IEEE P802.11
Wireless Access Method and Physical Layer Specifications

Title: Proposed values for the Contention Window (CW).

Authors:
Wim Diepstraten
AT&T WCND
Nieuwegein The Netherlands
Tel: (31)-3402-97482
Fax: (31)-3402-97555
Email: Wim.Diepstraten@utrecht.attgis.com

Abstract:
This document intend to provide an analyses to determine a basic parameter in the CSMA/CA protocol. This submission intends to cover only the specification of the Contention Window (CW) parameter.

Background:

In a CSMA access mechanism the collision probability of the access protocol is depending on a number of parameters. On one hand there is the length of the "Collision Window" (= the time it takes to detect that an other station is active), and the load on the medium.
On the other hand there is a very high probability for a collision immediately following a "Medium Busy" period, because multiple stations that defer for that will try to access the medium immediately after the medium becomes available again.
The basic mechanism in a CSMA/CA protocol is to reduce the collision probability there where it is mostly needed, by forcing a station in random backoff at that point. The backoff window size (together with the "Collision Window"=Slot time) will then determine the resulting collision probability, as function of the network load.

Analyses method:

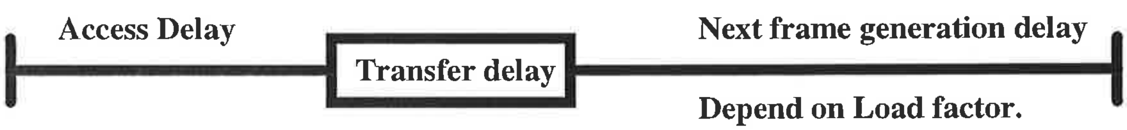
This submission is based on simulation of the access protocol in an environment with only one BSS, in which there are no hidden nodes. As tool the simulation program as described in Doc IEEE P802.11-92/26 (and 92/51) is used.
The criteria for choosing a Contention Window (CW) that are used are the effect on system throughput and delay anticipated per station, as a function of the load on the medium.
To determine the optimum CW, the following simulations are done:
- Determine Collision probability as a function of Network load at various CW values.
- Determine average delay per frame as a function of network load at various CW values.
- Determine network throughput as function of network load at various CW values.

The simulation model takes into account the effect of path attenuation and capture effects, so that not every collision does translate into multiple frames being lost.

Further these simulations are done with two different station populations, consisting of 10 and 30 active transmitting stations. This does not mean that a network size would be limited to a low number of stations, because in a network the traffic will be very bursty, and the probability that a large number of stations are actively wanting to transmit at the same time will be very low.
To analyse how the maximum throughput per station is effected, a simulation is provided of only a single station.

Traffic model:

The traffic model in the simulation tool needs some further explanation. The intend of this tool is to analyse the behaviour of the access mechanism implementation.
The model does not support buffered load.
The load is controlled by changing the average frame generation time per station. Each station will apply the load factor to generate the average of a random delay after the successful transmission of each previous frame.



The load factor is a factor derived from the raw data rate as it is distributed over all the stations. So a Load Factor 1 means that an average generation delay per station is a traffic load per station of 2 Mbps/n stations/Packet payload.
However the load on the medium access mechanism will be considerably different, because on the medium the additional overhead of the frame formats (PHY preamble + PLCP Header + MAC Header) will be take more medium bandwidth, than the net payload. When the load is increased to above the capacity that the channel can handle, then more stations will have frames queued up, so there will be relative more contenders for the medium, so a higher relative load for the access mechanism.
A separate chart is provided that translates the "Load Factor" into the effective load on the medium access mechanism, showing the average number of other contenders.

Simulation setup:

The simulation does only cover a 2 Mbps DS modem with the following IFS parameters. SIFS = 10 usec, PIFS = SIFS + Slot time = 30 usec, and DIFS = SIFS + 2*Slot time = 50 usec. The network topology is such that stations are randomly distributed over an area, such that all stations are within range of each other.
Each station will generate traffic driven by the Load Factor, to a destination that is randomly chosen for each packet.

Simulation results:

The simulation results show that a low CW will cause a high collision probability, that translates in many retries, which translates into a relative high transfer delay, and a lower total system throughput.
A large CW will translate into a much lower collision probability, so less retries, but resulting in a bit higher transfer delay, but still results in a bit higher total throughput.

