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Criteria for Evaluating MAC Protocols

Asynchronous data service is a necessity.
- export an 802.2 compatible service

Time Bounded service (e.g. real time voice) is an option.

Any protocol proposal should be scalable.

Keep it simple.

Mobility must be supported.

MAC protocols should be PHY independent.
- Degenerate case of single channel PHY
- Improved performance with multi-channel PHY

MAC protocols should work well with imperfect PHYs.
- wireless PHYs are imperfect
- must hide unique wireless issues within MAC

MAC Protocol Goals

Support:
- Asynchronous Data Service
- Time Bounded Service

Provide for:
- ad hoc, small, stand-alone LANs
- large extended wireless LANs
- seamless integration into wired infrastructure
- nomadic computers
  - mobility
  - power management

Deal with wireless transmission issues:
- errors, hidden terminals, adjacent BSAs
- should work well with overlapping service areas.

Minimize cost and complexity

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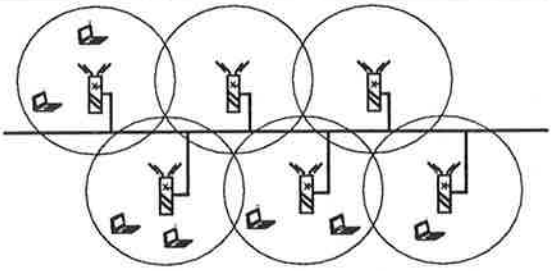
Basic Service Area

Wireless stations in a Basic Service Area

- Peer-to-peer communication among STAs within PHY range
- ad hoc networks
- MAC protocol must match wired LAN packet delivery standards
- deal with errors, hidden stations, etc

Extended Service Area



Interconnected BSAs form an Extended Service Area, ESA.

- existing wired LAN infrastructure is used

Wireless stations may move from one Access Point to another.

- wireless MAC protocol will ensure that the switch is transparent
- mobile stations maintain their high level sessions while in motion

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Infrastructure Extensions

Connect wireless stations to the Distribution System

- connect to existing wired LAN world...
- used to form an Extended Service Set
- BSS connected through DS

MPDU forwarding and filtering

- Access Points filter frames from the DS
  - relay those destined for their Associated STAs
- Access Points forward frames destined for nodes outside BSS
  - only for their Associated STAs

BSS Transitions

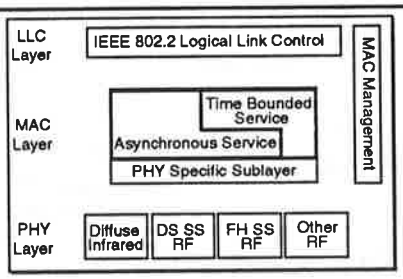
Power Management

Authentication and Security

Discussed in subsequent contribution

- MAC Management functions
- AP to AP protocol

WHAT Protocol Architecture



Every STA supports the Asynchronous Service

Time Bounded Service is optional

The wireless MAC layer provides an 802.2 interface

- compatible with existing LAN drivers and protocols
- makes WLAN look like other LANs
  - improves BER of medium, security, mobility
- solves hidden station problem

ESS configuration handled by MAC Management layer

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WHAT MAC Protocol

Asynchronous Service

- best effort delivery
- low delay
- 48 bit unique IDs

Distributed Coordination Function

- works with or without infrastructure
- "CSMA" with Virtual Collision Detect

Positive ACK Protocol

- retry
- duplicate detection
- adaptive back off algorithm

Time Bounded Service

- minimum delay variance
- Point Coordination Function for bandwidth allocation
- Distributed CF for bandwidth reservation

