IEEE P802.11
Wireless LANs

Wireless Local Area Network Requirements - IEEE P802.11/92-20

Comments

IEEE P802.11 Members

References: IEEE P802.11/92-20 and Responses to the letter ballot

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GENERAL

This document contains the compilation of the comments generated by the IEEE 802.11 committee members. The comments are relative to the "Wireless Local Area Network Requirement - IEEE P802.11/92-20" document. The comments are classified into two mains areas: a) comments general in nature and applicable to the document overall and b) specific comments focusing on particular section within the referenced document. Note that the comments of editorial nature are not recorded.

For convenience, following the 'General Comments' the document structure is based on the P802.11/92-20 format. The comments are inserted in the applicable section. All comments are preceded by the initial or the name of the comment's author extracted from the contributors list.
Sections of the P802.11/92-20 for which there is no comment are not highlighted in this document.

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- Bruce Tuch (B.T)
- Steve Wilkus (S.W)

GENERAL COMMENTS

- Rick Albrow -
The following areas of this document need to be expended:

1) There is a requirement for two classes of conformant MAC:

Class I Async only
Class II Async and Sync

2) It is not clear what the requirements are for a single MAC to support concurrent services with different characteristics, for example async + sync for a multimedia application.

3) The document does not make clear the requirements for channel capacity.

4) The MAC service user should be able to fully specify the required service, for example, for the synchronous service this would include throughput, maximum delay, acceptable quality of service etc..

5) Requirements for the synchronous service need to be considerably expanded, in particular whether it is connection oriented, serial-continuous-bit-oriented, protected/unprotected, bit rated etc..

6) Requirements for channel management need to be stated including the equitable arbitration between competing users for both asynchronous and synchronous services.

7) Requirements need to be stated for the mix of asynchronous and synchronous services in either:
- the same system; or
- uncoordinated adjacent systems.

8) The PHY SDU is defined as a symbol (which is reasonable considering the variety of disparate PHYs envisaged whilst the MAC SDU could have a large maximum size. Considering the unreliability of likely PHYs there is therefore by requirements on the MAC to include segmentation, retransmission and fragmentation protocols dependant on the characteristics of the underlying PHY. Section 3.4.1 should make this clear.

9) The requirement for a confirmed datagram service at the MAC layer should be considered.

10) Channel selection should allow, in addition, for PHYs using,
- TDMA; and
- TDMA/FDMA

11) There is a requirement to use multiple channels within the same PHY seeing as the capacity of a single channel cannot be specified.

- David Bagby -
This document is supposed to contain functional requirements for a wireless local area network. The document in fact goes much further and in several instances specifies or implies specific implementations. The constraints contained are incomplete, inconsistent and too restrictive.

I am strongly opposed to much of the technical implementation implied by this document. Rather than rebut the technical content of the document, I will simply note that it is inappropriate to this document and should be removed.

I will vote against any "functional requirements" document which directly or indirectly specifies an implementation approach. Our first step is to agree on the capabilities needed in a wireless LAN, only then should we proceed with determining an implementation approach.

The issues of security, and authorization are not adequately addressed.

Too much of the wording of this document is open to widely differing interpretations. It does little good to specify requirements if each reader see a different requirement.

- R. A. Buaas -
Attempt to do less in this document make it only a requirement document. Leave out possible implementations.

- Dale Buchholz -
I would like to congratulate the committee, especially Ken Biba, on its industrious undertaking and the quality of the information gathered and presented in the document. This document represents the best collection of user application data I have ever seen for LAN applications.

- Wim Diepstraten, Vic Hayes, Kiwi Smit, Bruce Tuch -
Document IEEE P802.11/92-20 is considered a very valuable Wireless Local Area Applications Evaluation document, but not a requirements documents. As such it can serve as an information source from which the ultimate requirement document can be developed. The requirement document must be binding, and must contain the basic requirements together with the definitions to clarify the requirements.
Requirements should be stated in a quantitive unambiguous way, with qualitive statements stated as objectives. The document must be complete, i.e. it should not contain "to be supplied" sections.

- Alan V.Flatman -
Abstract - In my opinion, this dilutes the usefulness of the document by "extracting all its teeth". I accept that this Requirements Statement should not be a "tablet of stone", but it should surely contain a number of agreed boundaries. It is worth noting that the document contains a large number of hard requirements (i.e. "shall") - Particularly in Section 3.4. I suggest the following rewording of paragraph 2:
"This document contains a set of requirements for Wireless LAN MAC and PHY entities. These requirements will be used to guide the development of 802.11 wireless LAN standards, and are expected to evolve within that committee."

- Steve Messenger -
In the MAC to PHY interface the document has specified that the Transmit Clock is to be supplied by the MAC to the PHY (sections 3.3 and 4.2) I believe it is best to have [transmit] clock originated from the PHY. Such an implementation would be both simpler and more flexible for accommodating both regulatory and applications requirements.

The document recognizes the necessity of supporting multiple PHYs. It would appear likely that each PHY may result in a different bit rate as a result of technical or regulatory restrictions. The regulatory issues are outside of the control of the committee, are difficult to predict, and may ultimately vary over different geographical regions.

If the transmit clock is provided by the PHY, then the design of the MAC is simplified and can be made independent of the bit rate and other PHY characteristics. The MAC standard should support operation over a broad, but clearly specified range of bit rates.

Allowing the PHY to originate the Transmit Clock (along with the Receiver Clock) will allow for the design of standard (and potentially some specialized non-standard) PHYs which accommodate the

requirement of specific regulations and applications. In addition, if the PHY originates the Transmit Clock, then simpler more efficient PHY designs can be implemented which can operate with lower power consumption.

- Ken Rattray -
Document delves into implementation specifics rather than sticking to technical requirements.

Document should deal with issues in terms of what should not explicitly be prohibited rather than specifically permitting them.

Majority of 3.4.3 belongs in 3.4.5 and the remainder (independent) needs to be stated more clearly.

- Nathan Siberman -
I think "non binding" document should not be balloted. The document has also a number of blank paragraphs which can not be voted yes or no.

- Francois Y. Simon -
As specified in the appendices of the document, the applications are using data transfer capabilities such as "Real Time" data transfer, "Periodic" data transfer, and "Multimedia". For each case (specifically when the topology of the network is "one to Many" there is a strong requirement for tight tolerance (bounded delay) MSDU arrival time delay. This basically characterize the isochronous transmission process.
The isochronous transmission is defined as "A data transmission process in which there is always an integral number of unit intervals between two significant instants".
In addition, an isochronous service must rely on QOS type parameters such as: transfer delay, bandwidth reservation, service type, and connection set up delay.
It is suggested that:

a) a definition of Isochronous be introduced in section 1.4

b) Isochronous service requirements and associated QOS parameters needs to be taken into consideration in the Requirement document, specifically when synchronous and asynchronous services are specified.

It is proposed that a 'place holder", perhaps preceding section 2.2, be reserved for future description of the environment in which the 802.11 standard would be applicable. This section would address the topologies to support:

- one remote station to one remote station
- one remote station to many remote stations
- many remote stations to many remote stations (this configuration would embrace the 'cell within a cell' concept.

- Steve Wilkus -
I agree with the need for such a document but this goes to far beyond the service requirements and over specifies the specific implementation of the standard.

- Timothy Kwok -
There are two main objections to the document. First, multimedia applications have been treated as one of the market areas to be supported in the requirement document. However, multimedia applications have emerged to be the most important class of applications that will encompass all major market areas (and different set of multimedia applications may be supported in different market areas). So if wireless LANs are designed for supporting multimedia applications in general, they would automatically satisfy many networking requirements of the various market areas. Therefore, a (orthogonal) classification by application types is recommended, in addition to the classification by market areas. Second, the two types of services that would be supported are guaranteed performance service and best effort service, rather than the asynchronous and synchronous service as proposed by the requirement document. Guaranteed performance service allows an application to reserve network resources (such as bandwidth) to ensure a

certain quality of service (QOS, includes bandwidth, delay and error), while applications using best effort service have to rely on the available network resource that remains from all existing applications that use guaranteed performance service.

- Donald C. Johnson -

I strongly support the need for a requirement document. I voted no on this first draft because I don't think it is ready yet to become an official requirements document. There are too many cases where the requirements are missing and much of the material is not really statements of requirements, but just statements of facts.

1. INTRODUCTION

W.D, V.H, K.S, B.T - Only a binding requirement document will have value, and will make work more efficient in the future. Only in this way the requirement document can be used to evaluate future proposals .

Several conformance levels must be specified, to cover for instance different station velocity ranges, performance level (bit rate) and BSA coverage size.

N.S - 5th paragraph - Remove "This is to be implemented with one PHY if feasible".

6th paragraph - add an optional distribution system...

1.1 SCOPE

D.A - Last paragraph - Add "Higher speed (than 1 and 20 Mbit/s) operation shall be possible."

R.S.C - Last paragraph - Add "quasi synchronous users, such as" before "packetized voice".

A.V.F - Third paragraph; 1st bullet - ...rapid deployment -"or configuration".

4th paragraph - ...alternative PHYs using "radio waves or light".

5th paragraph - ...shall support "fixed" stations...pedestrian "or vehicular...

6th paragraph - ...wireless "communication" may be...

D.E.L - "Packetized Voice" - This term has not been define in the document and is therefore unclear if it is referring to two way real time voice services, or bi-directional "paging" services. If the former, it should not be mandatory requirement of all systems. If the latter, it is not different from ordinary data and is an application issue and thus not be stated. In either case, the reference to "packetized voice" services need to be clarified and should be stated as "may" be supported instead of "will".

R.H.R - Last paragraph should be modified to read: "The Wireless MAC shall support conectionless service as defined in the MAC service definition at rates between 1 and 20 Mbit/s. Optionally, it may also support packetized voice services".

C.A.R - Replace [the 6th and 7th paragraph] with: "The standard shall support both of the following type systems:
Basic Service Area (BSA): an area in which each peer station has radio access to all others by a direct path or through a single fixed radio repeater.
Extended Service Area (ESA): an area comprised of more than one BSA and using a combination of elements including radio access points, required nodal equipments and distribution system together comprising a fixed infrastructure to provide connectivity between all stations within the ESA.

Stations must operate in either of two modes as is required to support autonomous operation of peer groups comprising a single BSA and larger scale systems and using an infrastructure comprising an ESA.

The last paragraph - Change to read "..Service definition at *specific selected* rates between.."

T.K - The need for the MAC to be interworking with current and future networking infrastructure, especially ATM networks, which are expected to be emerging in the local area by the time 802.11 has specified the MAC protocols, has not been addressed.

