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802 LAN Access Method for Wireless Physical Medium

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TITLE: **COMPARISON AND COMMONALITIES OF ASYNCHRONOUS SEQUENTIAL ACCESS AND ADAPTIVELY PARTITIONED PERIODIC FRAME MAC PROPOSALS**

SUMMARY

Two series of contributions on MAC have been presented to 802.11 which are now characterized as:

1. Adaptively-partitioned periodic frame (APF), and.
2. Asynchronous sequential access (ASA)

The two plans are quite similar in objectives and asserted functionalities but differ considerably in certain aspects of implementation.

The case for preference of the asynchronous access is presented. The time organization of a frame structure is unnecessary for a future capacity reservation which in any event only need be known to an intelligent controller. There is a strong possibility that the organization of functions by frame time rather than by transaction/transfer will cause avoidable delays and decreased reliability from undefined states between time separated but related events. The use of a slotted fixed length frame inevitably fragments the unused time space resulting in capacity loss.

This conclusion is believed to be generic with respect to regularly periodic frames with allocated slots and partitions for various functions. For comparison, the design presented by K. Natarajan was chosen as a representative of the slotted frame class because it is more carefully designed and completely described than other like proposals.

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COMPARISON AND COMMONALITIES OF ASYNCHRONOUS SEQUENTIAL ACCESS AND ADAPTIVELY-PARTITIONED PERIODIC FRAME MAC PROPOSALS

OVERVIEW OF COMPARED PLANS

Two series of contributions on MAC have been presented to 802.11

1. One of the plans using a regular periodic frame adaptively partitioned between uplink, downlink and random access services was first presented by K. S. Natarajan,[1] and later dimensioned and quantitatively analyzed by R. O. LaMaire.[2] This well described plan is taken as representative of a class.
2. A single channel MAC asynchronously but sequentially used for sharing and for avoidance of cochannel interference proposed by C. A. Rypinski[3 4] in 1991.

The two plans are quite similar in objectives and functionalities but differ in implementation. Both plans have in common contention on request, exclusivity of channel use for all subsequent transfers, division of packets into shorter segments for transmission, and provisions for retransmission of failed segment transfers. While detail changes and improvements have been made in both plans since the cited references, the principles involved appear to have remained constant. The two plans are compared in Table I below.

It will be asserted that "asynchronous sequential access" is a better choice relative to this and all other plans using uniformly periodic frames with regular time slots.

TABLE I -- TWO ACCESS METHODS

In the "**adaptively-partitioned periodic frame (APF)**" MAC functions are sorted by time as defined by frame structure including slots for requests, data inbound, data outbound and subframe headers. The steps of one transaction appear at assigned positions within the defined frame. These time positions are a secondary addressing system used in the header messages allocating them for use. There is contention possible on requests but not on subsequent steps.	In the "**asynchronous sequential access (ASA)**" plan there is one radio channel only operated at the highest rate feasible within the allocated bandwidth. MAC function grouping is immediately sequential for each transaction or transfer (in other MACs described as a 5-step-handshake). Each new transaction can begin as soon as the preceding transaction is completed. There is contention possible on requests but not on subsequent steps.
This MAC is first applied to a frequency hopping PHY where any one hopping pattern appears as a single clear channel. Current descriptions consider each hop pattern as an autonomous and independent system No provision of this MAC so far deals with interworking on different channels.	The frequency reuse problem is addressed by non-simultaneous operation of potentially interfering stations/access points within one cluster. The station is not required to change channels or patterns in any circumstance. Capacity may be moved adaptively between sites.
The maximum transfer rate is 1/Nth of the possible transfer rate in the total allocation where N is the number of hopping frequencies (N = 75 typical).	The peak transfer rate is that of the allocation. The maximum average rate of one access-point is 1/Nth of the peak rate where N is the frequency reuse factor (N = 4 assumed).

COMPARATIVE CONSIDERATIONS

Discussion of comparative factors is organized into the following categories:

a) Listing of commonalities

b) Discussion of points of difference

c) Normalization

d) Selected performance criteria

e) Implementation feasibility

Common Functions

* Both plans transfer most of the data in reserved space with no possibility of contention and a possibility of interference only from reuse of the channel in other nearby clusters.

* The following is from LeMaire,[2] and is equally true for ASA except for the slot widths.

