IEEE 802.11
802 LAN Access Method for Wireless Physical Medium

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TITLE: **ARCHITECTURE -- TOPOLOGY AND PROTOCOL STACKS**

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SUMMARY

There is linkage between protocol, topology and layer structure, which is unique to the wireless medium. For large scale systems, the radio medium requires co-use of one channel at dynamically selected sites far enough apart to be non-interfering and as close as possible for efficiency. A central control function is needed which is not present in any other 802 MAC.

There are a variety of known applications which are sufficiently diverse to make any measure of commonality a technical challenge. The small autonomous system in a personal or consumer context and the workstation desktop at first appear to be irreconcilable.

Possible types of Stations to be served are shown in ATTACHMENT A in which the Personal, Industrial are "low capacity" technologies at a medium rate of 1 Mbits/s, and the Workstation class at 16 Mbits/s or higher are "high capacity" technologies. The classification of the 4 Mbits/s office system can be either depending on density and number of users selected.

Together with a message based protocol ("ACCESS PROTOCOL FOR IVD WIRELESS LAN," March 1991 Contribution to 802.11) this contribution describes much of the topology and protocol layering for a complete system plan.

ARCHITECTURE – TOPOLOGY AND PROTOCOL STACKS

Table of Contents   Page

Figures

Attachments

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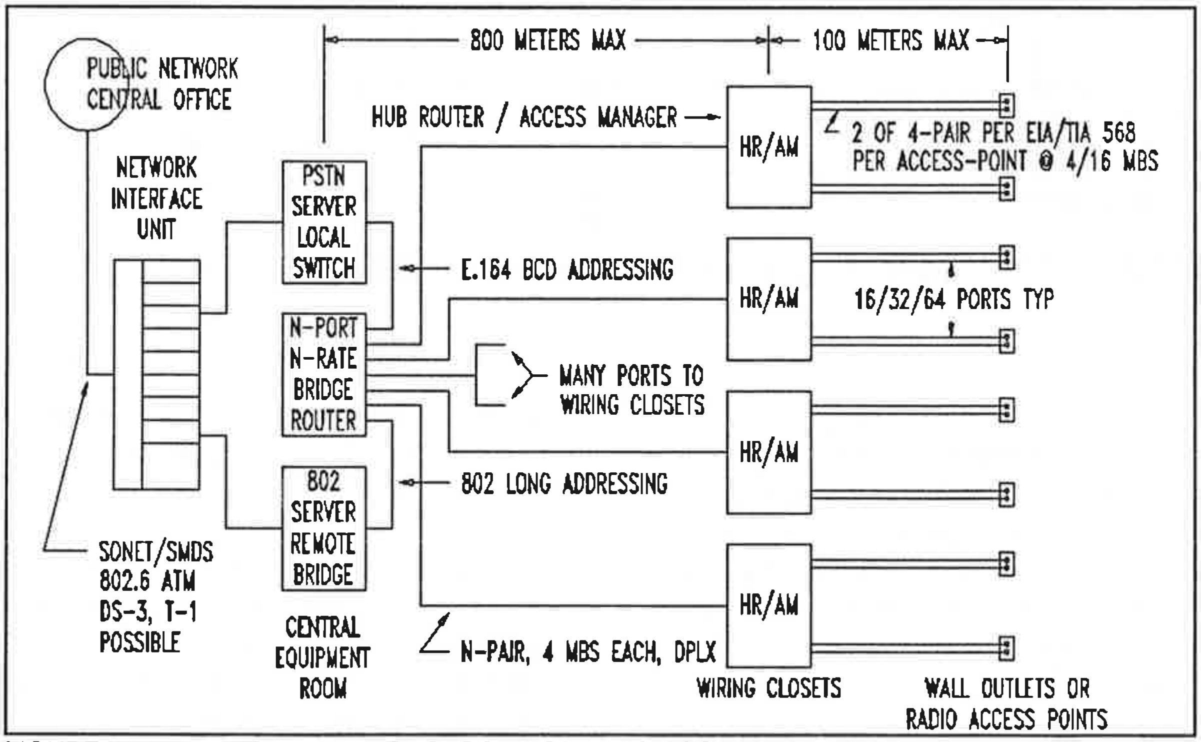

