

**IEEE 802.11**

**Wireless Access Method and Physical Layer Specifications**

***An Update***

***to the Hybrid Wireless MAC Protocol***

***Supporting Asynchronous and Synchronous MSDU  
Delivery Services***

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**Abstract**

Most contemporary LAN data services require low average transfer delay MSDU delivery while tolerating substantial delay variance. Many anticipated wireless LAN services - real time voice and video - as well as selected factory applications require data delivery services with predictable bandwidth and minimal transfer delay variance.

A previous paper [10] proposed a unified protocol to address these hybrid requirements with a hybrid wireless data delivery service. The basic Asynchronous Service provides asynchronous, low average transfer delay, statistical data services using a Listen-Before-Talk MAC protocol enhanced for improved error recovery and "hidden station" performance.

Layered atop the Asynchronous Service is a Synchronous Service providing reserved bandwidth with low transfer delay variance at the penalty of higher average transfer delay. Only stations offering the service to it's local applications need implement the complete Synchronous Service.

This paper extends the hybrid protocol architecture previously defined in several areas relating to network configuration, synchronous service, security and internetworking.

An updated glossary of defined terms and references are at the end of the paper.

## 1. Introduction

### 1.1 Requirements

The evolving set of requirements for wireless local area networks reflects a wide and seemingly conflicting range of needs.

A clear primary need is to support today's LAN applications both on current computer platforms but also as projected on future, smaller, more mobile platforms. These applications largely require asynchronous MSDU delivery with minimal transfer delay over as wide a range of channel load as possible. [1] [2] [3] [5] [6] [11]. For these applications, low average transfer delay is more important than minimizing delay variance.

The need for predictable transmission bandwidth and transfer delay is anticipated to be a mission critical requirement in some industrial applications. Consideration of possible future applications, particularly the integration of real-time voice and video sessions with asynchronous data access [5] [6] [11] additionally supports a requirement to provide some mechanism for a synchronous data service that minimizes transfer delay variance for reserved bandwidth.

Wireless LANs are anticipated to be configured bimodally - both in small, ad hoc networks with no preexisting infrastructure as well as in larger enterprise networks as a complement to 802 compatible wired internetworks thus providing connectivity both for mobile stations as well as for stationary locations where it is inconvenient to run a wire. [2] [3] [6] [11].

### 1.2 Approach

The integration of these services is a challenge. The chosen approach is to provide a hybrid MAC data delivery service that combines low delay services for asynchronous, statistical data applications (e.g. file access, file transfer, etc.) with a reservation based synchronous service for applications requiring known bandwidth and/or delay: interactive voice, video, industrial control. In many ways, the proposed system [10] can be considered an extensive refinement of the MAC architecture proposed earlier [8].

The proposed architecture is a layered design with:

- a peer-to-peer PHY layer supporting multiple media;
- a peer-to-peer MAC layer comprised of several sublayers: an asynchronous data service, a synchronous data service and an internetwork extension; and
- support for common P802 MAC sublayers of 802.2 and 802.10.

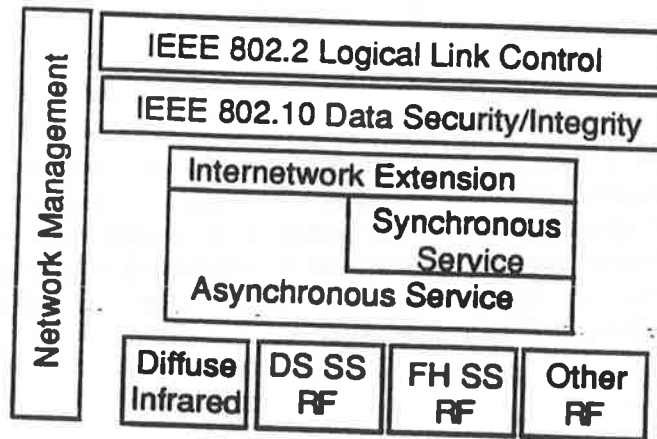


Figure 1.1: Hybrid Wireless Protocol Architecture

The foundation of the protocol is an asynchronous Listen-Before-Talk (LBT) MAC protocol with specific enhancements for reliability, hidden stations and support for adjacent, overlapping wireless LANs. Explicit provision is made within the protocol to provide a foundation for the synchronous sublayer... This layer provides low-delay, asynchronous MSDU delivery services between stations within direct media range of each other.

