IEEE 802.11
Wireless Access Method and Physical Specifications

Title: Wireless Hybrid Operation (WHO) MAC Protocol

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1. Abstract (for those familiar with doc. 93/40 [BIB93] and 93/62[BAU93a])

The WHO protocol uses the WHAT protocol with few changes. During the initialization phase of a STA, the STA is required to listen for a new Universal Header (UH) only present if infrastructure (defined below) is used. If not found, the STA proceeds with Asynchronous traffic as defined in doc. 93/40. If the UH is found in the standard search for existing BSA, the STA is required to process and observe an Access Boundary field in the UH delineating the boundary between an optional non-contention area and a mandatory contention area of the remaining Superframe (defined below).

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2. Introduction

The context for the WHO protocol is presented and a more detailed overview of the operation is described.

2.1. Background

At the May 1993 meeting, a MAC protocol that took elements of the WHAT protocol proposed by Xircom and the Reservation Based protocol proposed by IBM was presented [SCH93]. In that respect, this proposal does not differ. This proposal incorporates comments from a number of this committee's members as well as colleagues at my own company. It is hoped that the changes described herein overcome the original criticisms of the Hybrid proposal and result in a protocol greater than the sum of its parts.

2.1.1. Listen Before Talk Class allows DCF

The proponents of both major Listen Before Talk (LBT) protocols claim a number of compelling advantages over Reservation Based protocols. They include intrinsic peer-to-peer operation, deemed necessary by the Office market requirements document; simple, well known implementations; better operation with a single channel physical layer.

A low complexity means to small Ad-Hoc networks is part and parcel of the Distributed Coordination Function (DCF) access method in the LBT class.

2.1.2. Reservation Based Class requires PCF

Reservation Based proponents claim better operation under dense population (high traffic loads) and heavy interference conditions. They also offer a well understood means to provide Time Bounded services to wireless stations. In addition, the Point Coordination Function (PCF) offers a proven Power Management technique; vital for battery operated devices.

2.2. Motivation

The Wireless Hybrid Operation (WHO) protocol allows Ad-Hoc and "Infrastructure-less" networks to operate with a DCF, while requiring installations with infrastructure to use a PCF. It is believed that only in this manner are the best features of both approaches preserved and indeed the result is better than the parts. This document describing the WHO protocol will make this case.

2.2.1. Assumptions

It is possible to combine the DCF and PCF elements in a natural manner that fit typical "Office" usage. (Usage apart from the "Office" market requirements has not been explored, but it is expected that the WHO protocol also serves these markets by giving the implementor a choice of PCF or DCF operation.)

Small offices have fewer wireless nodes, therefore less traffic and therefore less need for the heavy hand of the PCF bandwidth allocation. In addition, it is less likely they have an existing infrastructure. Ad-Hoc operation, by definition, implies short range (e.g. within a meeting room) and has less need for infrastructure. (However, stand-alone "WLAN Accelerators" could expand range and increase available bandwidth through channelization in this situation.)

Large installations, it goes without saying, have more numerous wireless nodes, therefore heavier demands on the available bandwidth per unit area, and therefore more need for efficient, stable bandwidth allocation. It seems again natural that the PCF characteristics are utilized more fully in this environment.

In addition, a large class of Time Bounded services (i.e. voice and video conferencing) are only reasonable when a wired or optical LAN infrastructure is available, as typically found in large installations.

2.2.2. Definitions

Infrastructure defined: Infrastructure is defined as any station broadcasting the Universal Header (defined later). Stations are required to broadcast the UH when they are part of an Access Point.

(802.11 definition of an AP includes STA function). Other non-AP STA could broadcast the UH (thus becoming the PCF) at their discretion.

Superframe defined: A Superframe is easiest to explain in a slow FHSS system, but is also useful for other PHY layers using continuous time. In a FHSS system, the Superframe is some fraction of the time between hops. Transmission will not be from only one STA. This time (in absolute terms) is available in a new protocol element called the Universal Header (UH). Since the UH contains the length of the Superframe, other PHY layers not dividing time such as IR or DSSS can also use the Superframe construct.

2.3. Operation

2.3.1. General Operation Without Infrastructure

Systems without infrastructure would carry Asynchronous traffic only and tend to be small and/or Ad-Hoc. In all cases a node would power up and listen for existing BSA. If found, the Station (STA) is required to determine if a UH is being broadcast by any pre-existing infrastructure. Finding none, the STA has the option of initiating the cycles itself (thus becoming that infrastructure), or communicating with the WHAT protocol as presently described in [BIB93].

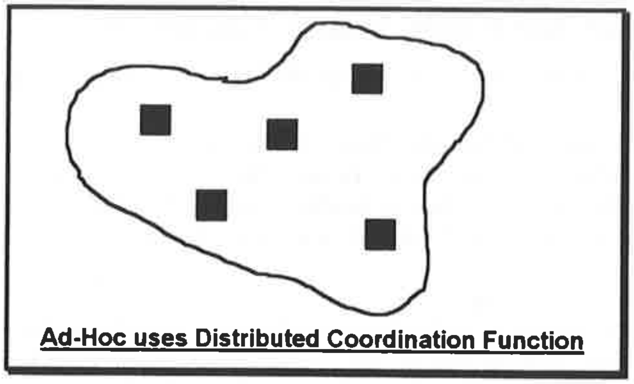


Figure 1.

2.3.2. General Operation With Infrastructure

Systems with infrastructure would carry Asynchronous traffic and have the option of carrying Time-Bounded and uncontended traffic. In all cases a node would power up and listen for existing BSA. If found, the Station (STA) is required to determine if a UH is being broadcast by any pre-existing infrastructure. Upon finding an existing UH (or choosing to broadcast the UH itself) with a matching NETID, the STA is required to interpret and act on a minimum of the ACCESS BOUNDARY field. This field contains an amount of time reserved for the non-contention area. It may be zero. If it is non-zero, the STA, as a minimum, must not perform the LBT protocol (that protocol used in the Contention area) for the duration of time specified. Optionally, the STA may request bandwidth in the non-contention area for use by Time-Bounded or Asynchronous non-contended traffic.

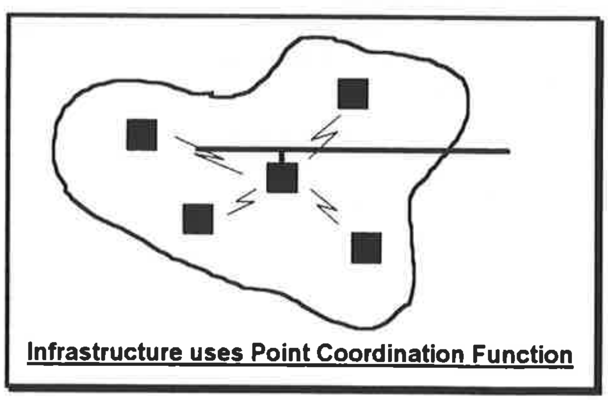


Figure 2.

3. The Protocol

The WHO protocol uses a DCF class media access scheme for the Ad-Hoc and Contention area of a Superframe in Infrastructure networks. It uses a PCF class media access scheme for Infrastructure networks.

3.1. General Rules without Infrastructure

Networks without infrastructure are by definition, Ad-Hoc. A DCF class protocol is used based on CSMA/CA described in [BIB93]. This accommodates efficient medium sharing even with single channel PHYs.

3.1.1. Operation

A STA powers up and listens for existing BSAs. If found, the Station (STA) is required to determine if a UH is being broadcast by any pre-existing infrastructure. Finding none, the STA has the option of initiating the cycles itself (thus becoming that infrastructure), or communicating with the WHAT protocol as presently described in [BIB93] and in section 3.3, Contended Service. Systems operating without infrastructure could not provide Time-bounded services or any reserved bandwidth for asynchronous data.

There is no concept of a Superframe in these Ad-Hoc networks.

3.2. General Rules with Infrastructure

Networks with infrastructure are able to take advantage of features only a PCF class media access scheme provides, such as Time-bounded services, Power Management services and robust operation in overloaded and heavy interference environments.

3.2.1. Operation

Systems with infrastructure would carry Asynchronous traffic and have the option of carrying Time-Bounded and uncontended asynchronous traffic. In all cases a node would power up and listen for existing BSA. If found, the Station (STA) is required to determine if a UH is being broadcast by any pre-existing infrastructure. Upon finding an existing UH (or choosing to broadcast the UH itself) with a matching NETID, the STA is required to interpret and act on a minimum of the Access Boundary field. This field contains an amount of time reserved for the non-contention area. It may be zero. If it is non-zero, the STA, as a minimum, must not perform the LBT protocol (that protocol used in the Contention area) for the duration of time specified.

If a multi-channel PHY is being used, the STA could choose to initiate another BSA. Additionally, if the NETID did not match, the STA could choose to start another BSA.

Optionally, the STA may request bandwidth in the non-contention area for use by Time-Bounded or Asynchronous non-contended traffic.

3.2.2. Superframe Format

The Superframe is defined by the transmission of a Universal Header (UH). A UH is only required if the wireless system has infrastructure, such as an Access Point. Superframes are not transmitted in Ad-Hoc or infrastructureless systems.

The Superframe is comprised of three main elements, two mandatory and one optional. The Universal Header is mandatory; it is transmitted by the PCF and must be received by all members of the BSS. The non-contention area is optional and if present can be used for Time-Bounded and packet data. The contention area is mandatory and simply defines the time boundary within which the WHAT protocol plays.

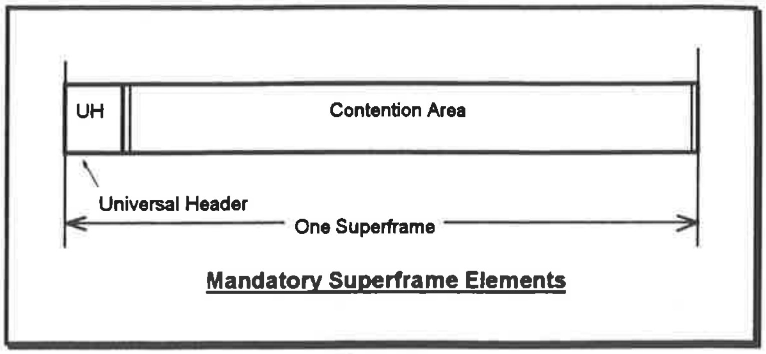


Figure 3.

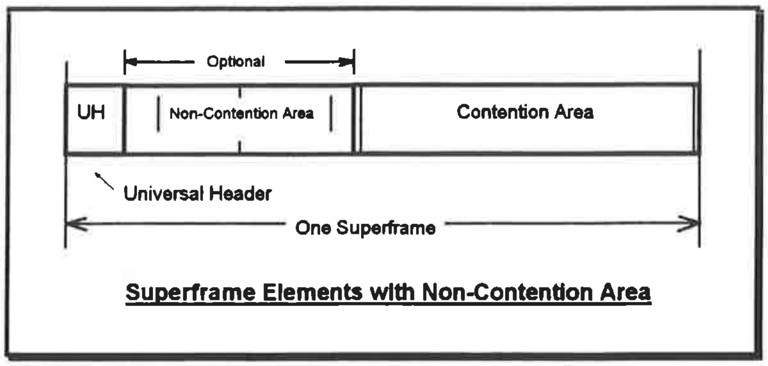


Figure 4.

3.3. Contended Service (Contention Area) Media Access

The contention area is intended to convey Asynchronous traffic exclusively. Asynchronous service has two MPDU formats: 1.) MPDUs addressed to a specific STA, 2.) MPDUs addressed to more than one STA such as multicast or broadcast MPDUs. Each MPDU contains multiple frames.

3.3.1. Directed MPDUs

Directed MPDUs are sent to a specific STA. They consist of four frames: RTS, CTS, DATA and ACK. Request to Send (RTS) is used to reserve the medium for transmission of the data frame. Clear to Send (CTS) confirms that the medium is reserved, and clears the channel within range of the receiver. The DATA frame contains the payload of the MPDU, and the ACK frame is an immediate acknowledgment indicating that the DATA frame was received without error.

