IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: Evaluation of the CODIAC Protocol

Author: Carolyn Heide
Spectrix Corporation
906 University Place
Evanston, Illinois 60201
Voice: (708) 491-4534
FAX: (708) 467-1094
EMail: 71041.3262@compuserve.com

Abstract:

This paper evaluates the proposed CODIAC protocol (described in document 93/54) with respect to (1) document 93/33 MAC Requirements and Comparison Criteria, and (2) document 91/138 which is the first issue of the infamous 21 MAC evaluation criteria.

Related Documents:

IEEE P802.11-91/138 Tentative MAC Adhoc committee
IEEE 802.11-93/33 MAC Requirements and Comparison Criteria
IEEE 802.11-93/40 The WHAT MAC Protocol
IEEE 802.11-93/54 CODIAC Protocol
IEEE 802.11-93/65 Performance of the CODIAC Protocol

Doc: IEEE P802.11-93/33 MAC Requirements & Comparison Criteria

The requirements and criteria in 93/33 are not numbered, they have numbered here, in the sequence in which they appear in that document, to make discussion references easier.

Some of the requirements and/or criteria here were a little general, or were difficult to interpret. The philosophy of this document has been to choose an interpretation of the criteria, and address that. Hopefully where that interpretation is incorrect the 802.11 membership will help the author clarify the question and come up with the answer. The result of that effort will be better questions as well as better answers.

1. Required MAC Services

1.1 Asynchronous Service (async)

1.1.1 Provides Unicast transfer mode ⇒ yes
1.1.2 Provides Multicast/Broadcast transfer modes ⇒ yes, and controls scope of multicast using the hierarchical flag
1.1.3 Meet the reliability requirements (with the possible exception of broadcast) ⇒ recovery from mechanisms (issues 19.1, 19.2, 19.5, 19.11): a positive ack protocol is employed to allow a low level retry mechanism to bring the MSDU delivery reliability up to the same level as other 802 protocols, with the exception of broadcast/multicast which is not acknowledged. ⇒ strategy for capacity control, maximum number of stations (issue 19.6, 19.7): The purpose of the two operating modes is to allow efficient media use under different capacities, and in centralized mode each implementation's strategy for management of request periods and data periods in centralized mode is its strategy for capacity control. In distributed mode the protocol will begin to break down at a certain number of stations, and the implementer should decide what action to take about that - whether to switch operating modes, or to make the degradation limit a parameter of the network. In centralized mode it is a function of the intended application. An application with huge numbers of stations with small payload and/or tolerance for large transfer delays can be supported, as can an application with smaller population with need of shorter transfer delays. The CODIAC protocol can be set up to accommodate either, without loosing compatibility. ⇒ stability under heavy load (issue 19.10): The centralized mode of the CODIAC protocol remains stable under heavy load by increasing transfer delay.
1.2 Time-bounded Service (TBS)
1.2.1 Should be designed to be an option ⇒ controllers could be implemented which do not service requests for TBS. ⇒ is NOT supported in distributed mode.
1.2.2 Should be dimensioned for voice support ⇒ 'dimension' can be up to the implementer. Frequency of superframes plus the distribution of their contents can be different per implementation, and can change within any given implementation according to the characteristics of the stations present at any given moment

1.3 Related Questions
1.3.1 Different Service levels may be specified ⇒ Fields can be put into registration requests, or even to the individual RTS frames. ⇒ In centralized mode the controller can service some stations more or less often, or on some fixed regular basis according to service level. ⇒ In distributed mode, there could be service levels in the RTS, and if a potential controller sees a particular service level request it could switch to centralized mode. ⇒ In the WHAT protocol, if a station sees a gap it could use a backoff algorithm before sending RTS that gave different backoffs to different service levels, and then listened again before sending the RTS. This might provide a small, and somewhat clumsy, amount of service level distinction
1.3.2 What are the limitations applicable to support the time-bounded service ⇒ Presence of a controller or potential controller
1.3.3 Does MAC offer mixed TBS/async implementation capability ⇒ yes
1.3.4 What is the burden on async implementation complexity ⇒ none. The two modes of operation are designed to allow support of small and large populations of async stations within a single BSA. Support of TBS just comes with the centralized mode of operation for free.

2. Support Infrastructure based Multiple Cell Networks

2.1 Global Connectivity
2.1.1 sta-to-sta within BSA ⇒ direct and indirect, choice of station or implementation
2.1.2 sta-to-sta between different BSAs ⇒ yes, via overlap or distribution system through AP
2.1.3 connectivity with existing network implementations ⇒ yes
2.2 Related questions
2.2.1 Is direct sta-to-sta supported in infrastructure mode ⇒ yes, in both modes
2.2.2 Can an ad-hoc network overlap in the same channel ⇒ yes

2.3 Infrastructure Considerations

2.3.1 Can any 802 compatible LAN as distribution system (DS)?
2.3.2 What are the supported configurations?
2.3.3 What are the unique functions needed from the DS?
2.3.4 What are the limitations for different supported configurations?
2.3.5 What are the provisions to support re-association across Routers, Bridges and Gateways?
2.3.6 What is the throughput performance per sta across the DS and what factors are determining it?