FIGURE 1 OVERALL TOPOLOGY FOR LARGE-SCALE SYSTEM

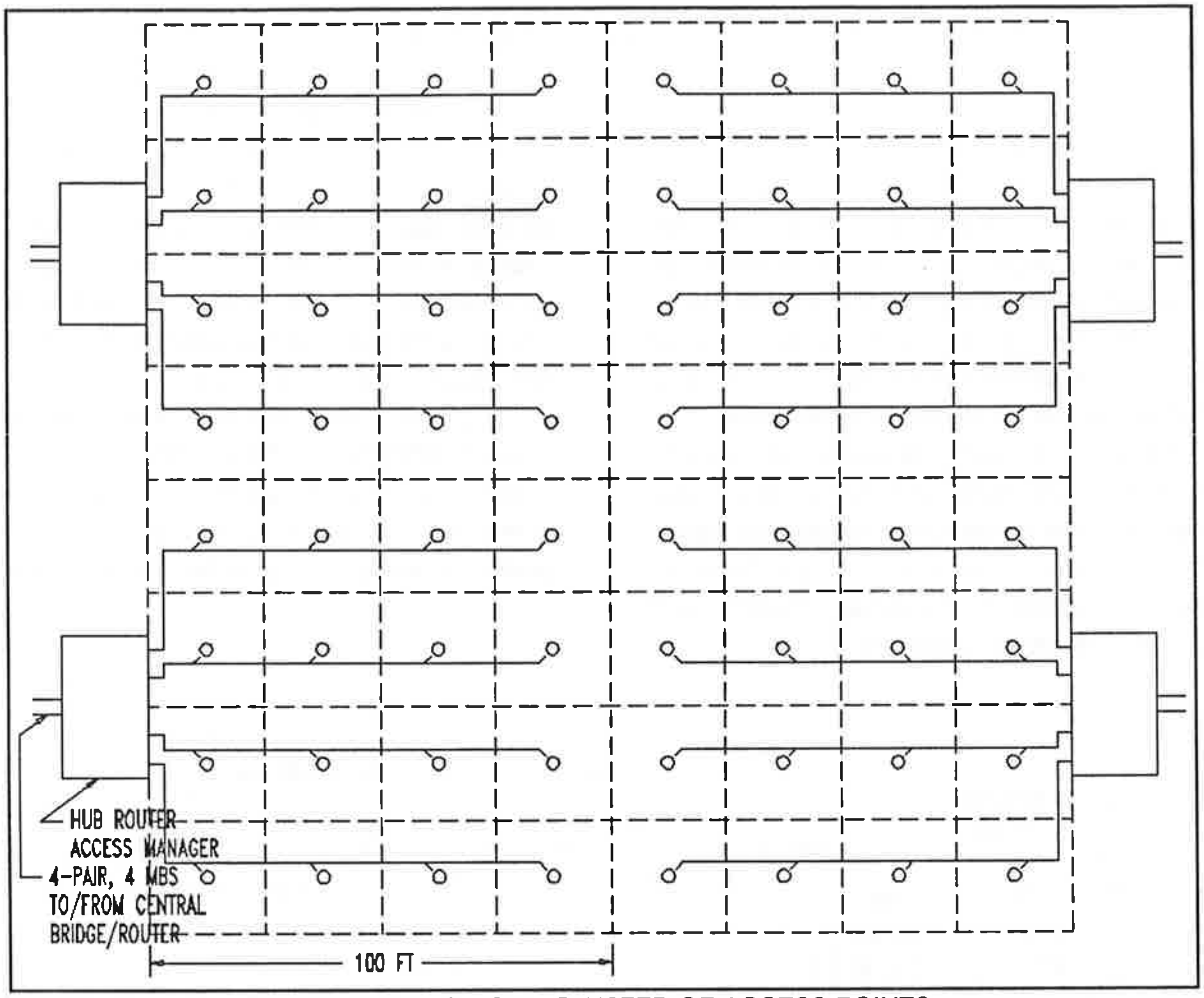

FIGURE 2 DETAIL PLAN FOR ONE CLUSTER OF ACCESS-POINTS

HIGH CAPACITY TOPOLOGY

The most general problem is the full function plan, because it is possible for a simple system to be a subset. The large system is a ubiquitous radio access throughout an intensively used premises area. With the radio physical medium, the single radio channel must be co-usable at separated locations.

