Tentative Minutes of the IEEE 802.11 MAC AdHoc committee

Ft. Lauderdale,Florida
November 12-13, 1991

Tuesday, November 12, 1991

Nominations for Chair were opened.

Robert Crowder, SHIP STAR Associates, was nominated by J Cheah, seconded by W. Stevens.
J Cheah moved to close the nomination. The vote was 16Y, 0N, 0A

Chairman Crowder solicited proposals on how and what the committee would work on.

Major Topics suggested:

1) Access method (proposed by J Cheah)
2) PHY-MAC interface (Marvin Sojka)
3) Exported MAC services (to upper layers) (K Biba)
   clarification - what sort of primitives must be defined? and what services theyoffer?
4) What's the output of this ad hoc meeting? (B Stevens)
5) What is the architecture(s)-we will entertain more than one? (Nathan Silverman)
6) Routing issues - may not belong in this group, but needs to be addressed. (S. Deering)

J. Cheah adds that all issues should be put on the table.

B Crowder: Are these topics for THIS meeting, or for the ongoing work of (this) group?

K Biba argues that the first 3 (ok, 4) will be enough to make substantial progress.
B Crowder Proposes that (4) become (0) (set objectives for this meeting), then only consider 1-3 during THIS meeting.
*Nathan Silverman*objects if this carries forward to future meetings, but would not object for THIS meeting.
No objections raised.
K Biba proposes order 3-1-2.(actually, 0-3-1-2)
No objections to this ordering.
From this point forward, items are "renumbered".

Item 0 - discussion

B Stevens: We should have an output document giving "conclusions" for each topic dis
cussed.
K Biba: We should scope out (narrow) range of possibilities.
Chandos Rypinski:: A "summary" of MAC proposals to-date, and develop classifications if possible.
J Cheah: We also need a table comparing and contrasting those proposals on the table.
B Crowder: We won't be able to get a "quality" judgment out of this group
K Biba: we would be well served if we could at least develop the criteria by which we canmake such pro/con judgments.
B Rosenbaum: Would like to see a list of action items developed.
B Crowder: I assert that all (but output and action items) are in the aggregate, the
Objective of evaluating proposed MACs.

I EXPORTED MAC SERVICES
1) 48-bit addresses - general agreement that this is required.
2) Minimum/maximum packet sizes: max may be larger than 1500 octets. Minimum???
3) Decision made to defer discussion of packet sizes until reference documentation is obtained. [ISO 10039, IEEE Functional Requirements]

II ACCESS METHOD

Scope

J Cheah: there are only 3 basic access methods on the table:

1) CSMA-based method
1.1 Ken Biba's flavor: "I have a range of flavors. There's a generic range of LBT protocols
2) Improved Contention Method (C.Rypinski's)
3) SALHODAMA

J.Cheah: moves that we strike "CSMA" and replace with "LBT" (no vote, just accepted)
J. Cheah: Does anyone actually advocate CSMA?
R.Buaas: CSMA should be included at least for reference.
Chair: Does anybody object to including CSMA "for reference only?"
K Biba: It's useful to go over "history", but let's concentrate on proposals that have advocates.
J Cheah: The job at hand is "what we have", not diverge into non-relevant
QUESTION:CSMA for reference:failed

*Biba:*Let's call it "enhanced LBT with acknowledgement" , with "valid data" (not just energy).
"It's some method that's not just "enhanced noise floor"
"Valid Data" proposed -
N.Silverman wants more precise (valid information) definition.
Crowder: If you look at modems in the industrial sector, it's common to find a "valid data" signal on the modems. Collisions might or might not appear as valid data.

1.2 Enhanced LBT with Acknowledgements (immediate MSDU ACK within MAC layer)

S Deering: there are a number of proposals with RTS/CTS/ACK structuring.

1.3 Distributed Channel Reservation protocol : "a three way handshake" LBT (RTS/CTS/DATA/ACK)
distributes "channel busy" information by both transmitter and receiver.

1.4 DCR with immediate MAC-layer ACK

Everyone is ready to go to category 2.

2: Time Division Slotted

2.1 Slotted Time Division Access with Frame Synchronization (Cheah)

2.2 Slotted Time Division Access without Frme Synchronization (Cheah)

3: Time Division Unslotted Centralized Control with Available Autonomous Operation
The essence is that things asynchronously - the next thing happens when the previous thing ends. The change is triggered by infrastructure. It IS a centralized system, but it has the option of peer to peer in presence of central controller, and an option of peer to peer in absence of central controller. (C.Rypinski)

(debate over K.Natarajan's proposal - trying to classify it).