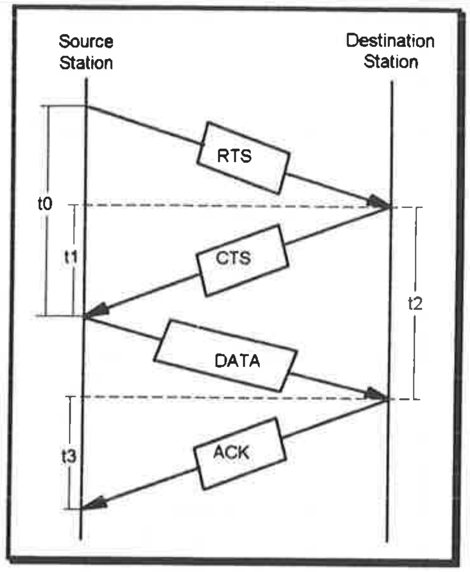


Figure 5.

3.3.2. Multicast MPDUs

Multicast and broadcast MPDUs are addressed to a group of STAs from a specific STA. They consist of two frames: RTS and DATA.

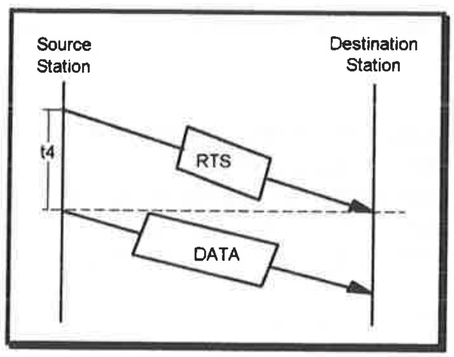


Figure 6.

Multicast and broadcast MPDUs do not have a specific destination STA to provide CTS or ACK frames. The removal of these frames decreases the delivery reliability of multicast and broadcast MPDUs. However, this is consistent with the level of service provided for multicast frames by other MAC protocols.

t4 is the Interframe Gap time. The frame formats for the multicast and broadcast RTS and DATA frames are the same as the RTS and DATA frame formats for directed MPDUs.

When AP are present, the sending STA can control the scope of multicast MPDUs. Multicast MPDUs are not forwarded by APs unless the HIERARCHICAL bit is set. in the Control field. If the HEIR bit is set, the AP will forward the packet to both the wired and wireless links. Multicast MPDUs stay within the BSS when the HIER bit is clear and propagate through the ESS when it is set.

3.3.3. Enhanced Carrier Sense

Carrier sense in the WHO MAC protocol is the same as that used in the WHAT protocol and includes two factors: 1.) the state of the channel as observed by the PHY layer; and 2.) a Net Allocation Vector maintained by the MAC layer that indicates when the network is busy. The Net Allocation Vector (NAV) describes when the network is idle or busy from the point of view of a particular STA. STAs maintain the NAV by listening to RTS and CTS frames.

Whenever a valid RTS or CTS frame is received, the NAV is updated to indicate that the network will be busy for the duration of the transmission of the DATA and ACK frames. Receivers can compute the total time the network will be busy by processing the **DATA TIME** field in the RTS or CTS frames.

Every receiving STA has a time out for receiving a DATA frame. This is described in Figure 3. as t2. t2 is the data time out. A STA that receives an RTS will mark the network as busy in the NAV. If a corresponding DATA frame is not received within the t2 time interval, the NAV is cleared. This limits the reservation time of an RTS that is never followed by the rest of the sequence. A truncated sequence will occur when a STA attempts to transmit to another STA that is not on the network, sleeping, out of range, or during interference.

STA will attempt to transmit only when the NAV indicates that the network is idle.

3.3.4. Channel Contention and Collisions

The contention area of the WHO protocol uses an adaptation of the Carrier Sense Multiple Access (CSMA) protocol. Before transmitting, STAs check to see if the network is busy (carrier sense), and defer to any transmission in progress. It is possible that more than one STA can sense the channel, conclude that it is not busy, and begin transmitting at the same time. When this happens, a collision occurs and what is essentially an arbitration cycle is initiated.

The WHO protocol uses a channel arbitration or contention resolution method specified in doc. 93/40 (WHAT MAC Protocol). This method uses an RTS/CTS exchange for this purpose. The RTS frame indicates a STA's intent to send a DATA frame, the destination address, and the length of the data transmission. The CTS frame is sent from the destination STA to the source STA, and it also includes the length of the DATA frame. After an RTS/CTS exchange, any STA that "heard" either frame will not attempt a transmission until the rest of the MPDU is finished. The channel is effectively reserved by a successful RTS/CTS frame exchange. This virtually eliminates collisions during the DATA frame transmission.

If a collision occurs, it will most likely happen during the arbitration phase of the exchange (i.e. during the RTS/CTS exchange). If an RTS is damaged, no CTS will be sent; the MPCU will not be completed. If the CTS is damaged, the DATA frame will not be sent. In either case, the source STA will know that it must attempt transmission of the entire MPDU at a later time. The RTS and CTS frames provide a virtual collision detect mechanism for the WHO protocol. The effect of collisions is minimized because the MPDU transmission will be stopped after the RTS frame or CTS frame when a collision occurs; other STAs that marked the network as busy in the NAV will clear that vector after the DATA time-out.

3.3.5. Positive ACK Protocol

WHO uses the WHAT positive ACK protocol. Low level acknowledgments are used to improve the reliability of the wireless medium. When a directed MPDU is sent, the source STA expects an ACK frame after each DATA frame. If an ACK is not received within a short period of time (), the ACK is assumed lost or never transmitted and the MPDU is scheduled for retransmission. This process is repeated N times. If no ACK is received after the Nth. attempt, a send failure is reported. Broadcast and multicast address MPDUs do not expect ACKs and are never retransmitted.

3.3.6. Duplicate Detection

The WHO protocol is identical to the WHAT protocol's property of guaranteed no duplicate packets delivered to upper layers. Transmitting STAs never send a new MPDU to the same destination during retransmission attempts of a previous MPDU. This assures that only one MPDU is outstanding per source STA / destination STA pair. The receiving STA may receive MPDUs from other STAs interleaved with retransmissions from one STA.

Each STA maintains a list of potential duplicate MPDUs. MPDUs are identified by their MPDUID. Sending STAs set the RETRY bit (in the CONTROL field of the frame header) whenever they transmit an MPUD more than once. If an RTS from an MPUD is received with the RETRY bit set, the destination STA will send the CTS and prepare to receive the DATA frame. The MPDUID list is scanned to see if there are any matching entries. if no match is found, the MPDU is not a duplicate, and reception proceeds as usual. If a match is found in the MPUDID list, the MPDU is a duplicate. The destination STA will send an ACK, discarding the MPDU. Once the ACK frame is received, the source STA will stop retransmitting the MPDU.

3.3.7. Retransmission Algorithm

When a CTS frame is missed, the source STA assumes that a collision occurred and schedules a retransmission of the MPDU. When an ACK frame is not received, it indicates that the DATA frame was damaged or the ACK frame itself was damaged. In either case, the MPDU must be retransmitted. The same back-off algorithm is used for ACK time-out retries and CTS time-out retries.

Each STA delays their retransmission for a random amount of time to reduce the probability of collisions. On the first transmission attempt for an MPDU, there is no back-off time. The source STA defers to other traffic and transmits as soon as the channel is free. For subsequent transmission attempts of the same MPDU, the source STA waits a random back-off time before sending the RTS frame.

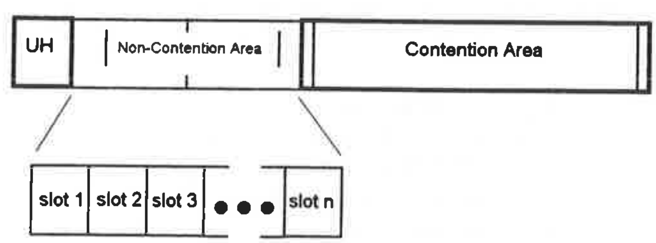
The back-off procedure uses a special timer that only counts down when the network is idle. The sending STA computes a random number, and uses it to set the initial value of the back-off timer. Each "tick" of the timer represents a slot time (t0 in Figure 5). The slot size is the time it takes a STA to reserve the channel for the transmission of a DATA frame (i.e. the length of an RTS frame, plus the length of a CTS frame, plus the overhead of the Interframe Gap).

After the back-off timer elapses, the sending STA senses the channel again and transmits if it is available. If the network is not idle the sending STA will repeat the back-off procedure.

There are no retransmissions of Multicast or Broadcast packets.

3.4. Reserved Service (Non-Contention Area) Media Access

The Reserved Service occurs in the non-contention area of the Superframe. It is an optional element of a Superframe. Bandwidth is reserved in the non-contention area by STA issuing a Reservation Request frame in the contention area. This message originates from the MAC Management section of the MAC. Reservations may be for asynchronous data or Time-bounded service. In either case, the PCF determines the bandwidth to allocate and notifies the STA via the UH fields ACCESS BOUNDARY, DOWNLINK TABLE LENGTH, UPLINK TABLE LENGTH and Non-Contention Assignments. t5 below is one slot length.



Non-Contention Area divided into Slots

Figure 7.

3.4.1. Bandwidth Allocation

The PCF, typically residing in an Access Point, determines slot length, the boundary of the non-contention and contention areas (ACCESS BOUNDARY field) and the allocation of slots to specific STA based on applied traffic. It may allocate bandwidth for asynchronous data types as well as various qualities of service of time-bounded data types.

3.4.1.1. Asynchronous

For STA that can accommodate operation in the non-contention area, it is most efficient that as much of the total traffic as possible be conveyed during this area of the Superframe. However, in order to reduce access delay, especially for systems choosing a long Superframe time, small data queues will use the contention area. The choice of which area to use is outside the scope of the standard, but will likely tend toward large file transfer (which result in large amounts of data queued at one time) being conveyed in the non-contention area, while small transaction type application data (e.g. key strokes and Network Layer ACK) would be conveyed in the contention area.

A STA with multiple MPDUs queued would attempt to transmit the first MPDU at the first opportunity in the contention area. The CONTROL field in that MPDU has been enhanced to accommodate a bandwidth request. The STA, knowing the length of the data queue, would be able to request up to seven (7) slots of time in the subsequent superframe's non-contention area.

> It has been pointed out that for the MAC to know the length of a data queue is impossible due to the separation of the MAC and the rest of the LLC layer. This may be a case where the model restricts efficient operation. There should be no reason this information is not available to the WLAN Controller and to blocks within it implementing the MAC function.

See the CONTROL Field section for specific bit assignments.

The bandwidth allocation function could be implemented by a number of algorithms optimizing fairness or throughput for a wide variety of uses. Because this function can be complex and the needs so widely variable for a class of STA; and because any algorithm does not impact the interoperability of STA with APs, no specific algorithm will be recommended. The standard shall be mute on this subject.

3.4.1.2. Time-bounded

Depending the Quality of Service (QoS) requested, Time-bounded services can be either acknowledged or unacknowledged, and contain varying amounts of bandwidth. The smallest amount of bandwidth that can be requested is one slot time. If the service is acknowledged, the amount of time for the payload is less that if the service is unacknowledged.

The actual assignment of slots to STA is done through a Layer 3 and above exchange called Call Control [POP92]. Messages are conveyed using the asynchronous services to negotiate a proper bandwidth assignment. Again, the algorithm used is outside the scope of 802.11, however the committee has tentatively agreed that the subset of CCITT Q.931 proposed in [POP92] shall be used for Call Control. (See Issue 15.3)

3.4.1.3. By Access Point (PCF)

The AP would be expected to allocate bandwidth for itself to STA capable of receiving it in the non-contention area. Many traffic models show that downlink (AP to STA) traffic will be as much as a 4:1 ratio over the opposite direction (on a number of bytes basis). Therefore, no message in the contention area would be necessary to request bandwidth for the majority of asynchronous traffic.

3.4.2. Acknowledge Policy

Each Asynchronous MPDU transferred in a slot consists of a DATA frame and an ACK frame. The acknowledge policy guarantees in-sequence arrival of MPDUs. It does this by immediately retransmitting any failed DATA frames in the next available slot.

