# Criteria for MAC Protocol for Wireless LAN

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## Abstract

This contribution is a short assessment of how the medium access control protocol for wireless LANs meets the *continually* evolving set of requirements and criteria that have been developed and modified during the last 2+ years in the 802.11 Committee.

## 1. Background

Over the past two-and-a-half years, the IEEE 802.11 Committee has developed a variety of requirements (Market Requirements, Functional Requirements, ...) and evaluation criteria for considering MAC proposals. Some of the applicable documents in this regard are listed below.

- Market Requirements document (IEEE DOC. P802.11/92-20).
- Functional Requirements (IEEE DOC. P802.11/92-57).
- 21-point MAC Evaluation Criteria (IEEE DOC. P802.11/91-138) [*IEE*91].
- MAC Requirements and Comparison Criteria document [*DIE*93]

A proposal from IBM was first offered in July 1991 [*NAT*91*a*]. This was subsequently updated in March 1992 [*NAT*92] after taking into consideration the following contributions [*BIB*91] and [*BIB*92]. A second update of the IBM MAC proposal is a companion contribution for this meeting [*BAU*93*d*]. Additional contributions addressing various issues have been presented in [*NAT*91*b*] [*KRI*92] [*LAM*92] [*NAT*93] [*BAU*93*a*] [*BAU*93*b*] [*BAU*93*c*]. Taken into account in the second update [*BAU*93*d*] are formal proposals and contributions of Biba et al, the many contributions of Rypinski, Takiyasu and other committee members. A purpose of this contribution is *to consider today's set of requirements and criteria and briefly evaluate the current proposal with respect to them*. For the sake of brevity, pointers to previous contributions are given where appropriate.

## 2. MAC Criteria

A set of criteria extracted from [*DIE*93] is considered in this section for "evaluation" of the MAC. Committee members are referred to the numerous contributions cited above for more detailed consideration of the MAC with respect to some of the criteria.

## 2.1 Are Required MAC Services Supported?

→ The MAC supports both asynchronous and time-bounded data delivery services.

For asynchronous data delivery, support is provided for:

- Unicast transfer mode, and
- Broadcast/multicast transfer mode.

Reliability requirements can be met with possible exception for broadcasts/multicasts.

Time Bounded Delivery Service is supported. Stations running applications that need the service can utilize the service. Real-time applications (such as voice, video or lower speed industrial/process control applications) that can run within the range of 1 - 20 Mbits/sec can be supported. The proportion of bandwidth reserved for asynchronous versus time-bounded delivery services is a matter of policy. The MAC is based on adaptive bandwidth allocation and provides the mechanisms for implementing any fair policy.

Additional observations that are relevant here are listed below.

- Different service levels can be specified by using appropriate policy for sharing bandwidth between asynchronous and time-bounded traffics.
- The MAC offers mixed synchronous/asynchronous capability. Stations that are asynchronous only, synchronous (i.e. time-bounded) only or have both requirements are supported by the same MAC.
- The burden on asynchronous implementation complexity is low considering the overall advantages offered by the MAC.

## 2.2 Are Infrastructure-based Multicell Networks Supported?

→ The connectivity options that are possible within the total architecture are listed below.

- Peer-to-peer data transfer within a BSA is possible (see [*NAT*92]).
- Peer-to-peer between different BSA's is not permitted. Transfers between stations in different BSA's is accomplished via the Distribution System.
- Connectivity with existing wired network implementations is possible. This includes common LANs, such as Token-Ring and Ethernet LANs, as well as other wired backbone networks.

Additional observations are:

- Direct peer-to-peer is supported in infrastructure mode. This is permitted as an optional mode for MAC operation (see [*NAT*92]).
- Ad-hoc networks can overlap in the same channel but the impact of such overlap will depend largely on how many networks there are, how many active stations there are per network, their offered traffic etc.

### *Infrastructure considerations*

- Can any 802 compatible LANs be used as the Distribution System?

  → Yes.

- What are the supported configurations?

  → There are no intrinsic limitations on supported configurations.

- What are the provisions to support "Re-association" across Routers and Bridges and Gateways?

  → There are no intrinsic limitations to Re-association across internetworking equipment.

- What is the throughput performance per station across the Distribution System and what are the factors?

  → This will depend on the Distribution System, WLAN configuration, offered traffic etc.

- What is the required infrastructure for the Time Bounded Services?

  → Infrastructure is not a mandatory requirement. If required, the infrastructure can be based on ATM, FDDI-II.

**MAC operation in a multiple BSA configurations in a single channel environment**

- Can the MAC handle overlapping BSA's using a single channel?

  → If overlapping BSA's share the same channel, the impact will depend largely on how many BSA's there are, how many active stations there are per BSA, their offered traffic etc. (see [*BAU*93*d*] Section on Single Channel PHY operation).

- What are the provisions for spatial reuse of the spectrum?

  → This depends on the following critical factors:

  - Cell interference topology, i.e., how the different cells overlap with respect to each other.
  - Power control techniques used.

  No specific power control techniques are being proposed. Control algorithms similar to those considered in [*DIE*92] can potentially be included in the MAC.

- What is the overhead involved to coordinate this?

