WHITEPAPER

StarPlus Hybrid Approach to Avoid and Reduce the Impact of Interference in Congested Unlicensed Radio Bands

EION Wireless Engineering: D.J. Reid, Professional Engineer, Senior Systems Architect

Introduction

In licensed frequency bands, use of synchronization is accepted as a preferred method to deal with interference problems associated with; numerous base stations and CPEs. Generally speaking, competing operators respect each other's "space" and frequencies by implementing frequency planning techniques, to reduce the effects of interference. In WiMax implementations, operators prefer to use GPS based synchronization methods. In short, GPS synchronization allows all base station radios to transmit simultaneously and listen for CPE receive signals when the base station is not transmitting. It is the high level of frequency planning and signal synchronization inherent in WiMAX system implementation which provides for an order and less disruptive communication methodology.

In unlicensed frequency bands, the rules for communication are not so clear. Frequency planning is typically not implemented. Power levels are also not usually coordinated. Channel bandwidths are not coordinated. Some systems may use bandwidths as narrow as 3.5 MHz, while others may use much larger bandwidths. Given that in most cases, there is a mix and mash of disparate radio systems operating in dissimilar fashion, the rules for "playing nice" are usually non-existent. This usually makes it impossible to synchronize communications effectively.

There are other inherent problems, some of which include; fixed WiMAX 802.16d, systems use fixed polling of CPEs for traffic often with synchronization, while WiFi, 802.11a and 802.11n systems, use CSMA-CA – and employ on demand schemes to serve CPEs where the CPE will transmit a Request to Send whenever a quiet slot appears on the frequency. On a larger scale, when there are unsynced stations, whether WiFi or other systems, base station or AP and CPE transmissions are quite random and in-system collisions, as well as collisions with same-space 802.16d synchronized signals, are inevitable. Given these factors as well as years of experience in both the licensed and unlicensed wireless communications, EION Wireless would like to proceed as documented in the next few pages.

Hybrid Solution for overcoming Adjacent and Co-Channel Interference in Crowded Unsynchronized Radio Bands

Interference consists essentially of two major elements. The first is from adjacent channels activity affecting the performance of a radio system when standard isolation techniques are not adequate. The second is from co-channel interfering signals that directly impact the desired radio system. To successfully mitigate the effects on a service both adjacent and co-channel interference must be addressed with appropriate techniques.

EION's solution uses a hybrid approach through application of segment filters combined with a Trade Marked, robust protocol, working in tandem - to reduce the overall detrimental impact on channel availability and system performance.

Techniques Reducing Adjacent Channel Interference problems

Even though the offending station(s) are not on the same channel, the broadband design of contemporary radios makes them susceptible to high-level adjacent channel signals. The mechanism that creates the interference is the Low Noise Amplifier or LNA in the analog front end of the receiver. This is very sensitive and covers a wide frequency range. As a direct result any signal(s) within the band the amplifier covers if too high in level will overload the amplifier resulting in the creation of spectrum by-products that will interfere with the desired signal also being received by the radio but at a much lower level. The spectral by products disrupt the desired signal and at the same time produce inter-modulation "noise" which contributes to the morass of distorted signals making the carrier to interference ratio unacceptable ($C/I < 6$ dB).

Much of the offending signals that will impact a radio's performance are usually located in the immediate vicinity of the Base Station being impacted. In fact it can be the other operators' radios or sector radios in the same network mounted on the same tower. Several methods used singly or in combination can effectively reduce adjacent channels levels to an acceptable level.

Radio-Antenna Placement, Antenna Alignment and Frequency Co-ordination

Before adding hardware such as filters to an installation, several tactics should be employed as standard operating procedure or SOP in the establishment of a base radio. In order of application the radio and antenna placement, antenna alignment and frequency co-ordination should be done to ensure minimal adjacent channel levels impinging on the radio. These techniques have been field tested and demonstrated a number of times successfully eliminating any impairments from adjacent channel radio systems co-located on the tower.

Radio-Antenna Placement

Separation of at least 1 to 2 meters between antennas is the first tactic to improve C/I levels. This effectively reduces the impact of interfering side lobes from the adjacent antenna. Also use of sector antennas in stead of Omni –directional units greatly increases isolation. Alignment is another important consideration. The sector antenna constricted antenna pattern can be utilized to null out the side lobes of adjacent channel radiation from another close by antenna. These tactics will be able to mitigate most interference when used along with good performing radio with good IF channel response.

