IEEE 802.11
Wireless Access Method and Physical Specification

Title: **Transmit Power Control Protocol provisions.**

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Abstract: This paper re-introduces Transmit Power Control. The concept was first introduced in July 92 [1], and it was part of the original WMAC proposal [2][3]. No specific reference was made in the DFWMAC proposal, because it was not part of the basic access scheme. Both the Radio PHY's that are currently being specified do use the concept of Transmit Power Control. This paper discusses the protocol elements that are needed for that.

Applicability to the "Foundation MAC":

Although it was part of the original WMAC proposal, this subject was not specified in the DFWMAC proposal, and is therefore not described in doc 190. It should therefore be considered as "new functionality". Since both Radio PHY's do specify the required use of Transmit Power Control when operating above 100 mWatt, this is an essential element of the standard.

Introduction

The concept of Transmit Power Control was first introduced in [1]. The main function of the Transmit Power Control concept is to limit interference potential by limiting the transmitter power level to a value that is adequate for proper reception. The main purpose would be to improve the medium re-use efficiency.
It is not a method to improve battery life of a station, as is discussed in [4], because the actual impact of active transmit power on the battery life is insignificant compared to its idle mode power consumption. However once an adequate Power (conservation) Management mode of operation is used to address the idle mode power consumption problem, then the transmit power consumption impact will increase again, so that Transmit Power Control can have a favourable effect on battery life also.

In both the FHSS and DSSS standard Transmit Power Control is mandatory above 100 mWatt.

Medium Re-use efficiency improvement:

The effect on medium re-use efficiency was simulated using a two network model, where the total throughput as function of the separation distance between the networks was shown. The simulations show huge potential re-use improvement, which is also a function of the size of the BSS, and on the network topology. The results show that improvements in the so called Client-Server traffic model are significantly better (re-use = factor 5-7) then for the Peer-to-Peer environment (re-use = factor 2-3). The Client-Server simulation environment is equivalent to an infrastructure based network where most of the traffic is going through the AP.

Dynamic Power Control Mechanism:

The main concept is that a station does learn the attenuation conditions for reaching a particular destination. The basic protocol element here is that there is a one byte field in each frame header, that indicates with which power level that frame was transmitted. Then when a receiver has the ability to determine the receive level of a frame, it can maintain a table with the measured attenuation per station it has communicated with, or even any station that it could hear.
In practise however it will primarily be the AP for which a station wants to maintain the attenuation history. An AP will have to do that for all the associated stations.

Stations can then determine (using an undefined algorithm) which level it should use to reach the intended receiver, maintaining adequate margins to overcome the effect of fading.
An other part of the basic mechanism is that a station needs to be able to set a transmit power level on a per frame basis, with a power level adequate to reach the destination. This should be done in combination with a variable "Clear Channel Assessment" threshold. The basic idea is that for every dB that the transmit level is lowered, the CCA-threshold can be made x dB less sensitive, with x between 0 and 1.

This means that a station does not need to defer for the same range when its transmit power level is decreased. So therefore it can increase its threshold up to the same amount. It should be understood that the intend is to decrease from a given nominal Tx-Power level, not to increase the power for a turbo boost operation. This would be possible only when the CCA-threshold is made more sensitive at the same time.

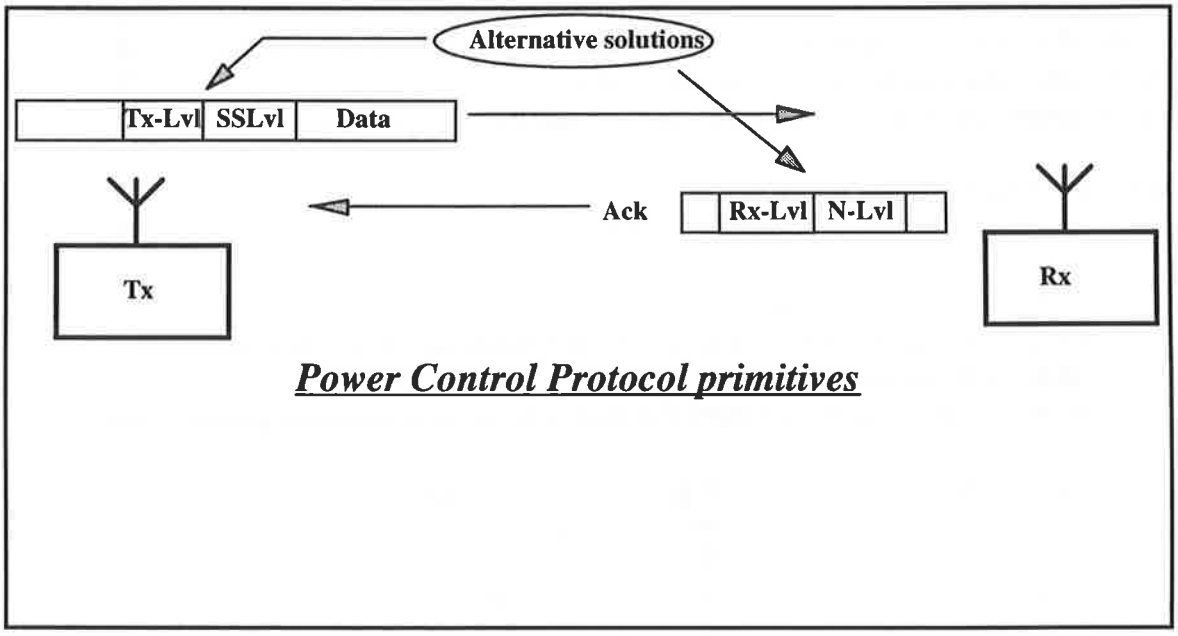
One other aspect covered in [1] is the inclusion of so called Silence level or noise level (SSLvL) at the location of the transmitter. When we assume that radio links are identical from Tx-Rx and visa versa, then there can still be a difference in background noise or human interference level at the remote location. This may limit the sensitivity of the remote receiver. This knowledge can then be incorporated in the Power Control algorithm. Proposal [1] suggests to include a single byte SSLvL field in the frame Header. Note that the Silence level is an average measurement at that station, not related to the received frame. So it is not the SNR during reception.