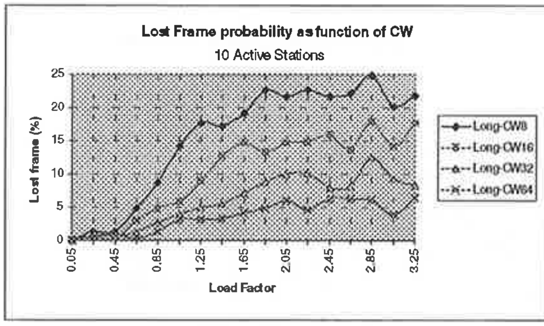


Fig: 1a

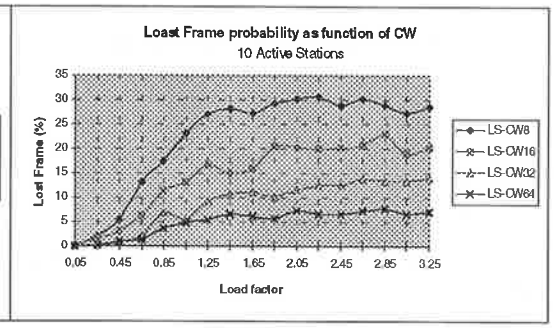


Fig: 1b

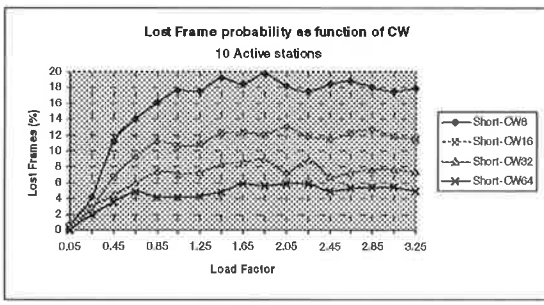


Fig: 1c

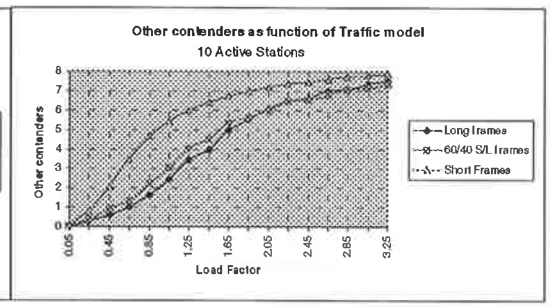


Fig: 2

Longer CW is lower "Collision Probability"
Figure 2 show the actual average number of stations, that a station is contending with.

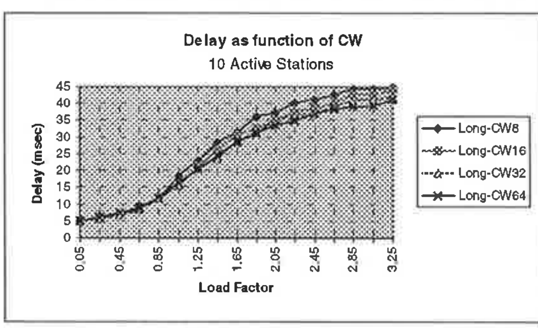


Fig: 3a

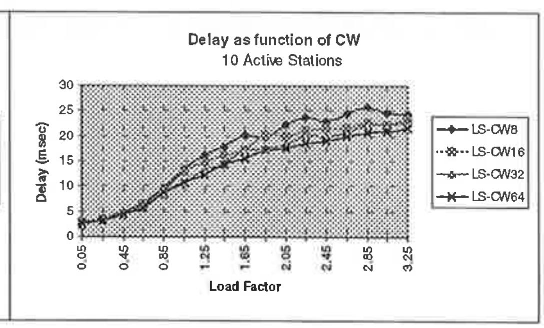


Fig: 3b

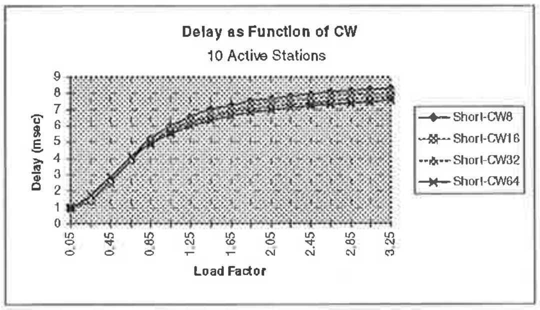


Fig: 3c

A longer CW translates to a lower transfer delay, so higher throughput per station.