"3. The protocol allows for robust performance in the presence of channel errors. In the proposed protocol, response messages are segmented into smaller packets (i.e., packets that are the length of an A or B slot.). When used with a Go-Back-N or a Selective Repeat error control protocol, the impact of channel errors can be reduced as compared with schemes that do not use message segmentation. The point here is that message segmentation is an inherent part of the proposed protocol. In some other protocols this is not the case."

The need for segmenting down to short payloads of 255 octets or less is also noted by E. Geiger.[5]

* Both plans have the possibility of contention on request for service, and both have detail means for making this event low probability and for resolving it when it does happen.

* Both plans require an intelligent central infrastructure function to administer the use of channel time. The APF frequency hopping PHY requires at least a common "metronome."

* Both plans broadcast instructions to stations on permitted use of channel time for requesting service and transferring of data. ("broadcast" means that all related stations receive the message whether they use it or not)

* Both plans consider that stations may be limited to one pending transaction at a time (closed-loop in LeMaire) or may parallel initiate multiple sessions (open-loop).

* Both plans assert compatibility and support for isochronous services, though this has not been explicitly described for APF.

* Both systems support peer-to-peer communication using infrastructure assistance when the direct path is available.

Differences

* The fundamental difference is in the organization of the use of channel time. In ASA, there is for stations a 5-step handshake consisting of messages with the functions:

AP:	Invitation	Grant	Ack
Station:	Request	Transfer	

ASA is organized by the transfer. APF is organized by message function within the frame.

Exactly the same steps are used. The invitation is announced in the header of the C subframe for response in one of the five 25 octet request slots which then may be used by the station. The grant is in the header of the B subframe which informs the station of the slots allocated in the B subframe for that transfer. APF may or may not include an ack placed in the immediately following C subframe header.

The minimum period of one transfer is the frame period for APF. In ASA it is the sum of the message lengths without interposed slot spaces.

APF must or should transport the same information in its fields as ASA does, but in addition the specifiers of the time slots used for the data transfer. The dimensions of this assignment is dependent on the level of simultaneous traffic and the descriptor of the traffic in the request message.

* Even with an adaptive boundary between up and down link frame space, fragmentation of unused channel time is inevitable in APF. In APF unused space accumulates in the multiple request slots and in the data slots where short transfers do not match the available slot width (LaMaire assumes fully loaded slots).

If the C interval must provide capacity for the peak load of unforecastable ad hoc groups, then the loss becomes much greater.

Avoidance of this loss is a primary goal of the asynchronous method in ASA. The next use begins when the previous use is completed. Multiple uses are sequential and not interleaved.

* The ASA plan makes registration (sign-on) and polling an integral part of resolving contention on request. At contention time, the possible contenders are known with a very high accuracy. A short poll will resolve the matter. Separate invitation messages are used for registration making improbable a request for an unknown station.

In the alternative, APF randomly distributes requests over 5 slots for possibly 20 stations, and then makes no explicit plan for resolving contention except backoff and try again one frame later.

Another plan uses dedicated seizure slots[6] for each user. Both of these plans allocate frame space for a function that is infrequently required.

* By avoiding interposed slot space between the request in the contention space and the header grant and occurrence of the allotted slot, two important problems can be avoided:

The access and transfer delay is reduced, and made more deterministic.

The number of improbable states that must be documented is reduced. An obscure but very important consideration is the feasibility of state diagrams. If one transaction has its parts separated by intervals during which changes in frame format could or should take place, this is difficult. In practice "system hangups" are often the result of unforeseen states between those that are expected.

* Also less obvious, is that useful repeat send depends upon prompt opportunity for resend. In ASA, it is possible to include a resend within the definition of one transaction, but with APF the earliest resend is one frame later. This would be unusable for resend of a connection-type service transfer.

Normalization

For numerical comparisons of different plans, it is desirable to normalize all of them to a common set of "givens" which might assume the following factors to be common:

1) Allocated frequency space: e.g., 83.5 MHz in the 2.45 GHz ISM band
2) Continuous area coverage from many access-points
3) Probability of failed and excessively delayed transfers

Design of a system plan should start from the potential of the frequency bandwidth allocated. A plan which does not provide for near 100% area coverage of a large premise is not adequate at the beginning.

For systems to be compared, they must have at least the same order of magnitude of reliability of transfer against Rayleigh fading, frequency hop contention, and other internal interference.

Systems offering the same ranges of services are easier to compare. It is hard to evaluate as one of several factors an omitted essential service.