⇒ This MAC has not made any assumptions about what the DS has to be. It makes no requirements from the DS that have not been assumed already. It does not restrict the way you can do implementations in a complicated world across routers, bridges and gateways.

2.3.7 What is the required infrastructure for TBS?

⇒ This MAC requires nothing from the infrastructure with respect to TBS that would not be required by any other MAC the provides TBS.

2.4 Operation with multiple BSAs with single channel

2.4.1 Can the MAC handle overlapping BSAs using single channel?

⇒ yes, but it really depends what is meant by 'handle' - the overlap cases have been considered and the protocol attempts to minimize the potential interference of such cases.

⇒ distributed/distributed overlap: yes, this is a null case.

⇒ distributed/centralized: yes, all stations can function, but there it does introduce a possibility of collisions, so there is some degradation to both.

⇒ centralized/centralized, depends on many things: If the network(s) have been established with knowledge of the overlap, the protocol can be implemented to function without interference between them; if the controllers concerned can communicate over the distribution system then they can implemented to be intelligent enough to adjust their use of the protocol use to accommodate the discovery of an overlap situation; if the controllers are completely isolated (this is the worst case) the stations in the overlap will provide interference until they determine they are in an overlap, and then they can stop interfering (which will mean stop communicating).

2.4.2 What are the provisions for spatial re-use of spectrum?
2.4.3 What is the overhead involved to coordinate this?

⇒ In the distributed mode of operation spatial re-use of spectrum is a given. Each station is only concerned with the use of the spectrum within its range.

⇒ In centralized mode spatial re-use of spectrum for a single channel environment requires spatial isolation of the BSAs.

2.4.4 What is the impact of overlapping networks on throughput?
2.4.5 What are the service limitations for this configuration?

⇒ addressed in document 92/54.

2.4.6 What is the re-associate algorithm, and what is the impact on response time and throughput?
2.4.7 What are the re-associate provisions for TBS?

⇒ The association algorithm is not yet specified, however ... it is intended that association with an Access Point be done using the data transfer procedure RTS/CTS/DATA/ACK. If in centralized mode a station will already be registered with a controller at this point.

⇒ When moving from controller to controller a station must register with a new controller, and this is a procedure which involves contention for registration slots. The impact of this is very dependent on how the implementation chooses to allocate registration slots.

⇒ It could be considered that this protocol has double overhead on moving between centralized mode BSAs, first to register with the controller and then to associate with the Access Point. This is the price to paid for having stations able to communicate within the coordination function without being associated with the Access Point. It is may be feasible to avoid this overhead by having a bit in the registration request which specifies the desire to associate as well as register (if the controller is also an Access Point).

2.5 MAC should be able to operate in a multichannel environment

2.5.1 What is the overhead involved to coordinate this?
2.5.2 Is there a limit (max or min) on the number of channels?
2.5.3 What is the re-associate algorithm and how seamless is it?
2.5.4 How are the channel re-use limitation aspects handled in the MAC?
2.5.5 What channel management functions are needed?

⇒ This MAC has not made any assumptions about what how channel changing in a multichannel environment will be accomplished. It does not restrict the way you can do implementations based on channel changing nor the number of channels required.

3. Support of Ad-Hoc Networks

3.1 Supports infrastructure-less (ad-hoc) networks.

⇒ yes

3.2 Can ad-hoc networks overlap with infrastructure networks and what is the mutual impact

⇒ yes

⇒ ad-hoc networks formed by stations which are using the centralized coordination function of a controller have no impact in the infrastructure network which might also be using that coordination function. (that is, no more impact than adding to the population)

⇒ in the case where stations functioning in distributed mode which overlap stations in centralized mode because the former cannot hear the controller, the mutual impact is difficult to estimate. There will be simulations done to investigate this.

3.3 Station connected to an ad-hoc and infrastructure network at the same time

⇒ Interpretation of the question is: can a station be associated with an AP, and converse with stations which are not.

⇒ yes.