A very important area that requires elaboration is the scope of applications to be supported. Since the MAC is expected to carry future applications, in addition the current applications, the support of multimedia

applications is extremely important, because multimedia applications are emerging and definitely the most important class of applications in the future. Multimedia applications include both real-time and nonreal-time delivery of either time-based (video, audio, animation) or nontime-based information (images, graphics, text) (Ref. IEEE P802.11/91-130)

Support of multicast and broadcast applications should be included.

Y.K - Last paragraph - The lower limit 1 mbit/s of the supported data rate seems too high.

1.2 METHODOLOGY

W.D, V.H, K.S - The definition section must contain a reference MSDU size specification for the transfer delay numbers. Note: 2 msec transfer delay for 64 byte octet is much different from a 2 msec transfer delay for a 1024 octet MSDU size. Suggest reference to be 50 octets, as used on page 25.

Session duration should be specified in number of packets rather than msec.

N.S - Figure 1.1, "Send/Receive Ratio - Specify where are the "received MSDUs" measured.

Figure 1.2, "Dimension" - Suggest to change to 'Range".

F.Y.S - The applications described in the document does not take into account the effects caused by the propagation of the signal which may differ greatly within the "space" type (i.e., open spaces, warren of corridors, small offices, etc). Recognizing that quantify the propagation characteristics for each application may be difficult to do, it is suggested that a note be added, perhaps in section 1.2, that all applications are assumed to operate in "free space".

T.K - Multimedia should not be considered as just being another market area, but rather a class of applications that would emerge in each of the market areas studied. In other words, multimedia applications requirement should be studied in each of the markets surveyed.

From a network point of view, an application is characterized by its traffic characteristics and the corresponding communication requirements (Ref. IEEE P802.11/91-130. The traffic characteristics of an application are specified by the message arrival (generation) distribution and the message length distribution. The notion of message requires clarification. First, there is the intrinsic message size generated by an application. For example, for video applications, a video frame can be consider as a message unit. Second, for processing efficiency within a computer, such application level messages may require segmentation to smaller units, which can be referred as computing level messages. (For audio applications, the opposite might happen; multiple audio samples might be assembled to form a single computing level message unit). The finely, for transmission into the network, a further level of segmentation may be needed to form a MAC level data unit.

Communications requirements of an application are categorized into: bandwidth, delay, error and connection duration (both active and idle periods distribution). For multimedia applications, bandwdth is the most important requirement to be satisfied to guarantee their performance. However, the bandwidth requirement is conspicuously missing from the requirement table in Figure 1.1.

Also, since the table of MAC service parameters is mainly applications dependent that market area dependent (each market area usually have multiple applications), a table should be constructed for each application rather than just once per market area.

Issue of multicast and broadcast connections should be studied. Such connections are very common in classroom or meeting scenarios.

1.4 DEFINITIONS AND ABBREVIATIONS

D.Ba - Section 1.4 for the document contains definition of terms. While we very much need a common vocabulary to discuss the issue with, several of the definitions provided are either defined via other terms (which are not defined) or are ambiguous in their wording.

It is my believe that many definitions are significantly flawed. I expect to discuss these concerns during the March 802.11 meeting. In particular I have grave concerns over the definitions of BSA, ESA, AP and inter-networking (as used in the body of the document). Within the document interface between MAC and PHY is inconsistent and insufficient to support multiple PHY layers cleanly.

Terms are used within the body of the document that are not defined in the definition section. This must be repaired

Too much of the content is open for interpretation.

W.D, V.H, K.S, B.T - Session must be clarified in section 1.4. A lot of definitions can be deleted in the final requirement document.

D.E.L - The definitions of use of the terms "ESA", "BSA", and "distribution system" imply system architectures which have not yet been agreed to by the voting committee members and have yet to be debated. The stated definition of BSA implies a peer-to-peer distributed network. It is not yet been determined whether or not some unit still acts as a cell controller, routing messages and/or controlling channel access, even if all units are within range of each other. BSA definition should not imply mean "within radio range of station".

D.S - The definitions section is fundamental cornerstone of the document and contains several inadequacies and inconsistencies yet to be resolved by the committee. In particular, I would like to see the definitions for AP, BSA, and ESA improved before this document is accepted.

Alien Station

C.A.R - Change to: "Roaming Station": A station technically compliant with 802.11 but present in a PLAN other the one in which it is authorized. Such station may be served or blocked as a matter of management decision for the PLAN in which it appears.

Attenuation Distance

L.V.D.J - "The path loss experienced by a signal that conforms to the IEEE 802.11 PHY specification as it propagates between a transmitter and a receiver. The distance is measured in dB and is typically a time varying quantity".

N.S - Add "antenna" after "transmitter" and "antenna" after "receiver".

BSA

C.A.R - "a Basic Service Area in which each peer station within the area has radio access to all others by a direct path or, if used, through a single fixed radio repeater".

Channel

D.Bu - I am a bit confused by the definition. Does it mean that each instance of use of a medium is a channel? If so, then is it true that a single radio channel (i.e., spectrum allocation) can support multiple channels (as we defined) simply because the spectrum is used to communicate with separate sets of stations? Are we in danger of being inconsistent with how most people view the word channel?

C.A.R - "A radio frequency spectrum assignment or subdivision of an assignment which may be used independently of any other adjacent assignment or subdivision of the assignment".

Coverage Distance

L.V.D.J - "The maximum attenuation distance separating a transmitter and a receiver at which a communication service of sufficient quality of service to meet the requirement of the IEEE 802.11 PAR is possible. The distance is a function of the interference level at the receiver".

N.S - It is not clear to what requirements it refers.

Denial of Service
C.A.R - Delete entirely

Directed Medium
R.H.R - Needs to be rewritten in language understandable to a LAN engineer.

C.A.R - Change to "Point-to-point Medium - A link between two points in which the radiated energy and the responsiveness to that energy is concentrated in the direction of the opposite point. Point-to-point radio links discriminate against off-line radiation sources but are not immune to them".

Distribution System
D.Bu - Recommend removing the phrases "out-of-band" and "(often wired)". The term "out-of-band" is restrictive in that "in-band" distribution systems are not allowed. Depending how you define "in-band" and "out-of-band", solutions may exist for both. The phrase "(often wired)" seems to unnecessarily bias the requirements in light of the fact that users really want a totally wireless LAN.

D.E.L - Is defined as using an out of band communication system. The distribution system may in some cases use the same data channel as the user stations. Strike "out of band".

C.A.R - "A distribution component linking active nodes of the infrastructure which provides the ESA function".

ESA
D.Bu - Recommend to remove the phrase "to extend the BSA of a station". The phrase seems inconsistent with the definition of BSA.

N.S - Can ESA be provided by a wireless repeater?

K.S.N - Range of frequencies is between 400 000 Ghz and 300 Ghz. This corresponds to the range of wavelengths indicated (750 nm to 1 mm).

C.A.R - "An Extended Service Area containing more than one BSA and using a combination of elements including radio access-points, required nodal equipments and a distribution system together comprising a fixed infrastructure to provide connectivity between all stations within the ESA.

Good Signal
C.A.R - Change to "Valid Signal - A received signal that passes all tests that can be performed in a PHY layer entity for conformance to the 802.11 defined format".

Guided Medium
C.A.R - Change to "Contained Medium - A transmission medium where the system design may assume that all signals present come only intentionally attached stations.

Integrity
F.Y.S - It is proposed that the word "integrity" be replaced by "data integrity" as integrity may also applied to a mechanical characteristic such as "terminal case integrity".

C.A.R - Edit to read "...prevention of *deliberate and* unauthorized..".

Interference Distance
L.V.D.J - "The maximum attenuation distance separating a transmitter and a receiver at which a transmitted good signal can be detected as a good signal regardless of whether a sufficient quality of service to meet IEEE 802.11 PAR could be provided by that signal. This distance is a function of the interference level at the receiver".

N.S - "sufficient quality of service to meet IEEE 802.11 specification could be provided by that signal". Definition unclear. My logic: if the signal is detected as "good", then there is sufficient "quality of service".

Jammer
D.Bu - Recommend the following rephrasing: An entity that generates signals that do not conform to IEEE 802.11 PHY layer specification but are observable by entities that do conform.

L.V.D.J - "An entity that intentionally places signals that are observable by entities implementing an IEEE 802.11 PHY layer entity without the specific intention of communicating with the specific instance of a PLAN user that is observing the signals".

C.A.R - "Non-conformant or deliberately misused conformant signal source which impairs communication between conformant 802.11 stations".

Local Area Network
D.Bu - Suggest removing this definition since everyone has his/her own ideas of a LAN. Besides, what we have stated should be obvious to those skilled in this area.

C.A.R - "Is composed of user stations each communicating with any of the others using a common transmission medium commonly managed".

Microwave Signal
N.S - Change 300 Ghz to 300 Mhz.

C.A.R - "An information-bearing electromagnetic radiation level between 1 and 100 GHz (for the purposes of this Committee)".

MSDU
D.Bu - According to ISO 7498-1984, the unit exchanged between peer-entities is an (N)-protocol-data-unit or N-PDU. An SDU is that part of a PDU whose identity is preserved from one end of the (N)-connection to the other. An SDU is then usually the data that as been passed across the boundary from the (N+1) service user to the layer (N) service provider as viewed from the N-layer. In LANs, it is generally viewed as being equivalent to the (N+1)-PDU. ISO7498-1984 does allow for times where such a one-to-one mapping is not the case. In these cases, SDU and PDU are not interchangeable.

In the context of the requirement document, MSDU is used to describe the time it takes to move user data across the wireless LAN from the instant it is delivered to the MAC (LLC-PDU, MSDU) until it is delivered to the destination LLC. This really is a measure of how long it takes LLC-PDUs to be delivered across the wireless LANs and not MSDUs. The definition should be changed to that of an LLC-PDU or, alternatively, be further clarified in order to align itself with ISO7498-1984.

R.S.C - Add "LLC" before "entities" in line 2 and before "peer" in line 4.

Clone definition of DLSDU (assumed ISO 7498) for MSDU.

MSDU Jitter
C.A.R - Delete definition entirely. See replacement term: *Transfer Delay Variation.*

Y.K - The definition of MSDU jitter is not clear. Does MSDU jitter mean (delay variance) / (mean delay)? Does "delay variance" mean "standard deviation of the delay"?

Native Station
C.A.R - Change to "Home Station - A station operating within the coverage area of the LAN with which it is registered and authorized.