An example of this operation: If three adjacent slots were assigned by the PCF for STA1 to transfer uplink data in a particular Superframe. The first MPDU fails from the STA1 perspective since no ACK is received. Knowing it has two slots remaining of the total assignment, it immediately retransmits the original MPDU in the second slot. Again, if no ACK is received, it may perform the same operation in the third slot assigned to it. In this manner the STA "chips away" at the data and insures some throughput even in the face of very heavy interference.

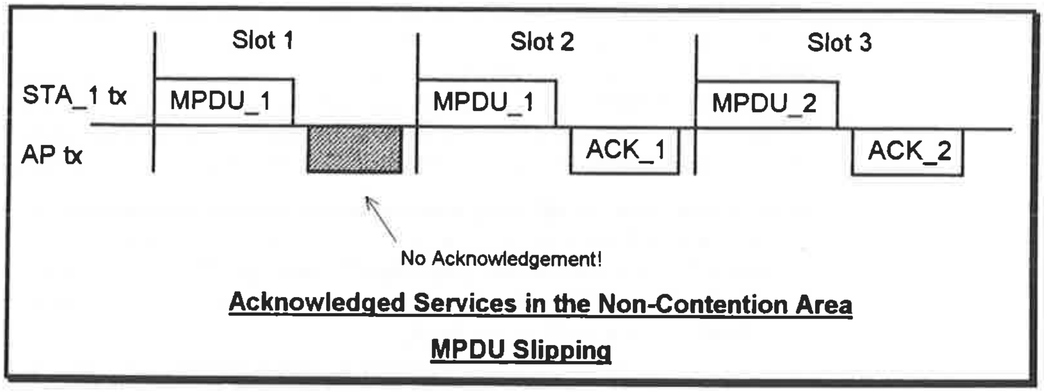


Figure 8.

This technique has the additional property such that no MPDU will be transmitted without all those ordered before it having been previously acknowledged by the destination STA.

3.4.3. Asynchronous Traffic

Any STA associated with the PCF indicates its capability of carrying asynchronous traffic in the non-contention area. If a STA so indicates, the PCF will attempt to convey all directed downlink (PCF (or AP) to STA) traffic in the non-contention area. Any Multicast or Broadcast traffic is transmitted in the contention area because it is a mandatory element of a Superframe.

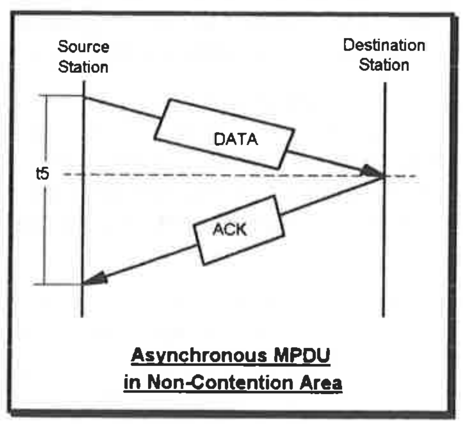


Figure 9.

3.4.4. Time-bounded Traffic

Any STA associated with the PCF indicates its capability of carrying Time-bounded traffic in the non-contention area through the Association MAC Management messages.

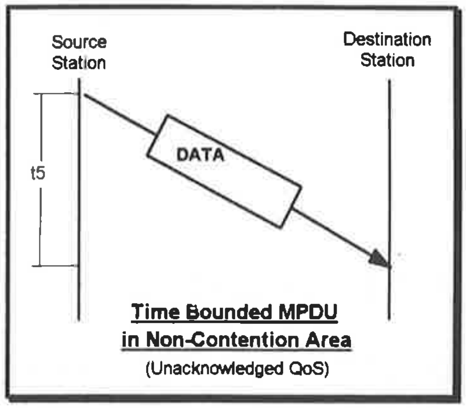


Figure 10.

3.5. Universal Header Structure

The Universal Header is a short frame that is always transmitted by the PCF at the beginning of a Superframe. The position of the UH defines the Superframe.

Field	*Length*	*Description*
PREAMBLE	x	PHY Dependent
START DELIMITER	1	Achieves byte boundary synchronization.
TYPE	1	Allows MAC to distinguish UH from other frame types.
CONTROL	1	Aids processing of frame. Defines fixed/vary. UH length.
PHY DEPENDENT	5	Defined on a per PHY basis.
DURATION	2	Length of time of the Superframe.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
ACCESS BOUNDARY	2	Defines time boundary in Superframe between non-contention and contention areas.
PENDING COUNT	1	Count down to change in Superframe length.
DOWNLINK TABLE LENGTH	1	Number of bytes in downlink table.
UPLINK TABLE LENGTH	1	Number of bytes in uplink table.
NON-CONTENTION ASSIGNMENTS	n	This area contains a variable length list of STA allocated bandwidth and non-contention reception in this Superframe.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	varies	TOTAL BYTES

3.5.1. PREAMBLE (PHY Dependent)

This area could accommodate multi-rate (rate-agile) PHYs in the manner described by submission 93/146.

3.5.2. START DELIMITER

This field is also PHY dependent, providing byte synchronization to the MAC.

3.5.3. TYPE

Reference section: 3.5.3.1. TYPE Field

3.5.4. CONTROL
Reference section: 3.5.3.2. CONTROL Field

3.5.5. PHY DEPENDENT Field
This field may have different uses depending on the PHY Type used. (Note: It is hoped that 802.11 specify PHY Types and that this field is defined within the standard for each PHY Type.)

3.5.5.1. ISM FHSS at 2.4GHz.

Field	Length	Description
Freq. f(N)	1	The NEXT frequency f(N) to hop to where N=1..83
Freq. f(N+1)	1	The 2nd. frequency to hop to..
Freq. f(N+2)	1	The 3rd. frequency to hop to..
Freq. f(N+3)	1	The 4th. frequency to hop to..
BitControl	1	Bitfield used by MAC Management
	5	TOTAL BYTES

3.5.5.1.1. Hop Synchronization
The PCF has two alternatives here. This field can be all zeros, in which case the existing hop synchronization technique of the WHAT protocol are followed. [Note: this is not specified in 93/40..] If the first byte of the field is non-zero, the four bytes define the next four hops in a FHSS 2.4GHz. ISM PHY.

Up to three successive Superframes could be lost by a STA and guaranteed hop synchronization could be maintained. In addition, an intelligent PCF could alter the hop sequence dynamically to avoid narrow band interferes. The means of detecting and avoiding these interferes is vendor unique.

3.5.5.1.2. BitControl
This field allows control of PHY parameters on a per hop basis. [These functions are not specified at this point.]

3.5.5.2. ISM DSSS at 2.4GHz.
Elements TBD.

3.5.5.3. Data-PCS.
Elements TBD.

3.5.5.4. Infrared.
Elements TBD.

3.5.6. DURATION
In order to accommodate slow dynamic Superframe time adjustment, the total length of the Superframe is broadcast in the UH. This field is intended to be used by new STA when acquiring a channel to allow it to accommodate a variable Superframe length. It is not intended to allow variable Superframe time on a per Superframe basis. This field is essential for an intelligent PCF to tune performance to offered traffic. (For instance, in a trade-off between access delay and maximizing throughput, or for minimizing Time-bounded path delay.)

The time is conveyed in 10uS increments allowing an indicated range of from 10uS to 655.4mS. Note that it is likely that valid values of this field are much different, and may vary in a vendor unique way.

3.5.7. NETID Field

This 16-bit identifier is unique to an ESS. It identifies a BSS. STA associated with a particular BSS will only accept frames with that BSS's NETID. This field is used to differentiate between MPDUs from overlapping BSA and to increase reliability of identifying the proper UH.

3.5.8. ACCESS BOUNDARY Field

This field defines the boundary between access methods. It is an indication of relative time from the end of the UH to the end of the contention area. It is based on time and not bits or bytes.

The time is conveyed in 10uS increments allowing an indicated range of from 10uS to 655.4mS.

3.5.9. PENDING COUNT Field

Field is normally zero, indicating there is no pending change in the length of a Superframe. If non-zero, field contains a count of remaining Superframes before a change can be expected. The field does not indicate what the new Superframe length will be. (See section: 4.3. Variable Superframe Length)

3.5.10. DOWNLINK TABLE LENGTH

Downlink table consists of pairs of bytes indicating Alias ID and number of slots assigned to current Superframe for a particular STA in the non-contention area. Downlink is defined as information transferred from the PCF to the STA. This field contains the number of bytes in the Non-Contention Assignments field and may be zero.

3.5.11. UPLINK TABLE LENGTH

Uplink table consists of pairs of bytes indicating Alias ID and number of slots assigned to current Superframe for a particular STA in the non-contention area. Uplink is defined as information transferred from the STA to the PCF. This field contains the number of bytes in the Non-Contention Assignments field and may be zero.

3.5.12. Non-Contention Assignments

This field is a list of byte pairs indicating STA Alias ID (assigned via a MAC Management message) and number of slots for both downlink and uplink non-contention data transmission. STA only need an alias ID if non-contention bandwidth is requested and assigned by the PCF. The non-contention area is divided into a downlink followed by an uplink area with no special mark delineating them.

Field	*Length*	*Description*
Alias STA ID	1	Identifies one STA uniquely within BSS.
Slots allocated.	1	Number of slots in downlink STA must receive.
Alias STA ID	1	same as above..etc.
♦		
♦		
♦		
Alias STA ID	1	Unique STA within BSS.
Slots allocated	1	Number of downlink or uplink slots (see table length fields)
	varies	TOTAL BYTES

3.5.13. Overall UH Length

There are compelling reasons to make the UH a fixed length, such as limiting the Superframe overhead and simplifying implementation. However, some implementations with a very large number of STA per BSS (e.g. 500 - 2000) should also be accommodated. (POS or Transaction Processing applications could use 802.11 protocols in a mode that supported a large number of STA in the non-contention area. This is especially important when using single channel PHYs.) A code is used to indicate whether a small fixed length UH is being used, or a variable length UH follows.

A code in the CONTROL FIELD is used to indicate fixed or variable UH length. Fixed would typically be used by office environment systems. It would provide for a limited number of non-contention slots (e.g. 30, 50, or 64). A variable length UH could configure the Superframe for 200 slots for instance. (200 slot assignments, at 2 bytes per assignment, in a fixed UH would consume too much bandwidth under normal "office" use where 5 to 10 STA are associated with one AP.)

3.5.14. Corrupted UH Operation

The loss of up to four UH is not a catastrophic event. However UH loss or corruption does effect PHY dependent parameters and the boundary between non-contention and contention areas.

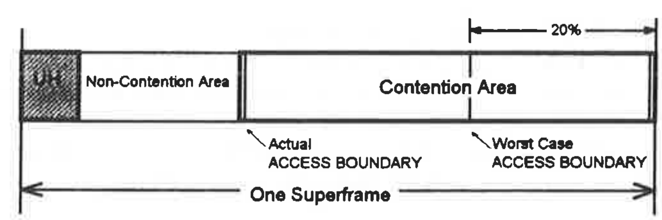
3.5.14.1. PHY Dependencies

STA not receiving a valid UH assume the same PHY Dependent parameters as received in the last valid UH. In the case of the FHSS PHY, the next four frequencies are known to the STA.

If more than four successive UH were missed the STA will stop transmitting LLC data until a valid UH is received. In the case of a FHSS PHY, it may assume it has lost hop synchronization and attempt to re acquire the sequence. If a known hop pattern (channel) were being used prior to loss of four UH, it may choose to hop to the fifth, sixth, etc. frequencies in that channel in an attempt to receive a UH, thus shortening the time to re acquire hop synchronization.

3.5.14.2. Access Boundary

The STA looses the ACCESS BOUNDARY field in the UH so it must assume the worst case contention area allocation. This time is TBD [e.g. 20%, or enough time for one maximum size data MPDU] of the Superframe time. Thus a STA missing a UH may have less opportunity to contend for bandwidth as STA hearing the UH, but it could still use the current Superframe.



STA Operation with Loss of UH

Figure 11.

3.5.14.3. Non-Contention Area Assignments

A STA missing a UH would lose the benefit of the Uplink and Downlink Tables. Therefore, if it was using the non-contention area for asynchronous data, it would have to listen during the entire non-contention area in case downlink data were transmitted to it. (In the normal case, if the alias ID did not appear in the Downlink Table, the STA could power down for this interval.)