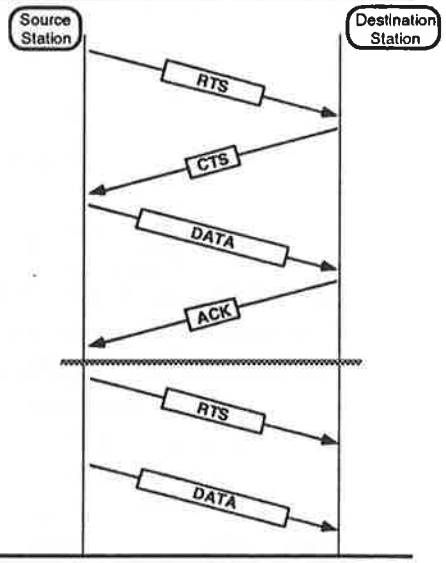
Asynchronous MPDU Format

MAC Protocol Data Units consist of multiple frames

- RTS, CTS, and ACK are short control frames
- DATA frame carries the payload

Directed MPDUs have four frames

Multicast MPDUs have two frames



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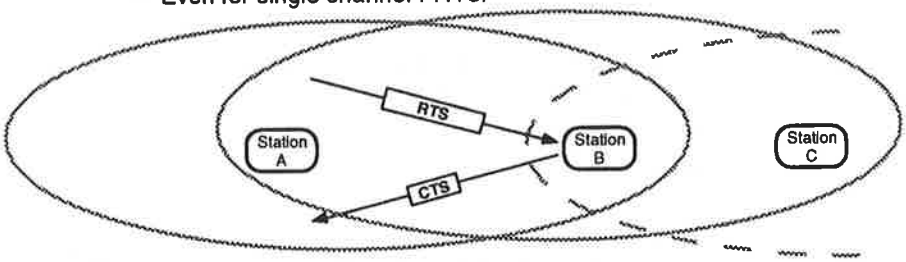
Enhanced Carrier Sense & Virtual CD

RTS/CTS exchange ensures efficient use of channel

- contention is resolved with small control frames
- minimizes effect of collisions
- each RTS and CTS frame contains DATA frame length
- receiving stations set timers to defer for length of transmission
- RTS/CTS with data length handles "hidden" nodes

Channel arbitration among overlapping networks

- Even for single channel PHYs!



Positive ACK Protocol

ACK is used to improve reliability of link

- overcomes multipath and interference problems

Transmitting stations time out and retry

Adaptive back off algorithm

- random back off
- back off time elapses only when net is idle

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New and Improved!

MPDUID
- identifies each frame of a specific MPDU
- helps duplicate detection
- minimal overhead

PHY Specific field

HIERARCHICAL bit
- default to using infrastructure
  - don't need to know address of AP
- peer to peer is an optimization
- control scope of multicasts

Adaptive Back Off

Announce Frames

Frames and field lengths...

Time Bounded Service

Limited in scope
- communication to and from a Point CF
  - Access Point
- doesn't use 48 bit unique IDs for data transmission
  - 48 bit unique ID used for "call" set up
  - 8 bit local ID for data transfer

Designed for real time voice traffic
- fixed length frames
- constant interval between frames
- "call" set up to start connection

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Time Bounded Frame Format

RTSO Frame

Each MPDU is a two frame exchange

Two types of MPDU: Inbound and Outbound

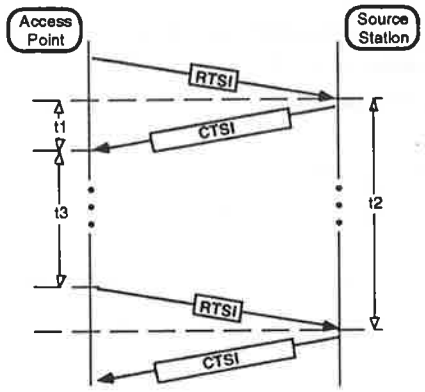
Four new frame types

- RTSI and CTSO
  - control frames
  - header only
- RTSO and CTSI
  - carry the header and data

Inbound MPDU

Carries data from a wireless STA to an Access Point.

- *In* to the wired infrastructure



Access Point controls timing

- initiates each MPDU exchange

Time t3 is available for other traffic

New MPDUs for the connection arrive at interval t2.

