LA-DCF: A New Multiple Access Protocol for Ad-Hoc Wireless Networks

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Abstract: *This paper describes the pros and cons of several generations of wireless multiple access protocols and describes a new protocol "Logarithmic Arbitration – Distributed Coordination Function" (LA-DCF) which uses "Binary Logarithmic Arbitration Method" (BLAM) optimization techniques to reduce delay and loss, and is designed particularly for integrated service environments. It simulates the ineffective performance of IEEE802.11 DCF for real-time data in an ad-hoc environment, and shows how LA-DCF meets the tolerances of adaptive real-time applications.*

1. Introduction.

Shared networks require a multiple access protocol (MAP) to control the approach each host has to accessing the channel, and the method of rescheduling the transmission after an unsuccessful access attempt. Several generations of wireless MAPs have now emerged.

An early protocol was CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) [1] which senses the carrier is busy, waits for it to go idle, doubles the contention window (the range of values from which a random backoff time is chosen) and chooses a random backoff period to wait before the next attempt. This is known as exponential backoff and leads to an effect known as the channel *capture effect* [2] whereby a successfully transmitting host will reset its contention window and is able to send subsequent frames while other competing hosts double their contention window. The result on channel efficiency is beneficial as a host that 'wins' a contest can transmit for longer without having to waste bandwidth in other contests; but the effect on delay and delay variance is extremely detrimental. IEEE802.11 Distributed Coordination Function (DCF) [3] requires that a host senses the carrier *during* backoff. This requires extra power which is a limited resource for many wireless devices but provides vital information. If another transmission is detected during backoff, the host "freezes" the backoff timer. Once the carrier is sensed idle again, the backoff timer is resumed. This not only removes the channel capture effect but ensures that a host that has been waiting for longer is more likely to reach the end of its backoff period and transmit than newly contending hosts. Alternative methods to remove the capture effect have been proposed [4]. LA-DCF uses the same carrier sense during backoff technique as DCF but makes more use of the information in order to estimate the current network load and hence reduce delay and loss.

Despite collision avoidance, frame loss due to collision can be a problem, especially at high loads. CSMA/CA leaves error control to the end-to-end transport protocol, but this can take too long to detect the loss and take action, causing channel inefficiency. DCF uses frame acknowledgement to overcome collision loss. If no acknowledgement is received the contention window is doubled and the frame scheduled for retransmission. Unfortunately the subsequent variations in delay affects the calculation of round trip times in transport protocols. Also, they are only used for the unicast case, not for multicast whose common use of unreliable transport protocols can be severely hampered by such collision loss. LA-DCF controls collision loss without requiring retransmission.

Distributed (ad-hoc) wireless networks have no central, fixed points for polling schemes, and token passing schemes are inappropriate for the more error-prone, non-static and not necessarily fully-connected wireless ad-hoc network. If, for example, real-time voice communication is required in an ad-hoc wireless environment, LA-DCF is the only known protocol that can support the delay and loss requirements required by modern adaptive real-time applications.

2. Logarithmic Arbitration – Distributed Coordination Function (LA-DCF)

LA-DCF is a protocol based on the DCF with an additional backoff procedure based on BLAM [5]. It is designed to replace DCF and offer greater performance primarily for real-time but also for non real-time traffic.

BLAM is a protocol designed to improve the CSMA/CD IEEE802.3 protocol. The specification describes a number of alterations to the basic CSMA/CD protocol, some of which are dependent on the wired medium. The backoff method, however, can be applied in a wireless environment. The backoff extension used by BLAM is based on "logarithmic arbitration" and is based on the observation that the size of the contention window is an estimate of the number of hosts currently attempting to transmit. If the estimate is accurate, then Q hosts are contending for the same number of slots. Thus, if no activity is sensed while backing off for two slot times, it is assumed that the initial estimate for Q was too large and the number is halved. It is this halving of the contention window that gives the algorithm its "logarithmic" name (following the tradition of "exponential" as used in the doubling of the contention window after collision detection in CSMA/CD.) This new contention window is then used to calculate a new backoff time, and the algorithm repeats until transmission is scheduled within two slot times. The original behavior of DCF in the event of sensing a busy medium during backoff remains unchanged: the host must freeze the backoff counter until the medium becomes free again. Figure 1 shows the detailed operation of the LA-DCF protocol.