Frequency Assignment

Though difficult to do in unlicensed bands, ensuring that there is no co-located radio on using an immediately adjacent channel is good avoidance tactic to prevent excessive C/I. This requires at least one channel spacing between the co-located radios frequency assignments. In doing this, both radios benefit with less in band interference occurring. The adjacent channel C/I has to be quite low (3 dB or less) before interference to be significant. Weaker adjacent channel interference form more distant co-located radios should not cause any significant issues

Filter Techniques

Using filters to block out the adjacent signals for example effectively eliminates the impact of co-located radios or near-by Base Stations operating in the same band. The filters in deployment split the operating radio band into segments so interfering signals can be effectively blocked (>30 dB stop-band) from impeding the desired weaker signals from remote CPEs. The use of channel or segment filters is common in microwave systems and filters are available with the required characteristics. This is a tactic reserved for difficult situations where all other tactics have failed to adequately reduce interference and can be used uniquely or in combination with other tactics.

Table 1: Overlapping of Channels used to get four sectors

Filter Number	Filter Segment	Bandwidth
Filter F1	5.725 to 5.765 GHz	40 MHz
Filter F2	5.760 to 5.800 GHz	40 MHz
Filter F3	5.800 to 5.840 GHz	40 MHz
Filter F4	5.835 to 5.875 GHz	40 MHz

Same approach can be used for the 5.470 to 5.725 GHz band – several sub bands can be established for frequency assignments.

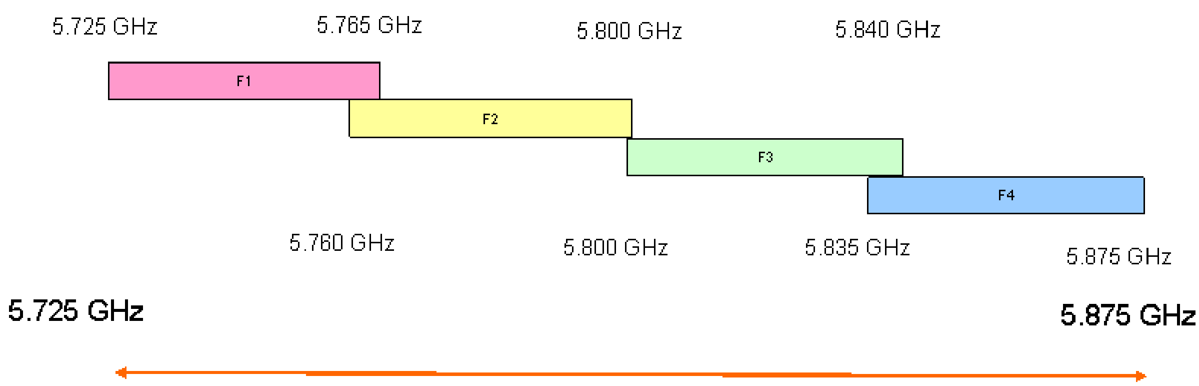

Figure 1: Overlapping of Channels used to get four sectors (graphical depiction)

In Figure 1 and

Table 1 above, the upper 5.x GHz band (5.725 to 5.845 GHz) has been divided into four separate segments of spectrum. Each segment is the pass band of filters that would be used along with the radios to ensure they are isolated from each other. High level signals from other stations would also be effectively reduced as sources of interference. Filter segment bandwidths can be selected to match the radio BW being used such as 20, 10 MHz and 5 MHz (which would be channel based).

The use of filter segments also allows the easier deployment of multi-sector base stations providing the basis for a frequency planning, re-use and reducing the need for large antenna separation and shielding.

Protocol Strategies for reducing “Co-Channel” Interference

With Co-channel, the interference itself cannot be removed; Synchronization of the operators system experiencing the interference will not reduce the problem since the sources of the interference are from other unsynchronized systems. Disruptions will occur when the synchronized base stations listen on the channel. The lock step TDD of the operators system will have very little or no benefit for mitigating the disruption to the carried services. The best tactic in this case is to implement a customized protocol which minimizes the impact of the interference.

In the 5.x GHz band most of the deployed equipment utilizes the 802.11a CSMA-CA standard protocol. In situations where multiple APs are on the same frequency, the WiFi standard uses Carrier Sense Multiple Access – Collision Avoidance. This in practice means that before any transmission is carried out, the AP or CPE will listen to the channel activity and if another AP or CPE is heard transmitting, the desired signal is held until the next attempt occurs and no transmission is heard. In a very crowded channel with many CPEs belonging to a variety of APs, traffic for any of these systems will be slow and the CA – Collision Avoidance process will break down.