In addition, the STA could not transmit uplink asynchronous data since it would not know if slots had been assigned to it.

If Time-bounded assignments were in effect before the lost UH, the STA would assume a continuing assignment of the same slot as the previous Superframe. These assignments change infrequently; an asynchronous exchange is necessary to tear down a connection oriented service.

3.6. Non-Contention Area Structure

3.6.1. Slot Definition

The STA asks the AP what the slot length is through the *Non-Contention Parameter Request* MAC Management message. This should be variable on a per BSA/BSS basis to accommodate widely varying Time-Bounded service qualities (e.g. telemetry, voice, video). The manner in which the AP determines the slot length should not be specified in the standard.

Unless a STA can utilize the non-contention area, it need *not* know what a slot is. It must only interpret the ACCESS BOUNDARY field.

3.6.2. Dynamic Parameters

3.6.2.1. STA Alias Address

To minimize overhead, traffic in the non-contention area uses 8-bit aliases to identify all STA within the BSS capable of using the non-contention area. These aliases are assigned by the STA containing the PCF (typically the AP)

STA Type	Decimal Range	Hex Range
Alias of Access Point	1-63	1-3F
Alias of STA	64-127	40-7F
Reserved for MAC Management	128-247	80-F7
Reserved for future use	248-253	F8-FD
Default STA address (not normally used)	254	FE
Broadcast address (not normally used)	255	FF

3.6.3. MPDU Frame Formats

3.6.3.1. Data

(Does not differ in structure from Contention Area Data Frame.) DATA is the transmission from source to destination that contains the payload of the MPDU.

Field	Length	Description
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x} Indicates Time Bounded data type.
MPDUID	2	See MPDUID field description.
DATA LENGTH	2	Length in bytes of the payload in Data Frame if CTS successful.
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
SOURCE ALIAS	1	Alias assigned during Association process.
Payload	n	Length of payload varies between 32 and <slot length> bytes.
FCS	4	Cyclic Redundancy Check -32 on entire frame.
	Varies. min: 52 max: Dependent on Slot Length	TOTAL BYTES

3.6.3.2. ACK
(Does not differ in structure from Contention Area ACK.) Acknowledge is the transmission from destination to source that indicates receipt of the immediately previous DATA frame with a correct MPDU Frame Check Sequence (FCS). Negative acknowledgments are not used in this protocol.

Need not be sent at common rate if using rate agile PHY.

Field	Length	Description
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
MPDUID	2	See MPDUID field description.
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	9	TOTAL BYTES

3.6.4. MPDU Header Fields
Those fields in common with the Contention Area MPDU Header Fields are described in the Contention Area section.

3.7. Contention Area Structure

3.7.1. Boundary
The contention area is a portion of a Superframe after the UH and the optional non-contention area. It is a mandatory element of a Superframe and will never be smaller than one maximum size Asynchronous MPDU. The contention area is intended for asynchronous LLC traffic either directly between STA or repeated through an AP as described in document 93/40.

3.7.2. MPDU Frame Formats
The contention area uses several MPDU frame formats. They are:

Abbreviation	Name	Length
RTS	Request to Send	17
CTS	Clear to Send	11
DATA	Data	varies
ACK	Acknowledge	9
ANN	Announce	7
HB	Heart Beat	7

3.7.2.1. Request to Send

Request-to-Send is a transmission from source to destination initiating the MPDU. It contains general MAC header information plus the 48-bit ID of the destination STA. The RTS frame reserves the wireless medium in the vicinity of the source STA. RTS is a fixed length frame.

Sent at common rate if using rate agile PHY.

Field	*Length*	*Description*
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
MPDUID	2	See MPDUID field description.
DATA TIME	2	Time duration of the payload in Data Frame if CTS successful.
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
DESTINATION ADDRESS	6	48-bit IEEE MAC address of destination STA, or 48-bit Multicast address
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	17	TOTAL BYTES

3.7.2.2. Clear to Send

Clear to Send is a transmission from the intended destination granting permission to transmit the DATA frame. CTS is not used for flow control in this context. A STA will not send CTS if the Net Allocation Vector indicates that the network will be busy during transmission of the CTS or ensuing DATA frames.

The purpose of the CTS is to clear the medium in range of the destination STA for the duration of the ensuing DATA frame from the source STA.

Sent at common rate if using rate agile PHY.

Field	*Length*	*Description*
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
MPDUID	2	See MPDUID field description.
DATA TIME	2	Time duration of the payload in Data Frame if CTS successful.
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	11	TOTAL BYTES

3.7.2.3. DATA

DATA is the transmission from source to destination that contains the payload of the MPDU.

Field	Length	Description
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
MPDUID	2	See MPDUID field description.
DATA LENGTH	2	Length in bytes of the payload in Data Frame if CTS successful.
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
SOURCE ADDRESS	6	48-bit IEEE MAC address of source STA, or 48-bit Multicast address.
Payload	n	Length of payload varies between 32 and 586 bytes.
FCS	4	Cyclic Redundancy Check -32 on entire frame.
	Varies. min: 52 max: 606	TOTAL BYTES

3.7.2.4. ACK

Acknowledge is the transmission from destination to source that indicates receipt of the immediately previous DATA frame with a correct MPDU Frame Check Sequence (FCS). Negative acknowledgments are not used in this protocol.

Need not be sent at common rate if using rate agile PHY.

Field	Length	Description
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
MPDUID	2	See MPDUID field description.
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	9	TOTAL BYTES

3.7.2.5. Announce

Announce is a single frame MPDU. It is used only when no infrastructure is present in small or Ad-Hoc networks to enable the BSS to coalesce. When infrastructure is present, the STA or AP acting as the PCF broadcasts the UH which obviates the need for Announce.

Field	Length	Description
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	7	TOTAL BYTES

3.7.2.6. Heart Beat

Heart Beat is a single frame MPDU transmitted by STA performing the PCF function in an infrastructure based BSS. It is used to verify the presence of associated STA that have Time-Bounded bandwidth allocated in the non-contention interval of a Superframe. Heart Beat is directed to a particular STA and that STA is required to respond with an ACK frame. Without this mechanism, Time-Bounded bandwidth allocated by the PCF may go unused if the STA loses contact with the BSS.

These frames are transmitted on an infrequent basis between one and ten minutes apart. If an ACK is not received in response, the PCF shall retry with further identical Heart Beat frames at least 4, but not more than 20 times. The retry of a Heart Beat frame need *not* obey the minimum frequency of one to ten minutes (i.e. immediate retry is desired esp. for FHSS PHY.). If no ACK is received, any Time-Bounded bandwidth allocated to that STA shall be removed. (Technique guards against Time-bounded bandwidth never being un-allocated.)

If the HB process fails, should STA be dis-associated completely?

Field	Length	Description
TYPE	1	See Type Field description.
CONTROL	1	CONTROL = {TB=0, Hierarchical=x, AP=x, Retry=x}
PHY SPECIFIC	2	See PHY SPECIFIC field description.
NETID	2	Unique to ESS. Identifies BSS of sending STA.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	7	TOTAL BYTES

3.7.3. MPDU Header Fields

The following sections describe the various fields in the contention area MPDU frames.

3.7.3.1. TYPE Field

All frames have an 8-bit TYPE field. The field is used to "steer" the attached packet to Asynchronous, Time-Bounded or Management entities in the MAC layer.

Bit Field								Name	Description
x	x	x	x	0	0	0	1	RTS	Request to Send
x	x	x	x	0	0	1	0	CTS	Clear to Send
x	x	x	x	0	1	0	0	ACK	Acknowledge
x	x	x	x	1	0	0	0	DATA	Data
x	x	x	x	0	1	1	0	ANN	Announce
x	**x**	**x**	**x**	**0**	**1**	**1**	**1**	**HB**	**Heart Beat**
x	**x**	**x**	**x**	**1**	**0**	**0**	**1**	**UH**	**Universal Header**
1	x	x	x	x	x	x	x	SYSPKT	System Packet: MPDU intended for MAC Management.
x	1	x	x	x	x	x	x	ENC	Encrypt: MPDU payload is encrypted. (Not necessary if encryption handled by 802.10.)
x	x	1	x	x	x	x	x	COM	Compress: MPDU payload is compressed. (Not necessary if compression handled by 802.10.)

(Bold indicates field differs in some way with 93/40.)

3.7.3.2. CONTROL Field

All frames have an 8-bit CONTROL field. The field is used to assist processing of the attached packet in the MAC layer.

Bit Field								Name	Description
x	x	x	0	0	0	0	1	TB	Time Bounded: Indicates this MPDU if intended for Time Bounded service.
x	x	x	0	0	0	1	0	HIER	Hierarchical: Indicates direct or store and forward operation. 0: Frame is intended for direct reception. 1: Frame must be repeated by AP
x	x	x	0	0	1	0	0	AP	**Access Point**: Only set by AP to indicate source of MPDU.
x	x	x	0	1	0	0	0	RET	Retry: MPDU is a retransmission of an earlier MPDU due to lack of ACK.
			1	0	1	0	0	UHLF	**UH Length is Fixed**
			1	0	1	0	1	UHLV	**UH Length is Variable**
x	x	x	1	x	0	x	0	ABWR	Async. **BW Request** for Non-Contention area. Number of slots requested contained in bits 7 [MSB], 6, 5 [LSB].

3.7.3.3. MPDU ID Field

This 16-bit field is used to identify frames of a particular MSDU. It is used to assist duplicate detection.

3.7.3.4. DATA LENGTH Field

This 16-bit field indicates the number of bytes in the payload of the Data frame MPDU.

3.7.3.5. PHY SPECIFIC Field

This two byte field is used to convey PHY dependent information required on a per MPDU basis. It is transmitted in the header of all the Asynchronous frames. One byte is used to indicate the channel number or next frequency (TBD) when using a FHSS 2.4GHz. PHY. This will speed initial channel acquisition of STA, and assist the seamless roaming process by making it easier for "hunting" STA to quickly determine the set of APs in range.

3.7.3.6. NET ID Field

This 16-bit identifier is unique to an ESS. It identifies a BSS. STA associated with a particular BSS will only accept frames with that BSS's NETID. This field is used to differentiate between MPDUs from overlapping BSA.

3.7.3.7. DESTINATION ADDRESS Field

This 48-bit field contains standard IEEE 802.3 type unique STA MAC level identifiers.

3.7.3.8. SOURCE ADDRESS Field

This 48-bit field contains standard IEEE 802.3 type unique STA MAC level identifiers.

3.7.3.9. FCS Field

This field uses well known Cyclic Redundancy Check algorithms of varying length. For RTS, CTS and ACK frames it is 8-bits in length. For Data frames it is 32-bits in length and uses the same CRC-32 algorithm as 802.3.

4. MAC Management

Note that MAC Management does not refer to Station Management functions. MAC Management is concerned with dynamic events and processes occurring on a per frame or per call basis.

4.1. MPDU Frames

TYPE Bit Field								Name	Description
1	x	x	x	x	x	x	x	SYSPKT	System Packet: MPDU intended for MAC Management.
1	x	x	0	0	0	0	1	ASSOC_REQ	Association Request
1	x	x	0	0	0	1	0	ASSOC_IND	Association Indication (response)
1	x	x	0	0	0	1	1	DISASSOC_REQ	Disassociation Request
1	x	x	0	0	1	0	0	DISASSOC_IND	Disassociation Indication
1	x	x	0	0	1	0	1	NC_PARA_REQ	Non-Contention Parameter Request
1	x	x	0	0	1	1	0	NC_PARA_IND	Non-Contention Parameter Indication
1	x	x	0	0	1	1	1	NC_BW_RES	Non-Contention Bandwidth Reservation
1	x	x	0	1	0	0	0	TB_BW_REL	Time-bounded Bandwidth Release
1	x	x	0	1	0	0	1		

4.1.1. Association Request message

The payload of this MAC Management MSDU includes parameters indicating:

1. NETID
2. AP ID
3. STA IEEE 48-bit MAC ADDRESS
4. AUTHENTICATION OPTIONS
5. ENCRYPTION OPTIONS
6. CAPABILITITES BIT FIELD: parameters include whether STA is capable of utilizing traffic in the non-contention area. If the STA has this capability, the AP could choose to transmit downlink information in the non-contention area.