Topology Reference: EIA/TIA 568

As shown in Figure 1 above for office environments, the topology of EIA/TIA 568 "COMMERCIAL BUILDING TELE-COMMUNICATIONS WIRING," (SP-1970A) is followed where there are "telecommunications (wiring) closets" and "equipment rooms." The primary physical medium is 24 gauge UTP (unshielded telephone pair) between "outlets" and wiring closets.

16 ACCESS-POINTs Per Cluster and Hub

This plan assumes that there is an active HUB in the wiring closet which supports groups of 16 radio ACCESS-POINTS. The port on the HUB uses signals specifically adapted to the UTP medium at rates up to 20 Mbits/s. The ACCESS-POINT is powered through two-pairs which carry the near base-band waveform ("CMSK LINE SIGNAL WITH MEASURED VIDEO AND RF SPECTRUM SHAPES," March 1991 Contribution to 802.11). The radio is a linear transport for the signal in the connecting pairs.

While a regular grid is shown in the detail of Figure 2 above, this is neither necessary or even desirable for actual installations. Horizontally omni-directional antennas are assumed in the model, however there may be other types actually used.

Reach-Rate Limitations of Common UTP and Implications

Because it is assumed that UTP will be used for runs of up to 100 meters between wiring closet and ACCESS-POINT, and for runs up to at least 500 meters between wiring closet and equipment room or intermediate point, the reach-rate tradeoff in UTP is a material consideration. If additional reach is required, better cable can be used.

The matter of reach-rate possibilities on 24 gauge UTP has been explored extensively in 802.9 (IVD LAN Interface). The limitations are the worst case of near-end crosstalk or impulse noise. High frequency attenuation causes the desired signal to be diminished relative to the noise floor. From among many more possibilities, three candidate modulations offered by different Companies have been recognized as finalists with asserted reach as follows:

	4	16	20	Mbits/s
PR4:	450	--	--	meters
NRZST:	450	150	100	meters
4-CAP	--	--	100	meters

Using the numbers above, it appears inappropriate to plan on over 4 Mbits/s between closet and equipment room. If more capacity is needed, more pairs must be used.

If there is no compensation for the amplitude and delay distortion in the UTP, the reach is about 25 to 40% of the compensated value. By using plenum grade insulation (rather than the more common PVC) for the UTP, the reach of an NRZST system was extended from 600 to 1000 feet at 16 Mbits/s. From EIA/TIA 568, Chapter 10, it is known that common backbone cable is slightly better than horizontal cable.

Alternative Mediums

The proposed access protocol is not limited to radio for access or UTP for backbone. Un-collimated infra-red can also be used for access; collimated or guided (F-O cable) infra-red can be used for links between ACCESS-POINTs and equipment room. <u>If the ACCESS-POINTs are linked by wireless, the power wiring needed might be more costly than the UTP</u>.

Scaling for 4 and 16 Mbits/s Plans

Lower rates permit greater reach and the use of obstructed radio paths. The decrease in capacity might discourage an increase in the number of users per ACCESS-POINT which is topologically possible.

The 4 Mbits/s medium might cover four times the area per ACCESS-POINT or an average of 16 User stations, however the traffic capacity per User would then be 1/16th of that of the 16 Mbits/s plan.

LOW CAPACITY TOPOLOGY

The strategy for a 1 Mbits/s system would be different. Each ACCESS-POINT would be an independent system, possibly with frequency channelization to separate co-premise systems. It would not have capacity for connection-type service (or not very much of it), but it would certainly provide more and faster service than a network using 9.6 kbits/s smart modems on PBX ports. The ACCESS-POINTs would be sufficiently separated that carpet type solutions would be inappropriate. Nonetheless, the same technologies and protocols would be usable for linking many ACCESS-POINTS into a common system.