With TrustLink, the core approach is not to use CSMA-CA for channel control but instead employ a dynamic polling system. Here, transmissions for the CPEs are synchronized to the base station and do not attempt to transmit until instructed to by the Base Station. By using a dynamic approach only those CPEs that have traffic to send or are to receive data are polled. Active, but traffic dormant CPEs are polled much less frequently reducing the number of extraneous messages substantially. This releases more time for live traffic handling and thus reduces overhead. In this arrangement, the polling is dogmatic, the AP will continue the polling and will resend if a Poll is unsuccessful until a time out occurs and Poll the next selected CPE.

The system will listen to the channel for activity before transmitting, and unlike 802.11a will immediately transmit not delaying by a random interval and grab the “gap” in activity.

This behavior is where the TrustLink can win out in such overused channels. By capitalizing on any gap in transmission and polling CPEs with traffic priority, traffic has a better chance of making through more often. In addition the CPEs – staying off the Air until polled reduce the number of extraneous RTS CTS messaging seen in 802.11a. The last advantage of the polling approach is that it will back off the CSMA-CA systems by keeping the channel active and thus force more random backoffs. Collectively, the opportunistic gap grabbing, streamlined messaging and backing off of CSMA-CA message result in significantly better throughput then conventional 802.11a in the same crowded channel environment.

Field observations were done in one of our deployments in Africa on point to point customer links where other active 802.11a stations were on a supposedly protected frequency assigned to the operator using EION wireless equipment. At that time, EION’s equipment could be switched form CSMA-CA to dynamic polling through a SW command. For point to point operation CSMA-CA was selected and attempts to have the link established proved to be difficult with the link failing or achieving only very poor traffic throughput. From a theoretical link design all was well, the major problem however were the presence of a number of other systems using the same channel in the area. Other channels were looked at and found to be the same or worse. It was decided to try dynamic polling to see if any improvements were possible. When the EION product was switched to dynamic polling mode, the link became stable and through put went from less the 1 Mb/s to 10 up to 20 Mb/s. This proved to be the case in other locations where channels were occupied by multiple stations.

In the lab environment, we emulated the situation where we had an active 802.11a system and also a 5.x GHz WiMAX interfering with first a CSMA-CA based system and then with our system employing TrustLink (see Figure 4) to see what differences could be observed. In Figure 2, the graph shows the decaying throughput occurring as the C/I ratio < 1 (or –dB). As the C/I approaches -3 dB (or ½) the desired channel’s (C’) throughput has all but collapsed as successive data frames are corrupted. The interactions of the protocol can be seen as the interferer is affected somewhat by the reception of C’ signaling. However, the downlink is impervious. In this situation, which matched what we observed in the field fairly well, the desired link C’ was almost totally overwhelmed by the close by interferer on the same channel.