N-layer and N-user
D.Bu - Suggest removing these definitions since they are defined in ISO 7498-1984.

R.S.C - Replace definition with the definition in ISO 7498.

Obsequious Station
C.A.R - Delete definition entirely.

Octet
D.Bu - Suggest removing this definition.

OPLAN & PLAN
A.V.F - Not worthy of definitions (P is superfluous).

D.H - PLAN should be in the left column; the definition "premises local area network" should be in the text.

C.A.R - Delete [both] definitions entirely. Change all uses of PLAN to LAN.

Change PLAN user to "LAN user - A station and its operator employing the services of a LAN.

Pernicious Jammer
D.Bu - Suggest changing "places" to "generates".

L.V.D.J - "An entity that places signals that conform to the IEEE 802.11 PHY layer specification but do not conform to the IEEE 802.11 MAC layer specification on the medium".

C.A.R - Delete definition entirely. See *Jammer* and *Interferer*.

PHY
R.S.C - Replace definition with definition in ISO 7498.

Priority
D.Bu - Suggest removing the definition.

C.A.R - "A parameter specifying delivery priority".

Radio Frequency Signal
A.V.D - What about 60 Ghz Oxygen bands ???

N.S - Change to the "common" definition of a radio signal.

C.A.R - "An information-bearing electromagnetic radiation between 30 MHz and 100 Ghz (for the purposes of this Committee)

Recalcitrant Station

C.A.R - Change to "Uncoordinated Station - An uncoordinated station is a member of a LAN that is timed and operated independently of any adjacent LAN. It is possible for the same distinction to exist between stations in adjacent BSAs within a common ESA".

Restricted Medium
N.S - Propose the following definition: "A closed medium cavity that attenuates signals outside the cavity such that signals generated inside the cavity do not suffer signal quality deterioration or whose signal quality stays within IEEE 802.11 quality requirements.

C.A.R - Change to "Confined Medium - A space effectively isolated from passage of electromagnetic or optical radiation through its boundaries".

Security
F.Y.S - It is suggested that the word "security" be replace by "data confidentiality" as suggested by ISO standard definition (ISO 7498-2), the term "security" covers a much larger area.

R.A.B - Restructure the security definitions and requirements to reflect security industry practice and terminology. Require authenticity of user.

C.A.R - "Provisions for the protection of transmitted data from observation by unauthorized stations or other monitoring means".

Service
D.Bu - Suggest removing this definition. It is not consistent with the definition of (N)-service in ISO 7498-1984.

Signal
C.A.R - "An information-bearing radiation or conductor current. The physical manifestation of information transfer".

Station
C.A.R - "A tangible entity which provides the services of the 802.11 LAN to an individual user with an 802.11 conformant PHY and MAC".

Station Density
F.Y.S - As an uninitiated reader may not be familiar with the term hectare as an area measurement unit, it is suggested that "(1 Ha=10,000 m2)" be added to the end of the definition.

C.A.R - "Velocity of moving stations requiring LAN services".

Transfer Delay
D.Bu - According to ISO 7498-1984, the unit transferred across the MAC/higher-layer boundary is a MAC-interface-data-unit may contain the whole or part of an MSDU. We need to be very careful about our use of standardized nomenclature. My recommendation is to replace the first sentence of the first paragraph with the second paragraph. then strike the phrase "This definition is equivalent to". Then replace "are" with "is" in the following sentence. Then replace MDSU itself" with "user data".

C.A.R - Change to "End-to-End MAC Transfer Delay - is the interval between when a point within the MSDU is submitted for transmission at the source MAC interface until the corresponding point in the MSDU is received at the destination MAC interface. The default corresponding point is the start delimiter but may also be the end delimiter adjusted by deducting the transmission time of the MSDU contained. For segmented packets where the end delimiter of the complete packet is the preferred corresponding point, the adjustment may not be different than if the packet were sent as one complete packet of length determined by the 802 Functional Requirements.

For locally repeated packets (within one BSA) or for packets repeated at a different access point in an infrastructure implemented network, the delay introduced by the duration of initial transmission is the normal adjustment with measurement between end delimiters, but not the second transmission delay resulting from store and forward and which is MSDU length dependent".

Throughput
D.Bu - MSDU is again a problem. If we are measuring packets-per-second, then MSDU should be changed to MPDU. In measuring the number of octets, we need to be clear about whether the number is related to the MPDUs (utilization) or whether it is related to just the user data (efficiency).

C.A.R - "is measured per unit time by the number of MSDUs successfully transferred or the number of octets contained in the data portion of the transferred MSDUs. This measure count each transmission and each reception as one transferred MSDU, and then may be used for one station, one access point, one network or as specified. For the case of two intercommunicating stations dependent on infrastructure function, the same MSDU may be counted once for each station".

Undirected Medium
C.A.R - Change to "Non-directive Operation - A station in which the user is not required to position or orient the equipment with respect to any other facility is defined as having the benefit on non-directive operation".

[OTHERS]
R.A.B - Recognize the "**hidden station**" and its implications; define it.

L.V.D.J - "**Native Jammer** - A station within the PLAN that is a jammer from the point of view of a specific instance of a PLAN user".

"**Interference** - Any signal that is not intended to assist in transmission of information to a specific instance of a PLAN user".

"**Alien Jammer** - A station within an OPLAN that is a jammer from the point of view of a specific instance of a PLAN user".

"**Non-conforming Jammer** - An entity intentionally that places signals that do not conform to either the IEEE 802.11 MAC specification or PHY specification but are allowable uses of the medium and are observable by an IEEE 802.11 PHY layer entity".

"**Narrowband Interferer** - A source of interference that occupies a portion of the bandwidth of the medium".

"**Wideband Interferer** - A source of interference that occupies the entire bandwidth of the medium.

"**Intermittent** - A source of interference that is present some of the time that a PLAN is in operation".

"**Constant** - A source of interference that is present all the time that a PLAN is in operation".

"**Fixed** - An adjective describing a norrowband interferer that changes the portion of the bandwidth of the medium all the time".

"**Sweeping** - An adjective describing a narrowband interferer that changes the portion of the bandwidth of the medium that it occupies with time.

"**Interference Level** - A weighted sum of the individual signals that are observed as interference at a given instance in time from the perspective of a specific instance of a PLAN user. The weighting function used to

obtain the interference level is described in the Medium Dependent Interface section of a specific PHY layer specification".

R.H.R -"PLAN - Premises Local Area Network" Should be added.

C.A.R - "Unintentional Interferer - A properly used conformant signal source which impairs communication between conformant 802.11 stations because of excessive radio coverage or system inadequacies".

"Distribution System Delay - is the degree to which the transfer delay is increased by a required interposed distribution or internetworking function".

"Delay Variation - Expresses the degree to which any of the above delays are not constant. Statistical terms may be used to characterize a delay distribution. A delay may have an average, median or worst case value as specified.

"Throughput Density - The aggregate throughput of all stations within a defined area per unit area".

"Throughput Capacity - the maximum aggregate throughput of all stations with a defined area all operating at the highest level of demand for which all delay and other 802 requirements are met. Capacity may also be expressed per unit area".

"Access Delay - the time interval between an MSDU is offered to the MAC interface and when transmission on the physical medium commences. This interval can be expressed statistically; and it may have an average, median or worst case value. The value is probably dependent on system loading for loads that approach capacity.
Fixed access delay is that portion of the access delay which is not loading dependent, but which comes from the minimum delay introduced by the access procedure.
Worst case access delay is a necessary parameter for providing isochronous services on a packet medium".

"Jitter - in binary polar line signals is unsystematic variation in zero crossing time from a nominal average or in recovered bit clock timing transitions. This type of jitter is usually a function of preceding data pattern, but may also be caused by added noise or distortion in the transmission path. (802 context)".

"Virtual Connections - continuous isochronous bit streams broken into short datagrams for transmission on a wireless medium and reconstituted in their original form at the destination are said to provide virtual connections.
This process requires a worst case transfer delay relative to the nominal transfer delay to achieve timely arrival of each new datagram. It does not require any particular value of a fixed delay except that public network use on voice unavoidable fixed delay, a provision for echo suppressors is required".

"Session - a time interval, the beginning and end of which are specified at a higher level, but generally is the period of time required for a users use of a single application. Permissible delays may be greater outside of a session interval than within".

"Setup Delay - is the time interval required for connection-type service to be established considering only the link between the station and the first level of processing. Specifically excluded, is D channel processing time required by an interconnected network".

"Broadcast Message - A message that is unselectively addressed to be processed by all stations on the network. With 802, such messages are identified by the value of the first bit in the destination address field. Such messages have many uses including discovery of routes to newly appearing stations. It is desirable to define and limit the scope of broadcast messages to something less than the universe of all stations on all interconnected local area networks".

1.5 CONFORMANCE

D.Bu - Suggest replacing "specification" with "standard".
Add IEEE Std 802-1990 Overview and Architecture.

W.D, V.H, K.S, B.T - It is likely that the Multicast/Broadcast transfer reliability cannot be guaranteed in a wireless environment. This reliability limitation must be addressed as a deviation from the general 802 MAC service definition.
It should further become clear what kind of applications use Multicast/Broadcast addressing, and their sensitivity to a larger (undetected) error probability.

A.V.F - Choose either IEEE 802.2 or ISO 10039, but not both.

Second paragraph - "for example, in the US" the standard shall conform to the following safety standards:-.

R.H.R - The use of the phrase "service Area" needs to be clarified as "basic service area".

C.A.R - Omitted from this list are relevant ISO and ISO/IEC documents. If a document is cited in the conformance section, its appearance in the reference section is redundant.
If the requirement for integrated voice-data services is accepted, then there are a number of additional references largely from CCITT documents.
There are yet more references which must and should appear in the finished standards document, but are not particularly needed now.

T.K - Since these 802 documents were developed mainly for traditional data (connectionless) applications, only part of these documents may need to be conformed just enough for interoperability. May need to find the minimal set in order to define a more efficient MAC to support future applications such as multimedia, which require guaranteed performance.

1.6 REFERENCES

D.Bu - For [2], the document is IEEE Std 802-1990
Add: IEEE Standards for Local and Metropolitan Area Networks: Logical Link Control, ISO 8802-2: 1989; IEEE Std 802.1-1989
Add: Type 3 Operation, ISO 8802-2:1989/AM2, IEEE P802.2-90/47
In [9-13] inclusive, the IEEE document numbers are missing the year. They should all be IEEE P802.11/91-xx.

R.S.C - Item [3], [4], and [6] = Update to 7/91.