  → This is a modest amount.

- What is the impact of overlapping networks on throughput?

  → The throughput per network may be lowered to an extent that depends on distribution of stations among the networks, type and magnitude of workload offered etc.

- What is the "Re-associate" algorithm, and what is the impact on throughput?

  → Mobile station initiates the "Re-associate" algorithm by sending a request to register with a new Access Point [*NAT*92]. The new Access Point requests the previous Access Point to relinquish ownership of the mobile station. After handshake between the Access Points is finished, the new Access Point confirms the "Re-association" to the mobile station. The impact on throughput is marginal.

- What are the "Re-associate" provisions for Time Bounded Services?

  → The provisions are similar to those used for the asynchronous services.

**MAC should be able to operate in a multichannel environment**

- What is the overhead involved to coordinate this?

  → The runtime overhead necessary for coordination in a multicell, multichannel network environment is expected to be small.

- Is there a limit (max or min) on the number of channels?

  → There are no intrinsic limits on the number of channels.

- What is the "Re-associate" algorithm, and how seamless is it?

  → The used algorithm is the same as the one previously proposed [*NAT*92] enhanced to take into account the fact that a new Access Point may use a channel different from the one used by the current Access Point. The algorithm is quite seamless for asynchronous traffics.

- How are the channel re-use limitations aspects handled in the MAC?

  → This depends on the following critical factors:

  - Topology of the multicell network, i.e., how the different cells in a multiple cell network environment, interfere with one another.
  - The particular PHY layer used within a cell. The choices of PHY include - SS FH, SS DS, Diffuse Infrared.
  - Power control techniques used.

  Efficient spectral reuse and optimal utilization for each specific PHY are accomplished using different optimization techniques.

## 2.3 Are Ad-Hoc Networks Supported?

- Can the MAC support infrastructure-less (ad-hoc) networks?

  → Yes. The same MAC is used in both infrastructure-based as well ad-hoc networks (See also [*NAT*92]).

- Can the Ad-hoc networks overlap with infrastructure networks, and what is the mutual impact?

  → Yes, the two may overlap. The extent of mutual impact depends on the PHY used. In fact, any number of logically different WLANs may overlap.

- Can a station be connected to an ad-hoc and infrastructure network at the same time?

  → No. The proposed scheme assumes a station is associated with one network at a time.

- What is the procedure to set up an ad-hoc network?

  → A variety of options are available (See [*NAT*93]).

- Is there a power saving mode supported in ad-hoc?

  → Yes. Power conservation techniques based on [*NAT*91*b*] are used.

- What security services are available?

  → See [*BAU*93*a*].

- Can multiple ad-hoc networks overlap (on the same channel)?

  → They can overlap. There is a performance impact that depends primarily on amount of traffic generated by alien (i.e., belonging to other networks) stations.

## 2.4 Will MAC support low power operations?

- What are the power management provisions supported by the MAC?

  → Techniques described in [*NAT91b*] are supported by the MAC. Additional techniques based on powering down the receiver and waking up when ready to communicate are not precluded by the MAC.

- Does the MAC support extreme low power stations that need battery life of months ?

  →No. It is very unlikely the current protocol supports such extreme low power station.

- What are the power management provisions for ad-hoc operation?

  →These are based on techniques described in [*NAT91b*].

- What is the impact of the "Re-associate" scenario on the power consumption?

  →Some control information is exchanged as part of the Re-associate procedure. The impact on power consumption is likely to be marginal.

- What is the effect on the performance: a) Station throughput performance and b) Response time ?

  → No effect on performance for the proposed power conservation techniques. Additional enhancements for power saving may have some impact on performance.

## 2.5 Will MAC support multiple PHY's?

→Yes. The MAC will support multiple PHY's. Optimal spectral utilization will be facilitated by adding a PHY-dependent optimization component to the MAC. See the updated MAC description [*BAU93c*] as well as [*BAU93d*]. The MAC will:

1. Support operation in the 1-20 Mbits/sec range of interest to IEEE 802.
2. Satisfy the regulatory requirements in the different bands currently available - DSSS in 915 MHz, 2.4 GHz and 5.8 GHz ISM bands, Frequency Hopper in 2.4 GHz and 5.8 GHz ISM bands.
3. The Etiquette for the User-PCS band (1.91 -1.93 GHz) is being developed now. Approaches for adapting the MAC for operation in the User-PCS band, assuming a certain draft etiquette, are described in [*BAU93d*].
4. Diffuse Infrared

- What is the method to include PHY dependent MAC functions?

  → See [*BAU93c*].

## 2.6 MAC Access Function Requirements

- What is the limit for the number of stations that can be supported by the coordination function?

  → There is no intrinsic limit on the number of stations. In practice, the number is determined by channel rate, offered workload, desired performance requirements etc.

- How fair is the access method?

  → The access method is fair (see [*NAT*92]).

- What is the stability of the access method during high load?

  →Excellent. See [*LAM*92] and [*LAM*93] for comprehensive performance models and their analyses.

- What is the throughput capacity of the access method?

  →Excellent. See [*LAM*92] and [*LAM*93] for performance models and their analyses.

