Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Ranging Process Analysis And Improvement Recommendations**
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Re:	Call for contributions on the Ranging (OFDMA)
Abstract	This document analyzes current Ranging scheme and recommends improvements
Purpose	To improve current IEEE 802.16 ab-01_01r1, the OFDM PHY layers
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Ranging Process Analysis And Improvement Recommendations

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1. Introduction (Ranging Overview)

Ranging in OFDMA mode assumes that within a cell, a local SS receiver has its carrier frequency and symbol timing (propagation delayed version though) already synchronized to the BS transmitter.

Ranging process as initiated by a ready SS, further permits the BS to estimate the arrival timing (with respect to the symbol timing of a BS receiver, usually it is delayed by the round trip propagation time between the BS and the SS) and power of that SS.

However, a Ranging signal synthesized by using a "virtually orthogonal" set of Ranging codes (e.g. segments of a long PRBS[1]) to modulate (e.g. BPSK) a common set of sub-carriers and then sum up as an IFFT processing does, does not preserve their correlation (both auto and cross) properties of the original set of Ranging codes.

In fact, the degradation with respect to the original Ranging codes can well be explained as follows;

> A Ranging signal conveying a ranging code, through attenuation and propagation delay over a wireless channel, a frequency proportional phase rotation will be introduced to distort each recovered bit of that Ranging code, and therefore its correlation (cross correlation especially) properties after the FFT processing in the BS receiver.

Since the selected ranging channel contains statistically sub-carriers of any frequencies across the channel bandwidth, the demodulated (by FFT processing) and phase rotated new Ranging codes will have their correlation properties degraded tremendously as compared to the their respective original ones.

In another submission titled as " Comments On OFDMA Ranging Scheme Described in IEEE 802.16ab-01_01r1 " will present some of the simulation results to demonstrate the degradation of auto correlation and cross correlation properties.

Nonetheless, this contribution will focus on analyzing the current scheme through some basic DSP math to conclude a few alternatives can be evaluated and selected to improve the Ranging scheme in the current 802.16ab-01_01r1 OFDMA modes.

2. Analysis Of The Current Scheme

2.1. Design Criteria Revisit:

Basically, we comprehended the system design criteria of a good Ranging scheme (especially the Initial long Ranging) should be;

1). Ranging range: all user SS's within the cell size (1~ 30km) for BWA fixed wireless applications and (1 ~ 3 km) for BWA mobile applications.
2). Efficiency versus Capacity: Ranging time required to get a number of SSs to succeed.
3). Operational conditions: are simulated by SUI's models.

2.2. Advantages & Disadvantages

Based on the above criteria, we have focused on mostly the signal processing basics of the current scheme and managed to recognize both its advantages and disadvantages, which lead us to believe further improvements, can be made.

Advantages are;

1) Ranging Process and Data Transmission concurrence* (imperfectly)
2) Using existing IFFT in the transmitter for SS

Disadvantages (imperfections) are;

1). Local spikes in Auto-correlation and cross correlation make it prone to false detection in presence of multi-users (SSs).
2). Vulnerable to multi-path fading because of bad correlation Properties.
3). Ranging efficiency and Capacities are under expectation. due to degradation of cross correlation between phase rotated Ranging codes,
4). Initial Ranging causes ICI from Ranging channel to data channels.
5). Requires Complex Ranging processing in the BS receiver (due to exhaustive timing search in linear steps, or IFFT processing equivalent).

3. Alternatives To Improve Ranging

3.1. First Scheme[2]:

In our another contribution [2] , we first attempted Ranging channel composed of L clustered sub-carriers and then realized, unless allowed hopping about a few (which is more complex for data channel allocation), it can not measure the CIR fairly (Since a set of clustered sub-carriers, with the number of elements less than N, represents only a partial bandwidth of the whole channel).

Therefore, hopping about a few (e.g. 4 ~8) Ranging channels, which are composed of clustered sub-carriers, was our first try.

3.2. 2nd Scheme[2]:

By calculating the phase difference between each two adjacent sub-carriers of a ranging channel, and then correlating with each Ranging code, we then attempted to measure each one's arriving time by so processing the received signal superimposed by Ranging signals from M SSs.

