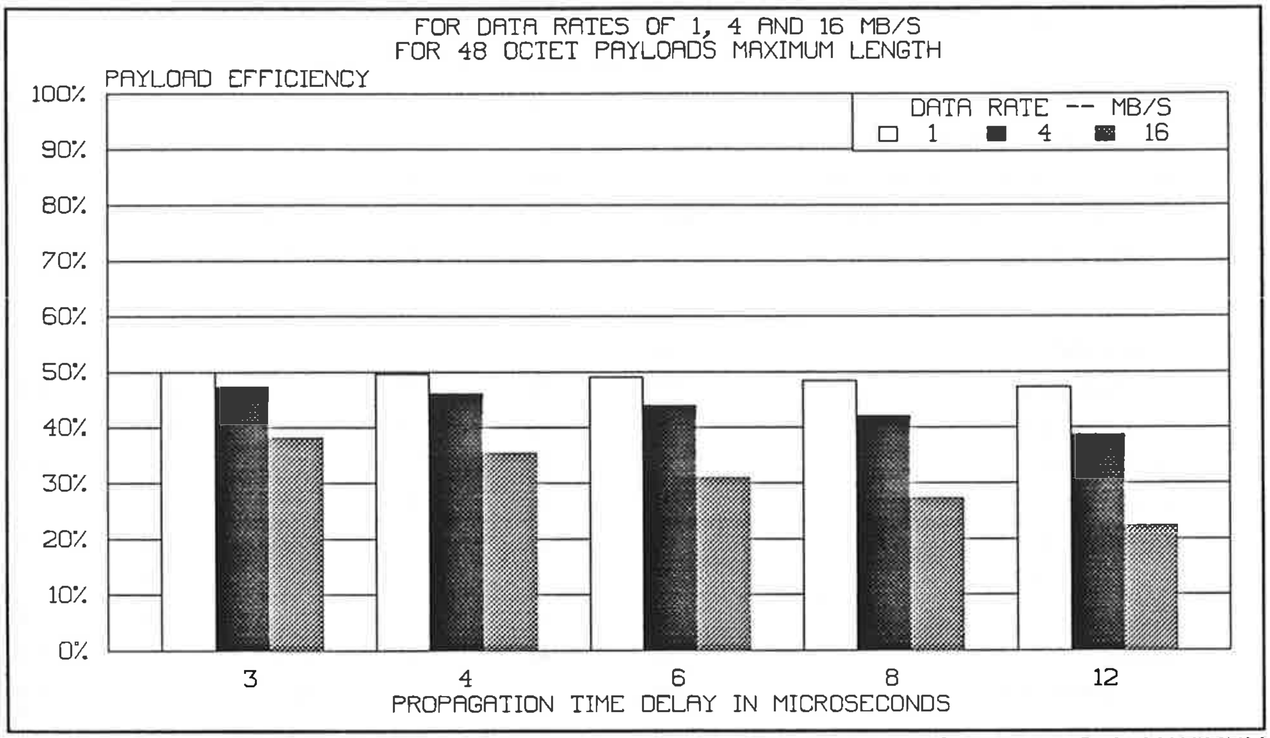


FIGURE 6 PAYLOAD EFFICIENCY VS.PROPAGATION TIME FOR 48 OCTET PAYLOAD MAXIMUM LENGTH

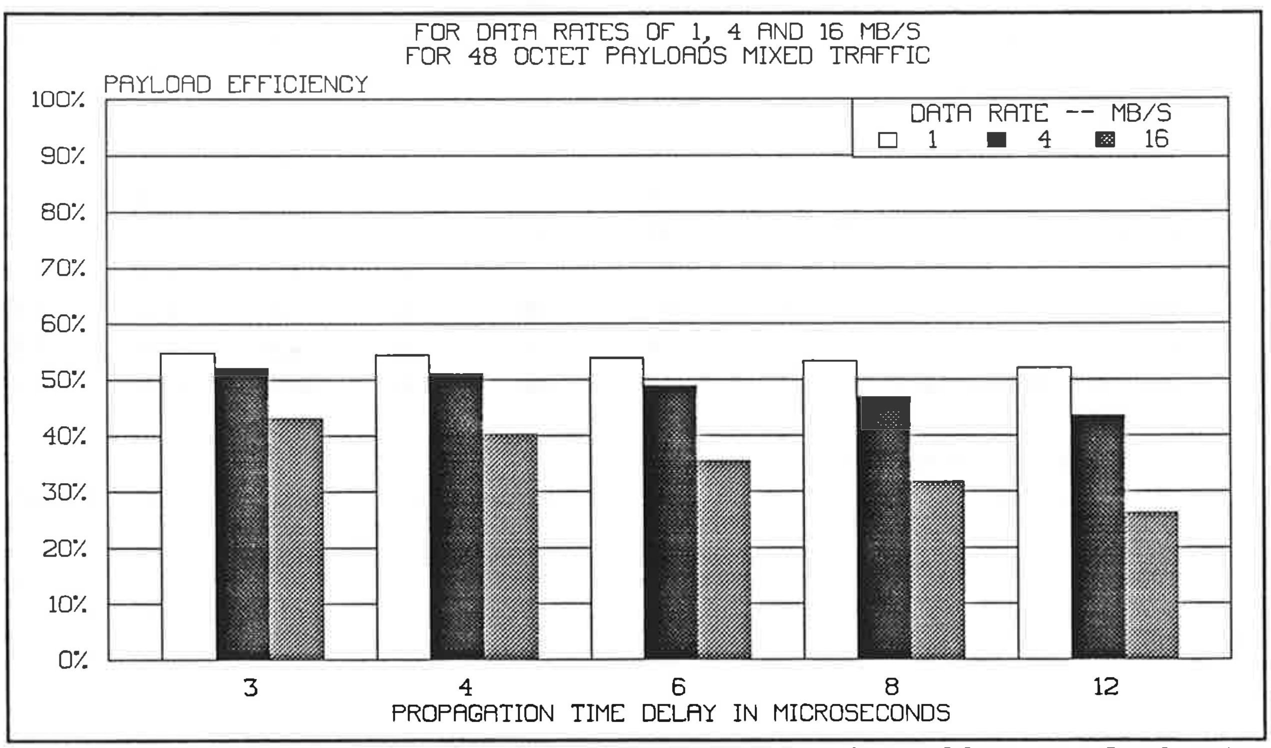


FIGURE 7 PAYLOAD EFFICIENCY VS. PROPAGATION TIME FOR 48 OCTET PAYLOADS MIXED TRAFFIC

ATTACHMENT C – FIGURE 8 – EFFICIENCY CALCULATION SPREADSHEET

1	FILE: 11AP11V.CAL 31JAN91							
2	TIME USAGE STUDY OF PROPOSED 802.11 ACCESS PROTOCOL FOR PROPAGATION TIME:							4 MICROSEC
3			BY MEDIUM SIGNALING RATE -- PERIOD IN MICROSECONDS OR OCTETS					
4	DATA RATE--MB/S:		1	2	4	8	16	24
5	PROPAGATION T MICROSEC:		4	4	4	4	4	4
6	DATA LENGTH MICROSEC-48 OCTETS:		384	192	96	48	24	16
7	DATA LENGTH MICROSEC-288 OCTETS:		2304	1152	576	288	144	96
8	ACK DELAY MICROSEC		60	32	18	11	8	6
9	MESSAGE TYPES							
10	PDF-DA2/SA2 +12 O	1	96	48	24	12.0	6.0	4.0
11	PDF-DA8/SA8 +24 O	3	192	96	48	24.0	12.0	8.0
12	INVITATION 5 O	5	40	20	10	5.0	2.5	1.7
13	POLL-DA2 7 O	7	56	28	14	7.0	3.5	2.3
14	NACK 7 O	9	56	28	14	7.0	3.5	2.3
15	ACK/RACK 7 O	11	56	28	14	7.0	3.5	2.3
16	NACK-REPEAT 7 O	13	56	28	14	7.0	3.5	2.3
17	GRANT 8 O	15	64	32	16	8.0	4.0	2.7
18	REGISTER 11 O	102	88	44	22	11.0	5.5	3.7
19	DE-REGISTER 11 O	104	88	44	22	11.0	5.5	3.7
20	REQUEST DA2 11 O	106	88	44	22	11.0	5.5	3.7
21	REQUEST DA8 15 O	108	120	60	30	15	8	5