- How robust is the access method for interference: a) ISM band interference and b) Co-channel interference?

  →The MAC protocol is very robust for different kinds of interference. MAC-level acknowledgments are used to detect and recover from transmission errors that might be caused by interference.

- What are the medium sharing characteristics in case of a overlap between BSA's that use the same channel?

  → See [*BAU*93*d*].

- What is the overhead associated with the access method?

  → The access method overhead is nominal.

- What is the method to support mixed Isochronous/Asynchronous traffic?

  → A SCHEDULER in the Access Point allocates bandwidth on demand from different traffic sources. Flexible, dynamic and demand-driven adjustment of available bandwidth is supported by the MAC.

- What is the bursty traffic performance of a station?

  → This is a function of a number of key assumptions that include: Channel speed, number of active stations, traffic workload patters etc. For a thorough and comprehensive analysis and performance characterization, please see [*LAM*93]. For a summary description, see [*LAM*92].

- What is the effect of time-bounded traffic on bursty traffic performance?

  → This is determined by the policy that specifies how much bandwidth is allocated for the two types of traffic. The MAC provides mechanisms for implementing a bandwidth sharing policy that is "above" the MAC. The guiding principle of the policy will be to place an upper bound on the extent of time-bounded traffic. Actual values for bounds can be based on channel speed and types of traffic that need to be supported at that speed.

- What is the isochronous robustness?

  → This is about as robust as asynchronous applications.

## 2.7 Access Method Independent Features

- What are the security provisions provided by the MAC?

  → See [*BAU*93*a*].

- Does the MAC support mixed bitrate operation?

  → This mode of operation has not been proposed but is not precluded by the MAC.

## References

[*NAT*91*a*] K. S. Natarajan, C. C. Huang and D. F.Bantz, *Medium Access Control Protocol for Radio LANs*, IEEE 802.11 Working Group paper, 802.11/91-74, July 1991.

[*NAT*91*b*] K. S. Natarajan, C. C. Huang, *Battery Efficient Operation of Radio MAC Protocol*, IEEE 802.11 Working Group paper, 802.11/91-102, Sep. 1991.

[*NAT*92] K. S. Natarajan, C. C. Huang and D. F.Bantz, *Medium Access Control Protocol for Radio LANs: An Update* , IEEE 802.11 Working Group paper, 802.11/92-39, March 1992.

[*KRI*92] A. Krishna and K. S. Natarajan, *Selection Criteria for Frequency Hopping Pattern Set*, IEEE 802.11 Working Group paper, 802.11/92-84, July 1992.

[*LAM*92] R. LaMaire, *Performance of a Reservation-based Multiple Access Protocol*, IEEE 802.11 Working Group paper, 802.11/92-108, Sep. 1992.

[*LAM*93] R. O. LaMaire, A. Krishna and H. Ahmadi, "Analysis of a Wireless MAC Protocol with Client-Server Traffic ," in *Proc. of INFOCOM Conference*, Vol. 2, pp. 429-438, San Francisco, CA, March 1993.

[*NAT*93] K. S. Natarajan and F. Bauchot, *Adhoc-Networks: A Viewpoint*, IEEE 802.11/93-3, Jan. 1993.

[*BAU*93*a*] F. Bauchot and K. S. Natarajan, *Registration Scenarios for Wireless LAN MAC Protocol*, , IEEE 802.11 Working Group paper, 802.11/93-2, Jan. 1993.

[*BAU*93*b*] F. Bauchot, *Wireless LAN MAC Protocol: Compression as a MAC Layer option to improved Throughput* , IEEE 802.11 Working Group paper, 802.11/93-29, March 1993.

[*BAU*93*c*] F. Bauchot, *Wireless LAN MAC Protocol: PHY layer transparency* , IEEE 802.11 Working Group paper, 802.11/93-30, March 1993.

[*BAU*93*d*] F. Bauchot and K. S. Natarajan, *MAC Protocol for Wireless LAN: 2nd Update* , IEEE 802.11 Working Group paper, 802.11/93-62, May 1993.

[*IEE*91] *MAC Adhoc Group Report*, IEEE 802.11/91-138, Nov. 1991.

[*BIB*91] K. Biba, *A Hybrid Wireless MAC Protocol Supporting Asynchronous and Synchronous MSDU Delivery Services*, IEEE 802.11 Working Group paper, 802.11/91-92, Sep. 1991.

[*BIB*92] K. Biba, *An Update to the Hybrid Wireless MAC Protocol Supporting Asynchronous and Synchronous MSDU Delivery Services*, IEEE 802.11 Working Group paper, 802.11/92-14, Jan. 1992.

[*BIB*93] P. Belanger and K. Biba, *The Wireless Hybrid Asynchronous Time-Bounded MAC Protocol*, IEEE 802.11 Working Group paper, 802.11/93-40, March 1993.

[*DIE*92] W. Diepstraten, *The Potential of Dynamic Power Control*, IEEE 802.11 Working Group paper, 92-76, July 1992.

[*DIE*93] W. Diepstraten, *802.11 MAC: Requirements and Criteria* , IEEE 802.11 Working Group paper, 93-33, March 1993.