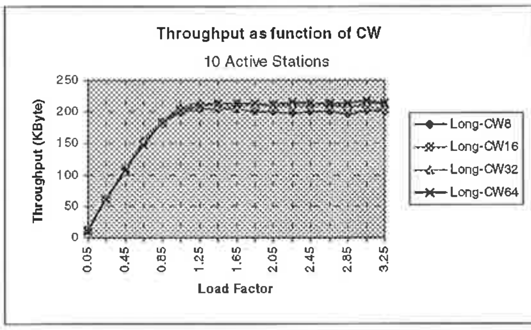


Fig: 4a

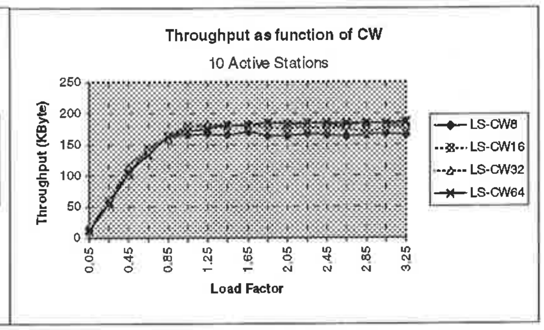


Fig: 4b

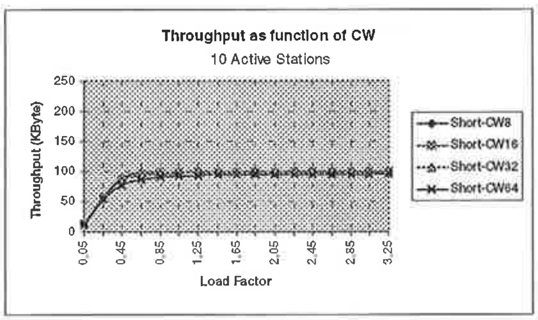


Fig: 4c

A longer CW translates to a higher system throughput. The turnover point where a longer CW will cause a lower throughput is not yet visible.

Simulations with 30 Active Stations:

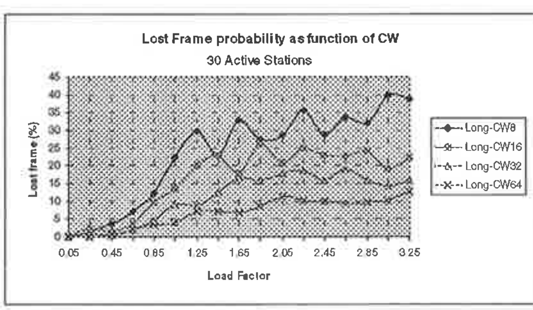


Fig: 5a

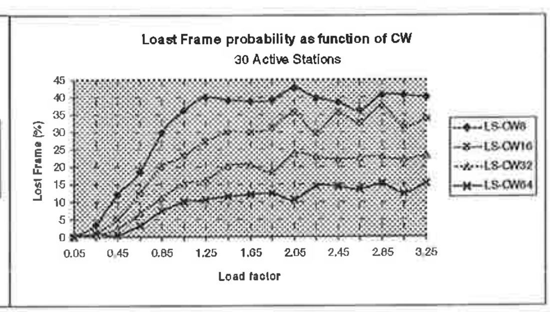


Fig: 5b

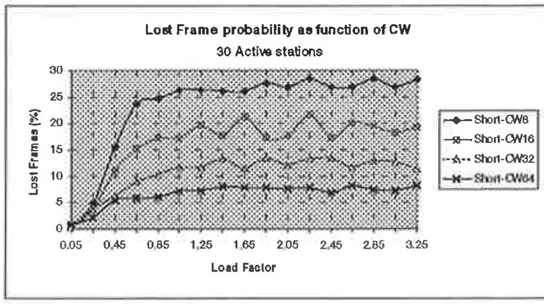


Fig: 5c

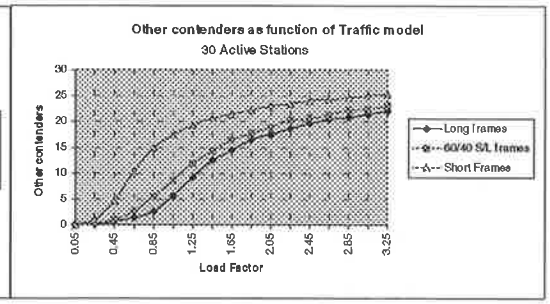


Fig: 6

The more stations are active, the higher the collision probability is, with relative large distance between different CW values.