K. Biba says that both C.Rypinski and K.Natarajan have a "framed" time division system, but not a "slotted" system.
B. Crowder calls it "irregular slots".

C.Rypinski's renumbered to 2.3 (from 3)

K.Natarajan describes his proposal: Contention-based and contention-free based access- a hybrid of reservation and random access. (the boundary between contention and non-contention may be moved). This is adaptive and dynamic. The balance may be readjusted at any time.

3.0 time Slotted with adaptive reservations and contentions

J. Cheah and C.Rypinski agree that this classification is inconsequential in the end.

K. Biba reluctantly brings up his "connection oriented extensions".

1.5) DCR with allocated bandwidth. (Biba's synchronous extension)

Channelization discussion...

4.0 - FUTURE Proposals

Is there anyone who objects to stopping proposal of additional MACs at this time? No.

Break

Crowder recognizes a motion to identify important comparison criteria.

Relationships of documents to MAC classes:
Doc 91-92: classes 1.1-1.5
Simulation results largely apply to 1.2 and a little bit to 1.5
Document 91-111 class 2.1
Document 91-54 class 2.2
Document 91-122 class 1.4
Document 91-19, 91-95, 91-80 class 2.3
Document 91-74, 91-102 class 3.0
No documents for class 4 (future MACs)

Discussion led to consensus to move forward to identify important comparison criteria.
The list of important MAC comparison criteria in 91/138A was agreed to by a vote of 27-0-0.

There was considerable discussion about interoperability of each proposal with other 802 LANs and bridges. It was observed that all 802 LAN standards are required to be interoperable. Therefore, this is irrelevant as a comparison criterion among the proposals)
It was also pointed out by K. Biba that there is an intimate relationship between bridging and "roaming stations", which will require profound consideration and discussion.

Wednesday, November 13, 8:40am

Crowder proposes that we need to "classify" the various proposals so that we can "codify" the spectrum of possibilities.

C.Rypinski: In my contribution this meeting, I attempt to list "generic characteristics".
I would like to grapple with the "functions", and not worry with what "name" they are commonly known by (e.g. CSMA). Ultimately, we hope to get a list of generic functions, from which we can narrow down from this list toward convergence.

S Deering: Isn't this what we spent all yesterday doing? I would hope we get on into the task of the "reduction" from many possibilities to few, with some "horse-trading" as necessary.

C.Rypinski: ... there are so many constraints ... the range of possibilities is somewhat limited. Amazed that nobody is advocating CSMA.

Discussion proceeded to say "yes, nobody is proposing 802.3". There was some exchange as to what exactly is meant "802.3" or "CSMA".

J. Cheah: We have pondered the problem of PHY and MAC for over 3 years, and the demise of a working group (802.4L) due to total impasse. Those who feel "impatient", in the few days they have attended (new participants)-- hopefully we are moving toward a point of convergence - it would be very encouraging to see movement toward convergence.

C.Rypinski: I would like to present the points at the beginning of my contribution, and see if there is general agreement or disagreement.

Crowder: (time is of the essence) I think each proposer should present for about 15 minutes (only), and then about 45 minutes of evaluation, based on a list of functions. We could also see all presentations.

There was a general discussion of today's "process". It was agreed that all presentations will be made first, then discussion.

Crowder: Each presenter gets to present one and only one proposal (i.e. those with multiple proposals must select one and only one from their total)

Ken Biba presentation:

An evolved class of "Listen before talk" class of protocols.

Assumptions:
1)Uncontrolled propagation environment (can't be predicted in advance, e.g. stations may move, etc.)
2)Must be "plug and play" (very easy to install and operate). Wants to be able to mail-order purchase, plug it in, and use it without hassle or engineering support. Needs to be "terribly robust", even at the expense of throughput.
3)MAC-to-MAC transfer delay, for datagrams, at nominal load. Most network managers run their networks at about 20% load to allow for occasional peaks. If you look at typical implementations, you will see that they exhibit low delay (on the order of disk access rotational delay)(sub-10ms)
4) History:Wired LANs came out of wireless networks (e.g. packet radio). There is a rich history of LBT protocols for wireless networking. Much experience exists due to this history.