The IEC/ISA Fieldbus standards are designed for operation with a WLAN Physical layer. Add references to these standards.

Add ISA-1991-359H - Fieldbus Data Link Services & ISA-1991-360I Fieldbus Data Link Protocol.

Supply documentation on all the de facto network standards referenced in section 3.4.1 and other places in the document.

C.A.R - In citing document there is confusion of which are references and which contain requirements affecting 802.11. It is recommended that (1) through (8) be placed in the conformance list if they are not there already, and the references (8) [taken to be 9] through 12 be omitted.
Even better, would be to put all of the relevant documents in the references section, and use the conformance section to call out specific and unique responsibilities of 802.11 apart from conforming to the references.

2. GENERAL REQUIREMENTS

C.A.R - There should be two groups of requirements: those derived from the results of the output documents of the business area survey, and those agreed to by the requirements subgroup following committee procedures. Any other requirements should be in this document, but might be separately offered to the 802.11 Committee.

2.1 OVERVIEW

W.D, V.H, K.S, B.T - Suggest to state the non-quantative requirements in section 2.1 as objectives.

C.A.R - Edit to read "The following summarize some key requirements derived from results of the user survey."

Data Delivery Services

D.Bu - The phrases "the substantial majority of anticipated" and "the minority of" should be removed. These phrases are subjective opinion that can be accepted or rejected based on the data supplied in the appendices. The decision depends on the reader's viewpoint.

C.A.R - "The application survey indicates a need for both packet and isochronous services. The packet services require low transfer delay, and the isochronous services require that average transfer delay be limited to values consistent with those in the telephone network and that variation in that delay not exceed values enabling correct reconstruction of the virtual connection."

T.K - The text should be replaced by: "Two classes of delivery services should be supported: Guaranteed Performance service and Best Effort delivery service. Guaranteed performance service is a reservation based connection oriented service that allows an application to negotiate with the network for available resource (such as bandwidth and buffer) in order to guaranteed the quality of service for the connection. Parameters to be guaranteed may include bandwidth (peak, average, etc), delay (average, variance and maximum), loss rate, etc. This is to support future applications such as multimedia applications. Best effort delivery service is a connectionless data service that attempt to deliver the packet with the lowest delay, given the available network resources (left over from the guaranteed performance service). However, there is no guarantee of delay and integrity of data from the MAC layer. Error recovery is achieved by higher layer protocols. This is to support current data applications that are mainly supported by connectionless protocols."

Station Mobility

K.S.N - It is not clear whether continuity of sessions is to be maintained for:

a) Both asynchronous and synchronous services, and

b) Roaming and handoff support are required for both type of service

These issues must be clarified and stated explicitly.

F.Y.S - The station mobility requirement should not preclude the continuity of session while in motion in a multi-segment network environment. It is proposed to add the following, after the word "motion" (1st paragraph): "...in a single or multiple segment network environment."

Ease of Use

D.E.L - This should be identified as desirable where possible but not listed as a requirement. It is impossible to install large systems which require contiguous coverage over multi-cells (i.e warehouse) without a site survey. The requirement for no license should be listed as desirable but not a requirement since it is beyond the control of IEEE. The FCC may open DataPCS band which requires licensing.

N.S - Remove "site surveys". It is unconceivable that users will have guaranteed reception without an even "[?] site survey" i.e find optimal position of the station for quality reception. At least I can see need for site

surveys for optimal positioning of access points. Without this I can see an unnecessary increase in cost to the user. Therefore site surveys should not be precluded.

C.A.R - "Most end users would prefer to install, move and operate wireless LAN equipment without site surveys or licensing procedures. The survey did not make clear difference between large and small scale users, and large scale end users in this survey were not presented with the advantages that surveys and licensing might offer."

Independent Network Operation

D.Bu - Suggest re-phrasing the first sentence to: The standard shall support the independent operation of two or more networks in geographical proximity without the need for external coordination. Suggest adding the phrase "between the two companies" to the end of the second sentence.

R.S.C - Line 8 - Add "manually" before "change", since an automatic channel switch is certainly acceptable and possibly desirable to prevent loss of performance.

C.A.R - Change to "Independent Operation of Adjoining Networks - Some scenarios described have a need for multiple small independent networks rather than a larger shared network. Each such independent network should be able to operate without being materially affected by the others even though there is overlapping wireless coverage."

Distribution System

D.Bu - Remove the word "wired" before "wired distribution systems". Remove the word "(optionally)". The distribution system should not be limited to IEEE 802 LANs and should include FDDI-I, FDDI-II, CDDI, and other accepted high-speed standards. In addition, does this paragraph imply that IEEE 802 would be the committee to define a wireless distribution system?

W.D, V.H, K.S, B.T - It is not unambiguous clear that the distribution system function is based on standard IEEE 802 LAN systems only (in case of asynchronous traffic). In addition nothing is mentioned about Isochronous distribution system. A clear statement of the intention is required.

D.E.L - Definition is not clear. If the communication within a cell (BSA) requires a cell controller, is this a distribution system? Also, although it is obvious the distribution network must interface to IEEE 802 standard LANs, it should not be required that the distribution network itself uses 802 standard LANs. For example, what about a wireless distribution network? The above also applies to section 3.4.5 "Range Extension".

R.H.R - [This section] needs to be expanded to include non-LAN extension. Restate as "Users may (optionally) add a distribution system based on standard IEEE 802 LAN system and wide area systems to extend the range and capacity of the wireless LAN."

C.A.R - Change to Infrastructure - Autonomous operation of two or more stations as an ad hoc group is required for some scenarios. Because of system size and services, infrastructure is essential to other scenarios. The same station implementation shall work in either type of system. It is also desired that a system starting in the autonomous mode may have the capability of adding various levels of infrastructure as they are needed."

Size

N.S - Remove "a future goal is ... at the end of the sentence. It is not the intent of the requirements document to hint implementations. Other "small size" implementations in a different form factor are feasible too.

F.Y.S - 2nd sentence - The wireless LAN adaptors could be external to small portables via already-standard parallel or serial ports. This may not be optimum, but should not be ignored or excluded. It is

suggested that the second sentence read: "The standard must be design such that the wireless LAN adaptors, internal or external to portable devices, can be implemented in a very small sizes."

Security / Integrity
W.D, V.H, K.S, B.T - The method used should be world-wide applicable without restrictions. This is an important aspect when mobile stations like notebooks are considered, which are used in world wide distributed enterprises. There should not be a legal restriction as to what algorithm to use in different countries.

C.A.R - "Physical access to a wireless media cannot be limited to those authorized. Procedures are needed for preventing unauthorized interpretation of intercepted data transmissions and for resisting interference from misused compliant stations."

Internetworking
R.S.C - Line 2 - Add "services which allow" before "seamless". This requirement can be interpreted to mean we provide reliable multicast/broadcast used by some de-facto protocols. I do not understand that this is necessarily a requirement on 802.11. It is certainly not traceable to the PAR.

T.K - A high priority should be placed on internetworking with future ATM networks.

N.S - Seamless interconnectivity needs to be defined. Otherwise remove.

F.Y.S - There will be applications with no wired LAN nearby. It is suggested that "..will coexist.." be replaced by ".. will often coexist..".

C.A.R - Edit to read "..must provide *adequate* interconnectivity..."

Multiple PHY Support
C.A.R - Edit to read "..taste that *multiple* PHYs..."

Cost Effectiveness
D.Bu - Suggest removing the phrase "higher performance" since it has multiple, subjective interpretations. For example, one interpretation is faster bit rate. It may be that a high-cost, low volume application has a radio that is less susceptible to errors, but maintains the same bit rate.

N.S - Remove "high volume implementations" after "low cost". Remove "lower volume implementations" after "higher performance".

C.A.R - Edit to read "...the standard *enable* both low..."

[Others]
W.D, V.H, K.S, B.T - Roaming support must be stated as a general requirement.

F.Y.S - "Remote Access" - The standard should be able to accommodate authorized access of a non-native remote station to the network. In addition there are standards (i.e., X.500) which defines global addressing and directory services. The following text is proposed in section 2.1 associated with "Remote Access": "The 802.11 standard shall support the ability for a non-native remote station to gain access to the network. This implies that the BAS gets authorization from the remote station's native BAS. The standard shall also provide a mapping between local and global addressing".

2.2 ARCHITECTURE
D.Bu - In Figure 2.2, the top level of the protocol stack should be labelled "IEEE 802.2 Logical Link Control". The "MAC Layer" label should be changed to "Data Link Layer". The text in the preceding paragraph should be changed to be consistent with the changes in labelling.

W.D, V.H, K.S, B.T - Figure 2.2 is very incomplete. To keep it general this section should be deleted, or also sync and bridging services should be covered.

R.S.C - Figure 2.2 - The title does not accurately depict the scope or (hopefully) the intent. "Architectural concept of 802.11" may be better, but in this case we must show Bridges, Connection Maintenance, possible Scheduling/Slot-time allocation, Key management and possibly an SMAP for WLAN and ???. I use here the normal literal definition of Media Access Control.

Replace "synchronous" by "quasi-syncrhonous" since WLAN can not provide a truly synchronous service.

R.H.R - [The section] borders on design issues, not requirements. In particular, it is making big assumption that a single MAC is the appropriate choice based on the requirements. This decision should be left to the working group to determine in order to satisfy the requirements of the uses of wireless LANs. There are strong arguments that can be made for developing multiple MACs that can communicate with a given PHY. This section should either be removed or expanded to include the possibility of multiple PHYs [note: it assumed that MACs was intended here].

N.S - Last paragraph - If requirements for synchronous services can not be differed at this time, they should be removed out of this document.

C.A.R - Last Paragraph - New text: "This architecture does not show the functions necessary for the integration of connectionless and connection type services. The experience of 802.6 and 802.9 indicates that a separate link layer is necessary for each of these. It is anticipated that a multiplexer will be necessary either above the physical medium or above the MAC depending on whether the PHY is packet or synchronous. In either case 802.2 and 802.10 layers will be identical and unchanged regardless of support for connection type services".

3. MEDIA ACCESS CONTROL LAYER

W.D, V.H, K.S, B.T - Sections 3.2.1 and 3.2.3 should be deleted because they relate to implementation, rather than requirements. In general there is a danger for incompleteness.

Section 3.3 should be deleted because it describes an internal interface, it does not relate too much to implementation, and is incomplete.

All "to be supplied" sections should be specified before "ballot". Suggest to change the text to "must be provided", thereby indicating that it is required to have an interface like that. This will allow to start work on the definition of the interface specification. Further it should be identified, to what it should interface (define the protocol stack).