All the schemes described so far still have Ranging channel interfering to the data sub-channels when any SS user is doing long Ranging (e.g. two symbol time for the first try and keeps on sending long Ranging signal unit it get responded from the BS).

3.3. 3rd Scheme:

In the 3rd scheme we have considered is to allocate time slots once in while to allow SS uers to do initial/long Ranging only.

For a given cell size, a Ranging time slot should reserve guard time long enough to allow Ranging signals to die out before the data mode starts.

Ranging signal of this scheme, can be synthesized by a set of Ranging channels, which are all composed of sub-carriers evenly distributed over the whole channel bandwidth.

3.4. 4th Scheme:

Lastly, we have thought about converting the each sub-carrier in the existing Ranging channel into dual-tones in order not to change the allocation algorithm for data sub-carriers.

The major challenge we have been facing with is how to avoid ICI between the Ranging channel and all data sub-channels.

Due to the complexity involved in changing the current sub-channel allocation algorithm , we throw out the 1st scheme.
To summarize, we have proposed three alternatives;

1). Assign a single Ranging channel composed of L sub-carrier pairs.
2). Use dedicated time slots (once in a while say every second) for initial/long ranging, and during those time slots a set of Ranging channels composed of L sub-carrier pairs evenly distributed across the channel bandwidth is used for Ranging.
3). Convert existing each sub-carrier of the Ranging channel to dual tones, and that is just a Concept and needs more work to realize.

4. Recommended Improvements

Obvious improvements can be made are;

1.Ranging Signal (needs single spike like for auto correlation response and flat noise floor like For cross correlation response).
2.Ranging Code (non-optimal Cross correlation needs to use a Gold code set composed of PN

Codes finite length, 2^N).
3.Minimize ICI from initial Ranging sub-channel to Data Channels.
4.Simplify Ranging processing in the BS.

5. How To Revise Current Document

5.1. For Ranging Channel Allocation

We also realized even though, the aforementioned schemes 3.2, 3.3, and 3.4, can not only improve the correlation properties of a Ranging signal significantly but also simply BS Ranging processing. However, it also requires to change the current allocation sequence for data and Ranging sub-carriers, and modify the existing allocation algorithms accordingly.

Basically, a Ranging channel needs to be assigned and taken out before the allocation algorithm mapping data sub-carriers to data sub-channels proceeds.

Similar to taking out the pilot sub-carriers, a Ranging channel is taken out again before the allocation algorithm mapping data sub-carriers to data sub-channels proceeds.

The permutation base will contain less number of sub-carriers (e.g. Reducing from 32 to 30 for allocating 106 sub-carriers for the Ranging channel in the OFDMA 2048 FFT size).

5.2. For Ranging Time Slot Allocation:

In MAC layer, before Ranging is initiated, a SS will always be receiving and decoding messages from the BS, and arriving of a Ranging time slot will be one of those.

6. Conclusion

In order to understand the current ranging scheme , we have done some mathematical analysis and computer (Math lab & System View based on PC) simulations and concluded the following;

1). Ranging channel needs to be assigned differently, and by assigning pairs at well distributed locations, Multi-Ranging codes can be better separated (less cross correlation assured by both IFFT of clustered sub-carriers or averaging of phase difference between sub-carrier pairs over the Ranging channel) and their arriving timing be more efficiently and accurately estimated.

2) Ranging code to be Orthogonal like a Gold code set (composed of truly orthogonal PN codes of length of power of 2) is recommended to further reduce the cross correlation between them.

3). To avoid Ranging channel interfering to Data channels, using (to be informed by BS through a message in MAC layer) dedicated time slots for Initial long ranging is recommended.

4). Associated with modification of allocating algorithms for data sub-channels are described in 5..1.

5). Associated with addition of a message (or a bit of an existing message) informing This is a Ranging slot in MAC layer, from BS to SS is described in 5.2.

It is intention of this contribution to improve the current Ranging scheme and further simulations will be provided in the near future.

7. References

[1] IEEE 802.16ab-01_01r1 page 170~172
[2] Timing & Power Estimate Basics For Multi-user Ranging