Generic Architecture:
Assume that we have a "space of stations". Connectivity is not a full mesh, and it is likely to be time-variant. Furthermore, we may find divisions. For example, the "dentist's office" may overlap with the "doctor's office", which may overlap with the "twin tower" next door. Due to the "mail-orderable" product delivery, there is no way to predict topology. Graceful degradation in such complex environments is mandatory.
Must be able to scale into the existing enterprise networks.... (roughly 50/50 ethernet/token ring)
Would like to be able to install a few nodes, add attachment to backbone, ...

Ken did some focus groups:
Full time network managers (larger networks).
Part time network managers (small networks)
Large network users: performance, reliability, security concerns
Small network users: what does it cost?

Protocol:

Based on a variation of Localtalk: Proposed for ham radio by Phil Karn.
Each packet action is a four-way message exchange: RTS/CTS/DATA/ACK

```
RTS  -->
     <-- CTS
DATA -->
     <-- ACK
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The RTS and CTS messages serve to inform nearby stations that the channel is being acquired, reducing "hidden" and "exposed" station difficulties. In effect, the RTS/CTS exchange "clears the band" in the vicinity of both sender and receiver.

Peer-to-peer between any two nodes which can hear each other. The RTS/CTS guarantees that sender and receiver can hear each other before consuming bandwidth for data.

Extension: there exist access points which can be optionally added to a backbone to enable range extension (to enable peer-to-peer beyond their common ranges) and to allow access between wired and

wireless stations. I assert that we can interwork with existing spanning tree and source routing methodologies.

Performance: I did simulations to model operation under realistic environment scenarios, including:

Incomplete connectivity
Errors on the channel
Adjacent networks

(graph drawn of applied load vs. throughput)
(at load = 1.0, throughput approaches 90% for a very clean channel. Errors cause throughput to drop rapidly)

Did a comparison of LBT vs. TDMA structuring, particularly to look at tradeoffs. (time called)

J.Cheah Presentation:

The protocol presented is used in most of VSAT implementations. Well understood, though not in LAN environment.
Analogy: If you come to a crossroad in the countryside, you just go through (aloha)
Crossroad in town, you use stop signs (csma).
In the city, you need traffic lights (??).

Basic premises:
1. PHY needs many symbols before synced
2. All nodes within propagation distance can listen to everybody else.
3. Packet loss rate/BER varies widely so self adjustment should be possible to suit environment.
4. High reliability nodes can be designed without penalizing low cost one.
5. PN code with good properties are very low yield in asynchronous mode.
6. Access point & node has the same hardware
7. Automatic redundancy.
8. Automatic Network Access Authentication

Suggest Barker code approach. There are no Barker codes longer than 13 bits.

Peer-peer
1. Listen for ticks
2. (no ticks); generate ticks; self-assign; tx
3. Stop ticks.

Node to Access point
1. listen for ticks
2. aloha; wait for assignment
3. use assignment

Node to backbone
EBSA operation
1. same as above

Node roaming:
1. terminate on low signal
2. restart on new

Conclusions:
1. throughput
a) throughput is only indirect affected by adjacent network in terms of noise floor
b) throughput is directly controlled by the generating source transparent to nodes
c) throughput efficiency is the theoretical maximum for all access methods with fixed access delay probability.
2. Reliability
a) Uncoordinated redundancy protection
3.It does not degrade the network by repeating unsuccessful packets when the receiver is not there.

4. Ease of producing PHY layer . No need to search for low yield/high performance codes. Simplicity in hardware (due to use of Barker code).

Chandos Rypinski's Presentation;

First - fundamental philosophies. I believe in Erlang C blocking. This means a user requests a channel. If he is blocked, his request is queued. The queue may be sequential or random. If the message length is on the order of millisecond or so, it is unlikely that you will have to wait longer than this in most cases. A queue controller can give 80-90% channel utilization.
One way is to have a "setup channel".
C.Rypinski observes that the RTS/CTS of Biba's proposal is philosophically very close to his,(however C.Rypinski's protocol would have a "permission to RTS" from a controller, to improve high capacity performance.
I call this system "message based".
Tables of the message sets for access point and station is displayed.

Bridgability:
There are a couple of ways the radio system can be configured. (shows Backbone-hub and bridge/radio mac chart).If you choose to use any 802.x backbone to span multiple access points, you make "roving" of stations from one access point to another into a "routing event", would prefer to make it a "non-routing event".