The protocol stacks will be identical to those with no Class II provision, possibly differing somewhat in the arrangement of fixed portions.

PART II -- PROTOCOL STACKS

OVERVIEW

The layer design is much influenced by topology and the mandatory compatibilities at the scope boundaries. In addition, optional LLC Class II (Connection-type) is a significant added detail. For the protocol stacks, two types of stations are assumed:

Class I = LAN only,
Class I & II = LAN and connection type services (higher signaling rates only)

In addition, the stacks for a MAC bridge HUB at the wiring closet and a LAN/Isochronous separating bridge at the equipment room are shown. This presentation is greatly influenced by implementation considerations, and may not be sufficiently abstract for Standards use.

A major assumption is a medium independent interface between the PMD and the MAC where different types of PMD can be connected.

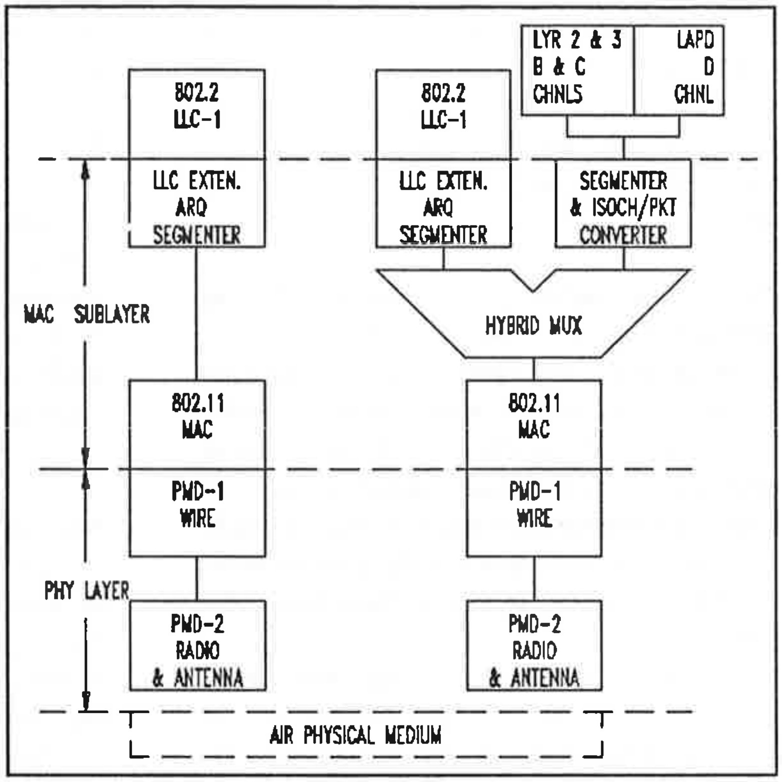

FIGURE 3 PROTOCOL STACK FOR LAN ONLY AND LAN AND CONNECTION-TYPE SERVICES

STATION PROTOCOL STACK

Both of the station stacks shown in Figure 3 have two peculiarities: an LLC extension (convergence) above the MAC proper, and two PMD sublayers. In addition, an H-Mux is shown for the dual function station.

Automatic Repeat Function

The motivation for the ARQ (automatic repeat) function is the impossibility of getting the low outage and error rates from a radio medium assumed by the present 802 LLC, and stated in the current draft of 802 Functional Requirements. Since retransmission is a defined responsibility only for a higher layer, this position is at the upper limit of the 802.11 scope. The LLC-I deals only with unacknowledged packets.

It is arguable that ARQ should be a MAC sublayer, but it is shown as it is so that the ARQ implementation can be separately decided for LLC Class I and II. The reliability realization for connections is different than for packets.

In implementation, the ARQ is simple. It is no more than the decision to send *ACK, NACK* or nothing at all based on frame CRC, and to dump faulty frames.

Segmentation

LLC-I packet size requirements are given at 6.8 and do not limit 802.11.

Segmentation is introduced to limit the access delay that any one user can create and to divide the available transmission capacity between users under high use conditions.