The figures 3.3 to 3.6 do not seem to have any value in a requirement document. Only the targets (figure 3.7 and 3.8) are needed with perhaps a statement on the applications which are covered. The same goes for the figures 3.9 and 3.10 and associated text.

R.H.R - Sections 3.2 and 3.3 have nothing to do with requirements. They represent design issues which should be determined by the working group when it defines the MAC interface. The information is valuable but should be submitted as a separate contribution.

D.S - There are many implementation details contained in this "requirements" document, e.g., the specific MAC semantics and interactions between PHY and MAC layers suggested in chapter 3. These details are inappropriate for a requirements document and should be discussed in a separate "MAC Proposal" document.

C.A.R - Delete section 3.2.1 to 3.2.6 entirely.

3.1 INTRODUCTION

D.Bu - I applaud the effort to be consistent with ISO 8802-2:1989; however, the information recorded is only a subset of that found in the corresponding pages of the ISO standard. There should be a statement to this effect in the opening paragraph with a reference to the specific pages/sections of ISO 8802-2:1989 that are paraphrased.

First paragraph, page 16 - The term "MSDU" in the second sentence of the first paragraph should be changed to "MPDUs" as that is what is delivered between MACs.

Second paragraph, page 16 - Suggest removing the phrases "substantial majority of anticipated", "the minority of" and "a minority of data". These are subjective assessments and could be accepted or rejected on the basis of the data in the appendix. Suggest removing all instances of the term "MSDU". Suggest changing the word "jitter" to variance since the term is not fully defined until later in the document.

Top paragraph, page 17 - The term "MAC" should be changed to "LLC" in all instances.

C.A.R - [Edit to read]: "The Media Access Control Layer provides the following functions: MSDU data delivery, shared PHY media arbitration and *access control, and may also include support of* security, integrity, authentication, internetworking and network management."

3.2 MAC EXPORTED SERVICES

R.S.C - In line 8 of the second paragraph - Delete "highly".

Line 9 of the same paragraph - Add "and distributed control" following "video services".

Line 10 of the same paragraph - Add "regular scheduling of and" before "variance". Add "The following MAC services are for the Asynchronous service of 802.11." Services for the Quasi-synchronous are TBD. For a reference to possible services, see ISA-1991-359H.

MA-UNITDATA-STATUS is not included in ISO 10039 (dated 7/91). We need to decide if this function is truly needed, and if YES then find a different way to model this function.
[Note: This comment is also applicable to section 3.2.3].

K.S.N - Missing sections 3.2.4, 3.2.5 and 3.2.6 must be resolved.

C.A.R - Second paragraph - New text: "The 802.11 PAR and the application survey indicate the need for both an asynchronous packet and a connection type service both needing limited transfer delay. In a few cases variation in transfer delay from nominal may also be a consideration beyond that of timely arrival for virtual connections."

Last paragraph - Add text: "Indications for the status of a session may be required. In addition, the top of the MAC may be a superset of bottom of the packet LLC to provide indications for use in an interposed packet-connection multiplexer layer.

T.K - The second paragraph should be replaced by: "Two classes of services should be supported: guaranteed performance service and best-effort delivery service. Guaranteed performance service is a reservation-based connection-oriented service that allows an application to negotiate with the network for guaranteed quality of service by reserving available resources (such as bandwidth and buffer). Parameters to be guaranteed may include bandwidth (peak, average, minimum, etc), delay (average, variance and maximum), loss rate, etc. This is to support future applications such as multimedia applications. Best-effort delivery service is a connectionless data service that attempt to deliver the packet with lowest delay, given the available network resources (left over from the guaranteed performance service). However, there is no guarantee of delay and integrity of data from the MAC layer. These are mainly for applications that can tolerate highly unpredictable delay variance. Error recovery is achieved by higher layer protocols. This is highly oriented to support current data applications that are mainly supported todays connectionless protocols (or commonly referred to as datagrams delivery service) such as Appletalk or IP packets, running over 802.2 LLC. Interoperability to support current applications is very important.

3.2.1 MA-UNITDATA REQUEST

R.A - Class of service is not defined and Priority requires a clearer definition.

R.S.C - The wording needs to be cleaned up to match other 802 standards. e.g.; Line 2 of the 4th paragraph: Delete "entity" from "group MAC address".
[Note: This comment also apply to section 3.2.2 and 3.2.3].

3.2.2 MA-UNITDATA INDICATION

R.A - The description of Reception Status here is not clear as the following paragraph states that only free frames will be reported.

R.S.C - Last paragraph - The requirements document does not need to, and should not, address whether the MAC/PHY interface (and thus PHY) is half or full duplex.

3.3 MAC REQUIREMENTS OF THE PHYSICAL MEDIA LAYER

D.Bu - Figure 3.1 - Remove "signal detect" since channel busy indication is only pertinent to those MACs that need such an indication (e.g., CSMA or LBT). Other MAC candidates may not need such a signal.

D.A - Add to figure 3.2:
- Signal Name: Power Control

- Direction: MAC>>PHY
- Description: Control over PHY transmit power level. May be implementation specific.

R.S.C - Second paragraph - Add 'and diversity control" after "management".

In figure 3.1, Quality of Service - replace "propagation" by "reception" since this all the PHY can know. [Note: This comment applies also to Figure 4.1].

D.H - Figure 3.2 reference to "Transmit Clock" indicates MAC>PHY. Clock generation and recovery are PHY layer functions, as is properly referenced in Figure 3.2 for the "Receive Clock". The description should be clarified. If MAC is the intended home for "Transmit Clock", I should vote to not approve. [Note: This comment apply to Figure 3.2 and also 4.1].

T.L.P - Transmit clock must be PHY -> MAC direction as every modem designer knows.

N.S - Figure 3.1 - "Signal Quality" signal should be added [?] [?] PHY to the MAC.

Figure 3.2 - "Channel Select" - This should be included in the Control information otherwise I propose to spell-out the control information parameters.

F.Y.S - Figure 3.2 - "Channel Select" - TDMA radio PHY as well as Frequency Hopping should not be excluded. It is suggested that the existing text of the last sentence be precede by "For example" and be inserted in parentheses.

C.A.R - 1st paragraph - Delete paragraph entirely (Presumption of channelization).

Figure 3.1 - Delete line items "Quality of Service" and "Signal Detect".

Figure 3.1 - Add new line: "Valid Signal" "PHY-MAC" "Indication that valid signal is present/absent when bit clock out is valid/invalid".

Figure 3.1 - Add text below: "No decision has been taken by the 802.11 Committee that a station PHY shall report signal present or absent whether measured by analog signal level or by presence of bit clock lock. A minimal indication is shown above pending a decision to expand this function."

The issue of scrambling has not been addressed. If scrambling is defined as PHY function, then also the start delimiter must be recognized in PHY. A means must be provided for the MAC to know when to start processing. The transition of the valid indication from invalid to valid may mark the first information bit. If the message is held in FIFO buffer at the top of the PHY awaiting unload by the MAC, than only an indication of data present is necessary. But the presumption of such a buffer implies an unnecessary time loss.

Figure 3.2 - Delete line item "Channel Select".

Figure 3.2 - Add text below: "No decision has been taken by the committee on channelization or the means of accomplishing it. If channelization is performed in the PHY, and a channel select function would be required. If it is done by time division, it is a MAC function, and no channel select function would be required."

3.4.1 CORE FUNCTION

D.Bu - Third paragraph - NDIS is a driver interface specification and not a protocol like the others listed. the underlying protocol for LAN Manager is IEEE LLC Type 2. In the next sentence, the phrase ", particularly Type 1," should be removed since 802.11 is required to support all 3 types of LLC, especially Type 2 for LAN Manager and SNA.

R.S.C - Add "regular scheduling of traffic and" before "low variance".

3nd paragraph - add "de jure and" before "de facto", add "OSI' before "IPX".

3nd paragraph, 4th line - The service described in section 3.2 is actually Type 3 not Type 1.

Add at the end of the 3nd paragraph - "Comparability with existing proprietary networks, such as DecNet, Data Highway 1 & 2 and Modbus, and standard networks, such as MAP, are crucial to acceptance of 802.11 in the manufacturing market. The emerging ISA/IEC Fieldbus standard will be equally important, it will specify a Radio PHY layer.

5th paragraph, line 2 - Add "thought to be" before "far more tolerant" - no documented, experimental evidence in support of tolerance for 1% loss rates has been submitted to the WG.

Last paragraph, last line - Add "nominally" before "achieve".

K.S.N - 3nd paragraph - "Effective support of IEEE 802.2 LL will insure...". Suggestion: Remove the crossed out portion (Type 2 and 3 of IEEE 802.2 LL may be equally important as Type 1).

F.Y.S - 1st paragraph - It is proposed to replace the 'multipoint and broadcast' by 'multicast'. The multicast address is able to define a group of stations (multicast group). Note that the multicast addressing does not preclude broadcast. It is also proposed that a minimum number of multicast group to be supported by a single station such as 64 or 256 be specified in the requirement document. The second sentence would read: 'Both point-to-point service directed from a single transmitting station to a single receiving station and multicast (in which a MSDU is directed from a single transmitting station to several receiving stations must be supported".

C.A.R - Delete the first 3 paragraphs. New text: "**MSDU Delivery** - The core service of the standard is the prompt, successful delivery of MSDUs source station to a destination station or, for so implemented systems, to any destination in an outside network. In addition, a station may be the originator or the destination of a broadcast message.
In an autonomous group of Stations, the certainty that a transmission originated by one station, will be heard by all others on the network that exists for a wired 802 LAN, does not exist for a wireless system without infrastructure. Therefore, the Committee may make an exception or define a conditional compliance for this case.
The quantitative requirement for prompt delivery on the wireless network is simply that the user will be unaware of a difference from that at wired desktop station. It may be necessary for the committee to accept some degradation from this goal, and to quantify the result.
In order to meet goals on worst case delay, it may be necessary to have a near deterministic system so that values can be predicted.
Similarly, the 802.11 standard must offer the same degree of compatibility with important existing upper level software as other 802 physical mediums. It is implied that this will be the case as a consequence of meeting the specific requirements of 802.1 LLC Type 1.

Connectionless and Connection-type Service Integration - The connectionless service is mandatory for 802.11, and the connection-type service is necessary option that the 802.11 Committee and many surveyed users require to be supported. The PHY level multiplexers specified by 802.6 and 802.9 have not been defined as implimentable by 802.11. MAC level multiplexers imply that datgrams for circuits are no different than those for packets for more exacting worst-case delay requirements.
Most connection-type services are inherently full-time duplex, and this cannot be accomplished on a single radio channel except with time division duplexed higher rate packets."