3.4 What is the procedure to set up an ad-hoc network. ⇒ There are possible several ways. ⇒ In the absence of a controller, stations are in distributed mode and can converse at will with no setup procedure. ⇒ In the presence of a controller stations can enter its BSA, register without associating, and then converse with other stations in centralized mode. They have, with no setup, formed in ad-hoc network. ⇒ If centralized ad-hoc is desired, an implementer could build boxes which are controllers if they want to carry around boxes to create ad-hoc networks. ⇒ If centralized ad-hoc is desired, an implementer could build stations which are potential controllers that switch to centralized mode if they hear no other controller, or if they sense network congestion in distributed mode.
3.5 Is there a power savings mode supported in ad-hoc ⇒ only if ad-hoc in centralized mode, i.e. in the presence of a controller.
3.6 What security services are available ⇒ with respect to 802.10 functions, the same as any other MAC.
3.7 Can multiple ad-hoc networks overlap (same channel) ⇒ absolutely, this is what WHAT is all about.

4. MAC must support low power operations

4.1 What are the Power management provisions supported by the MAC ⇒ the centralized mode can be optimized around maximizing receiver off time. ⇒ use of overlapping controllers and repeated request periods can aid in minimizing signal strength needed by stations.
4.2 Does the MAC support extreme low power stations that need battery life of months ⇒ yes, it could be implemented that way. Request sync frames can inform a station exactly when it must next turn on its receivers.
4.3 What are the power management provisions for ad-hoc operation. ⇒ ad-hoc networks using centralized mode have all the power management capabilities of infrastructure networks ⇒ distributed mode operation has poor power management.
4.4 What are the different service levels associated with different Power Management modes. ⇒ in centralized mode stations can power down at specific times they know their service will not be affected by their inability to receive. ⇒ in distributed mode if stations power down there is no way of guaranteeing that they won't miss service affecting information.
4.5 What is the impact of the re-associate function scenario on the power consumption ⇒ this MAC makes no special demands on power consumption involved in re-association.
4.6 What is the effect on performance: station throughput; and response time ⇒ implementations can balance power consumption, throughput and response to time. Optimizing for power consumption means structuring the superframe as much as possible, this increases overhead and lowers throughput. It can also increase access delay, as a station may have to wait for a very controlled part of the superframe before it can access the medium.

5. MAC need to support Multiple PHYs

5.1 Support at least 1-20 Mbps ⇒ yes
5.2 Need to support the regulatory requirements in the different bands ⇒ This MAC has not made any assumptions that would preclude support of regulatory requirements.
5.3 What are the generic provisions to support the different PHYs 5.4 What is the method to include PHY dependent functions ⇒ not defined, but centralized mode is well suited to the dissemination of information which all stations must get, such as PHY dependent function parameters.

6. MAC Access Function Requirements

6.1 What is the default coordination function for ad-hoc and infrastructure modes ⇒ It doesn't make any difference, you can use be centralized or distributed in either ad-hoc or infrastructure. ⇒ Stations could be made that only functioned in centralized mode, they would simply not talk if they don't hear a controller. ⇒ Stations could be made that only functioned in distributed mode as long as the knew how to factor centralized transactions they overheard into their NAV. ⇒ Most practical is stations that default to distributed mode until they hear a controller, then they switch to centralized mode.
6.2 What is the limit for the number of stations that can be supported by the coordination function ⇒ small for distributed mode, see WHAT protocol specifications. ⇒ large for centralized mode, dependent only on bandwidth it can go as high as you want.
6.3 How fair is the access method ⇒ both modes are very fair. ⇒ centralized mode is completely deterministic, and therefore completely fair, except for registration. At registration the worst that can happens is a delay if a weaker station picks the same registration slot as a stringer one. This is very implementation dependent, because the more slots you have the more fair it gets. ⇒ distributed mode, see WHAT protocol specifications.
6.4 What is the stability of the access method during high load ⇒ distributed mode becomes unstable. An implementation could be smart enough to switch to centralized mode on detection of the instability. ⇒ centralized mode is completely stable.
6.5 What is the throughput capacity of the access method ⇒ addressed by document 93/65
6.6 How robust is the access method for interference: ISM band; and co-channel ⇒ the positive ack protocol allows this MAC to be as robust as wired LANs in the presence of interference.
6.7 What are the medium sharing characteristics for overlap between BSAs using the same channel ⇒ addressed by document 93/54

6.8 What is the overhead associated with the access method ⇒ overhead is dependent on the implementation. ⇒ in distributed mode the overhead is the RTS/CTS exchange. ⇒ in the most optimized arrangement of centralized mode the overhead is three fold: (1) one request time slot for each registered station; (2) the number of registration slots allocated by the controller; (3) the CTS sent by the controller to each station transmitting; and (4) the ACK sent by each receiving station. ⇒ hard numbers for various implementation possibilities are provided in document 93/65.
6.9 What is the method to support mixed TBS/async traffic ⇒ centralized mode of operation naturally handles mixed TBS and async traffic with the controller deciding the allocation of each.
6.10 What is the bursty traffic performance of a station: MAC to MAC; and, end to end ⇒ addressed by document 93/65
6.11 What is the effect of TBS on async traffic performance ⇒ if the presence of TBS traffic causes the BSA to switch from distributed to centralized mode, the async stations will incur an access delay between the RTS and CTS (because the RTS is now separated into the request period). However, the station looses the delay it previously incurred waiting for a gap in the NAV. ⇒ when the BSA was in centralized mode to start with, the async traffic is unaffected by the TBS traffic.
6.12 What is the TBS robustness ⇒ TBS robustness is the same as any traffic in centralized mode.