Performance Criteria

The key output of a system performance analysis includes worst case and median delay. Confidence requires determinism. These values are very important to the provision of time-bounded services used by multimedia applications. Systems which cannot provide this kind of information are of diminished value.

It is interesting to note that such work was done in the context of putting voice on 802.5 token ring[7] and presented at the July 93 802 tutorial on multimedia applications. The analysis compared asynchronous and synchronous access, and concluded delays were lower with asynchronous access for reasons including many of those describe above.

All systems should be normalized to a criteria of gross Mbps/unit area for better or for worse.

Implementation Feasibility

One of the major choices that can be made to simplify MAC, is the avoidance of secondary addressing schemes. Channelization in any form creates a secondary address in which the ends must negotiate an agreement on which communication will take place. It also raises the probability of access to a station which is on an unknown channel. If addressing is used, then there must be a parallel plan to assure universal accessibility of stations.

When slots are used a further secondary addressing scheme is created. A difficulty arises when there is bandwidth on demand and wide bandwidth requires plural slots. To make a new high bandwidth assignment may require a reassignment of connections in other slots. This is a messy event to manage, and it is worse when the reconfiguration information takes more than one frame to transfer.

The minimum width for slots carrying management information is that necessary to send the whole information in one frame.

Other indices include the thickness of paper to describe it, and the minimized need for simulation as a way to specify performance.

Longevity

It is important to maximize the useful life of a standard. One way to shorten it is to build into the access methods decisions on traffic types and patterns, message lengths, priorities. It is likely that the agreed dimensions in any frame/slot structure will result on compromise decisions on some of these factors. In time conditions will change, and the protocol becomes increasingly inefficient held hostage by the installed base.

It is intended that the ASA protocol philosophy is as insulated from this type of difficulty as is possible.

ATM Compatibility

A further factor is ATM (asynchronous transfer mode) compatibility. It is apparent that many high traffic wired LAN systems are moving away from the shared bus to a switching hub. This is in part motivated by more capacity per user without changing the user transfer rate, and will be motivated in the future by a common communication medium for both connections and packets.

Such a shift is inevitable for wireless systems for at least the voice-data commonality. The wireless system is inherently a point-to-multipoint architecture where.each access point looks like a front end concentrator to a switch port provided that the radio system has minimally different transport characteristics.

Using a cell-like transmission molecule in the wireless system is a step in the direction of end-to-end ATM communication. This has been an objective for the ASA system from the beginning.

CONCLUSIONS

The asynchronous access method provides significant advantage relative adapatively-partitioned regular periodic frame structures because of the previously given reasons which are condensed and summarized as follows:

1) There is no fragmentation of unused space.as a result of transfer organized use of channel time.
2) The minimum and worst case access and transfer delays for a given set of transmission parameters are smaller.
3) There is minimal built-in assumptions about traffic distribution and characteristics.
4) The definition of the MAC is simpler and easier by an order of magnitude than for any channelized or slotted system,
5) The risk of undefined hangup modes is far lower.
6) The ultimate capacity and breadth of function of a given frequency space is greater.
7) The single channel wider band radio will be simpler, easier to make frequency independent.

This conclusion should be used to focus the efforts of 802.11 more productively.

References:

1. "Medium access control protocol for wireless LANs (an update)," K. S. Natarajan, IBM Research Division, IEEE 802.11/92-39, 3/92

2. "Performance of a Reservation Multiple-Access Protocol," R. O. La Maire, IBM Research Division, IEEE 802.11/92-108, 9/92

3. "Sequentially-used Common Channel Access Method, C. Rypinski, IEEE 802.11/91-95, 8/23/91

4. "Architecture and Access Method Analysis for Integrated Voice-data Short Reach Radio Systems," C. Rypinski, WINLab Workshop (Rutgers), 4/28/92

5. "An RF Data Transport Protocol - The RF adaptation Sublayer and RF Physical Layer Specifications ...," E. Geiger, Apple Computer, 802.11-93/104, July 93

6. "CODIAC Protocol -- Centralized or Distributed Integrated Access Control," C. Heide, Spectrix, 802.11-93/54, May 93

7. "Voice on Token Ring (Asynchronous vs. Synchronous Access," H. R. van As, T. Wicki, P. Zafiropulo; IBM Research Division Zurich Laboratory, July 93 802 Tutorial on Multimedia