



COMMS DEVELOPMENT GROUP

Version 1.0

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MAC Protocol Theory of Operation

This applications note details the operating theory of the Mitel MAC protocol such that its operation can be confirmed to regulatory bodies in attaining approval certification.

The radio controller used with the Mitel Semiconductor 'Wave' chip-set, referred to as [xxxxxx], uses a CSMA/CA based protocol for frequency hopping radios.

Transmit Duty Cycles

The dwell time - the time spent on each channel is 80.00 milliseconds.
Data is exchanged through one of two transaction sequences which are:

1. RTS-CTS-DATA-ACK (Request to Send, Clear to Send, Data, Acknowledgement)
2. DATA-ACK (Data, Acknowledgement)

The decision on which sequence to use is based upon the length of data. Data blocks greater than 200 bytes use sequence 1. Shorter data blocks use sequence 2. These transactions will only occur when there is enough remaining dwell time for the entire transaction to take place.

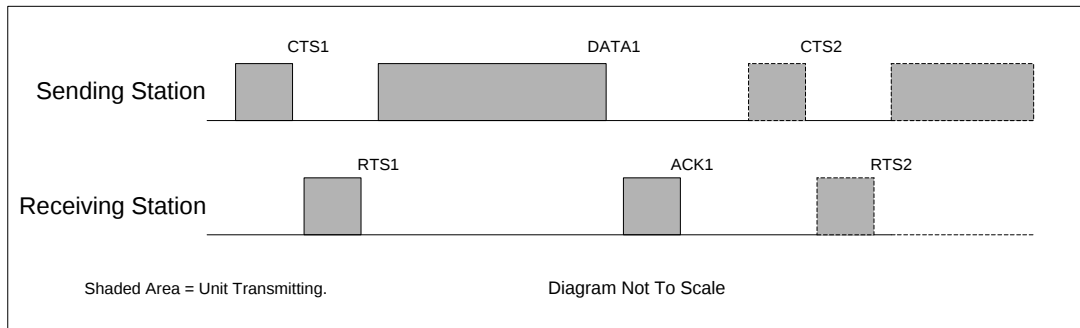
- 1) Each RTS frame takes 0.470 ms to transmit.
- 2) Each CTS frame takes 0.420 ms to transmit.
- 3) Each ACK frame takes 0.410 ms to transmit.
- 4) Each DATA frame takes $0.342 \text{ ms} + (0.0085 \times \text{bytes}) \text{ ms}$ to transmit.
- 5) The RTS-CTS interframe gap is 0.355 ms.
- 6) The CTS-Data interframe gap is 0.320 ms.
- 7) The Data-Ack interframe gap is 0.360 ms.
- 8) The inter-transaction gap (Ack to next CTS) is 0.300 ms.

The largest data frame that can be transmitted is 1514 bytes.

a) Unicast Traffic

The worst-case duty cycle (e.g. the longest time spent in Transmit Mode) occurs when only two stations are present on a given network – the transmitter and the receiver. If more stations are present, each one will have to contend for access to the channel, resulting in a reduced duty cycle and thus reduced emissions from any one unit.

The Timing diagram for the worst case is as follows:



$$\begin{aligned} \text{Transaction Time} &= \text{RTS} + \text{CTS} + \text{IFG} + \text{DATA}(1514) + \text{IFG} + \text{ACK} + \text{IFG} \\ &= 15.431 \text{ ms} \end{aligned}$$

$$\text{Sending Station "Tx" Time} = \text{RTS} + \text{DATA}(1514 \text{ bytes}) = 13.681 \text{ ms}^*$$

$$\text{Receiving Station "Tx" Time} = \text{CTS} + \text{ACK} = 0.830 \text{ ms}$$

*(Note that this is the worst case in that the sending station spends the most time in "Tx")

$$\text{Primary "Tx" Duty Cycle} = 13.681 / 15.431 = 0.8866 \text{ or } 88.66\% \text{ (Sending Station)}$$

Since five transactions could be performed in one Dwell Time:

$$\text{"Tx" Duty Cycle for Total Channel Dwell Time} = 13.681 * 5 / 80.00 = 0.8550 \text{ or } \underline{85.50\%} \text{ (Sending Station)}$$

"Tx" Duty Cycle per Title 47, Part 15.35 (c) of CFR ("pulse train less than 0.1 seconds" or 100ms) is the Overall "Tx" Duty Cycle and is calculated as:

$$\begin{aligned} \text{Overall "Tx" Duty Cycle} &= (\text{"Tx" Duty Cycle for Total Channel Dwell Time}) * (\text{Dwell Time}) / 100\text{ms} \\ &= 0.8550 * 80.00\text{ms} / 100\text{ms} = \underline{0.6840} \end{aligned}$$