7. Access Method Independent Features

7.1.1 Security provisions: What is the impact on the existing infrastructure when security is required 7.1.2 Security provisions: What are the different levels of security provided. ⇒ 802.10 security.
7.2 Does the MAC support mixed bitrate operation ⇒ it probably can be made to do so by pausing the stations at one rate and issuing a superframe at another. This is high overhead, the bandwidth cannot be re-used on a single channel system to do this.
7.3 How does the MAC support the defined DSS functions ⇒ defined DSS functions are accomplished by data transfer methods, exchange of RTS/CTS/DATA/ACK.
7.4 What extra requirements for other 802 standards are imposed by the MAC and architecture ⇒ This MAC and architecture do not impose any requirements on existing 802 standards.
7.5 What are the parameters affecting inter Access Point interoperability ⇒ this MAC has not made any assumption affecting Access Point interoperability.
7.6 What are the managed objects of the MAC ⇒ not yet defined.

Doc: IEEE P802.11-91/138 Tentative MAC AdHoc committee, (last page of which is the 21 MAC Comparison Criteria)

There has been some worry about the original '21 criteria', are encompassed by anything for use in MAC evaluation. They originally appear in document 91/138. Most of them are specifically referenced in issues in the issues log - all but items 3 and 18. The 21 criteria are listed here with either reference to a document where they are addressed by issue number, or they are addressed specifically here.

1. Unauthorized network access impact on throughput. **Issue 6.3** ⇒ addressed in document 93/54
2. Ability to establish peer-to-peer connectivity without prior connection (e.g. without "knowledge of the presence of your peers"). **Issue 14.4** ⇒ addressed in document 93/54
3. Issues of throughput ⇒ addressed in document 93/65
4. Delay characteristics. **Issue 22.1** ⇒ addressed in document 93/54
5. Maximum number of stations. **Issue 19.7** ⇒ addressed in document 93/54
6. Ability to service various traffic including data/voice/video. **Issue 15.9** ⇒ addressed in document 93/54
7. Support of multiple PHYs transparently. **Issue 24.7** ⇒ see Topic 5 in the previous section addressing criteria from document 93/33
8. Robustness in the presence of co-site dissimilar networks. **Issue 19.8** ⇒ addressed in document 93/54
9. Power consumption. **Issue 13.6** ⇒ addressed in document 93/54
10. Area coverage implications of MAC timing constraints. **Issue 9.2** ⇒ addressed in document 93/54
11. Fairness of access. **Issue 25.5** ⇒ addressed in document 93/54
12. MAC facilitation of "access fairness" (insensitivity to near/far bias). **Issue 25.6** ⇒ addressed in document 93/54
13. Support for different traffic priorities. **Issue 26.1** ⇒ addressed in document 93/54
14. Robustness in the presence of non-reciprocal wireless medium. **Issue 21.2** ⇒ addressed in document 93/54
15. Time-to-market vis-a-vis implementation complexity. **Issue 3.1** ⇒ addressed in document 93/54
16. Same MAC must work in a minimum and a maximum system (network size independence). **Issue 9.3** ⇒ addressed in document 93/54
16.1 Interoperability of "low cost" & "reliable" MAC. **Issue 7.2** ⇒ the flexibility of the CODIAC protocol allows implementations to make just this sort of trade off. A distributed mode operation implementation can be very low to develop, as could a simple superframe implementation of the centralized mode. As reliability under increasing population density is required this can be achieved by adding complexity to the centralized mode operation. All this can be accomplished without loosing compatibility between the various implementations.
18. The ability to support handoff between service areas - aka roaming. ⇒ this MAC supports service area 'handoff' by providing support for access point identification. Nothing about this MAC imposes any restrictions on the implementation of service area handoff.
19. Implications on the complexity of the PHY. **Issue 24.5**

⇒ Issue 24.5, topic: PHY types, says that it is a re-phrased of this statement into "What are the implications of the complexity of the PHY". This is a very different question. ⇒ to address this item as stated, the Spectrix protocol does not impose any complexity on the PHY. ⇒ Issue 24.5 is addressed in document 93/54
20. Broadcast/multicast reliability. **Issue 17.2** ⇒ addressed in document 93/54
21. Preservation of time ordering of SDU to end systems. **Issue 20.4** ⇒ addressed in document 93/54