22	ACK 7 O	110	56	28	14	7.0	3.5	2.3
23	NACK 7 O	112	56	28	14	7.0	3.5	2.3
24	PDF SO SA2 +9 O	114	72	36	18	9.0	4.5	3.0
25	REGISTRATION SEQUENCE							
26	INVITATION	5	40	20	10	5.0	2.5	1.7
27	T		4	4	4	4.0	4.0	4.0
28	REG/DEREG	102/104	88	44	22	11.0	5.5	3.7
29	T		4	4	4	4.0	4.0	4.0
30	RACK	11	56	28	14	7.0	3.5	2.3
31	T		4	4	4	4.0	4.0	4.0
32	TOTAL TIME TO REGISTER:		196	104	58	35.0	23.5	19.7
33	CYCLE SEQUENCE--ZERO ACTIVITY							
34	INVITATION (16X)	5	640	320	160	80	40	27
35	T+WAIT (16x)		1088	576	320	192	128	107
36	POLL	7	56	28	14	7	4	2
37	T+WAIT		68	36	20	12	8	7
38	TOTAL ACTIVITY TIME (QUIESCENT):		1852	960	514	291	180	142

1	CYCLE SEQUENCE--QUEUED MAXIMUM SEGMENTS							
2	INVITATION (16X)	5	640	320	160	80	40	27
3	T (16x)		64	64	64	64	64	64
4	POLL	7	88	44	22	11	6	4
5	T+WAIT		193	97	51	29	23	24
6	REQUEST DA8 (16X)	108	1920	960	480	240	120	80
7	T (16x)		64	64	64	64	64	64
8	GRANT (16X)	15	1024	512	256	128	64	43
9	T(16X)		64	64	64	64	64	64
10	SO PDF SA2 (16X)	114	1152	576	288	144	72	48
11	PDF PAYLOAD 288 OCTETS		36864	18432	9216	4608	2304	1536
12	T (16X)		64	64	64	64	64	64
13	ACK (UNDELAYED) (16X)	11	896	448	224	112	56	37
14	T (16X)		64	64	64	64	64	64
15	TOTAL ACTIVITY TIME (LOADED 288 O):		43097	21709	11017	5672	3004	2118