Atop the basic data delivery services of the asynchronous sublayer, the synchronous sublayer provides a data delivery service with guaranteed bandwidth and predictable delay between stations in direct media range of each other. It does this by imposing a coordinated, timed, frame system on the shared channel between nodes and an allocation system to dedicate timed sections of bandwidth to particular stations. This reservation time division multiplexed sublayer provides for an MSDU data delivery service for traffic that

- requires dedicated bandwidth that cannot be contended for and can tolerate higher average transfer delays; or
- requires lower delay variance among MSDUs but can tolerate higher average transfer delays.

The synchronous service is designed as an optional extension service. Stations not providing synchronous services to their applications need not implement the complete synchronous service though they need to implement the bandwidth reservation portion.

The internetwork extension sublayer adds four key services to the fundamental data delivery services of the asynchronous and synchronous delivery services.

**Relaying**

The relaying portion of the internetwork extension sublayer provides for MSDU delivery between stations out of direct media range of each other. This delivery is accomplished through the relaying of MSDUs from one station to another via the intervention of store-and-forward, filtering MSDU

## 2. Adaptive Configuration

### 2.1 Introduction

It is desirable to configure a wireless LAN system to provide a variety of MSDU transfer configurations and services. Options include the "routing" of MPDU traffic within a coverage area (either directly between peer stations or relayed via access points) and the quality of MSDU delivery service (either the Asynchronous Service for bursty data traffic or the Synchronous Service for low delay variance traffic). The goal is to permit adaptive WLAN configurations including:

- peer-to-peer only;
- hierarchical only;
- mixed @ access point granularity;
- appropriate allocation of service quality to the expected traffic through the access point's coverage area; and
- time and load adaptive.

With these extensions, it is believed that this protocol is an effective superset of a number of suggested wireless protocol structures including [9].

### 2.2 Architecture

The coverage area of an access point can have six major configurations based on two parameters: structure and offered services.

Two fundamental configurations of structure determine the transfer path of MPDUs between stations served by an access point. In the first case, peer-to-peer, MPDUs are transferred directly from the sending station to the destination stations if the two stations are within PHY range of each other. MPDUs are relayed through the access point only if the stations are not within range of each other or are not registered at the same access point.

In the second case, all MPDU transfers are relayed through an access point regardless of the communications link status between the source and destination stations. This configuration will, in general, be less efficient than the peer case since all MPDUs are transferred twice (once from the source station to the access point and then from the access point to the destination station) thus decreasing channel efficiency and increasing nominal transfer delay. However, in cases of poor PHY coverage, this configuration will increase the robustness of the system since a station need only have communication with the access point in order to communicate with all stations registered at the access point.

The Hybrid Protocol offers two class of MSDU transport services: the Asynchronous Service and the Synchronous Service. Each access point can configure its coverage area to support one or both of these services for stations registered at the access point. When an access point offers the Synchronous Service (either alone or in conjunction

with the Asynchronous Service) a Scheduler function must be configured at the access point to allocate reserved bandwidth for the Synchronous Service.

### **2.3 Protocol**

The required protocol must implement two mechanisms: first, a protocol to configure the coverage area of an access point and second, a protocol to enforce the "routing" of MPDUs within the coverage areas.

The proposed mechanism for configuring an access point's coverage area is contained within newly defined fields within the **announce** MPDU periodically issued by the access point. These fields advertise the configuration the access point has determined for stations registered within its coverage area. The presence of an access point issuing announce MPDUs configures the coverage area of the access point. Stations registering with the access point will configure their operation consistent with the configuration advertised within the announce MPDU.

The newly defined announce fields are two.

structure	Defines the routing of MPDUs between stations within the coverage area of the access point. It has two values: "peer" configures the coverage area permitting direct station to station communication with access point intervention only when there is no direct path between the stations; and "hierarchical" configures the coverage area requiring all station to station communication to be relayed via the access point. The default value is "peer". If a station can detect no beacons, it defaults to "peer" configuration. A station configures its operation to
service	Defines the MSDU transport service classes supported by the coverage area of the access point. It has three values: "AsyncOnly" configures the coverage area of the access point as providing only the Asynchronous Service; "SynchOnly" configures the coverage area of the access point as providing only the Synchronous Service; and "AsyncSync" configures the access point and providing both services. In the latter two cases, the access point will have a Scheduler function for the Synchronous Service configured.