4th paragraph - Not satisfactory -- further study required.

T.K - Second paragraph - "The standard will..." should be replaced by "The standard will support two types of services: best-effort delivery service and guaranteed performance delivery service. Best-effort delivery service is a connectionless protocol highly oriented towards supporting existing layer 3 protocols that are mainly connectionless datagram protocols such as IP and Appletalk."

3.4.2 PERFORMANCE

D.Bu - My biggest objection to the document lies in this section and is related to Figure 3.4: MSDU Jitter vs. Transfer Delay for Surveyed Applications. The data in the graph is accurate; however, the interpretations found in the related paragraphs are a bit misleading. The jitter value 1.0 is chosen as the breakpoint between asynchronous and synchronous services. It is suggested that the 3 points along the nominal transfer delay of 30.0 and less than 1.0 represent the synchronous category. Partly this is true; however, the transfer delay standard deviation for these points is 4-6 ms. Therefore, all applications with a transfer delay standard deviation less than or equal to 6 ms should be considered synchronous. This included several points above the 1.0 jitter value. The line of demarcation should actually be a diagonal through the points (1.0, 6.0), (6.0, 1.0), and (30.0, 0.2). This leads to the conclusion that the jitter is not the important parameter, but rather the actual transfer delay standard deviation. To further support this point, consider an application with a nominal transfer delay of 1000.0 msec and a transfer delay standard deviation of 500 msec. The MSDU jitter is then 500/1000 = .5. This would clearly place it under the synchronous category under today's interpretation, but the 500 msec transfer delay standard deviation is clearly on the high end of all applications surveyed, so it should be classified asynchronous.

My recommendation is to replace Figure 3.4 with a histogram of the actual transfer delay standard deviation values such as the one found in Appendix M. In addition, I would recommend that all mention of MSDU jitter be removed from the document, including but not limited to its definition in section 1.4, all references in section 3.2, all references in section 3.4.2, and Appendix S.

Last paragraph, page 21 - Suggest removing "tolerance (e.g. MSDU jitter)". Suggest removing the phrase "(much less than the average MSDU transfer delay)".

Figure 3.6 - The units in MSDU Size Distribution should be octets for both cases.
3.4.3 Configuration

R.S.C - Certain Applications which are known to be Quasi-Synchronous are classified as Async, by traditional scholastic criteria this fact calls the classification criteria into question. It may be true that a better differentiator of the need for Quasi-Synchronous service is than the Max Transfer Delay is less than the MSDU arrival Rate - I will investigate this when I have the survey results on Diskette). This revised definition will move the Mfg. Distributed Control application, well known to be QSync, to that category and will not displace the current Sync applications.

Last paragraph - Add at the end "or which includes a need for time/slot scheduled services".

Figure 3.8 - Based on the above reclassification and new data in Appendix C, revise Q-Sync targets as follows:

- Nominal Transfer Delay = 5 ms
- Max. Transfer Delay = 10 ms
- MSDU loss rate = 0.0001

Note that this loss rate may elicit the need for two classes of service as contemplated in the PAR.

K.S.N - Robustness, second paragraph - "robust operation likely will include...". The sentence is vary vague. We suggest making it more precise or removal of the sentence.
If robust operation is a requirement, then it must be stated explicitly for both:

. asynchronous services
. isochronous services

R.H.R - Figure 3.3 does not help the reader draw any conclusions about the data. A clear indication of this is the size of the standard deviations. It does not "document the range of values" as stated in the second sentence of the first paragraph of this section. This summary should either be omitted or reorganized. A possible reorganization would be to analyze where significant clusters occur for each of the categories as well as stating the overall range.

The explanation of figure 3.4 in paragraphs 2, 3 and 4 is very difficult to follow. There should be additional annotations on the graph itself to indicate where the various grouping occur.

N.S - Figure 3.3 - Change "Service Initiation Time" to a higher number to allow for low cost, low power consumption implementations as well as for some of the FCC slow hopping systems at 2.5 [?]/sec. This is one of the "set-up time". I propose 30 sec. maximum.

Specify units for MSDU jitter.

Figure 3.5 - Same as above [except for "MSDU jitter"].

Figure 3.7 - Change "Maximum Transfer Delay" to 400 ms (to allow SHFH implementations @ 2.5 [?]/sec, with one retry.

F.Y.S - Figure 3.3 - The figures summarize mean, median and standard deviation values based on the survey of more than 50 LAN applications. It is suggested that this section describes how the MAC service measures of the individual applications were combined to arrive at the summary table specified in figure 3.3. In particular, it is suggested that explicit note be made of any weighting factors used to arrive at Figure 3.3. If no weighting factors were used, please state so.
The comments above are also applicable to Figures 3.5 and 3.6.

C.A.R - Figure 3.3 - Replace "MSDU Jitter" with "MSDU Delay Variation". This change should be made to all subsequent occurrences in the document.

Comments on use of Jitter - There is a fundamental difficulty in the use of the term jitter for the remaining parts of the document.

Packet or LLC Type 1: Delay variation is relatively unimportant compared with limiting the worst-case of delay likely to occur for each service. While early delivery is not harmful, it is often not beneficial if it cannot be replied upon.
Delay is a function of medium signaling rate. The less competent the access method, the higher the medium rate required for a given limit on the probability of a given access delay being exceeded.
It is probably impossible to get a single medium signaling rate to fit everything from desktop to industrial robot. The surveys show that all desirable properties are rarely required simultaneously, and this fact is not considered very well in this analysis of the data.

Connection-type Traffic with Q.921/Q.931 Layer 2 & Layer 3: The delay and other practices for public network extendable connections are already well defined, and it is useless to ask users to give their opinion of what think they are. There is plenty of work for 802.11 to deal with isochronous services, but the design parameters cannot be obtained from a survey.
In particular, jitter is not relevant. In another contribution copied here as an attachment [this section is not reproduced here] to this paper, the means of providing a virtual circuit with a packet medium is described. The serial output must be identical to the serial input except delay in time some number of milliseconds which does not vary. In isochrounous service, clock jitter is defined in parts per million with specified averaging period, and mismatched clocks are more characterized in terms of "slip".

It is true that video and one-way connections can tolerate more transfer delay, but it is not clear that the physical medium or MAC will know the difference between packets carrying delayable vs. ordinary connection content.

Comments on use of statistical terms - There is a general difficulty in the use of statistical terms for this kind of data. First, the meaning of Standard Deviation is obscure when the shape of the probability curve has no resemblance to any of the commonly used shapes. Further, when the Standard Deviation is larger than the mean or median value, it does not have any usefulness.

The consolidation of this kind of data as a statistical distribution function is not a valid application for the mathematics and the result is not usable after combining. For me to vote approval, this matter must be corrected.

T.K - Since the survey of applications submitted to P802 are of such a wide variety and it is possible to an accurate prediction of their relative weight in future scenarios and their mix is certainly differs widely for different environment, so it is misleading to take calculate average and deviation of the different parameters. However, it is still representative to graph the range of values of the different parameters submitted to the P802.

Again, the two classes of services to be supported are guaranteed performance service and best effort service. Hence, Fig 3.5 through Fig. 3.8 related to asynchronous and synchronous service should be removed. New figures related to guaranteed performance service and best effort service needs to be investigated.

3.4.3 CONFIGURATION

R.H.R - The 3nd paragraph starting "In many cases,.." should be deleted. It assumes a PHY coverage area and then makes a design conclusion. Since the PHY coverage area is not yet known, will vary based on the particular PHY, and will be determined by the working group, this paragraph is not appropriate for the requirements document.

T.K - Again, it is misleading to take calculate average and deviation of the different parameters. However, it is still representative to graph the range of values of the different parameters submitted to the P802.

3.4.4 DATA SECURITY AND INTEGRITY

Data Security

R.S.C - 2nd paragraph - Add ", when this is a user requirement" after "reception".

Add "public domain" after "standard". Add "and Key Management system" after "algorithm".
[Note: This comment applies also to the 'Data Integrity', 2nd paragraph."

3.4.5 RANGE EXTENSION AND INTERNETWORKING

Range extension

R.S.C - Last line of 1st paragraph - Add at the end "by provision of MAC services conforming to ISO 10039 and IEEE 802 MAC Service Definition.

R.H.R - The first paragraph should be reworded to state: "In order to accommodate applications who's coverage area exceeds the unrepealed good signal distance of a given PHY, the standard should allow for extended distribution systems. These extensions will include IEEE 802 conformant LANs and wide area networks that relay 802.11 MSDUs.

Internetworking

T.K - Since ATM LANs are expected to emerge by the time the standard specification is finished and would become the dominant network infrastructure, internetworking with ATM protocols is extremely important.

3.4.6 NETWORK MANAGEMENT

D.Bu - There should be some reference to 802.1F Layer Management Guidelines.

N.S - Power Management - Power management should be an optional feature. Impact of unpowering and repowering on service initiation (reinitiation time) and transfer delay should be considered. The standard should allow implementations with no power management.

Transmit Power Management - Transmit power control should be an optional feature. Impact on delays, cost and complexity should be considered. The standard should allow implementations with no Tx power control.

4. PHYSICAL MEDIA LAYER

W.D, V.H, K.S, B.T - Suggest to delete most of section 4.2 and sections 4.3 to 4.3.5, because they are not requirements, but more implementation details.

What is needed in this section:

- Specify that a standard MAC/PHY interface is required (to allow multiple PHYs).
- Specify the PHY services.
- Specify the requirements for a PHY/Management interface.

R.H.R - [This section] is entirely design issues and should be removed from the requirements document and be made part of a separate contribution.

4.1 INTRODUCTION

4.2 PHY LAYER EXPORTED SERVICE TO THE MAC LAYER

D.Bu - Figure 4.1 - This is a repeated figure, i.e., Figures 3.1 and 3.2 capture the identical information. We should eliminate either figure 4.1 or both 3.1 and 3.2.

L.V.D.J - Figure 4.1 and the brief text paragraph of the text before and after would need to be omitted (this table is largely redundant in light of figure 3.1's presence.

N.S - Figure 4.1 - If definition of Quality of Service is accepted then I suggest we add a signal quality parameter. Channel select part of control information.

4.3 PHY CHARACTERISTICS

4.3.1 GENERIC CHARACTERISTICS COMMON TO ALL PHY LAYERS

D.A - Item 4 of the list: Add "Further, attenuation between two stations cannot be assumed to be reciprocal".