16	PDF PAYLOAD 48 OCTETS		6144	3072	1536	768	384	256
17	TOTAL ACTIVITY TIME (LOADED 48 O):		12377	6349	3337	1832	1084	838
18	PAYLOAD EFFICIENCY 288 O:		85.5%	84.9%	83.7%	81.2%	76.7%	72.5%
19	PAYLOAD EFFICIENCY 48 O:		49.6%	48.4%	46.0%	41.9%	35.4%	30.5%
20	CYCLE SEQUENCE--QUEUED SEGMENTS HALF STATION ORIGINATE, HALF LONG ADDRESS							
21	INVITATION (16X)	5	640	320	160	80	40	27
22	T (16x)		64	64	64	64	64	64
23	POLL	7	88	44	22	11	6	4
24	T+WAIT		193	97	51	29	23	24
25	REQUEST DA2 (4X)	106	352	176	88	44	22	15
26	REQUEST DA8 (4X)	108	480	240	120	60	30	20
27	T (8X)		32	32	32	32	32	32
28	GRANT (8X)	15	512	256	128	64	32	21
29	T(8X)		32	32	32	32	32	32
30	SO PDF SA2 (8X)	114	576	288	144	72	36	24
31	APO PDF SA2 (4X)	1	384	192	96	48	24	16
32	APO PDF SA8 (4X)	3	768	384	192	96	48	32
33	PDF PAYLOAD 288 OCTETS		36864	18432	9216	4608	2304	1536
34	T (16X)		64	64	64	64	64	64
35	ACK (UNDELAYED) (16X)	11	896	448	224	112	56	37
36	T (16X)		64	64	64	64	64	64
37	TOTAL ACTIVITY TIME (LOADED 288 O):		42009	21133	10697	5480	2876	2012
38	PDF PAYLOAD 48 OCTETS		6144	3072	1536	768	384	256
39	TOTAL ACTIVITY TIME (LOADED 48 O):		11289	5773	3017	1640	956	732
40	PAYLOAD EFFICIENCY 288 O:		87.8%	87.2%	86.2%	84.1%	80.1%	76.4%
41	PAYLOAD EFFICIENCY 48 O:		54.4%	53.2%	50.9%	46.8%	40.2%	35.0%