Segmentation is a distinct function above the MAC, and it is differently performed for Class I and II on the higher level side. For Class II, a requirement to condition the signal to a known interface form will be present in order to use existing LAPD and B-channel hardware.

Segmentation is much involved in forming and interpreting the frame and content of the messages passed on the medium, and so must work closely with the MAC. It is assumed that the interface between them is not exposed or defined in the 802.11 Standard.

PMD Sublayers

PMD-1 converts a logic-level form of the data to an analog form suitable for transmission over UTP. PMD-1 also does clock recovery and scrambling (if required).

PMD-2 translates the PMD-1 line signal to and from the radio operating frequency. This is the only part of the structure which depends on frequency allocations and radio modulation method.

It would be possible to define an integrated PMD with both functions. This possibility should not be precluded in the Station, but it must be independently considered for ACCESS-POINTs.

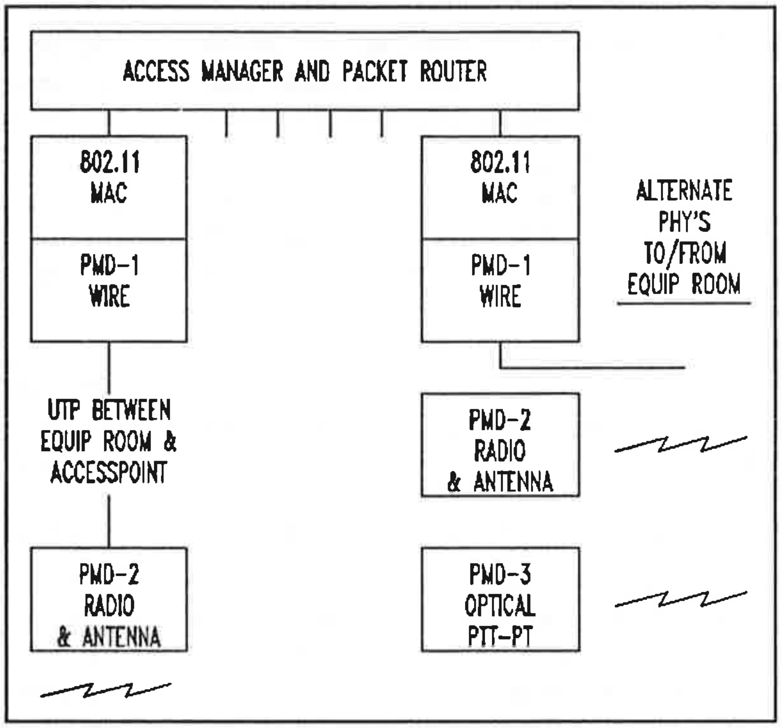

FIGURE 4 PROTOCOL STACK FOR MULTI-PORT HUB AT THE WIRING CLOSET

H-Mux

The Hybrid Multiplexer is only required in combined Class I and II Stations. Its function is to separate Class I and II data units. When passing data units to the MAC from higher levels, it must buffer and give precedence to the connection-type Class II.

The H-Mux does not create or change data units, and so it is a relatively simple hardware function.

WIRING CLOSET MULTI-PORT MAC BRIDGE

The economics of this function are based on multiple users per port and many ports per equipment. It is also economically helpful to minimize function by avoidance of protocol translation and interfaces to foreign networks.

Main feature: The protocol on the link to the Equipment Room uses the same MAC as do the links to ACCESS-POINTs. The rate on the down and up hierarchy ports may be the same or different.

The protocol stack arrangement is shown in Figure 4.

ACCESS MANAGER and Packet Router

This is the inherent common equipment in the bridge function. Some of its function are also found in the LLC extension sublayer in the station.

The ACCESS MANAGER functions include the following:

1) sequential or restricted parallel use of ACCESS-POINTs providing the timing of *INVITATION, POLL and RACK* messages created in the MAC.
2) processing of received *REGISTRATION* messages, and maintaining a directory of registered user stations by short address (SA-2) and best port and alternative ports for access.
3) Polls user stations and processes *ACK* when received thereafter.