If no response within t1, ignore.

- no retries

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Outbound MPDU

Carries data from an Access Point to a wireless STA.

- *Out* from the wired infrastructure

Access Point controls timing

- initiates each MPDU exchange

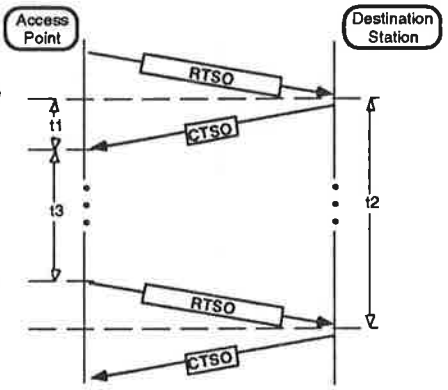
Time t3 is available for other traffic

- t3 = GAPTIME

New MPDUs for the connection arrive at interval t2.

If no response within t1, ignore.

- no retries



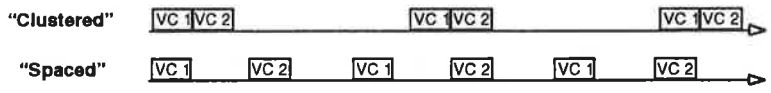
Bandwidth Allocation

Point Coordination Function within Access Points

Wireless STAs negotiate with AP to setup call

Access Point:

- determines if bandwidth is available for a new call
- assigns a local 8 bit identifier — VCID
- starts connection at appropriate time
  - when net is idle
  - manages gaps for other traffic
- allows for multiple bandwidth allocation policies



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Bandwidth Reservation

Distributed Coordination Function

- within all STAs
- reservations are spread only to affected nodes

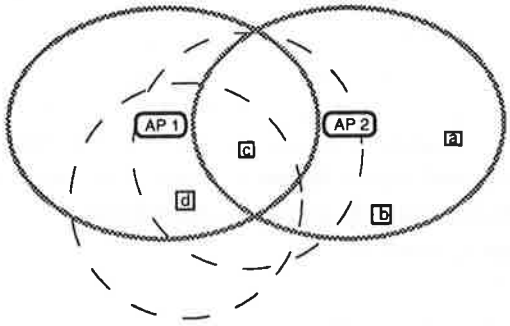
Reserve ahead protocol

- GAPTIME field defines when the next transmission for this VCID will occur
- all Time Bounded MPDUs are same length
- any STA hearing the MPDU marks the network as busy

Ensures that Time Bounded frames win the contention battle for future transmissions.

- MORE field allows reservation for N MPDUs in the future
- Also reserves each transmit opportunity N times

Overlapping Service Areas



Case 1: Node c is registered with Access Point 1

- node d is unaffected by traffic to AP2

Case 2: Node c is registered with AP 2

- node d defers to node c's Time Bounded transmissions to AP2
- d doesn't need to coordinate with AP2
- d will not defer to connections from b or a to AP2

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Summary of Time Bounded Service

Simple

- structure is imposed only when needed
- bandwidth reservation is an extension to the carrier sense mechanism of Asynchronous Service
- minimum impact on Asynchronous only STAs
- complexity in the APs

Dynamic

- information about the state of the network is propagated very quickly

Minimal overhead

- two frame MPDU
- 8 bit local VCID vs. 48 bit unique IDs
- call set up instead of bandwidth requests

Distributed CF of Asynchronous service preserved

Point CF add for Time Bounded bandwidth allocation

WHAT Protocol Summary

Scalable in terms of size and complexity

- works well for small ad-hoc workgroups
- can support thousands of nodes through an ESS
- Time Bounded and Asynchronous Services coexist
- structured or peer to peer communication under STA contol

Degrades gracefully in harsh conditions

- overlapping BSAs
- extreme interference

Economical to implement

Implementation experience supports assertions