R.S.C - Item 8 of the list - Add "native" before "station". This statement is incomplete. Reception of a valid frame must imply transmission by another station, or we can never build a WLAN.

A.V.F - 4th line - ...more "electromagnetically" benign...

N.S - Item 7 of the list - Requires explanations. This violates the quality principle, unless one of the stations is out of spec.

Item 8 of the list - I have no clue what this means. Some station must have transmitted this signal.

C.A.R - This section needs redrafting for clarity and accuracy, it is not acceptable as written. The assertion of 2) is not accurate as written.

4.3.2 SPECIAL CONSIDERATIONS FOR ISM BAND SPREAD SPECTRUM PHY LAYERS

K.C.C - Special consideration for ISM Band Spread Spectrum PHY Layers must be completed to get approval.

K.S.N - Needs to be resolved.

4.3.3 SPECIAL CONSIDERATIONS FOR INFRARED PHY LAYERS

D.A - Item 1 of the list - Change last sentence to "In other words it is possible in some cases to design a restricted medium using IR signalling."

R.S.C - Item 1 of the list - Should not "removed" be replaced by "softened"; what happens when a door to another WLAN open.

D.A - Item 4 of the list - Change to read "Incoherent diffuse reflection indoor infrared propagation tends to produce coverage areas free of multipath fading, however shadowing can occur."

K.C.C - Item 4 of the list - Fading is not appropriate and may be replaced by "shadowing".

4.3.5 SPECIAL CONSIDERATION FOR 60 Ghz PHYS

N.S - Is this in line with distance and cost requirements?

[APPENDICES]

D.Ba - We are voting on the wrong thing in this LB (Letter Ballot), the appendices should be the focus of the LB. From these we may derive characteristics required of a WLAN system. The portion of the document covered by the letter ballot is derived from the data in the appendices, yet the data is not part of the ballot. This make no sense.

J.C - The appendices J-S deal with MSDU characteristics which are never introduced formally in the committee and were never discussed. Thus, putting the question of the validity of the data aside, it is not appropriate to include them among those data that the committee at large has accepted.

Even though the appendices are serving no binding purposes, the existence of data not formally filtered through IEEE 802.11 voting membership in a formally balloted document is not the right thing to do.

W.D, V.H, K.S, B.T - It is noted that the Nominal transfer delay definition has changed significantly during the development of the document. It is therefore questionable whether the numbers given in the appendices are correct according to the latest definition. Note that currently the number should reflect the delay for a 50 octet packet.
It should also be noted that according to the definition the delay of only one segment is covered. In applications where the server is located on the backbone, or located in an other BSA the performance will be impacted by the additional "store and forward", and access delays of multiple segments.

New retails applications related to automatic shelf labeling, as documented in contribution #IEEE P802.11-92/15, are not included in the latest document.

D.S - Some key requirements are not covered adequately, specifically the security, authentication, and data integrity areas. I would like to see these requirements more thoroughly addressed, perhaps in the application specific contexts of the appendices.

APPENDIX A, Education

A.3 CONFIGURATIONS

D.A - Table change to reflect dense urban campus density:
station density - 50/hectare - 2000/hectare - 100/hectare

APPENDIX B. Finance

B.2 CONFIGURATION

A.V.F - Application duration surely 8 hours (not 4 hours), consistent with preceding text (3nd paragraph, page 35).

APPENDIX C. Industrial Automation/Manufacturing

C.1 INTRODUCTION

R.S.C - Add at the end "Comparability with existing proprietary networks, such as DecNet, Data Highway 1 & 2 and Modbus, and standard networks, such as MAP, are crucial to acceptance of 802.11 in the manufacturing market. The emerging ISA/IEC Fieldbus standard will be equally important, it will specify a Radio PHY layer.

C.5 MONITORING AND CONTROLLING

R.S.C - The data rates cited do not appear to include any Application or lower layer PCI - suggest these values should be Data rate / station = 25 Bytes per Transducers and 2048 bytes/20 ms for PLCs.
Distribution of Data Traffic = short traffic = Constant for both; +1-3/day of 1 MByte up/download of PLC.

C.9 OTHER MANUFACTURING APPLICATIONS

R.S.C - The first 3 applications need to be separate sections.
Add C9. Mfg. Monitoring is the scanning of process variables (temperature, flow, etc.) on a regular, but possibly jittered, basis. Data is displayed and alarmed for process operator monitoring and is usually logged and/or stored on disketted. In the Drug and Food industry, long term retention on this disk record is an FDA requirement. This same facility and "campus" HVAC and utilities monitoring. Connection to remote/inaccessible areas is often the motivation for WLAN as an extension of the wired LAN.

C10. Mfg Coordination is the coordination of Mfg. devices such as PLCs, Robots, AGVs, Conveyors, Carriers, NCs by a Cell controller. It involves up/downloads of Mfg. Programs and Recipes and the collection of files giving Batch/Part processing conditions and actual characteristics. Connection to mobile or moveable devices is the motivation for extending the wired LAN. It is easy to identify a "master" AP or APs with such system.

C11. Distributed Mfg. Control is the sharing of the control function for a single production area among several/many mini PLCs or Process Controllers. PLC remote I/O is an example of this application, this application is emerging as a major growth Area since it leads to a paradigm shift from central to distributed controls. The ISA/IEC Fieldbus standard anticipates a WLAN PHY layer. Its data Link standard is a good model for a WLAN in this and other instances of the Manufacturing environment. This application maintains a truly distributed database among the WLAN participants to minimize traffic loading while maximizing information transfer. It also maintains "spatial, temporal and database consistency" between the variables used in each control calculation. Connection to mobile or moveable devices or extending the wired LAN. It is easy to identify a "master AP or APs with such systems. Process Control Alarm Reports are a subsection of this application.

C.9.1 APPLICATIONS

R.S.C - Change the table.

Manufacturing Monitoring
* MSDU Arrival: 50% 250ms Qs, 50% 1s-60s Irreg.
* Nominal Txfr Delay: 50ms
* Tx Delay Std. Dev.: 10ms, 100ms
* Max. Tx. Delay: 100ms

Manufacturing Coordination
* MSDU Arrival: 50% 1s-1000s Irreg., 50% 1s Poisson
* Nominal Txfr.: 500ms
* Tx Delay Std. Dev.: 100ms

* Max. Tx. Delay: 750ms

Distributed Manufacturing Control
* MSDU Arrival: 80% 20msec QS, 20% 100msec QS
* Nominal Txfr.: 5ms, 20ms
* Tx. Delay Std. Dev.: 2ms, 4ms
* Max. Tx. Delay: 10ms, 50ms

APPENDIX E. Meetings

E.2 APPLICATIONS

F.Y.S - Appendix E captures some of the ad-hoc networks applications. However, this can be expended to include an additional 'groupware' application. Groupware is an application which supports a group of users interactively, discuss, modify, annotate and create ideas, text diagrams, spreadsheets on a real time basis. It is proposed that a third column be added to Table E.2 under a heading "Groupware":

- MSDU Size Distribution	90% 80 octets, 10% 1024 octets
- MSDU Arrival Distribution	Poisson 100 ms
- Nominal Transfer Delay	< 20 ms
- Transfer Delay Std Dev	< 10 ms
- Maximum Transfer Delay	250 ms
- MSDU Loss Rate	10**-3
- Service Initiation Time	250 ms
- Station Speed	Walking
- Destination Distribution	0 (100% to other mobiles)

APPENDIX F. Office

F.2.2 EXPLICIT STANDARDS SUPPORT

A.V.F - Should not include 802.4 and 802.6 as these are not office LANs. Also 802.9 and FDDI support (must??) very ambitious. I suggest that this section is made more generic.

F.2.7 MAC SERVICE REQUIREMENTS

D.Bu - The column labelled Real-Time Voice implies either an all digital network or echo cancellation at the end-points. An alternative method based on ATM-type technology that reduces the need for echo cancellation would have the following column:

- 31-64 octets
- 4-8 msec
- < 2 msec
- < 2 msec
- 8 mesc
- < 10 ** -2
- 1000 msec
- 2 m/s
- 0

This column should be added to the table since it represents a legitimate way to handle the delivery of real-time voice. In addition, similar numbers can be delivered for slow-scan video by multiplying the number of octets in a packet by 6 (384 Kbit/s).

F.2.1 APPLICATION SERVICES

Environment control

R.S.C - Change last line to "control application, e.g.; a lower rate version of C.9 - Manufacturing Monitoring or of C.11 - Distributed Manufacturing Control".

Distributed Computation

R.S.C - Add at the end "or by a distributed database/control model like C.11. - Distributed Manufacturing Control".

APPENDIX G: Retail

G.2 APPLICATIONS

A.V.F - 3nd paragraph on page 64 - Robustness is surely a critical requirement for most retail applications (certainly payment-related transactions).

APPENDIX I: Multimedia Services

T.K - Replace the original text by the following:

"AN APPLICATION CLASSIFICATION AND A SUMMARY OF NETWORK REQUIREMENTS

I.1 INTRODUCTION

Multimedia application has emerge to be one of the most important applications of the coming decade. Multimedia applications can be considered as the most general form of applications. Any network that is designed for the future should be able to support multimedia applications. Therefore, characterization of multimedia applications is very important for the design of the wireless local area network protocols that is intended to be a standard for the coming decade and beyond. I a previous contribution (IEEE p802.11/91-130), a preliminary study of multimedia applications requirements have been presented in detail. The purpose of this section is to summarize those requirements. However a more detail investigation is still needed to understand the exact requirements of applications in general.

I.2 WHAT IS AN APPLICATION

An application is defined as a task that requires communication of one or more information streams between two or more parties that are geographically separated. Two main attributes of an application are the types of information communicated and their corresponding delivery requirements.

Information Types - In general, information can be classified as time-based and non-time-based. Time-based information is defined as those that must be presented to the user at specific instants to convey its meaning. Typical time-based information are video and audio, while non-time-based information includes still images, graphics, text, etc. An application may include both time-based and non-time-based information. Synchronization of different information types is an important issue when the application involves simultaneous transfer of different information types.

Delivery Requirements - Applications can be classified according to its delivery requirements into real-time and non-real-time applications. A real-time application is defined as one that involves information delivery for immediate consumption. In contrast, for non-real-time applications, the information is stored at the receiving party for later consumption. the former requires sufficient bandwidth, while the latter requires sufficient storage. (Conversation on the telephone network is considered real-time applications, while electronic mail across a data network is a non-real-time application). In other words, communicating partied for a real-time application participate at the same time, while for a non-real-time application participate at different time.