4) Tracks status of priority and non-priority queued traffic and monitors new *REQUEST* messages to provide a *GRANT* enable indication to the MAC.
5) Option: contains means for dynamically determining simultaneously usable downward hierarchy ports, and simultaneous use restrictions from activity in contiguous clusters.

The Packet Router function includes the following:

1) It receives and processes *REQUEST* messages from the lower level MAC(s) to:
   a) compare the DA with the Directory listing of registrants to decide that the packet is local/not-local, and
   b) if local, which port it is to go out.
   c) notices the SID field to determine whether priority or routine processing is appropriate, and
   d) whether automatically generated *GRANT* messages are required for segmented packets, and
   e) if required to inform the ACCESS-MANAGER to schedule them and the MAC to send them.
   f) to monitor status of buffer memory, and when sufficient resources are available, to furnish *GRANT* and enable the MAC and ACCESS MANAGER
2) it receives, processes and, if necessary, buffers *PACKET/SEGMENT DATA FRAMES* from both lower and higher hierarchy ports:
   a) for retransmission on the appropriate port via its MAC when enabled by the ACCESS MANAGER, and
   b) provides an *ACK* indication to the MAC when received correctly as determined from the frame CRC.
3) provides all functions necessary to support always ready to receive from higher level ports including:
   a) responses and indications to the MAC as required from LLC to execute the 802.11 protocol from a station.
   b) buffers to be ready immediately regardless of the status of destination port.
4) maintains records of management information which is sent as a periodic packet to the higher level HUB.

MAC Sublayer

As a matter of implementation, it is expected that MAC will be specified with capacity to be either the upward or the downward end of a link, and that it discovers which it is by listening when first activated or by configuration.

Default ACCESS MANAGER

It is also possible that the MAC can include the isolated, single system ACCESS MANAGER which is activated by default when no *INVITATION* messages are heard after power-on. This would be sufficient to enable a small group of stations with mutual radio coverage to inter-operate.

PMD Sublayer

The purpose of the split PMD is shown in Figure 4. A common Hub may control a number of ACCESS-POINTs using UTP star-wired from a wiring closet.

It is also shown that there may be a choice of mediums between the wiring closet and the equipment room including fiber-optic cable.