4.1.2. Association Indication message

The payload of this MAC Management MSDU includes parameters indicating:

1. NETID
2. AP ID
3. STA IEEE MAC ADDRESS
4. ASSOCIATION RESPONSE CODES
5. STA ALIAS ID: Used in non-contention area. (If STA has this capability)

4.1.3. Disassociation Request message

4.1.4. Disassociation Indication message

4.1.5. Non-Contention Parameter Request message

This is a fixed message sent from the STA to the AP requesting that the AP reply with parameters that enable the STA to communicate in the non-contention area.

4.1.6. Non-Contention Parameter Indication message

The AP responds to the Non-Contention Parameter Request message with this directed message to the STA. Parameters indicated in the message are changeable, but static for the duration of a call or session. These parameters include:

- Alias assignment (Could be done at Association time...)

- slot length,
- qualities of service available

4.1.7. Non-Contention Bandwidth Reservation message

Reserves both Time-bounded and Asynchronous bandwidth in the non-contention area. Parameters include:

- TYPE
- NETID
- AP ID
- SLOTS REQUIRED
- SERVICE TYPE

The SERVICE TYPE field dictates whether asynchronous or Time-Bounded services are requested:

- Simplex
- Duplex
- Time-Bounded
- Asynchronous
- Direction In/Out

Note that Asynchronous bandwidth can also be reserved through the CONTROL Field in a DATA MPDU, obviating the need for a specific message. See Bandwidth Reservation.

4.1.8. Time-bounded Bandwidth Release message

Through the Call Control messages at Network Layer and higher, STA would issue this message at the MAC Managment layer to release some or all of an existing bandwidth allocation.

4.2. Seamless Roaming Technique

4.2.1. "Media Busy" fields usage

Seamless roaming is defined as moving from one BSS on one channel to another BSS on another channel without imposing any special conditions on upper layers (i.e. LLC and above). It is a concept that is only important when infrastructure is present and therefore the PCF can be taken advantage of. The UH contains the ACCESS BOUNDARY and Non-Contention Assignments fields that can be used as a "media busy" indication to all STA. If there is sufficient non-contention time allocated, a STA could determine it had no need to participate in the non-contention area and could better use the time to search or scan for other PCF.

If no non-contention time were allocated, the STA is not capable of determining whether it might receive traffic destined for it. One choice the STA could make is to search for other BSA (PCF) in the contention area, taking the risk of missing MPDUs destined for it in that Superframe.

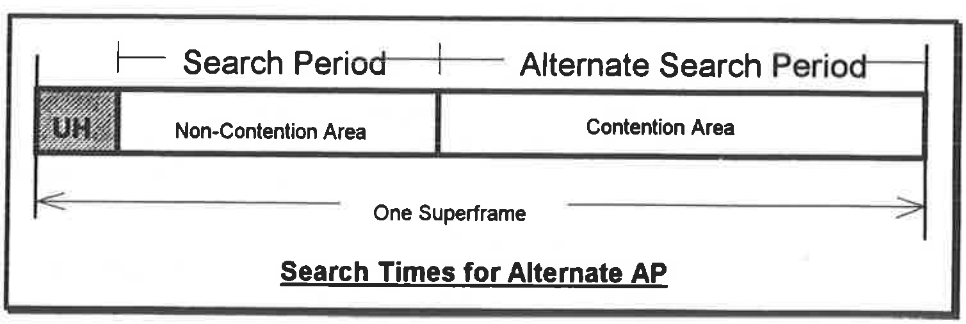


Figure 12.

In this manner, a table of possible new BSAs could be built. If and when the STA determined that the present link to its AP has degraded beyond some threshold, the switch to a better BSA could be made in one Superframe time. Of course, the STA would need to Reassociate with the new AP.

4.3. Variable Superframe Length

Superframes must be allowed to vary in length to accommodate various access delay, quality of service and throughput trade-offs. The manner in which the length is chosen should be left to the implementor; it does not effect interoperability. A mechanism of changing Superframe length dynamically is described.

Assume a STA can be in range of a limited number of AP at one time; say 5 max. It would attempt to maintain "synch" with all 5 at one time, such that it could seamlessly roam to any within one Superframe time. (See section on Seamless Roaming) Let's say that one of the AP has decided to change the Superframe length. Thus if the STA does not know about this change, it will lose sync. Bad deal, but it doesn't have to happen.

In order to maintain sync. with the 5 AP, the STA "visits" each periodically. Assume it visits one AP every 3 to 5 hops to minimize this overhead and a max. hop length is 100mS. Therefore to visit all 5 AP takes 5AP * 5hops/visit * 100mS/hop. So worst case, the STA will update its timers for each AP once every 2.5seconds. A more nominal time would be 4AP * 4hops/visit * 50mS/hop giving 800mS. Why is this important?

Well, an AP wishing to change Superframe length must give notice over some time period, if for no other reason so as not to loose contact with it's own set of STA. If an AP is required to give notice for up to 2.5 seconds, any STA trying to maintain synch. with it could continue to do so. The "foreign" STA would be guaranteed of intercepting one or more UH indicating the pending change. The UH contains a PENDING COUNT field not only indicating the duration of the hop, but also a count-down to when that hop length was going to change. A zero PENDING COUNT field indicates no pending change.

5. PHY Specific Issues

5.1. Data Rate Agility

The WHO Protocol is constructed to allow differing PHY data rates within a Superframe, with the caviot that all STA must hear the UH in Infrastructure networks. Therefore, like other proposals, multiple rates could be supported, but a common rate must be implemented by all members of a BSS.

6. Evaluation Against Measurement Criteria

Evaluation, as other protocols have been, against criteria presented in: 802.11 MAC: Requirements and criteria (Wim Diepstraten, NCR). (doc. 93/33) TBD.

7. Conformance Levels

7.1. Minimal STA

As a minimum, a STA must implement all the mandatory elements of the WHO protocol. These include:

- Contention only operation in a "no infrastructure" network (Ad-Hoc operation)
- Interpret and act upon a UH ACCESS BOUNDARY field (Infrastructure operation)
- Asynchronous traffic conveyed in the contention area of an infrastructure based network
- Direct or Peer to Peer traffic paths in the contention area

7.2. Full Featured STA

A STA may implement some or all of the optional features of the WHO protocol to enhance performance and functionality. Some of these include:

- Asynchronous traffic in the non-contention area
- Time-Bounded Services in the non-contention area

It is presumed that for STA capable of non-contention area operation, that all of the downlink (AP to STA) traffic will be conveyed in this non-contention area.

7.3. Point Coordination Function

A STA could also implement the optional functions that enable it to perform the PCF function. Each STA need not have these functions since Ad-Hoc networks are possible with the minimal functions of 7.1 above. PCF functions include:

- Ability to generate the UH: BW allocation, slot assignment
- Time-Bounded Services
- Power Management Services
- MAC Management Services
- Station Management Services

8. References

[BAU93a]: IEEE 802.11 Submission 93/62, Wireless LAN Medium Access Control Protocol: 2nd. Update, Frederic Bauchot.

[BIB93]: IEEE 802.11 Submission 93/40, The Wireless Hybrid Asynchronous Time-bounded MAC Protocol, Phil Belanger, Ken Biba

[NAT92]: IEEE 802.11 Submission 92/39, Medium Access Control Protocol for Radio LANs:, an Update, K. S. Natarajan, C. C. Huang and D. F. Bantz

[POP92]: IEEE 802.11 Submission 92/81, Signalling for 802.9 Circuit Switched Services; Sanjay Popli

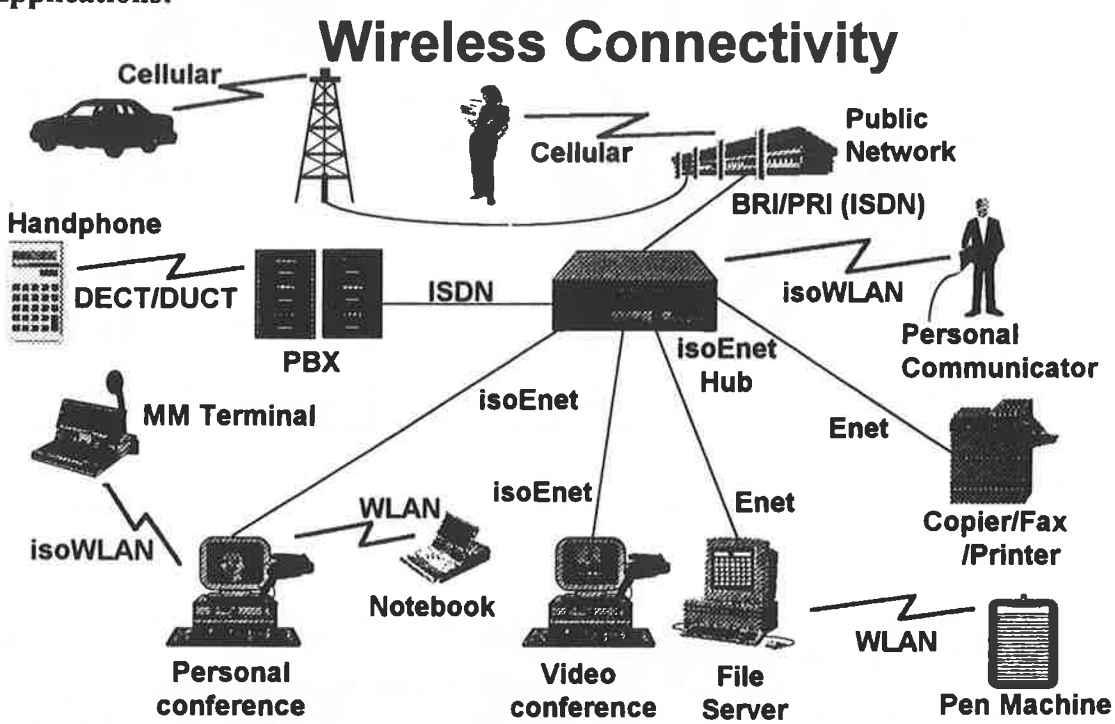
[SCH93]: IEEE 802.11 Submission 93/75, A Compromise MAC Protocol Concept, Jim Schuessler

Annex A.

There has been some question as to what applications isochronous networks address and uncertainty over whether an infrastructure would be in place to convey iso-services. This annex addresses these questions in a presentation style.

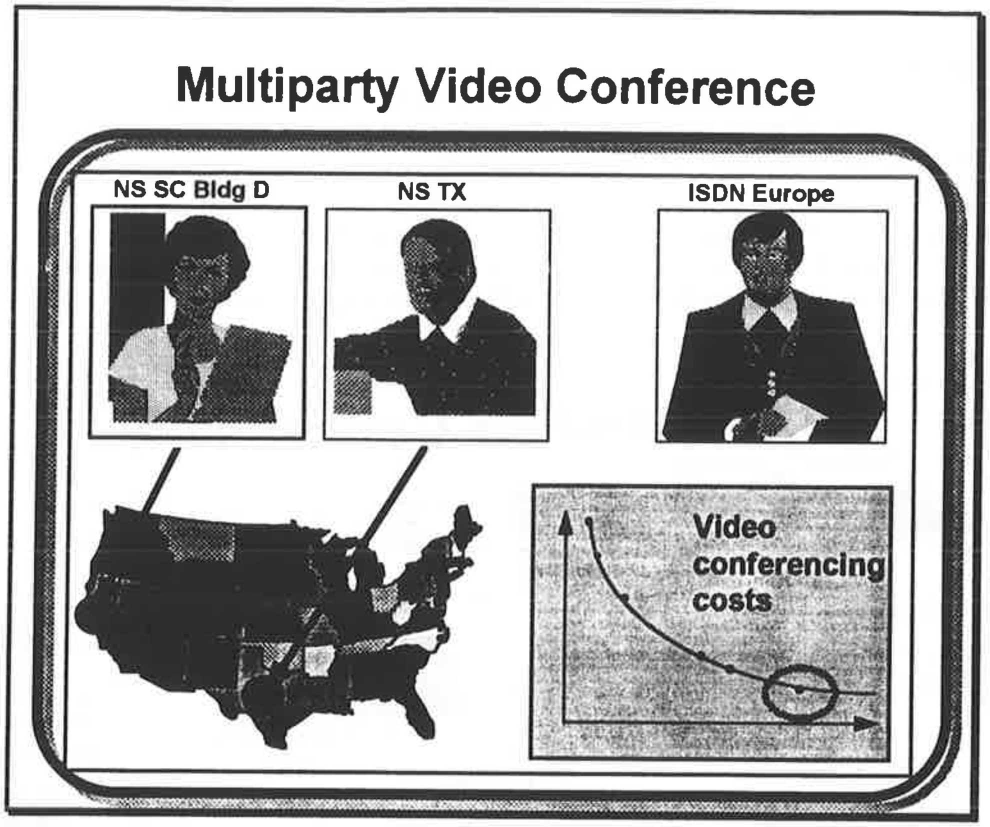
We believe there are three categories of events that must be present to enable a market for isoWLAN. First, there must be compelling applications. Second, there must be accepted standards for isoNetworks, voice and video compression and call control. And third, there must be a real international infrastructure available at relatively low cost.