In all cases, arbitration of access to the channel will use the base LBT algorithm defined for all stations regardless of their configuration. And as in [10], allocation requests of a configured Synchronous Service are made to a Scheduler function either via Asynchronous Service MPDUs, if configured, or via allocated Synchronous Service bandwidth. Subsequent discussions will center on appropriate Scheduler allocation algorithms reserving bandwidth between the Synchronous Service and the Asynchronous Service and between stations contending for Synchronous Service allocation.

In the case where a station is in the coverage area overlap of multiple access points, the station has the choice of which access points to register with. It will attempt to register with the access point that best represents the quality of service requested by its' user.

An access point can reconfigure it's structure and service at the granularity of announce MPDUs. The policy dictating such changes is to be determined. In this way, the WLAN and distribution system can be reconfigured to adapt to load and performance changes.

The proposed protocol enforcement mechanism is quite simple - add a flag in each MPDU's RTS header. Stations only receive MPDU's for which the flag is set. Access points can receive MPDUs regardless of the flag's state. The semantics of setting the flag are

peer                    flag always set by sending station.

hierarchical        flag never set by a station served by a hierchically configured access point. Flag set only by access point on MSDUs destined to be received by stations in its service area.

The network management sevicees of the MAC (still to be specified) will support remote configuration of access points.

### 3. Synchronous Service Coordination

A key problem for the Synchronous Service, left unresolved in [10], is the coordination of reserved bandwidth allocation among Schedulers serving overlapping coverage areas. The proposed extensions provide the necessary mechanisms to coordinate these Schedulers when necessary.

There is clearly no problem if there are no stations simultaneously using the Synchronous Service in the area of overlapping coverage area. However, if such stations exist using the Synchronous Service that can hear Synchronous Service beacons from multiple Schedulers, the potential for conflicting reserved bandwidth allocation exists. In these cases, the appropriate action is for each station detecting a conflicting bandwidth allocation reject the allocation and report the conflict to its own Scheduler including the identity and allocation vector for the conflicting Scheduler. The Scheduler may then either allocate new bandwidth on its own risking a possible future conflict or it may coordinate with the conflicting Scheduler through the distribution system to resolve allocations ahead of time.

~~This mechanism does not require Schedule/Scheduler communication - a requirement for resolving conflict between Schedulers of disjoint administrations serving overlapping coverage areas in which no communication between Schedulers can be required. It is highly robust to changes in PHY propagation characteristics in which access points and Schedulers serving a given station may change dynamically with changing propagation characteristics.~~

Access points providing 802.11 Synchronous Service must be interconnected via a wired LAN distribution system that provides a similar quality of service: IEEE P802.6 or perhaps FDDI-2 or ATM services.

#### **4. Authentication**

Unlike wired networks in which physical measures (e.g. physical access control of the premises) are generally sufficient to control access to LANs - wireless LANs, in general, required other mechanisms for this purpose. Central to any such mechanism is station authentication in order to determine if a station requesting access to the WLAN is the station it claims to be.

It is proposed that a digital signature method using public key encryption technology be used to validate stations requesting access. Each station is assigned a public decryption key and a private encryption key in addition to its unique station address. A station requesting access can encrypt its identifying information using the private encryption key. Other stations and access points can authenticate requesting stations as to their identity by decrypting this encrypted request using public decryption keys. Protocols to support this process are to be specified.



### **5. Security and Integrity**

Users of wireless networks perceive a greater threat to network data privacy/security vulnerability than for wired networks. These threats include both compromise of MSDU information to inappropriate readers (e.g. security/privacy) as well as inappropriate modification of MSDU information (e.g. integrity).

The expected 802.11 MAC and PHY requirements include provisions for security and integrity of transported MSDUs. Interoperability requirements with wired 802 LANs (and compatible networks) suggest that these mechanisms should, in large part, interoperate with wired LAN mechanisms.