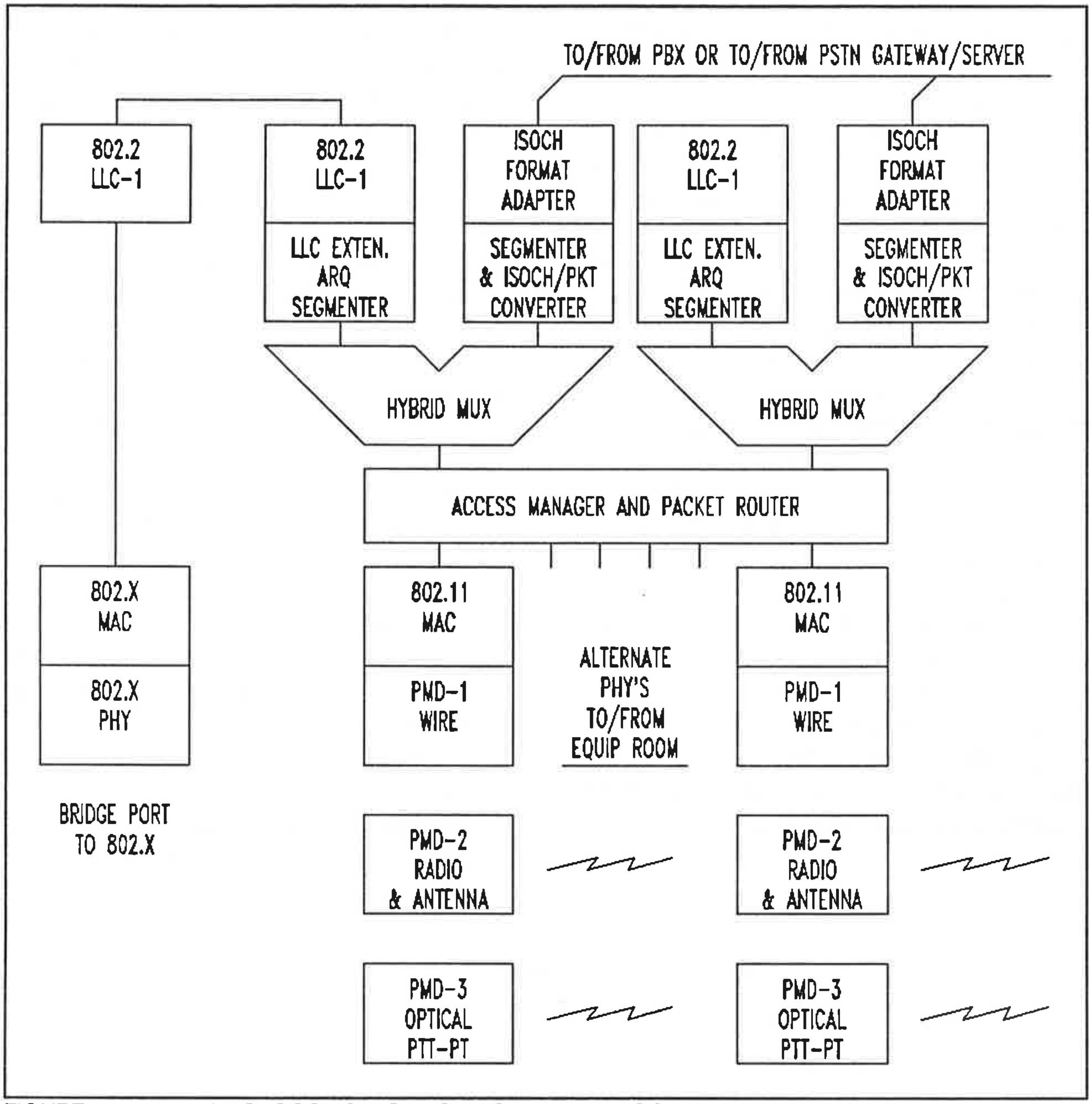

FIGURE 5 PROTOCOL STACK FOR EQUIPMENT ROOM MULTI-PORT BRIDGE

EQUIPMENT ROOM MULTI-PORT BRIDGE WITH EXTERNAL INTERCONNECTS

The top of the three level topological hierarchy is the equipment room usually used for a PBX or for the multiplexers for Centrex service. A possible layering for this function is shown in Figure 5.

All of the layers and sublayers in this Figure are the same as earlier described except for the "format adapter" appearing for the first time.

The Directory function is much larger than in the lower level of the ACCESS MANAGER, and it is updated by management messages rather than by direct contact with stations.

Isochronous Interface

As shown, there is no execution of LLC Class II protocol in this unit. The system works like a distributed concentrator with multiplexed line interfaces for BRI or subsets. For any given station address, there is no fixed transmission space. That space is allotted only on demand. The multiplexed interface from a public or private switch would have dedicated slot space per station, and the format adapter performs the electrical part of this conversion.

The obvious compatibility is with Centrex where the lines appear in multiplexed groups possibly T-1 formatted. There is a need for mapping of 802.11 users to the slots and groups in the multiplex. It is contemplated that the 802.11 system is arbitrarily mapped and a PSTN Gateway resolves the difference if necessary. It is also possible that the mapping is a programmable property of the public switch side.

This arrangement does not need to defined now. It is only necessary to show that a satisfactory arrangement is possible.

C-channels would have to be demand assigned through the interface as well, and that would be taken up as a further extension requiring Q.921/931 processing.

Remote Bridged LAN

This possibility is not shown but does exist. The unconnected 802.2 LLC would be the connection point upon which a remote bridge is built.

Local Bridged LAN

This arrangement is shown where this function is part of the HUB. It is possible to place a local bridge anywhere in the system as a station or at the wiring closet using an ACCESS-POINT port. The bridge must include the layers shown for the LAN only station in Figure 3.

ACCESS MANAGER and Packet Router

In this case the ACCESS MANAGER is working with multiple wiring closets rather than stations. A different and much simpler algorithm is used because each port is independently usable without interaction. On the other hand, the aggregate traffic flow is larger because of the concentration.