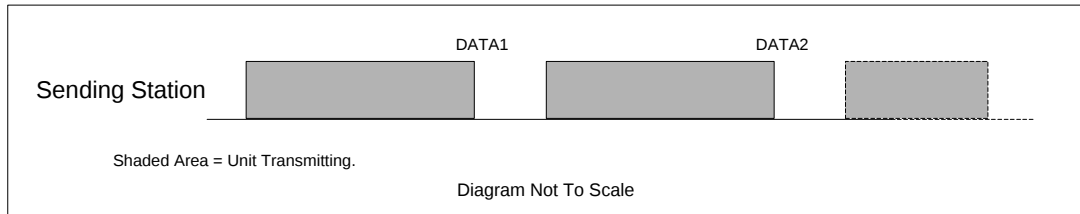
Note that this Correction Factor, when Field Strength is measured in units of Voltage, is equivalent to

$$\text{CF} = 20 \log_{10}(0.7093) = \underline{-3.3 \text{ dB}}$$

b) Broadcast Traffic

If the transmissions by a station are 'broadcast' packets, then the worst case consists of maximum length transmissions (1514 bytes), separated by an inter-frame gap (0.300ms)

The Timing diagram for the worst case is as follows:



$$\begin{aligned} \text{Transaction Time} &= \text{DATA}(1514) + \text{IFG} \\ &= 13.511 \text{ ms} \end{aligned}$$

$$\text{"Tx" Duty Cycle} = 13.211 / 13.511 = 0.9778 \text{ or } 97.78\% \text{ (Sending Station)}$$

Since five transactions could be performed in one Dwell Time:

$$\text{"Tx" Duty Cycle for Total Channel Dwell Time} = 13.211 * 5 / 80.00 = 0.8256 \text{ or } \underline{82.56\%} \text{ (Sending Station)}$$

"Tx" Duty Cycle per Title 47, Part 15.35 (c) of CFR ("pulse train less than 0.1 seconds" or 100ms) is the Overall "Tx" Duty Cycle and is calculated as:

$$\begin{aligned} \text{Overall "Tx" Duty Cycle} &= (\text{"Tx" Duty Cycle for Total Channel Dwell Time}) * (\text{Dwell Time}) / 100\text{ms} \\ &= 0.8256 * 80.00\text{ms} / 100\text{ms} = \underline{0.6605} \end{aligned}$$

Note that this Correction Factor, when Field Strength is measured in units of Voltage, is equivalent to

$$\text{CF} = 20 \log_{10}(0.6605) = \underline{-3.6 \text{ dB}}$$

Derivation of Average Time of Channel Occupancy in a 30 sec period per 15.247 (a) (1) (ii)

The maximum Time of Channel Occupancy including settling time is 80.00ms.

Time needed to cycle once through the hop table (79 channels) = $79 \times 80.00\text{ms} = 6320.0\text{ms} = 6.3200\text{seconds}$.

Number of cycles through hop table in a 30 second period = $30 \text{ seconds} / (6.3200 \text{ sec/cycle}) = 4.7468\text{cycles}$; therefore, in worst case, a given channel will be visited 5 times in a given 30 second period.

Therefore maximum time of channel occupancy in a 30 second period
= $5 \times 80.00\text{ms} = 400.00\text{ms} = \underline{0.400\text{seconds}}$.

The maximum permitted is 0.4 seconds.

Average time of channel occupancy in a 30 second period = $4.7468 \times 80.00\text{ms} = \underline{0.379\text{seconds}}$.

Frequency Hopping Sequence

Under user control, the protocol can be configured to use one of 78 'hopping patterns', numbered 0 to 77.

For a pattern number 'x', and an index 'i' for the next frequency (i = 1 to 79 inclusive), the channel number used by the station is defined by the equation:

$$f = [b(i) + x] \bmod (79) + 2$$

The parameter $b(i)$ is defined by the following table:

i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$
1	0	11	76	21	18	31	34	41	14	51	20	61	48	71	55
2	23	12	29	22	11	32	66	42	57	52	73	62	15	72	35
3	62	13	59	23	36	33	7	43	41	53	64	63	5	73	53
4	8	14	22	24	72	34	68	44	74	54	39	64	17	74	24
5	43	15	52	25	54	35	75	45	32	55	13	65	6	75	44
6	16	16	63	26	69	36	4	46	70	56	33	66	67	76	51
7	71	17	26	27	21	37	60	47	9	57	65	67	49	77	38
8	47	18	77	28	3	38	27	48	58	58	50	68	40	78	30
9	19	19	31	29	37	39	12	49	78	59	56	69	1	79	46
10	61	20	2	30	10	40	25	50	45	60	42	70	28		

This channel number 'f' then determines the channel frequency used:

$$\text{Frequency (MHz)} = 2400 + f$$

Coordination of Separate Networks

The protocol is capable of being used in multiple networks; e.g. different hopping sequences and different network "keys" or names assigned to different networks allow separate networks to co-exist in the same area. However there is no way to co-ordinate the separate network hopping sequences in such a way as to prevent occasional "collisions" between the separate networks. Therefore, when multiple networks are operated in the same area, occasional collisions will result in degradation in system performance.