The proposed approach is the support of the 802.10 security, key management and integrity protocols with explicit 802.11 support of a specified encryption algorithm.

## **6. Multichannel PHY Extensions**

Anticipated wireless PHYs will be of both single channel and multiple channel varieties [11]. The proposed MAC, while capable of providing adequate service with only channel - even in the cases in which the channel is shared among adjacent administrations, benefits in several ways from the use of multichannel PHYs. Multichannel PHYs present the opportunity to assign channels to the coverage areas of individual access points and/or for the coverage areas of adjacent but disjoint administrations. Depending on the efficacy of the isolation between channels, this channel assignment has the potential for three benefits:

- 1) adjacent coverage areas can be assigned to differing channels thus increasing the overall capacity of an ESA versus the same ESA constructed using a single channel;
- 2) coverage areas of adjacent administrations can separate the traffic and performance characteristics of traffic in each administrations PLAN thus minimizing the impact of traffic on one administration's network on another, overlapping administration's network; and
- 3) potential to modestly improve the high load performance of LBT protocols used within a coverage area.

However, these benefits do not come with no cost. The effective use of multichannel PHYs requires enhancements to the proposed MAC in three areas: station initialization, station roaming within an ESA, and configuration of the access points and distribution system of the ESA to maximize isolation of coverage areas.

The proposed enhancement for station initialization is the following steps:

- 1) scan each channel supported by the PHY;
- 2) for each channel, listen for period sufficient to receive announce MPDUs from all access points within range of the station;
- 3) the station chooses an access point based on perceived error properties (e.g. signal strength), appropriate administration, etc and tunes its PHY to the channel appropriate for that access point; and
- 4) the station attempts to register with the selected access point.

This algorithm should be sufficient for PHYs and ESAs with modest numbers of isolated channels ( $\leq 20$  or so).

A similar algorithm can be performed for roaming stations. When a station deregisters from its old access point and is ready to move to a new access point, it performs the same algorithm used for initialization. However, in the case of roaming, it is highly desirable to minimize the time period required to find a new channel since (as described previously) new access point registration could happen as often as once

per second. In this case, the previous access point can be queried (e.g. a guidance protocol) for advice as the likely next channel for a roaming station to use. In this way, typical channel tuning time during roaming can be dramatically shortened in many cases at the price of access points coordinating information on overall ESA topology. The specific protocol enhancements communicating roaming advice to roaming stations as well as the coordination protocol between access points are to be specified.

The last enhancement must support the automatic configuration of access points within an ESA where each access point can be assigned a channel on which to provide service. In this case, it is desired to configure channel assignment to access points in such a manner as to minimize PHY overlap between access point coverage areas while minimizing the degree of external configuration required. The author conjectures that a distributed configuration algorithm among access points can be devised to support such autoconfiguration in most cases. The details are left to a subsequent contribution.

## 7. Roaming and Source Routing

It is an important requirement that the WLAN and its distribution system support roaming stations: stations that move - and maintain communications sessions while in motion - distances further than the propagation distance of the underlying PHY.

In [10], a basic mechanism supporting roaming through a distribution system comprised of access points interconnected via standard IEEE 802 compatible LANs and bridges was described. It is believed that the basic roaming mechanisms defined in [10] are complementary and compatible with the function of 802.1D conformant spanning tree bridges. However, issues arise when the proposed wireless distribution system is used with source routing bridges.

Roaming stations using a distribution system comprised of access points interconnected with IEEE LANs and IEEE 802.1D conformant spanning tree bridges are insensitive, except for end-to-end delay, to the precise route a specific MPDU takes from the source to the destination. Indeed, as a station roams, each MPDU might take a different path to the destination and the learning process of the spanning tree bridge algorithm permits bridges to follow stations as they roam through this "internet" of wireless and wired LANs.

However, source routing bridges extend knowledge of the topology of the interconnected networks to the source and destination stations through the discovery process. The source and destinations can select a route through these interconnected LANs and bridges and specify this route as a sequence of bridge ids in each MPDU.