It is not proposed that this function be part of the Standard.

MAC Sublayer

This function is the same as previously described in the station and wiring closet equipments.

Multiple Choice PMD

This function is the same as previously described for the opposite end in the wiring closet.

TABLE I – CATALOG OF SYSTEM TYPES

P1 Minimum Size, Cost, Battery Drain for **Personal Use**

Physical Medium:	ISM bands at 0.9 & 2.5 GHz
Transmitter Power:	100 mW
Signaling Rate:	0.5 or 1 Mbs
Capabilities:	LAN and intercom coded voice
	Primary peer-to-peer with minimal common equipment
Reach at 1 Mbs:	1 km unobstructed
	100-200 meters cluttered path

I2 Small Size, Moderate Power Drain for **Industrial Mobile Use:**

Physical Medium:	ISM band at 5.9 GHz
	Future 1.9 GHz allocation
Transmitter Power at 5.9 GHz:	100 mW
Signaling Rate:	1 or 2 Mbs
Capabilities:	LAN and intercom coded voice
	Enhanced ARQ error correction
	Strong equipment and path redundancy
	Address management for external bridgeability
Reach at 1 Mbs:	400 meters unobstructed
	40-80 meters cluttered path

C4 Small Size and Low Power Drain for **Desktop/Portable Use:**

Physical Medium:	ISM band at 5.9 GHz
	Future 1.9 GHz allocation
	Single UTP
Transmitter Power at 5.9 GHz:	20 mw
Signaling Rate:	4 Mbs
Capabilities:	LAN, POTS and ISDN B-Channel
	ARQ error correction
	LAN 48-bit Addressing
Reach at 4 Mbs at 5.9 GHz:	100 meters unobstructed
	10-20 meters cluttered path

W16 Moderate Size and Power Drain for **Desktop/Workstation Use:**

Physical Medium:	ISM band at 5.9 GHz
	Future 1.9 GHz allocation
	Uncollimated IR Optical
	Single UTP
Transmitter Power at 5.9 GHz:	20 mw
Signaling Rate:	16 Mbs
Capabilities:	LAN, POTS and ISDN BRI, H0, PRI
	ARQ error correction
	E.164 and LAN 48-bit Addressing
Reach at 16 Mbs, 5.9 GHZ:	28 meters unobstructed
Reach at 16 Mbs, Infra-red:	14 meters unobstructed

W24 Same as W16 except: Physical Medium--IR only, Signaling Rate--24 Mbits/s

TABLE II -- APPLICATIONS FOR SYSTEM TYPES

P1: Battery-powered Personal/Portable Equipments

Equipment Types:
- Laptop computers
- Personal telephones
- Hand-held data acquisition terminals

System Environments:
- Autonomous small systems with radio coverage to each other
- Autonomous small systems with line level PSTN interconnect
- Shopping mall small to medium size systems
- Campus indoor/outdoor networks

I1: Industrial Applications Including Mobile Stations

Functions:
- Order wire
- Maintenance network
- Supervisory control
- Status reporting and data acquisition
- Backup networking

System Environments:
- Factory
- Transportation hubs
- Chemical process plants
- Building security and HVAC

C4 Supplemental Office Access System with mobile, heavy portable and powered stations

Functions:
- LAN with 4 Mbits/s capacity and performance
- Secondary telephone capacity

System Environments:
- Supplement to fixed wiring for temporary and moving stations
- High capability retail stores
- Normal capability hospitals
- Indoor campus networks

W16 Primary Office Access System with mobile, heavy portable and powered stations

Functions:
- LAN with 12 Mbits/s capacity and performance
- Telephone capacity for concentrated ISDN services up to and including PRI

System Environment:
- High usage offices
- Engineering departments
- Laboratories
- Highly automated process plants

W24 Primary Office Access System with heavy portable and powered stations

Functions:
- LAN with 18 Mbits/s capacity and performance
- Telephone capacity for concentrated ISDN services up to and including PRI and a non-blocking B-channel for every station

System Environment:
- High usage offices
- Engineering departments
- Laboratories
- High capability hospitals