My view is that you have to solve the high capacity problem first, and then the low capacity problem is a subset.

If you are to use time efficiently, it must be organized. "Organized" will always be more efficient than "random".

An architecture chart is shown.
Any bridging into another LAN occurs at the "hub controller". Any anomalies of the radio environment can be "cleaned up" at this hub. Movement of stations from access point to access point has no "routing significance".

This is particularly applicable to the extreme capacity situation. There's a difference of opinion between J.Cheah and me. His plan - bit clock is pre-acquired. In my case, it's acquired burst-by-burst.

I have trouble with efficiency. If you are using a CSMA system,(presents frequency reuse chart, showing 4, 9, 16, and 25 channels).We're talking "microseconds" between access opportunities. Given maximum length packets, access delay could go up to 2-3 ms. I support, within capacity constraints, anything that ISDN can do.

Summary
1) uses a single (radio) channel
2) uses the "bitstream and clock" to achieve all functions
3) absolute control of overlap (via hub control)
4) messages are all header-payload format
5) maximum size and segmentation required
6) all fields in headers are those required to do the job.

A pictorial diagram is shown of a "typical system", and then discusses "antenna" issues (i.e. laptops with whip antennas are going to perform poorly).

K.S. Natarajan Presentation

-Slow frequency hopping
-communication:
-mobiles and servers on DS
-between mobiles (direct and indirect)
-ad hoc
-Half duplex radio link
-Isochronous and asynchronous services

-Hybrid MAC
-contention-free (reservation)
-contention-based
-adaptive boundary

Frequency hopping: a "hop" is a "frame".
A frame is divided into three periods:
-outbound (a.p. to mobile, contention-free)
-inbound (mobile to a.p. contention-free)
-contention-based
Boundary between contention-free and contention-based is variable and adaptive
A- Broadcast/Multicast or Directed (battery saving, see #102)
B- Allocated Inbound
-registration requests (mobile users)
Hopping considerations
-can isolate cells with choice of hopping patterns
Handoff - with loose synchronization of A.P.s
Observation: good channel utilization under heavy load. Short access time under light load.
"Simple" implementation

This concluded the presentations.

--Questions for Clarification--

Steve Deering: to C.Rypinski--When you put up your wiring layout diagrams. You seem to imply that some property of that distinguishes your proposal from K Biba's. What is that?

C.Rypinski: In my case, the wiring in between each access point and the hub controller carries the traffic only for that access point. The "hub" is essentially a backplane with "high bandwidth". the transfer of "parallel" information among a number of access points provides high capacity vis-a-vis non-infrastructured alternatives.

Deering: One view is that the hub is just a "multiport bridge". C.rypinski agrees. In fact, the equipment which interfaces with the radio access ports may be sharable (time sharing controller with radios)

A fundamental question that I ask you to consider is : if a message is received at more than one access point, is this an asset or a liability?

N. Silverman: Throughput - how will it quantified and compared?

*C.Rypinski:*wrt MAC, the best you can do is optimize the usage of the "media time".

Criteria:
1. Impact of unauthorized network access on throughput

It is suggested that "interference from adjacent networks" is the criteria.

J. Cheah suggests that CSMA will surely collapse in this regard. *Ken Biba* disagrees. For instance, give "synchronized adjacent frequency hopping networks" would not exhibit this effect.

C.Rypinski: the effect of numerous anomalies in the medium is characterized as the absence of valid data. The MAC has to process the meaning of any valid data and do something appropriate. Two forms of "hostility". Microwave ovens for instance, just screws up the medium. Intentional hostilities (i.e. the "hacker") is the second case. Sufficient security is that the management of the network has to have a criteria for determining who is authorized to operate on this network.

LBT - In the case where a single channel is shared with adjacent networks, access authorization limits effects of "hostile" signals. Second, adjacent networks will gracefully share the medium to the degree that this is possible (natural consequence of RTS/CTS scheme).

J. Cheah: DAMA - Demand Assigned Multiple Access (official term). By nature of DAMA, "tamper-

ing" is avoided because the protocol explicitly assigns bandwidth. Registration function required to effect this tamper resistance.

K.Biba: LBT also needs registration to resist tampering.

J. Cheah: To allow uncoordinated collocated operation, you need to implement some form of "orthogonality". This is effected by choice of codes.

Marvin Sojka: How does the system "tie together" in the presence of multiple channels and/or codes?