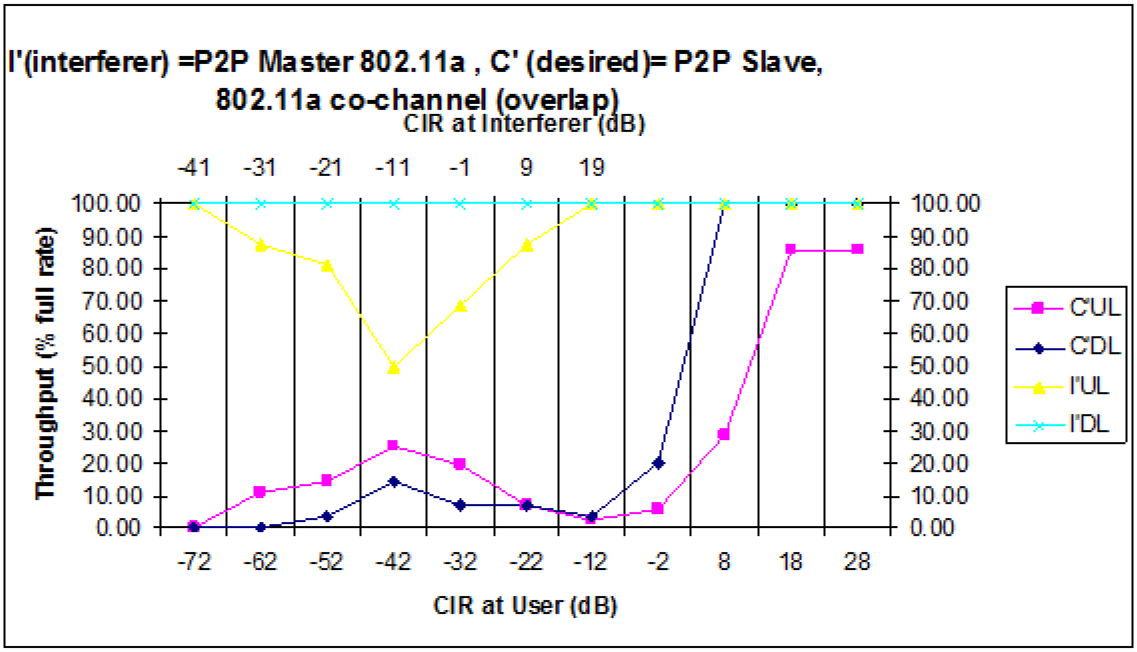

Figure 2: 802.11a co-channel (overlap)

In figure 3 we used WiMAX as the interferer to an unsynchronized 802.11a system using CSMA-CA. As the C/I ratio was decreased, the 802.11a system dominated the channel effectively shutting down the WiMAX SS. This was expected to some degree since the 802.11a CPE system will take full advantage of the channel during the receive TDD gap disrupting the SS every time it goes into a receive mode. Enough successive disruptions caused the SS to disassociate from the WiMAX Base. It was seen at a point where the WiMAX signal becomes very much stronger such that the 802.11a system started to collapse (CA protocol). At this point some marginal recovery of the WIMAX system occurred.

In the field synchronized WiMAX systems will be very vulnerable to the random like transmissions of other unsynchronized systems. Indeed, the rigid timing of the WiMAX TDD will be a disadvantage since no adaptation can be done to delay transmissions if the channel is busy with unsynchronized traffic – hence collisions are inevitable. In comparison a system employing dynamic polling implemented with the ability to observe the channel before transmitting can hold off until the channel quiets. Unlike CSMA-CA, no random back off transmission delay occurs and the channel is effectively seized by the system without causing a collision.