However, it is important to distinguish between the delivery requirement of the application from the intrinsic time dependency of its information content, which can be time-based or non-time-based. Video conferencing and image browsing are typical examples of real-time applications, while downloading digitized movies and electronic mail belong to non-real-time applications. The examples given for real-time and non-real-time applications have been chosen to include both time-based and non-time-based information types (see Table I). In the case of image browsing for real-time applications, even though the image is itself non-time-based information, to ensure interactive response for the user, a maximum response time constraint is required to satisfy this application. On the other hand, for non-real-time applications like downloading a digitized movie, even though the information content is time-based, the entire movie can be treated as a single file transfer like electronic mail because the movie is not being displayed in real-time at the receiver. Therefore, the networking capability required to support application depends on both the information content and the delivery requirements of the application.

Delivery Requirement	Information type	
	Time-Based	Non-Time-Based
Real-Time	Video Conferencing	Distributive Computing Collaborative computing Interactive Browsing
Non-Real-Time	Downloading movie	Electronic mail

Table I. Examples of applications with various information types and delivery requirements.

I.3 APPLICATION REQUIREMENTS

The communications requirements of an application fall into three categories: bandwidth, delay and error. Bandwidth is the dominant requirement: if bandwidth is insufficient, delay and error may be introduced, which then must be addressed by the network to assure the quality of service for the application. (Error, it should be noted, can be introduced independent of the adequacy of bandwidth). The following discussion of these requirements on bandwidth delay error needs further investigation.

Bandwidth - The bandwidth requirement of an application is determined by one of two methods, depending on its information types and delivery requirements (see Table III).

For a real-time application that generates time-based information, the bandwidth requirement is equal to its natural traffic generation rate. The natural traffic generation rate is simply the amount of information generated by the application per unit time. Such bandwdth requirement may be constant or variable, referred to as constant bit rate or variable bit rate applications, respectively. Constant bit rate applications include traditional PCM coding of voice that generates 64 Kbit/s, and common video conferencing system requiring 2 * 56 Kbit/s. However, a lot of these traditional constant bit rate applications are intrinsically variable bit rate. For example, voice itself is variable bit rate intrinsically, because voice can be sampled only when someone is talking and nothing needs to be sent otherwise. Similarly, video information needs to be sent only for the changes in image content, thus video compression algorithms intrinsically generates variable bit traffic. The reason these applications, which are intrinsically variable bit rate, are encoded as constant bit rate applications is that current networks are primarily circuit switched based, which support only fixed bit rate connections. Thus, today, applications are encoded to satisfy the constraint of existing networks, while a more ideal case should be networks designed based on supporting current and future applications with diverse requirements.

Delivery Requirements	Information Types	
	Time-Based	Non-Time-Based
Real-time	Traffic Generation Rate	Response Time & Information Volume
Non-Real-Time	Response Time & Info. Volume	Response Time & Information Volume

Table III Factors determining bandwidth requirements in point-to-point application

For all other applications, namely, either non-real-time applications, or applications sending non-time-based information, the bandwidth requirement is a function of the response time requirement (the total delay allowed before all the information are transferred) and the amount of information being communicated.

Obviously, to support any application satisfactorily, the bandwidth provided by the network should always exceed the bandwidth requirement of the applications. However, the bandwidth can be insufficient temporarily in the packet switched network, which is possible because the network bandwidth is shared with others using statistical multiplexing (a random process). Hence, network buffering is required to avoid dropping of information, which in turn introduces buffering delay. Moreover, if buffering is insufficient, then it may be necessary to drop information, a process which introduces error. Such delay and error introduced due to insufficient instantaneous bandwidth must be within the delay and error constraint of the applications to maintain the required quality of service. (This is discussed in more detail later.) Therefore, bandwidth must be guaranteed for an application not only to satisfy its bandwidth requirement, but also to limit the delay and error introduced that may exceed its delay and error constraints.

Hence, to maintain the quality of an application in a packet switched network, the network protocol should be designed to first require each new application to negotiate with the network for available bandwidth before a connection be setup by the network (to guarantee that the new application will not need more bandwidth than is available for the existing applications being supported). Second, the protocol can guarantee the bandwidth for the new application once it is accepted by the network. This implies two criteria for the protocol: it is connection-oriented and reservation-based.

It is also important to note that traditional data networks (such as ethernets, the Internet, token rings), though based on packet switched methodology, have no notion of bandwidth. Applications cannot request a particular bandwidth, because no bandwidth reservation schemes were implemented. Therefore, these networks cannot guarantee any quality of service and are not suitable for supporting many interesting multimedia applications that involves real-time applications carrying time-based information.

Bandwidth requirements for Wireless Networks

In the (single hop) wireless network (with or without a base station), all the users on the network share access to that medium, and each packet sent by any user is automatically broadcast to everybody. This has two implications: an advantage and a disadvantage. First, the bandwidth resources consumed in multicast or broadcast connection is the same as that for point-to-point connection, because every user automatically receives all packets sent out by any user (and discards those packets not addressed to itself). Second, the bandwidth cost of a two way connection is the sum of the two one-way connections, because each party of the two-wy connection needs to consume the bandwidth from the same available medium. Therefore, the

total bandwidth requirement on a wireless network depends on, in addition to the delivery requirement and information types of the applications, the number of users on the network, the number of parties involved in each application (point-to-point vs multipoint) as well as the connection types of each application (i.e., whether it is symmetric or asymmetric).

To determine the network bandwidth required in each scenario, it is useful to find the bandwidth requirements of a set of basic point-to-point one-way applications that comprise the various information types and delivery requirements. The total network bandwidth requirement is equal to the sum of various combination of these basic application depending on the number of users as well as the different attributes of the applications. Such basic application are shown in Table IV. Note that, however, the bandwidth requirement derived from response time is a peak bandwidth requirement, and the duration of such requirement is a function of the total amount of information to be transferred. The bandwidth requirements of each of these applications are shown in Table V.

Delivery Requirements	Information Types	
	Time-based	Non-time-based
Real-Time	Video, Audio communication	Fast image Transfer
Non-real-time	Movie File Transfer	Slow Image Transfer

Table IV: The basic applications for which the bandwidth requirements are determined

TIME-BASED INFORMATION WITH REAL-TIME DELIVERY

Video	**Uncompressed**	**Compressed**
Videoconference	9/36Mpbs	p * 64 Kbps (H.261)
NTSC	appx. 200Mbps	1.5 Mbps (MPEG)
HDTV	appx. 1 Gbps	20 Mbps
Audio		
Voice telephony	64 Kbps	16 Kbps
CD Quality Stereo	1.4 Mbps (2 * 706 Kbps)	256 Kbps (MPEG) (2 * 128 Kbps)

TIME-BASED INFORMATION WITH NON-REAL-TIME DELIVERY

Video (2 hours)	**Compressed Movie Size**	**Peak Bandwidth**	
Delivery Time		15 min 1	8 hrs 2
NTSC	1.35 Gbytes	12 Mbps	0.375 Mbps
HDTV	18 Gbytes	160 Mpbs	5 Mbps

REAL-TIME AND NON-REAL-TIME DELIVERY OF NONTIME-BASED APPLICATIONS

Images	**Uncompressed** Mbytes	**Compressed (JPEG)** Mbytes	**Peak Bandwidth**	
Response Time			0.1 sec	10 mins
Photo: 3 1K * 1K * 24 bit	3	0.06 - 03 (Lossy)	4.8 - 24 Mbps	8 - 40 Kbs
X-Ray: 2K * 2K * 12 bit	6	3 (Lossless)	240 Mbps	0.4 Mbps

TABLE V Bandwidth requirements in point-to-point one way application.

Table notes: 1) Less than the typical time required to go to local video store. 2) Overnight delivery. 3) Photo size, resolution and color depth varies.

Delay - The issue of network delay in a packet switched network arises from insufficient instantaneous network bandwidth. If bandwidth is insufficient in any parts of the networks, buffering is required (unless information is allowed to be dropped), a process which then introduced a random amount of the delay to the information being delivered.

For real-time delivery of time-based information, the delay requirements are absolute delay and delay jitter constraints. The absolute delay is important for real-time communication like video conferencing or conventional telephone conversation because feedback is expected within a certain time period for natural conversation to take place. The delay jitter is the variance of absolute delay incurred from packet to packet for the same information stream. If the bandwidth requirement is always satisfied by the network, then no jitter would occur in the delivery. The delay jitter must be constrained for time-based information because they must be presented at a certain rate for natural consumption by the user. The jitter constraint can be determined by the interval between consecutive samples of the time-based information when it is generated, because a sample is supposed to be displayed at the receiver after each of such interval. For example 30 frames/sec video can allow a delay jitter of 33 msec, while tradition 8 Khz voice telephony can allow a 125 usec delay jitter. However, if the absolute delay constraint is large compared to delay jitter constraint, for example, if 10 sec absolute delay can be allowed for video (such as video on demand), video frames can be buffered for a period of 10 sec to provide more flexibility for network delay jitter incurred (jitter allowed is increased to 10 sec from 33 msec), assuming there is sufficient buffer at the receiver for removing jitter.

For non-timed based information or non-real-time delivery of time based information, the major delay requirement is the absolute delay, which must be less than the response time required by the application.

Again, in traditional dat networks, there is no guarantee in both absolute delay or delay jitter constraints, because the protocol in these networks had been designed to guarantee delay. Furthermore, data integrity has been of much higher priority than delay requirements in these networks. Hence, in order to ensure no error in dat transfer, their protocols have been designed to retransmit data detected with error, thus introducing more delay. Therefore, applications with either delay or response time constraints cannot be supported satisfactorily in these networks.

Error - Packet switching, because of its statistical nature in multiplexing and switching, can introduce a random amount of the delay when the instantaneous bandwidth is not available at parts of the network and the information needs to be stored temporarily in buffers. Two types of error may occur from this process. First, buffer may be insufficient and information needs to be discarded. Retransmission of such information is useful only when application is not a real-time application carrying time-based informations. Second, in the case of real-time application carrying time-based information, the delay introduced by buffering this information may exceed the delay jitter constraint, which will make that piece of information useless even when it finally arrives at the receiver (which makes retransmission futile); this is equivalent to the piece of information being dropped because of buffer overflow, i.e., leading to additional error.

In the wireless environment, an additional source of error arises from the unreliable communication channels, due to noise and unfavorable propagation conditions.

Finally, the above discussion of these requirements on bandwidth, delay and error needs further investigation (especially the latter two)".