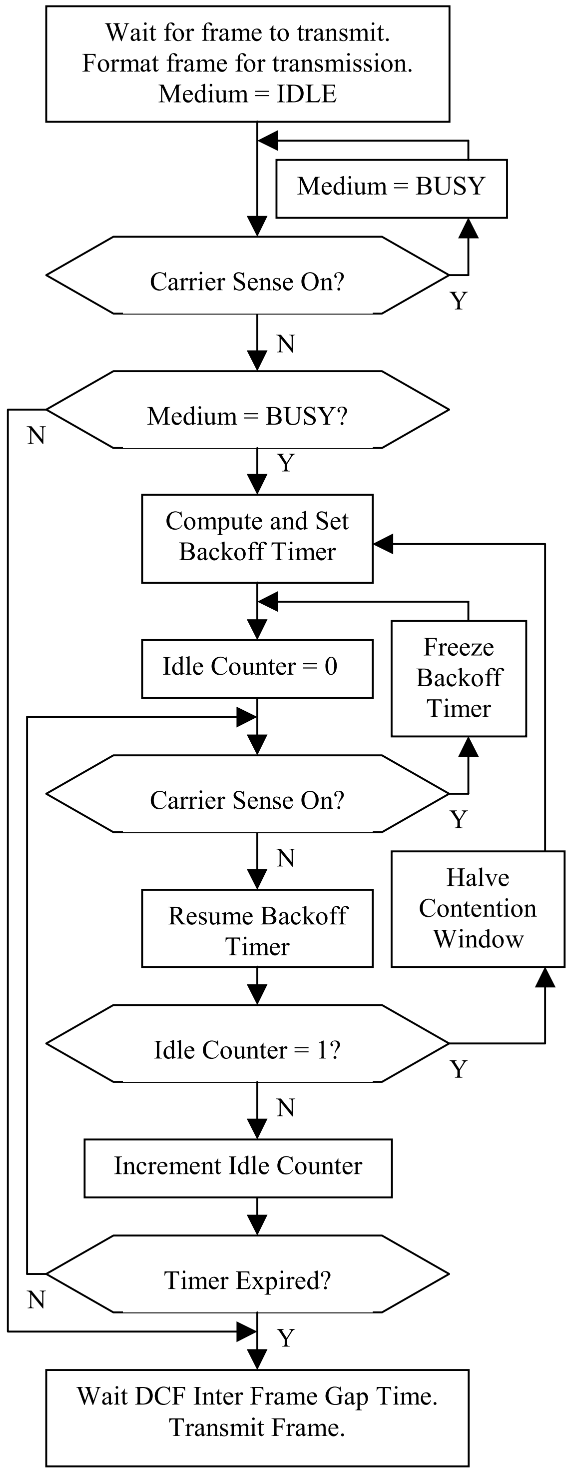
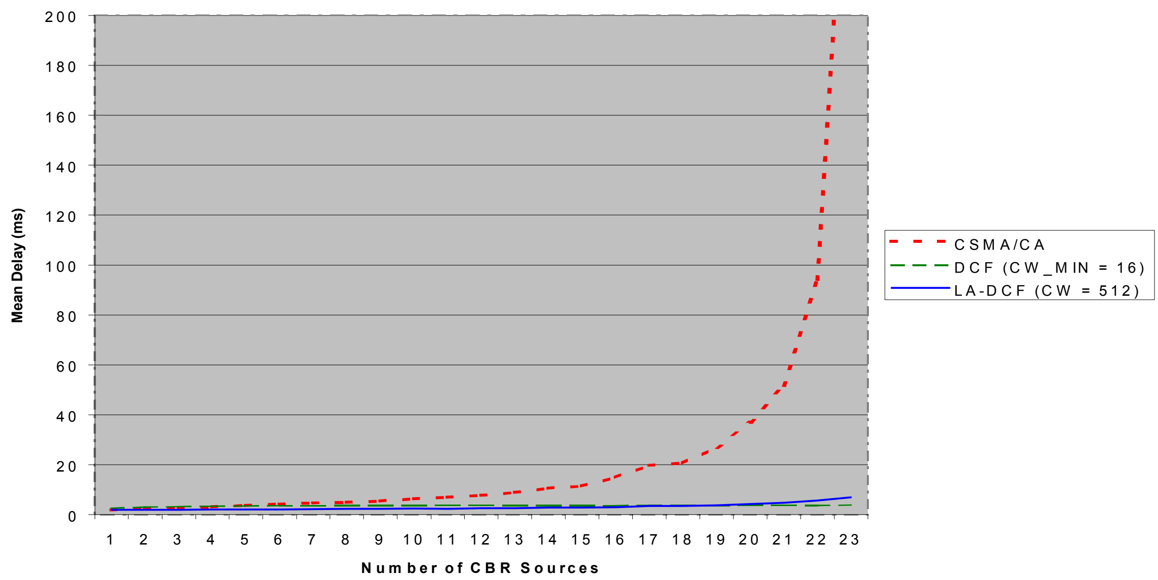


Figure 1: LA-DCF Transmit Process.