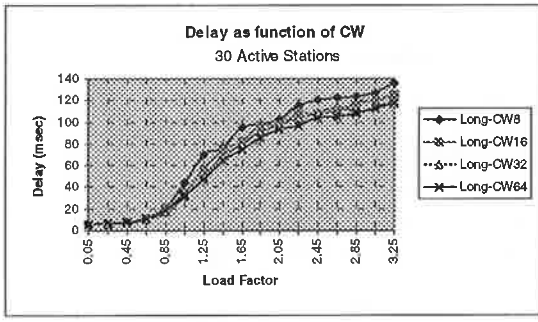


Fig: 7a

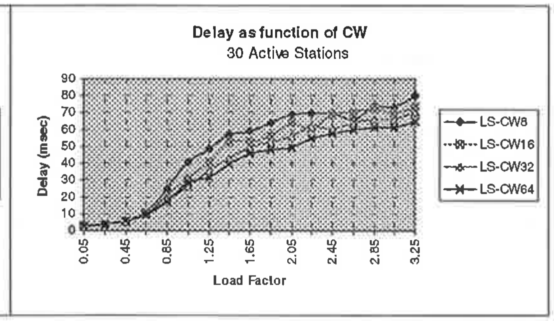


Fig: 7b

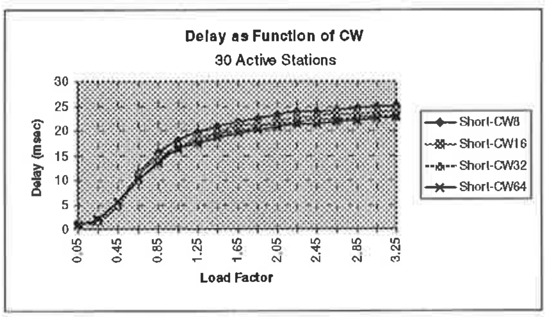


Fig: 7c

There is a relative large difference in delay with a clear advantage for larger CW values.

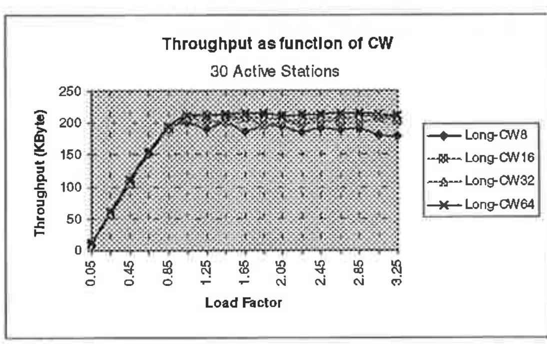


Fig: 8a

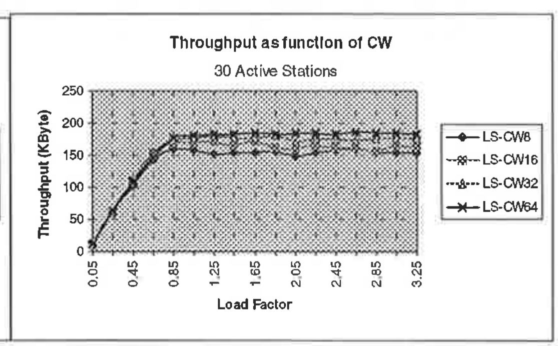


Fig: 8b

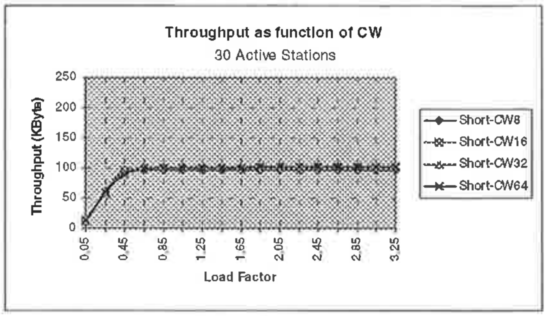


Fig: 8c

The preference for a larger CW is clearly visible, except for the Short frames only case.