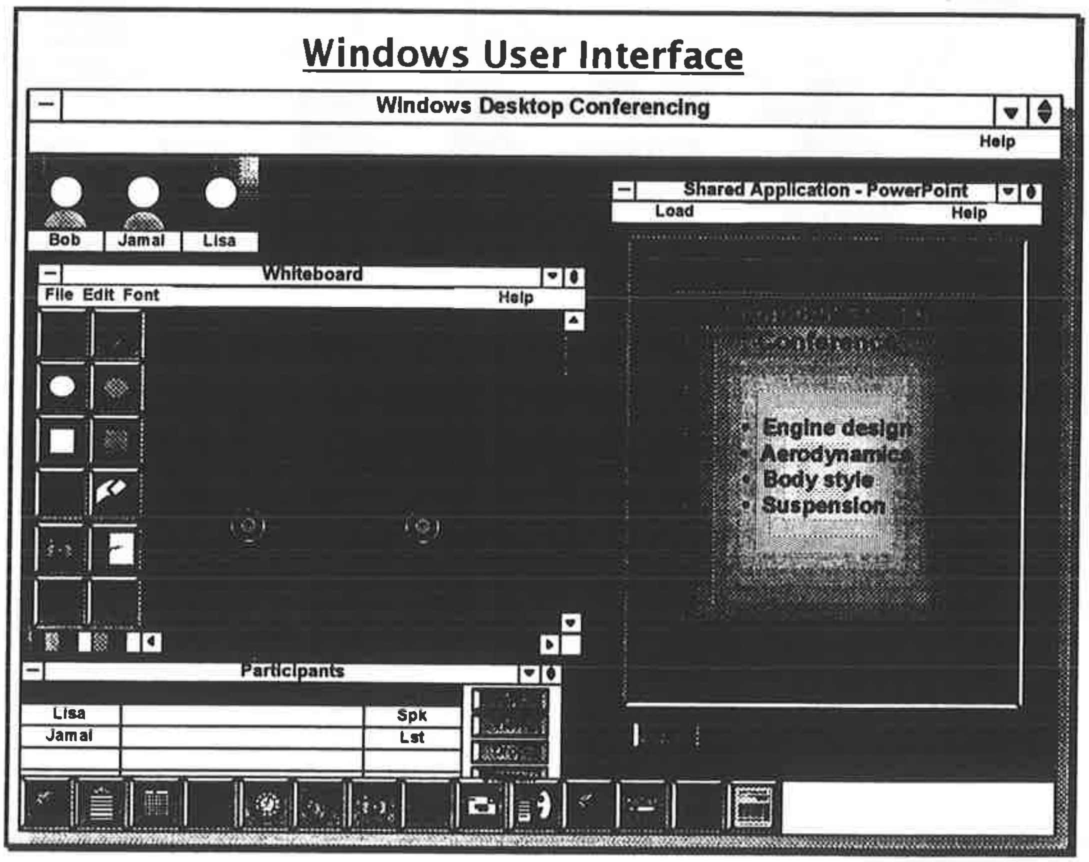
Applications:



Sample Applications

- Video Conference
- Residencial / Consumer Audio and Video
- Intelligent Phone
- Video Playback / Authoring
- Hyper-Media
- Personal Conferencing
- Collaborative Computing
- Personal Communcators


Multiparty Video Conference
NS SC Bldg D
NS TX
ISDN Europe
Video conferencing costs


Windows User Interface
Windows Desktop Conferencing
Help
Bob
Jamal
Lisa
Whiteboard
File Edit Font
Help
Shared Application - PowerPoint
Load
Help
Engine design
Aerodynamics
Body style
Suspension
Participants
Lisa
Spk
Jamal
Lst

Standards

isoEnet Becoming a Standard

- Plan is to make isoEnet IEEE802.9 standard
- 802.9 was a small committee attempting to define an Integrated Systems LAN
- In July 92, National proposed Call Se*up procedure, and IBM an Addressing scheme based on AT&T proposal, accepted in Nov 92.
- National proposed isoEnet to committee Nov 92 as a Project Authorization Request (PAR), with IBM and Apple's support
- Proposed as a PAR in March 93 and subsequently accepted.
- Now main task of committee

Call Setup Developments

- IEEE 802.9 Integrated Voice / Data LAN
  - call setup in final draft, will be a standard late 1993
- ANSI FDDI-II
  - planning to adopt same call setup scheme
- IEEE 802.11 IsoWLAN
  - proposed same scheme as 802.9
- ATM Forum
  - almost identical scheme to isoEthernet

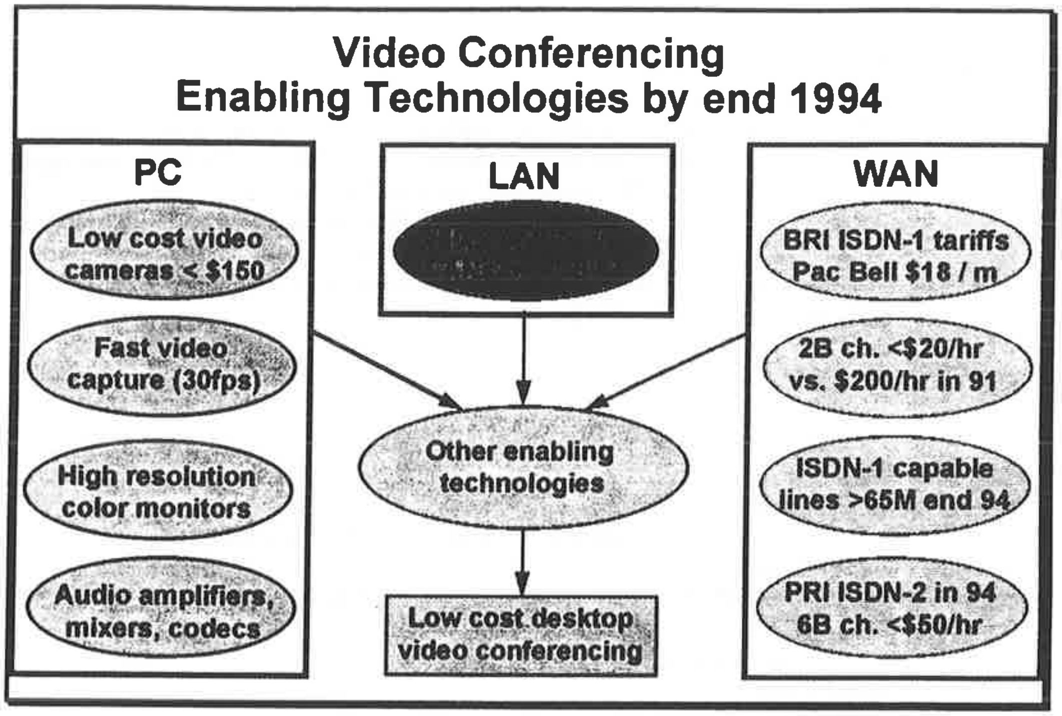
IsoEnet Industry Acceptance

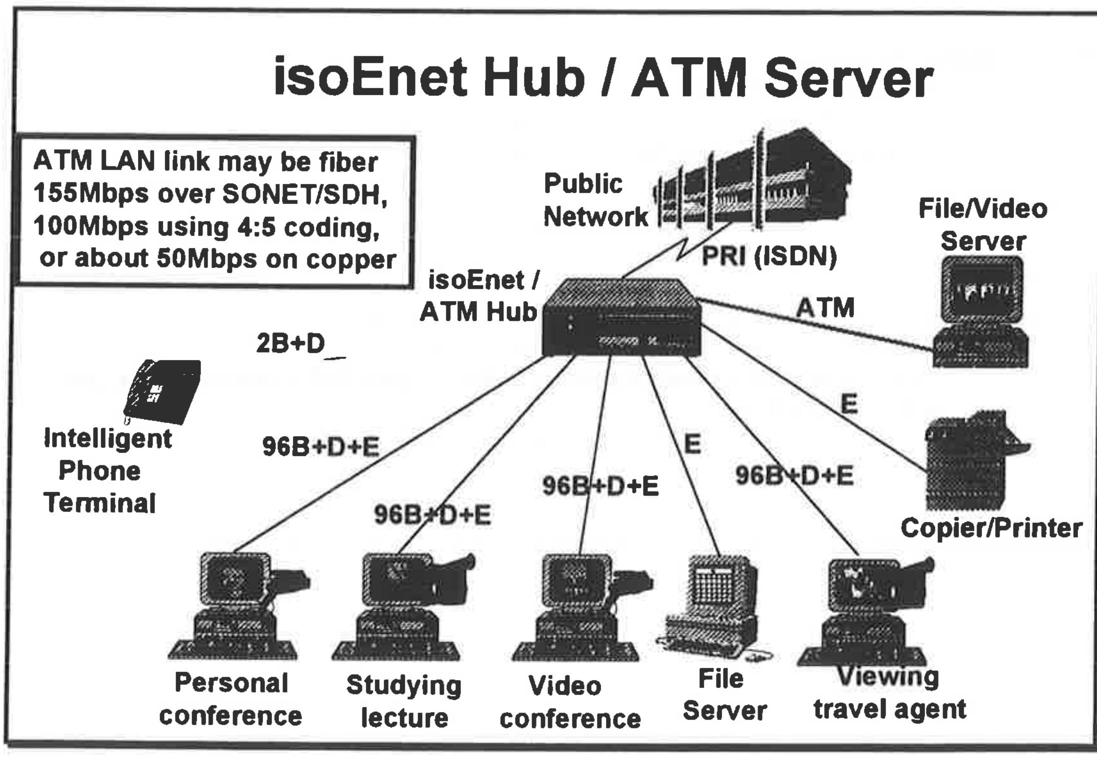
- 802.9 approved PAR
- Multimedia Communications Forum initiated.
- Several companies active in IsoEnet