ACCESS PROTOCOL FOR IVD WIRELESS LAN

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GENERAL DESCRIPTION

SCOPE AND INTENTIONS

PRINCIPLES OF OPERATION

WIRELESS MEDIUM AND CENTRAL CONTROL

ASYNCHRONOUS ACCESS

STATION ORIGINATE MESSAGE SEQUENCE

STATION TERMINATE MESSAGE SEQUENCE

SINGLE REGISTRATION SEQUENCE

INVITATION TO REQUEST/REGISTER MESSAGE SEQUENCE (ESR)

CYCLE SEQUENCE FOR ONE MESSAGE PASSED
ON EACH OF 16 ACCESS POINTS

ACCESS MANAGER

DEFAULT ACCESS MANAGER

INVITATION TO REQUEST/REGISTER MESSAGE SEQUENCE (BSR)
WITH DEFAULT ACCESS MANAGER

PEER-TO-PEER DIRECT AND REPEAT FUNCTION

SEGMENTATION AND USE OF SHORT ADDRESS LABELS

ADAPTATION TO VIRTUAL CIRCUITS

CAPACITY, EFFICIENCY AND DELAY

OBSERVATIONS

CONCLUSIONS

PROPOSED CONVERGENCE MOTIONS

PRINCIPLES OF OPERATION

- Access centrally controlled for a local area with potential mutual exclusivity
- (Default mode access control may be activated in any station)
- Contention may occur on first try upward access, but for downward traffic there is no contention
- After first try contention, sorting or polling can be used
- Asymmetrical Protocol: request-grant upward -- station ready downward
- Second message cycle begins asynchronously upon completion of first
- Error correction by automatic message repeat only when necessary
- Long addressing is supported at 8 octets with 802 format 6 octet subset
- Short addressing is normal at 2 octets locally administered
- No minimum length packet or padding
- Long packets are SEGMENTED at a maximum payload of 288 octets
- The same protocol is used between hubs on UTP for networking
- Configurable parameters are used to adapt the system needs

WIRELESS MEDIUM AND CENTRAL CONTROL

- For a MODEL, 16 Access Points are used sequentially and act as one channel with multiple radiation/reception points

- Coverage is often redundant and overlapping

- Only central control can deal intelligently and quickly with the interaction of multiple sites within and out of the 16 AP cluster group

- Considering propagation time in air and wire, central control is most efficient when the distance between control and Station is small

- 4 μseconds = 400 meters of cable and 400 meters of air

- If the Access Protocol provides all necessary handling information in header or label, then the packet may be processed independently of where it is received, and then multiple reception creates path diversity from Station to Access Point

ASYNCHRONOUS ACCESS

- With central control, the second use of the channel may begin immediately when the first use ends