Single Station performance as function of CW:

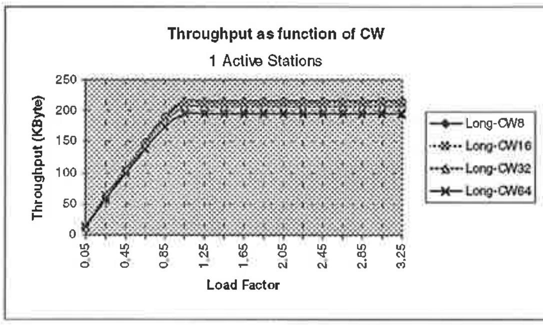


Fig: 9a

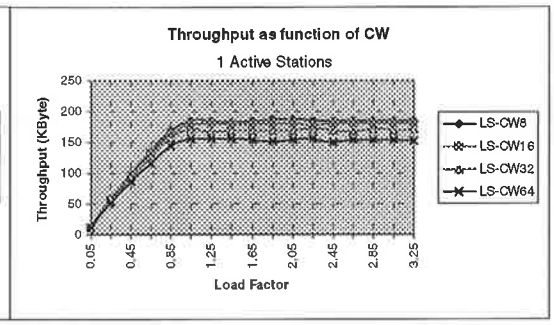


Fig: 9b

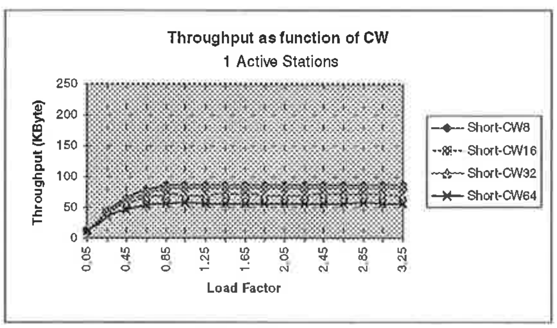


Fig: 9c

Here the relation is the other way around as can be expected. When there are no contenders, then a larger contention window will clearly translate into a lower performance.

RTS/CTS simulation results:

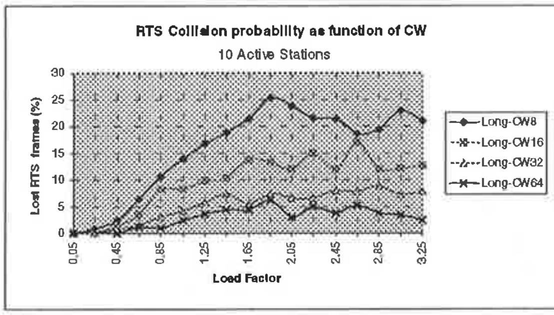


Fig: 10a

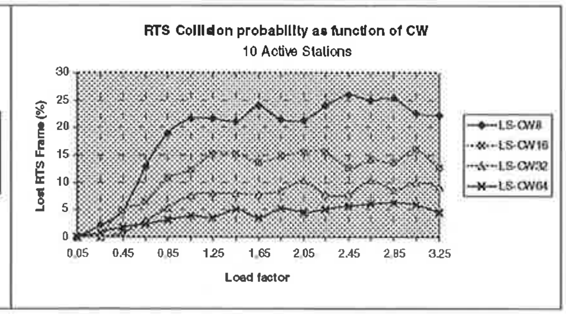


Fig: 10b

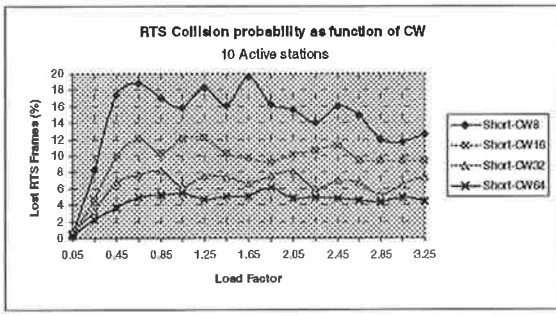


Fig: 10c

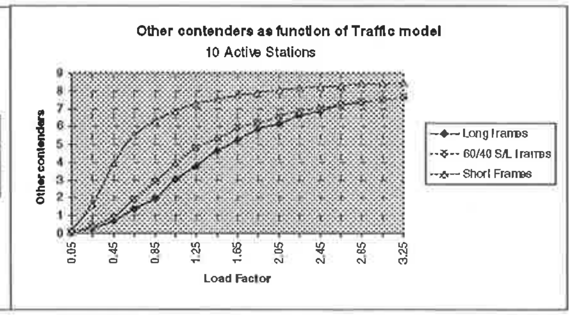


Fig: 11

Here the collisions are between RTS frames, not the data frames, although the simulation shows some additional lost frames.