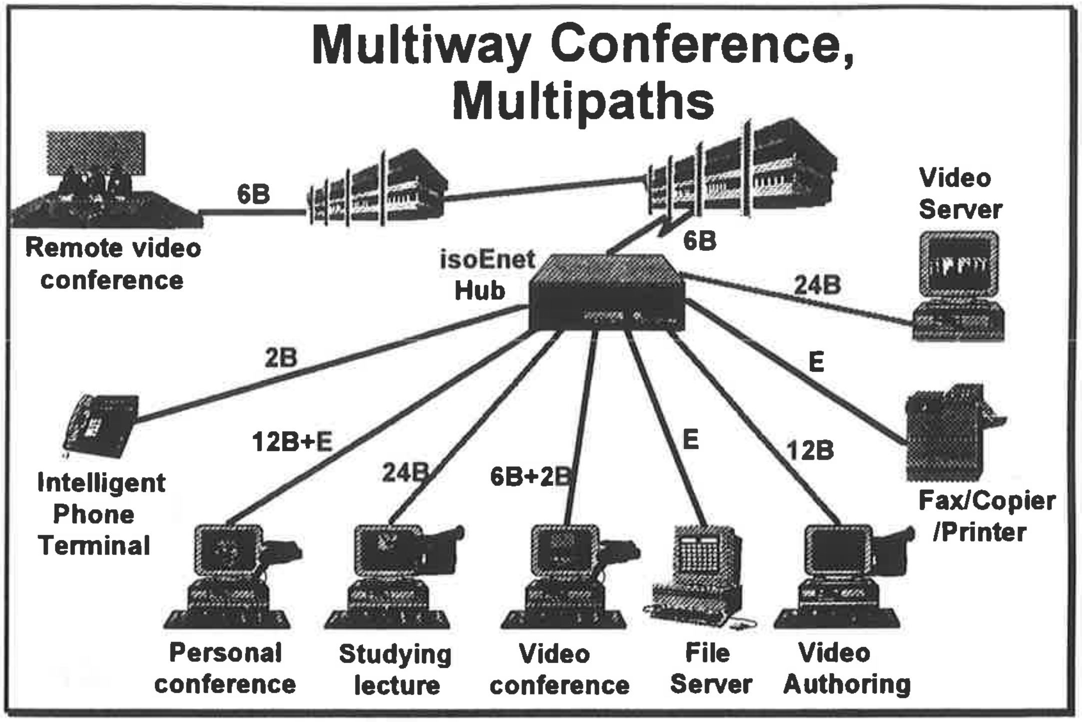
isoEnet Status

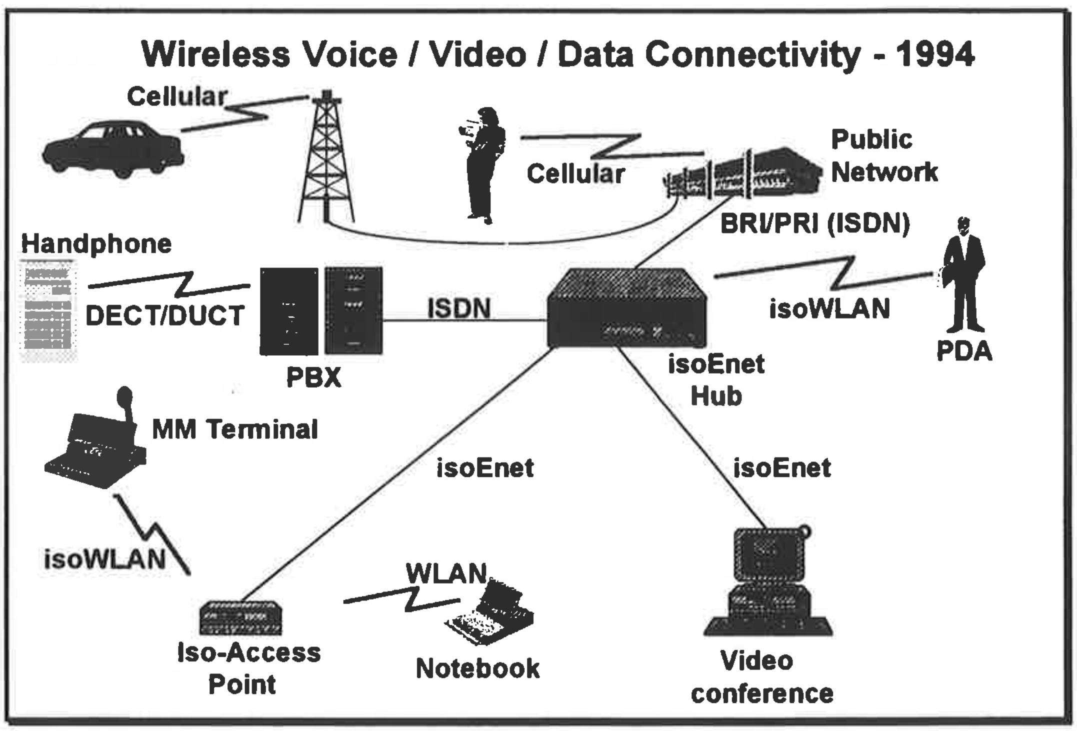
- Initial silicon early '94, dependent on committee
- Products and applications introduced in '94
- National and its partners intend to make isoEnet de-facto multimedia LAN standard for PCs
- National intends to replace Enet with isoEnet

Creation of International Infrastructure






Multiway Conference, Multipaths
6B
Remote video conference
isoEnet Hub
6B
Video Server
24B
2B
E
Intelligent Phone Terminal
12B+E
24B
6B+2B
E
12B
Fax/Copier /Printer
Personal conference
Studying lecture
Video conference
File Server
Video Authoring


Wireless Voice / Video / Data Connectivity - 1994
Cellular
Cellular
Public Network
BRI/PRI (ISDN)
Handphone
DECT/DUCT
ISDN
isoWLAN
PBX
PDA
isoEnet Hub
MM Terminal
isoEnet
isoEnet
isoWLAN
WLAN
Iso-Access Point
Notebook
Video conference

Wireless Hybrid Operation

◆ "The WHO Protocol" ◆

◆

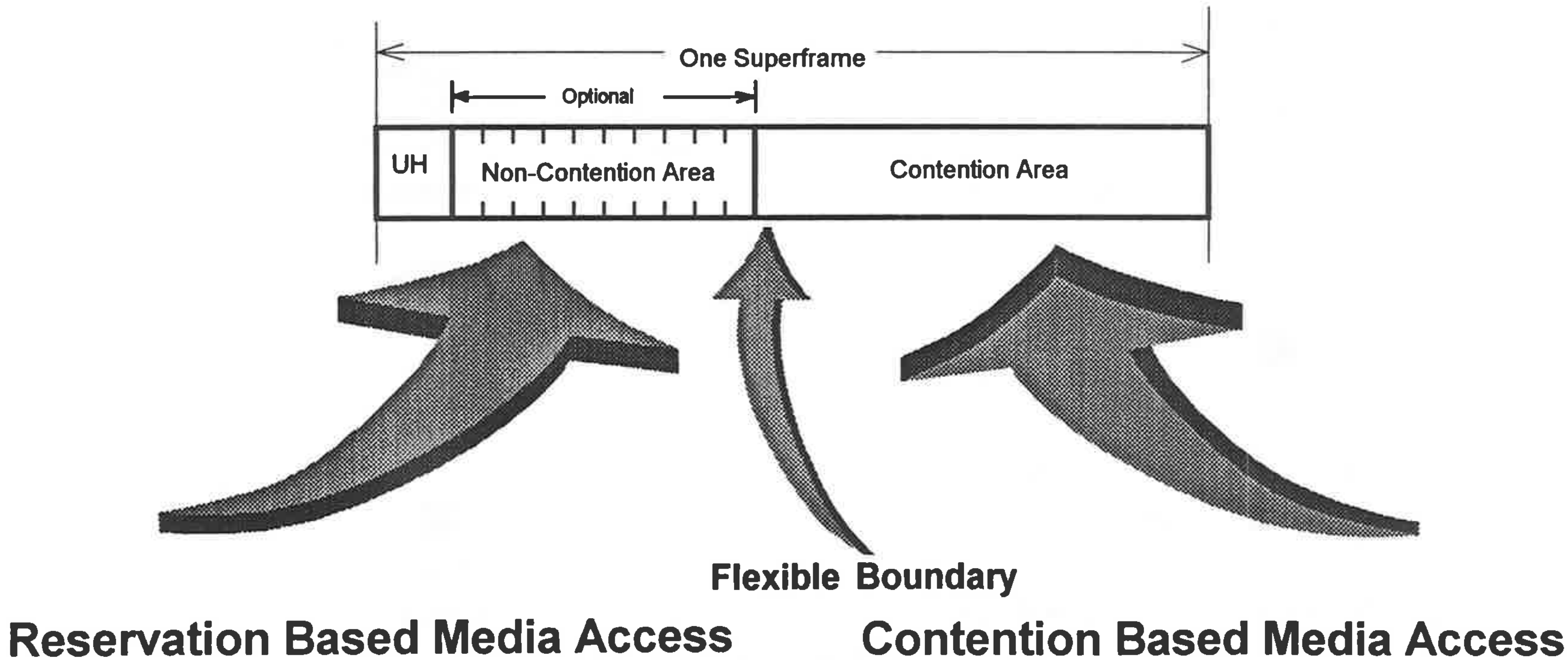
◆ An Introduction ◆

Objectives

- **Preserve Advantages of Distributed CF in Small Installations**
  - Intrinsic Peer-to-Peer Operation: Less Complex Implementation
  - Well Understood, Simple Ad-Hoc Service Provisions
  - Smooth Bandwidth Sharing in Overlapping BSA (esp. in single channel PHY)
- **Preserve Advantages of Reservation Based Protocols (PCF) in Larger Installations**
  - Stable, Efficient Bandwidth Allocation in Overloaded and Heavy Interference Conditions
  - Well Understood, Proven Time-Bounded Service Provisions
  - Power Management Features

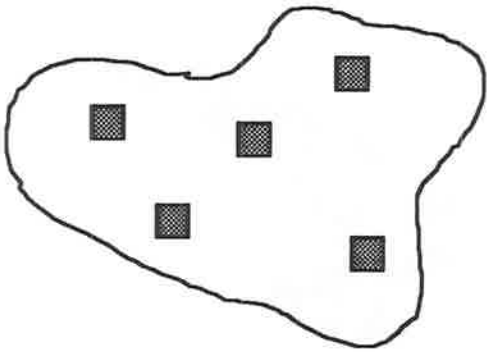
Hybrid Method for Infrastructure Networks

◆ The Merging of Two Access Schemes

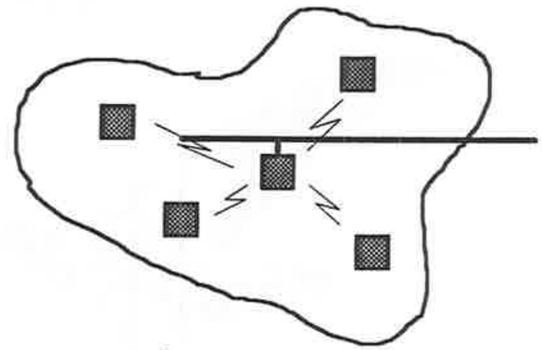


Modes of Operation

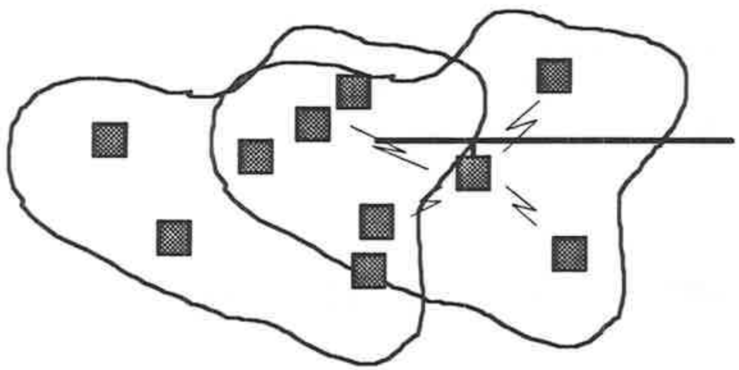
Ad-Hoc Uses Distributed Coordination Function