J. Cheah: Rejection depends on frequency or code discrimination. Absence of some discriminator would mean that DAMA could not reject inadvertent "jamming" from collocated stations.

J.Grau: The definition of a "channel" is important here. Some of us feel that a "code" is a channel, though other definitions are held as well.

S Deering: I observe that if any of these schemes (codes) provide orthogonality....

(much active discussion of uncoordinated collocated environment)

J. Cheah's scheme fundamentally depends on the presence of a single access point "time reference".

In response to a question, *J.Cheah* asserts that in the presence of multiple collocated uncoordinated networks, all of them will synchronize their "tick marks".

Question: K.Baba's system has a segmentation of networks by network ID. Multiple networks share medium. ?????: I'm not sure about J. Cheah's "tick marks". Are they coded differently per access point? *J. Cheah*: no - there is only one type of "tick mark". The code is synchronous - you can use Gold code, at least. The code will be assigned (from) a code table at network initiation. I suggest a simple (H???mar) code, from a total set of 100 codes, using a subset table of about 5 codes.

B. Rosenbaum: I'm sensing some confusion here. I understand that your (Cheah's) approach uses two codes: a Barker code for synchronization, and another code for DS coding. Who sends out the Barker (sync) code? It seems that everyone assumes that an "access point" sends out the "ticks (sync code)".

J. Cheah: All stations come up and listen for a tick. the first station to send a tick "primes the pump". Then, the code table is used to listen to the network. If it's an access point, (assumption: unlimited power available) it can serve as the "reference" for the "network".

"all stations within earshot will synchronize"

B.Rosenbaum proposes the classic "hidden terminal" problem with two "tick generators" which are hidden from each other, and a common station which hears both generators.

Scenario:

Beginning of Universe. The first Tick Generator comes up in the primordial ether. A second TG comes up which is mutually hidden with the first. Station comes up, hearing .....

WAIT - let's look at how we're using our time today. We've spent 45 minutes of 90 minutes on criteria 1, with no end in sight.

Crowder doesn't want to interrupt the flow because he feels that the technical depth is better than ever seen before in 802.11 history.

How does C.Rypinski's system handle this?

Network definition administratively declares network domains (in naming space, not geographic space). C.Rypinski recognizes adjacent networks, but not overlapping networks.

Basically the whole system doesn't allow a station to transmit until a clear set of hurdles are cleared (registration, permission grant, ack).

C.Rypinski observes that some confusion between his and J. Cheah's approach is due to the fact that some of Jonathan's "discrimination" is PHY-based, while C.Rypinski's system discriminates strictly at the message level.

C.Rypinski adopts the acronym SAM (serial asynchronous multiple access)

More discussion about how does SAM perform at the "geographic boundaries" of adjacent LANs.

Marvin Sojka observes that all systems except LBT consume bandwidth to organize the LAN, which looks like interference to adjacent LANs. For LBT, this is essentially a "non-issue", since there is no sense of a "master" point of control (of course the performance implications still exist).

Much discussion and brainstorming over how DAMA performs in the hidden terminal environment, particularly the issues wrt multiple tick generators.

B. Stevens: let's assume an arbitrary "channel", call it "C". Multiple codes (i.e. DS) are a multiplier of "C" i.e. kC. Let's deal only with the case of k=1.

J. Cheah: I will agree with that.

Dale Buchholz: I hear three separate threads being discussed here:

a. slotted aloha when everything's synced
b. If nothing is lined up, it's no worse than LBT
c. ??

J. Cheah describes the "enormous" (e.g. 2 mi diameter) network with "tiny" (e.g. 2 ft.) station-to-station distance (pathological case),
the "end-to-end" tick slip will be significant.

N.Silverman asks for clarification of what a "channel" is. There are domains of frequency, code, spatial, time (sync), time (multiple access) (and more?). Carry this question into discussion with PHY group.

C.Rypinski's system does not include inter-network synchronization. The correlation is 1:1 between network and [hub] controller.

In the example of two geographically adjacent SAM systems, at the boundaries, there will be a non-deterministic "jamming", which may be described as ALOHA in nature. (not necessarily agreed).

A point of detail was raised by Crowder that K Biba's proposal claims to be totally distributed control, however, when considering the synchronous service "enhancement", there is an implication of a "point of control" for synchronous access management. Ken responds (pictorially) that this will be the role of "access points" (implying a static geographic network layout). The access points send out "beacons" (which do not use the RTS/CTS/DATA/ACK structure) to offer "synchronization" to the stations.