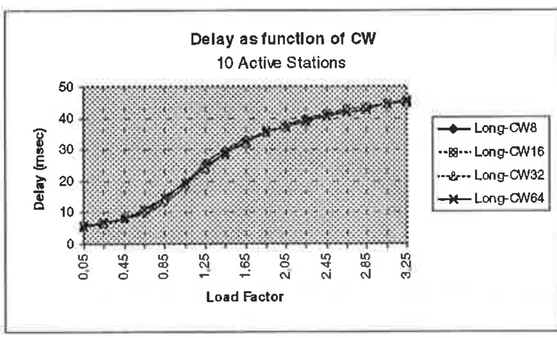


Fig: 12a

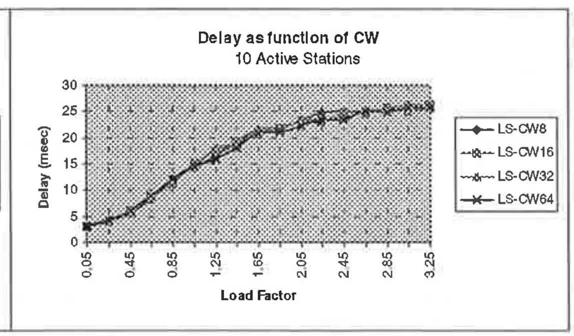


Fig: 12b

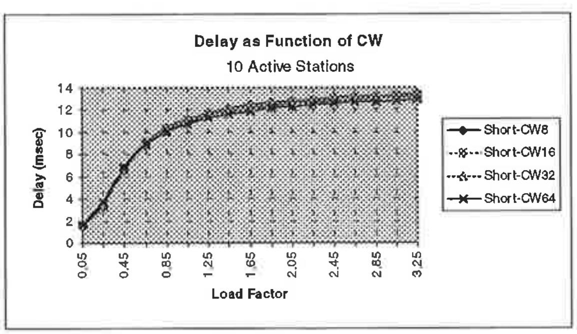


Fig 12c

Delay is larger then for figure 3 (non-RTS/CTS), but the system seems less dependent on the CW value.

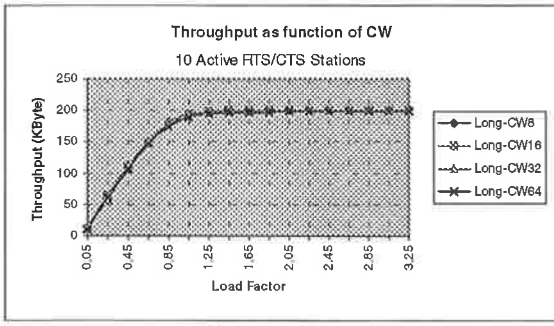


Fig: 13a

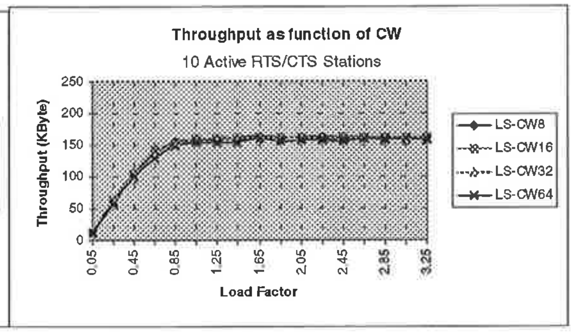


Fig: 13b

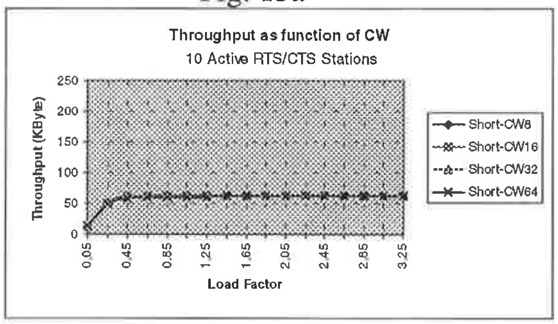


Fig: 13c

RTS/CTS shows significant lower throughput especially for short frames as expected, but less dependent on the CW duration.

Conclusion:

The simulations indicate that a CW of 32 to 64 provides the best result for delay and system capacity. This will however impact the throughput maximum for a single station. The best trade-off seems to be to use a CW of 32.
Therefore I propose to adopt to specify the CW at 32 slots.

It should be understood that this simulation is only valid for a DS PHY. The CW relation will be there for any PHY, but the performance figures will not be valid, due to the difference in raw bitrate and PHY characteristics. The effect of hop dwell time overhead, and fragmentation is not modelled in this simulator. Further the difference in IFS times will have effect on the total throughput, and delay characteristics.