- The allowance for propagation time is actual and may be much less than worst case

ACCESS MANAGER

- Activated by hardware switch and implemented in a local multi-port bridge/concentrator/router at wiring closet
- Sends Invitation to Request/Register sequentially on 16 Access Points
- If priority Station-terminate packet/segment has appeared in queue enables, send on the appropriate Access Point regardless of position of normal traffic sequence
- After each Invitation, listens for Request or Register message
- If registration is received with long address, short address is assigned and the best Access Point noted in directory
- If Request is received and if resources are available to handle the packet, sends Grant message, accepts message from Station and sends Ack. Grant is not withheld as a function of busy status of local destination address.
- If contention occurs on Request, sorting protocol is activated
- After each no-response listening interval, sends one message or segment of queued traffic
- After each cycle of 16 Invitations, Polls one registered Station
- If another Invitation source is heard, a system minor alarm state is generated

DEFAULT ACCESS MANAGER

PURPOSE: To enable a small number of Stations to communicate directly in the absence of any fixed facility. All stations must be within radio range of all others, or else the Station with active Access Manager needs the repeat option activated.

- Activated only if no Invitation message is received after power-on and within about 15 seconds
- Sends Invitation to Request/Register periodically--every 4 milliseconds at 1 Mbs
- After each Invitation, listens for Request or Register message
- If registration is received, short address is assigned sequentially. A directory of long-short address conversion is maintained.
- If Request is received, sends Grant message
- The addressed Station, addressed short or long and if available, accepts message from Station and sends Ack
- If relay option is active and if Request is received and if no ACK from addressed Station, Access Manager copies message and retransmits message.
- If multiple Requests are received, sorting protocol is activated
- After each no-response listening interval, sends one message or segment of queued traffic
- If default Access Manager hears another Invitation message source, the frequency of Invitations is dropped to one-fifth. If after this change, and the outside Invitations continue at the same rate, the default Access Manager goes off. (Not in text of contribution -19.)

PEER-TO-PEER DIRECT AND REPEAT FUNCTION

- In a large system, peer-to-peer direct is only possible for shorter distances and small groups
- Any Station cannot always communicate with all other nearby Stations, but any Station can always communicate with the registered Access Point
- Peer-to-peer direct communication may use half the radio channel time and sometimes half of the delay of repeated messages
- When direct peer-to-peer is permitted, the successful transmission is directly acknowledged immediately upon receipt, and the unsuccessful direct but successful to Access Point is ACKnowledged with delay from the Access Point

SEGMENTATION AND USE OF SHORT ADDRESS LABELS

- Normal mode is locally assigned Short Address -- 2 octets
- Assignment to Stations is made upon Registration with Long Address
- Stations may Register with E.164 Address
- Stations initiate traffic outside system or where Short Address is unknown using Long Address

CONCLUSIONS

1. It is possible to use a single protocol for:
   A. Radio, optical and wire mediums, and
   B. Minimum, medium and high function STATIONs, and
   C. Short and medium distance, and
   D. Systems with a few to many hundreds of STATIONs, and
   E. LAN and connection-type services;

   provided that provision is made for:
   F. some configurable options, and
   G. a medium independent interface to allow a few different types of PHY.

2. An entirely asynchronous protocol can be evolved on the principle that the next step begins when the current step is completed; and that a higher time utilization can be obtained in this way.

3. Adaptively used peer-to-peer communication can be provided without absolute dependence on its existence.

4. All necessary functions can be obtained from a library of less than 16 different message types--half upward, half downward.

5. Propagation time is a very critical parameter for high signaling rates, and it limits the distance between station and control point. For 16 Mbits/s, 4 μsec may be an upper limit.

6. The selection of maximum message length for time efficiency is controlled mainly by tolerable peak access delay but also transmission delay. A good compromise is in the range of 144-288 octets.

7. For wireless systems, major improvements in utilization can be obtained from reducing the number of contiguous coverages which cannot be used simultaneously.