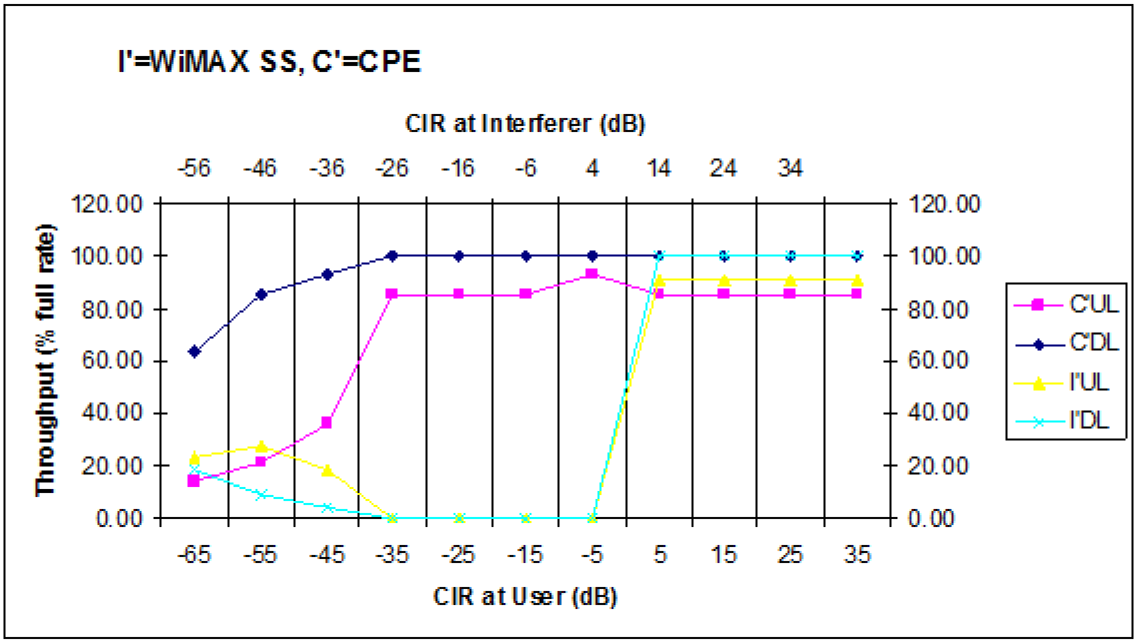

Figure 3: WiMAX and PtP 802.11a co-channel

In the run shown in Figure 4, the same test set-up was done except the firmware for C" now utilized protocol now incorporating TrustLink the results very effectively demonstrated how 802.11a reacts when in contention with dynamic polling. Data throughput though diminished was maintained on the TrustLink system over a wide range of interference levels. The impact on the 802.11a system's throughput to contention was shown to be very significant as the presence of the TrustLink signals. As the C/I grew worse beyond -12 dB, it was evident that the Interferer was starting to backoff on the number of transmission since it was hearing the reattempts to get data through by the Master and Slave units of the desired link. The CSMA-CA random transmission delay was now giving more opportunities for the TrustLink system to take advantage of the gaps in channel usage by the Interferer and thus data throughput improved substantially.

In a real environment, it means despite high levels and numbers of Interferers on the same channel, the TrustLink channel will still maintain connectivity and reasonable throughput. There will a breaking point of course, however at that juncture the Interferers have collapsed as well.

From our field and lab observations TrustLink helps maintains channel viability in situations where volatile levels of interference is seen on the channel.

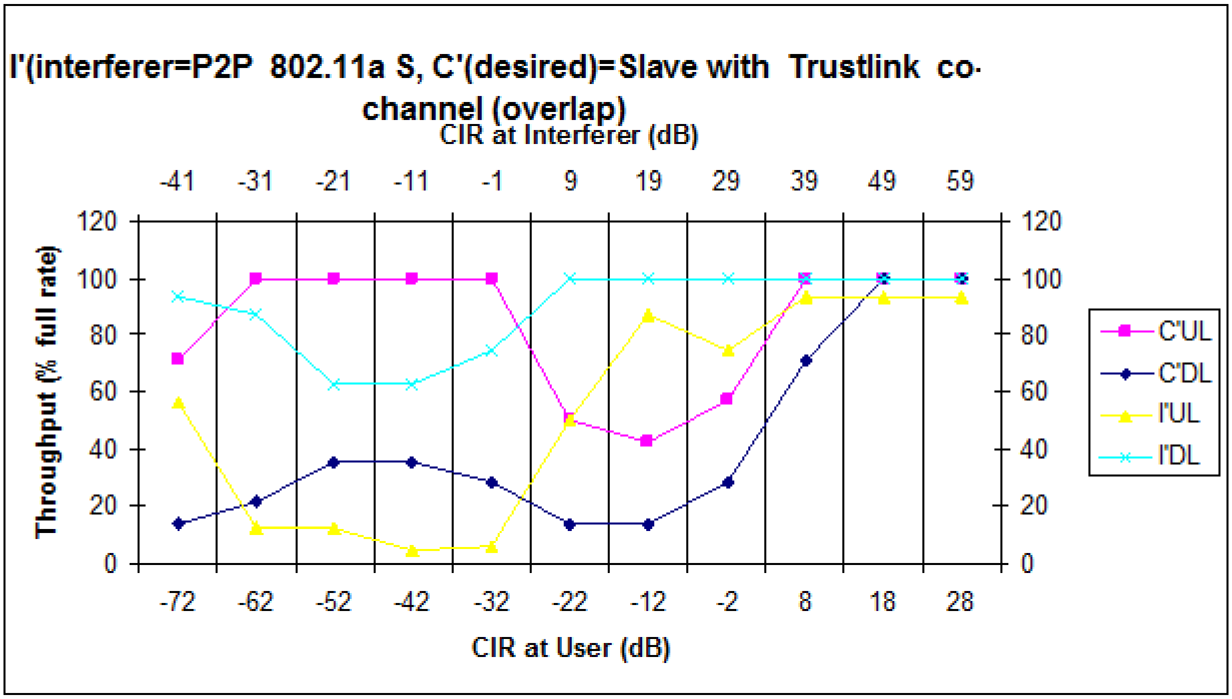

Figure 4: TrustLink Co-channel (overlap)

Conclusion

Since universal synchronization is not yet viable in unlicensed radio bands, the hybrid approach is as effective answer to provide the Quality of Service level that is seen in licensed spectrum system. It is our firm expectation that the Hybrid approach of StarPlus will provide superlative performance in congested band situations exceeding what is experienced with conventional systems.

It is our recommendation that synchronization is not required at this time in the StarPlus 5300 product. Once we review our results with you and you have an opportunity to ask us your questions, we believe you will agree we have a solution that will meet your needs.