Mixed operation possible

The idea is that not all stations are forced to implement a Power Control algorithm (unless they want to use a power level above 100 mWatt), but that every should put the Transmit Level field in the frame header.
This allows a station that wants to use Tx-Power Control to do so and take advantage of it, while other stations in the same environment don't. So a station that does implement Tx-Power Control can interoperate with a station that don't without any problem.
Also it should be clear that all broadcast/multicast frames should use the nominal Tx-Power, or the highest power level needed to reach all destinations (known within the AP).

Alternative approach.

An extension or alternative to the previous proposal is the following:
A more optimum approach is that a station returns the measured receive level of the frame it just received directly in the Ack. The advantage here is that the absolute accuracy level of the receive signal level facility in the PHY is not critical. You get a direct indication of the level at the remote receiver as the remote receiver experiences it. So any variation in the remote receiver RF-gain and sensitivity will not have an effect, so no margin for these effects will be needed then.



When all receivers would be required to implement this Rx-Lvl measurement function, then it seems that the Tx-Lvl indication field in the MAC Header would not be needed.
The Rx-Lvl function is I think mandatory because it is required to determine when a station needs to roam to an other BSS anyway.
In addition to the Rx-Lvl also the noise/interference level (N-Lvl) measured at the remote can be included in the Ack frame.

When a station knows how its signal is received, and it knows its own transmit level, then all ingredients are there to calculate the attenuation path. An averaging process will likely be needed to compensate for fast fades.
Please note that the algorithm is not to tune the transmit level such that the receive level is just above the receive threshold. An other function of the transmit level is to send out enough energy to assure that stations that are within interference range to the remote receiver do defer. This is explained in [1].

This would bring us to the conclusion that instead of putting a Tx-Lvl and N-Lvl parameter in the Tx frame header, it is a more direct solution to put the Rx-Lvl and N-Lvl in the responding Ack. This seems a more straight forward solution because the "attenuation history" can then be maintained in the transmit process. The absolute (Rx-Lvl) measurement accuracy is far less important in this alternative approach.
A disadvantage is that a remote that wants to maintain a history of the frames from the AP does get all kind of different readouts, which are meaningless when there is no knowledge of the level with which the frame was transmitted. This means that stations can only get reliable readouts when monitoring Beacons and other broadcasts for instance, which are to be transmitted at the nominal(maximum) level.

Dynamic behavior requirements:

The concept requires that both the Tx-Lvl and CCA-threshold in the PHY are controlled by the MAC on a per frame basis. This is clearly required in an AP which can have frames queued for a number of different stations.
The following procedure shows what needs to happen on a per frame basis.

MAC wants to transmit a frame.

- MAC will determine required "Tx-Lvl" and "CCA-Thresh" and sets the PHY accordingly.
- MAC will follow the basic CSMA/CA access procedure.
  (CCA should be inactive at least the xIFS duration before TX is allowed)
- MAC will transmit the frame
- MAC (or PHY) will reset the CCA-threshold to the nominal sensitivity level.

- MAC will receive an indication of the Rx-Lvl from the PHY, and will maintain a history file of the attenuation per destination.

Note that this procedure assumes that the MAC or PHY will set the CCA threshold back to the nominal value, otherwise additional delay may occur after the threshold setting to allow the CCA to react.
So any new setting would be to a less sensitive setting which would automatically cause the required access delay as appropriate.

Summary of items to be standardized.

The following is what is needed in the standard to allow vendors to optionally implement this when required (like above 100 mW).

All stations need to implement:
- a Rx-level measurement facility on a per frame basis.
- Fill in the Rx-Lvl and N-Lvl field in the Ack frame.
- "Put a Tx-Lvl indication in the Tx frame header of every frame (not the Ack)" (MAC should know the setting of the PHY output level if fixed)

Stations using Tx Power Control should implement:
- Variable Tx-Power level under control of the MAC.
- Variable CCA threshold level under control of the MAC.
- The standard need to specify the relation between Tx-Level and CCA-threshold level.

Conclusion:

Dynamic Power Control has been re-introduced to be included as new functionality in the Foundation MAC. Compared to the original proposal in [1], an alternative has been introduced which has the advantage that the absolute accuracy of the receive level measurement function in the receiver is not critical anymore.
A summary is given of what needs to be standardized.

References:
[1] "The potential of Dynamic Power Control", W. Diepstraten NCR-WCND-Utrecht; July 92, IEEE P802.11-92/76
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[3] "Distributed Access WMAC Synchronization and Power Management Mechanisms", W. Diepstraten NCR-WCND-Utrecht, G. Ennis Symbol Technologies; July 93, IEEE P802.11-93/95.
[4] The importance of Power Management provisions in the MAC", W. Diepstraten NCR-WCND-Utrecht; July 93, IEEE P802.11-93/94
[4] "DFWMAC Distributed Foundation Wireless MAC Protocol", W. Diepstraten NCR-WCND-Utrecht, G. Ennis Symbol Technologies, P. Belanger Xircom; November 93, IEEE P802.11-93/190. See also P802.11 93/191, P802.11-93/192, P802.11-93/193.