3. Simulation of the Protocol

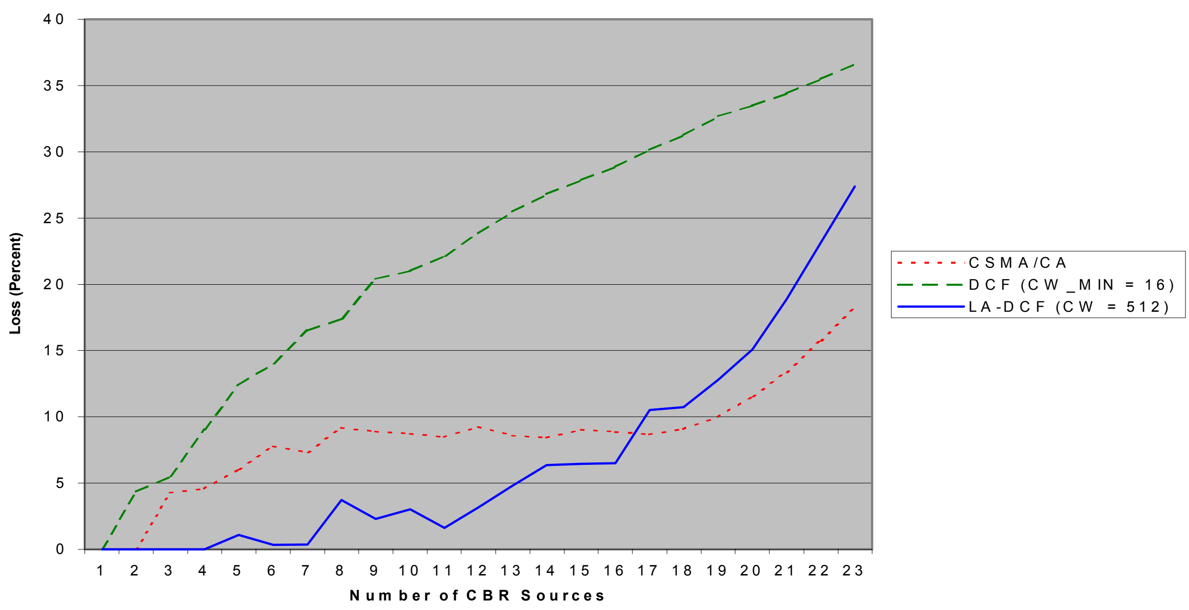
The simulation package "ns" was used to simulate the performance of the protocols. A number of nodes were created with "CBR" connections transmitting 210 byte packets every 20ms. The network parameters of the "WaveLAN" NCR product were used, which include a wireless network bandwidth of 2Mbps. At this rate, 23 connections correspond to approximately 100% load level. The time at which each stream was started was randomly generated within the first 20ms. Since the network is fully connected, and the packets fall below the RTS/CTS use threshold, this mechanism was not used. Since the frames were addressed to a multicast destination no acknowledgements were used.

Graph 1: Mean Delay at Various Network Loads



Graph 1 shows that CSMA/CA performs badly at higher loads exceeding the tolerances of real-time applications. DCF and LA-DCF produce substantially lower delays suitable for real-time applications at all tested load levels.

Graph 2: Packet Loss at Various Network Loads



Graph 2 shows that DCF loss quickly escalates and becomes unacceptable for real-time applications at mid-load values. LA-DCF and CSMA/CA control loss over the load range meeting real-time application tolerances. LA-DCF performs better at low loads, CSMA/CA at higher loads.

4. Summary

The results show that the choice of multiple access protocol does have a significant impact on network performance and consequently influences the suitability of the network for real-time applications. CSMA/CA, DCF and LA-DCF are within the non-deterministic category and belong to the same class of collision avoidance, carrier sense multiple access protocols. The only significant differences are the presence, or not, of the capture effect and the behaviour and convergence speed of the backoff algorithm.

The DCF and LA-DCF delay figures are very low compared to CSMA/CA, and remain constant across all load levels making them suitable for real-time applications.

Whilst CSMA/CA frame loss is mostly within acceptable bounds, the frame loss figures for DCF are excessively high for most of the load range and are, in these regions, beyond real-time application tolerance levels. Whilst DCF uses a retransmission scheme to reduce loss, the inevitable effect on delay is undesirable for real-time applications, and the scheme has not yet being extended to the multicast case. By using carrier sense information to better use, LA-DCF exhibits low loss without requiring additional error control mechanisms.

LA-DCF shows it is possible to retain the low delay figures obtained with DCF whilst producing acceptable loss rates comparable or better than DCF and CSMA/CA over most of the load range.

References.

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