Infrastructure Networks Use Point Coordination Function

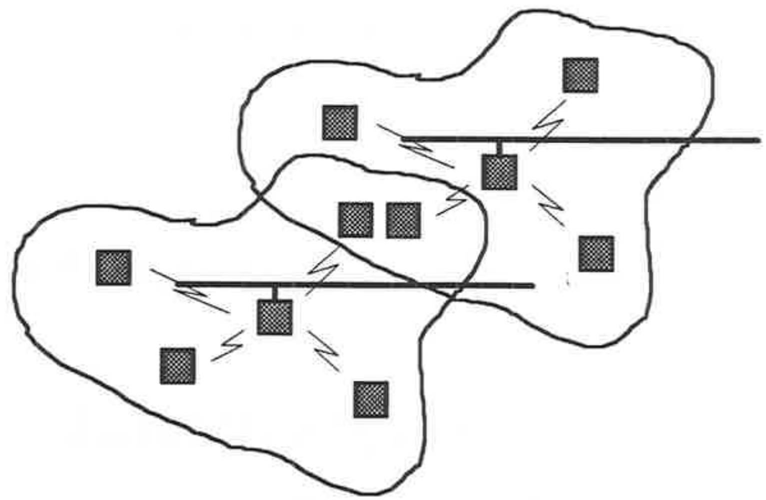


Ad-Hoc and Infrastructure Networks Coexist



Possible with Single Channel PHY

Multiple Infrastructure Networks Coexist



Requires Multiple Channel PHY

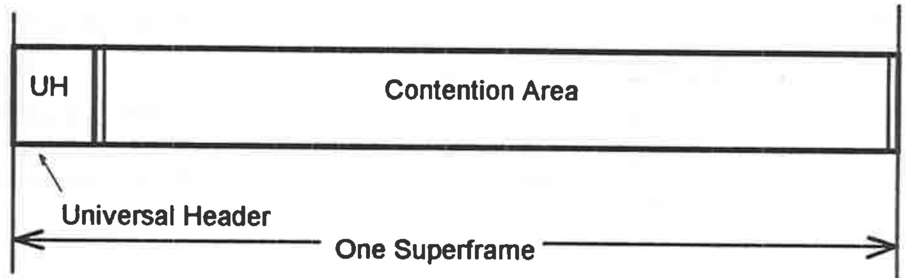
MPDU Frame Types

- Two Additional Frames

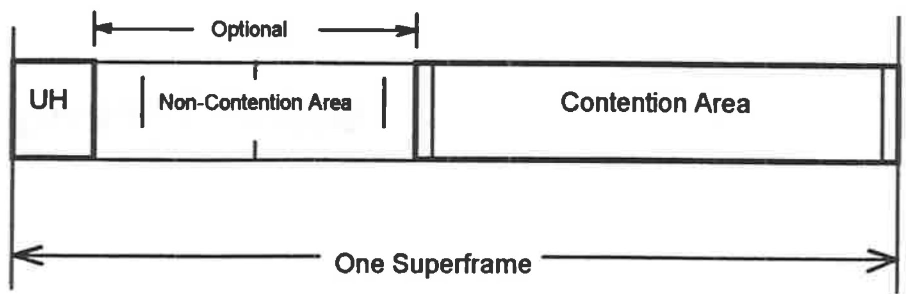
WHAT Frames		WHO Frames	
		UH	*Universal Header*
RTS	Request to Send	RTS	Request to Send
CTS	Clear to Send	CTS	Clear to Send
DATA	Data	DATA	Data
ACK	Acknowledge	ACK	Acknowledge
ANN	Announce	ANN	Announce
		HB	*Heart Beat*

Universal Header

- Used only in Infrastructure Based Networks
- Always Broadcast by PCF at Start of Superframe



Mandatory Superframe Elements



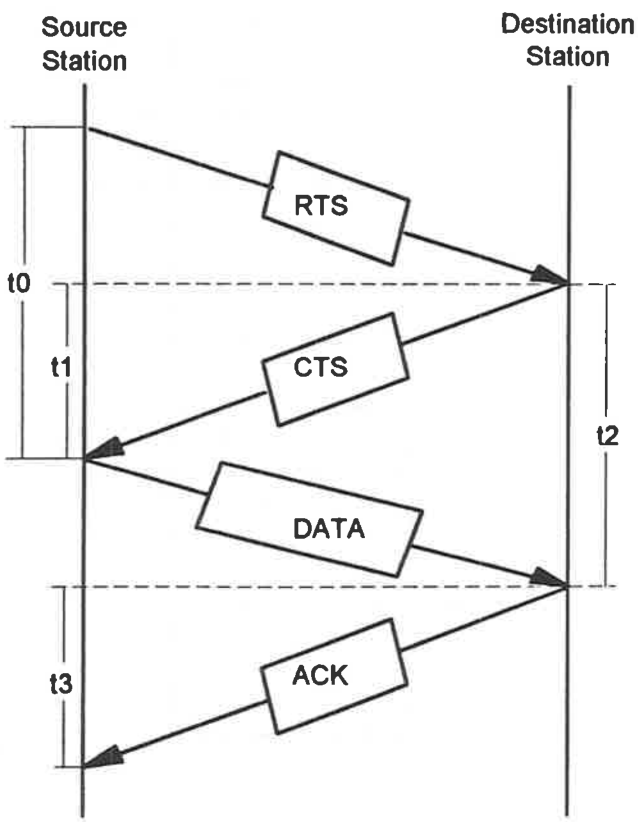
Superframe Elements with Non-Contention Area

UH Structure

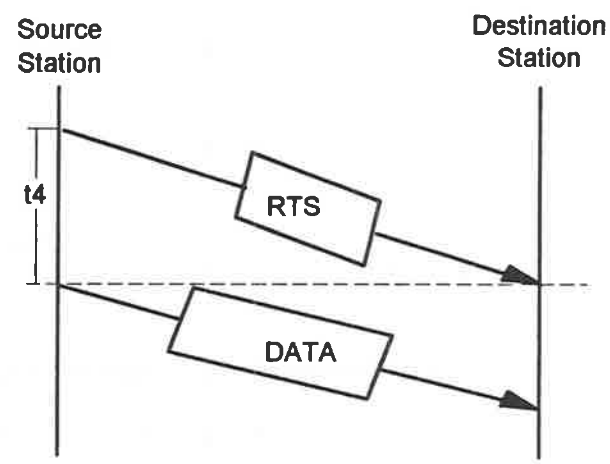
Field	Length	Description
PREAMBLE	x	PHY Dependent
UNIQUE WORD	1	Achieves byte boundary synchronization.
TYPE	1	Allows MAC to distinguish UH from other frame types.
PHY DEPENDENT	5	Defined on a per PHY basis.
DURATION	2	Length of time of the Superframe. (not in bytes)
NETID	2	Unique to ESS. Identifies BSS of sending STA.
ACCESS BOUNDARY	2	Defines time boundary in Superframe between non-contention and contention areas.
DOWNLINK TABLE LENGTH	1	Number of bytes in downlink table.
UPLINK TABLE LENGTH	1	Number of bytes in uplink table.
NON-CONTENTION ASSIGNMENTS	n	This area contains a fixed or variable length list of STA allocated bandwidth and non-contention reception in this Superframe.
FCS	1	Cyclic Redundancy Check -8 on entire frame.
	min: 15 max: varies	TOTAL BYTES

Contention Area and Ad-Hoc Operation

- Identical to WHAT Protocol

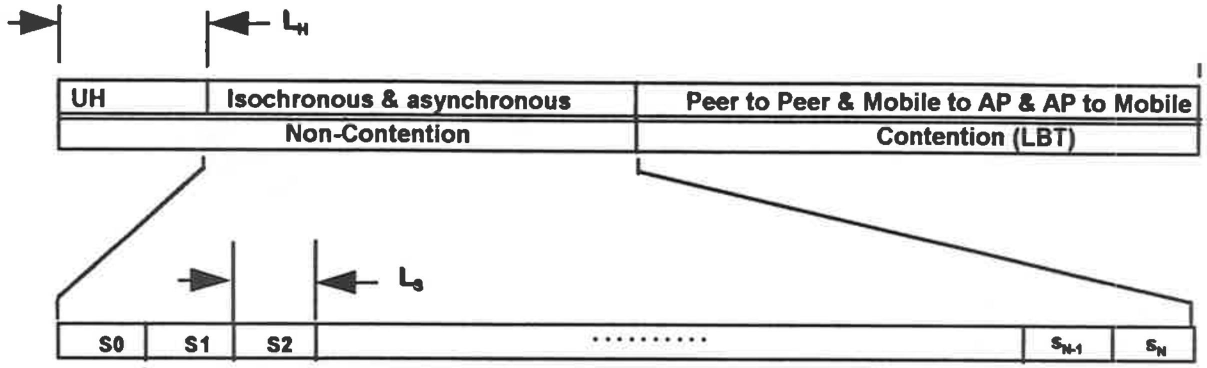


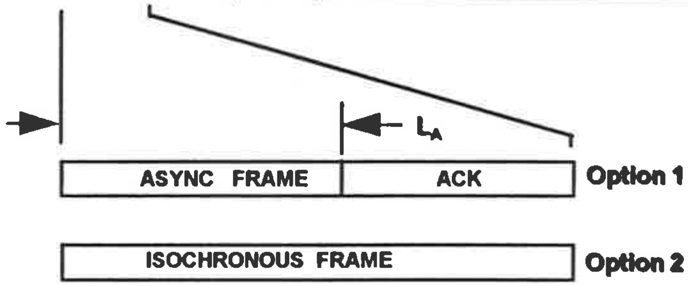
Directed MPDU



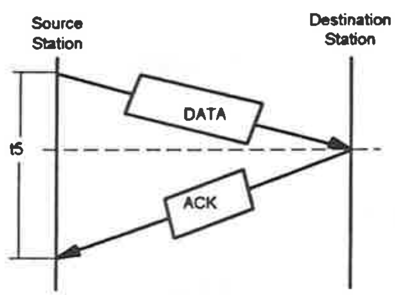
Multicast MPDU

Non-Contention Area Operation

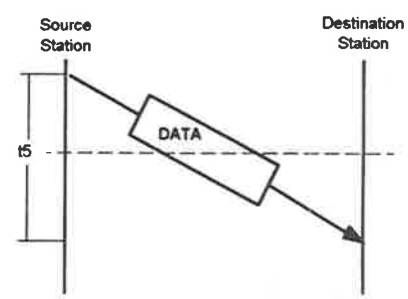




1. Option 1 is the frame structure for an asynchronous frame with acknowledgment.
2. Option 2 is the frame structure for an isochronous frame without acknowledgment.



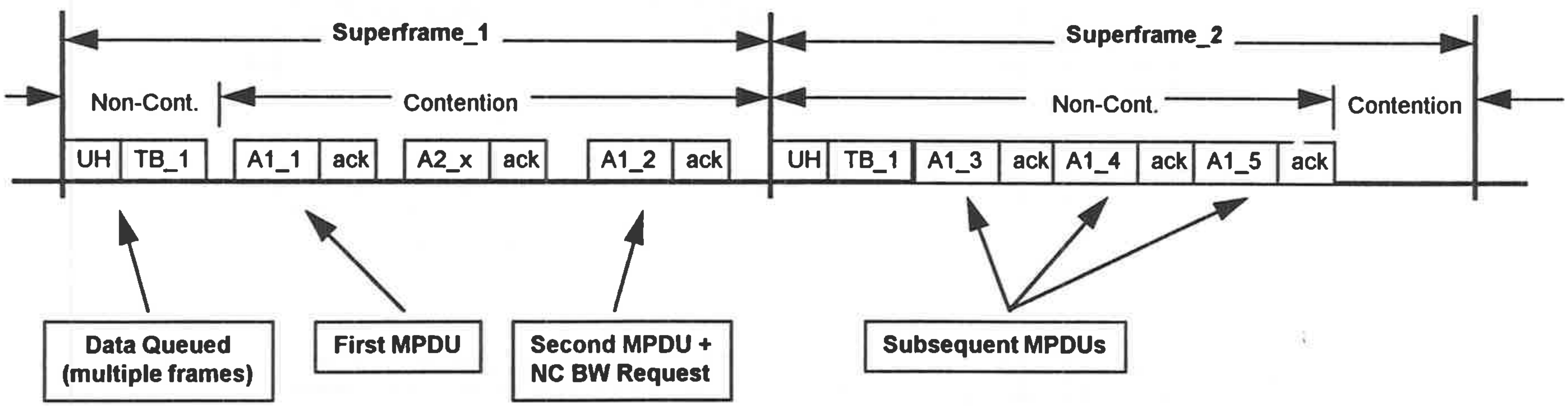
Asynchronous MPDU In Non-Contention Area



Time Bounded MPDU In Non-Contention Area

Non-Contention Bandwidth Allocation for Asynchronous Data

- Low Access Delay and Reliable, Efficient Throughput



Advantages of Deterministic Access in Infrastructure Networks

- Maximize reliability. No dependence on CS function.
- Minimize Time-Bounded Delay Variance (jitter)
- Minimize overhead between frames in Non-Contention area. (reduces to tx/rx turn-around time)
- Reduce by half the PLL Sync. time in the Preamble for frames in the Non-Contention area.
  - Significant gain for ACK and other minimum payload frames. (savings of 23%/frame)