In order to support roaming stations in which wireless access points are interconnected with LANs and bridges using source routing, two solutions are possible. First, as source and destination stations (possibly both) roam, old discovered routes may become invalid. A source station will discover this through abruptly increased MSDU loss rate. In such a case, the higher layer protocols must be capable of responding by reinitiating route discovery in order to specify a new route for subsequent MSDU. However, in order for this approach to be effective, the time to recognize the situation as well as discover new routes must be less than the typical time in which a route will be valid for a roaming station. Informal calculations suggest that for 100m PHY propagation ranges and for pedestrian speeds of 2 m/s, routes may be valid for typically 30-60 seconds (e.g. time between access points). The network system must be capable of handling the overhead traffic of rediscovering routes for moving stations about once per minute per station - this would (informally) appear to be a tractable load.

A second method is to configure the distribution system of LANs and source routing bridges such that discovered routes are always valid during roaming. For example, if all access points of an ESA are interconnected on a single IEEE 802.5 token ring, all source routing bridges serving that token ring will remain accessible, and hence all source routes, regardless of where the station roams - that is, which access point is currently serving the roaming station. However, this restriction may prove overly constraining with respect to network topology and capacity planning.

## 8. Glossary

Access Point	A station that provides internetwork MSDU relaying, roaming, power control and access control services to either/both the asynchronous data service or/and the synchronous data service.
Address	A 48 bit entity that either uniquely identifies a station or signifies a multicast or broadcast destination.
Administration	A management entity distinguishing one enterprise from another. For example, two adjacent, independent businesses would be two administrations.
Allocation Vector	Per station database of allocated channel bandwidth. The <u>net</u> allocation vector defines all bandwidth, "visible" to the station, during which the station is prohibited from transmitting asynchronous service MSDU. The <u>station</u> allocation vector defines all bandwidth during which this station can transmit synchronous MSDUs.
Asynchronous	Data traffic that characteristically has a statistical arrival distribution. Typifies most LAN data traffic.
Beacon MSDU	Transmitted at the beginning of each frame by the scheduler, the Beacon MSDU
BSA	Basic Service Area. The fundamental wireless LAN service area defined by the unrepeated transmission range of the particular PHY layer.
CRC	Cyclic Redundancy Check. A 32 bit polynomial checksum calculated and appended by an MSDU's sender for use by the MSDU's receiver to detect errors in transmission.
Distribution System	The intercommunications mechanism for an ESA consisting of a (likely) wired backbone 802 compatible network serving a collection of access points.
ESA	Extended Service Area. A set of intercommunicating BSAs sharing a common administration interconnected via a distribution system.
Frame	The overall timing structure the Synchronous Service imposes on a channel in order to synchronize station transmissions. Each frame begins with a beacon MSDU transmitted by the scheduler controlling the synchronous service.

MSDU	MAC layer Service Data Unit - the fundamental unit of data delivery between MAC entities.
LBT	Listen-Before-Talk. Label given to a class of distributed algorithms for channel allocation in which an attempted transmission is preceded by sensing current activity on the channel. If the channel is busy, the attempted transmission is deferred to a subsequent time.
LWT	Listen-While-Talk. Label given to a class of distributed algorithms for channel allocation in which an attempted transmission is both preceded by sensing current activity on the channel as well as comparing data sent by the current node with data contemporaneously received from the channel. If the channel is busy before transmission begins, the attempted transmission is deferred to a subsequent time. If during the transmission, channel received data does not match sent data, a collision is detected and the transmission is scheduled for retransmission.
NetID	A 16 bit, locally constructed, identifier for the ESA's administration. It is allocated to a station when the station registers with the ESA distribution system.
Payload	The higher layer supplied contents of the MSDU.
Preamble	A known, fixed bit pattern preceding MSDU elements to provide for clock and bit synchronization between transmitting and receiving stations.
Relaying	The store-and-forward function of the distribution system consisting of access points and backbone wired networks providing MSDU transfer services between stations not in direct PHY media range of each other.
Scheduler	Centralized bandwidth allocation function for the synchronous service. At least one scheduler must be configured for each BSA offering the synchronous service. A scheduler is always implemented within an access point.
Slot	A fixed length unit of channel time. The quanta of allocation by the synchronous data service scheduler within a frame.
Synchronous	Data traffic that has a predictable, periodic characteristic and requires data transport services that minimize transfer delay variance of the traffic.

### 9. References

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