S.Deering notes that Localtalk handles broadcast by sending out an RTS, delaying for the time that a CTS (if present) would occupy, and then sends the broadcast datagram without requiring a CTS. *K Biba* agrees that this is close to LBT behavior.

Registration of stations in LBT network is probably accomplished via a public key system which provides a straightforward "plug and play" installation and operation. Ken has not fleshed out this concept but is comfortable that this is reasonable.

Registration accomplishes a "virtual connection" between a mobile station and the "fixed backbone" which thereafter provides the mechanism for bridging this mobile station's traffic into the backbone.

A discussion was raised regarding clarification between the definition of the ESA and 802.1 bridges. Are they the same? Do they [and how] overlap? Is this an architecture question? Question for PHY group.

Adjourned at 12:30

Question:What does this group do following the conclusion of this session?

Motion: K Biba moves that we continue the MAC group in ad hoc fashion
vote: 27-2-1 motion passes

Proposed: Future 802.11 meetings include 1.5 days in MAC ad hoc, plus 0.5 days in MAC plus PHY ad hoc.

Don Loughery,802 Chair: warns against comparing one proposal against another. Instead, we should first adopt a Functional Requirements document and use it as the reference for comparison. This allows a "winner" to emerge. Pitting one against another generates "losers." Watch out.
You need to establish your "target". I'm willing to allow the need for a BRIEF, expose period. But absolutely avoid "no, you can't do that!"

Jim Schuessler: We HAVE the list of criteria. What we DON'T have is an idea of the relative values of the various criteria.

J. Cheah: Let's go off and let each presentor develop a response paper to the "21 questions" list (off-line) in time for availability at January meeting. For the rest of this meeting, let's work on the functional requirements.

B. Crowder: I feel very strongly that each presentor must present ONE proposal, and that all its aspects and features are always included in its discussion. Optional features complicate the understanding of a proposal in that they tend to "pop in and out".

S.Deering: We have a problem of "what does complete mean?" (in the absence of established functional requirements)

Rifaat: Can we agree to recommend to take time at the next meeting to finalize requirements, THEN continue work in the ad hoc group?

A. Flatman: Isn't it premature to plan the activity of an ad hoc group before it is determined that it will even exist?

Rifaat: Propose: Tuesday morning to finalize requirements and update list of 21 criteria. Next full day for MAC ad hoc, next .5 day for joint MAC/PHY.

K Biba: Requirements MUST be available BEFORE any DECISIONS can be made wrt one proposal or another. In addition, ongoing TUTORIALS must continue to further illuminate the issues.

Proposal for MAC ad hoc (expose):
1 hour for presentation with interactivity
2 hours for open discussion

NOTE: from 802.11 WG meeting on November 14, 1991

The continued existance of the MAC and PHY AdHoc groups and the continuation of their Chair's was approved. The plan above was agreed for the Chapel Hill meeting.

MAC Comparison Criteria

The following list of important MAC comparison criteria was agreed to by a vote of 27-0-0.

1. Unauthorized network access impact on throughput.
2. Ability to establish Peer-to-peer conectivity without prior connection eg. without "knowledge of the presence of your peers"
3. Issues of throughput,
4. Delay characteristics
    a. MAC to MAC delay: includes Access Delay (latency) & any ACK in the MAC layers
    b. Propogation Delay
    c. Transfer Delay for datagram traffic
        1. Nominal load
        2. High load
    d. Stability at Overload
    e. MAC Setup Delay (connection oriented services or Streams)
5. Maximum number of stations
6. Ability to service various traffic, including data/voice/video
7. Support of multiple PHYs transparently
8. Robustness in the presence of co-site dissimilar networks.
9. Power consumption
10. Area coverage implications of MAC timing constraints
11. Fairness of access
12. MAC facilitation of "access fairness" (insensitivity to near/far bias)
13. Support for different traffic priorities
14. Robustness in the presence of non-recriprocal wireless medium.
15. Time-to-market vis-a-vis implementation complexity
16. Same MAC must work in a minimum system and a maximum system (network size independence)
16.1 Interoperability of "low cost" & "reliable" MAC
17. (retired [Nathan's] number)
18. The ability to support handoff between service areas - aka ROAMING
19. Implications on the complexity of the PHY
20. Broadcast/multicast reliability
21. Preservation of time ordering of SDU to end systems (this is a requirement of LLC)