Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/20/>**
Title	**Response to C802.20-06-14r1.**
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Source(s)	Jim Tomcik Qualcomm, Incorporated 5775 Morehouse Drive San Diego, CA, 92121 Voice: (858) 658-3231 Fax: (858) 658-2113 Email: jtomcik@qualcomm.com
Re:	IEEE 802.20 session #20, May, 2006
Abstract	This document provides responses to the questions concerning MBFDD and MBTDD Wideband Modes, posed in contribution C802.20-06-14r1.
Purpose	FYI.
Notice	
Release	
Patent Policy	

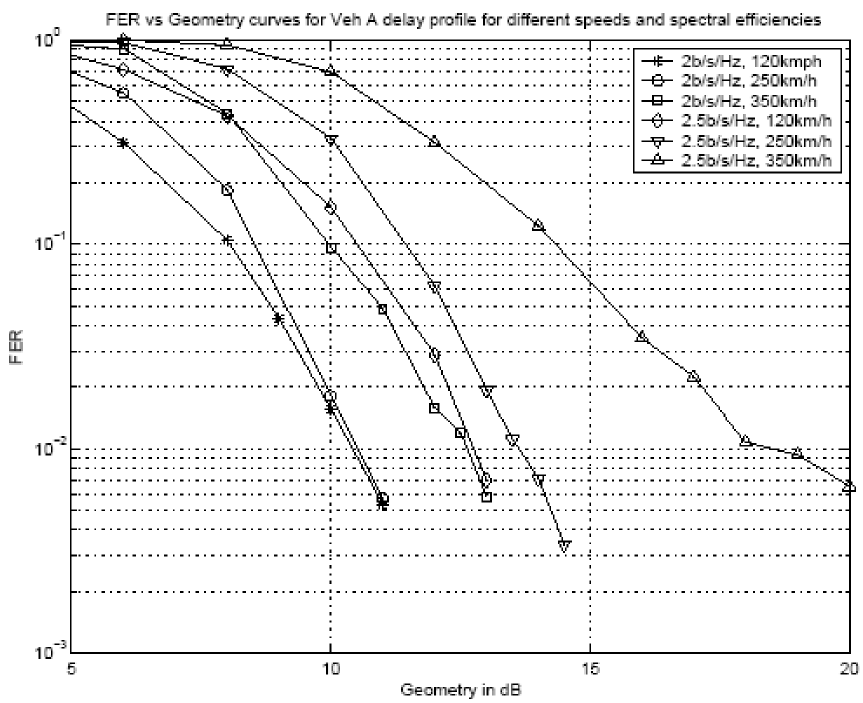
1. Introduction

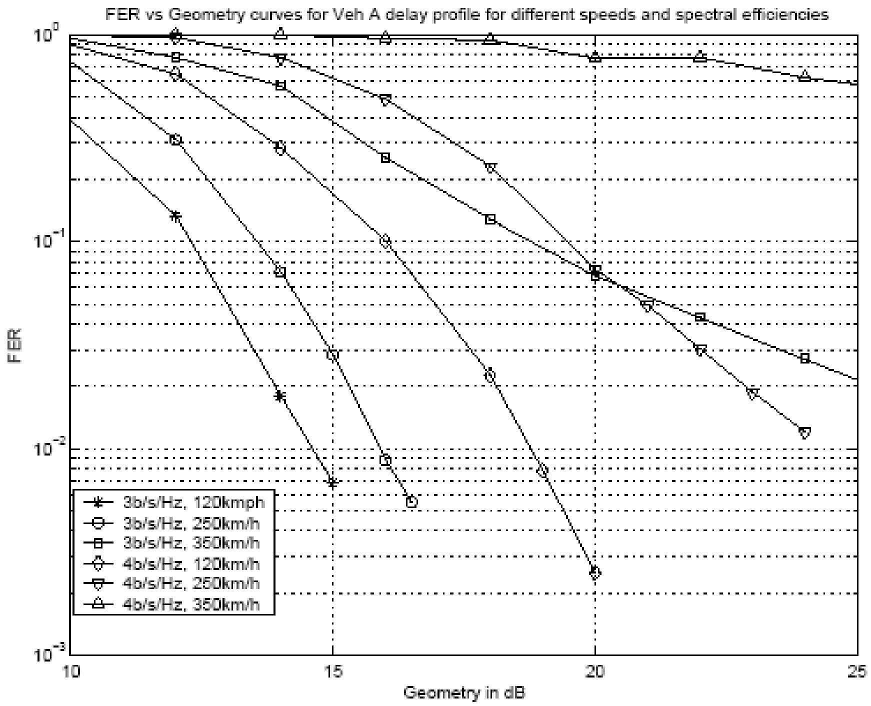
During the March Plenary meeting of 802.20, a contribution (C802.20-06/14r1) was submitted with a list of questions on the confirmed 802.20 proposals. This document provides responses to those questions dealing with the FDD and TDD Wideband Mode technologies.

2. List of further questions on MBFDD/MBTDD proposals

1. The subcarrier spacing of 9.6 kHz may be inadequate to support fast channel environment. What is the speed limit for feasible operation? Could you show the simulation result supporting this?

   Response: The two figures below show the performance of different spectral efficiencies on a Rayleigh fading channel with an ITU Veh A delay profile at different speeds. These simulations incorporate the effects of Doppler ICI and actual channel estimation. As can be seen from these plots, the system is capable of supporting 2 b/s/Hz even at 350 km/h. Up to 3 b/s/Hz can be supported at 250 km/h, and 4 b/s/Hz can be supported at 120 km/h. Thus we can conclude that system performance degrades gracefully with increasing speed.





2. With the various CP lengths supported, the frame size would be different too. How would the system support these? How often would the frame sizes changed? How would this be supported in a TDD system?

   Response: It is a preferred deployment scenario where CP duration and therefore frame duration is fixed across the entire deployment. Some exceptions may apply in FDD on the boundary of, e.g., areas with large delay spreads that are adjacent to areas with small delay spread where different CP duration can be used. In FDD, this leads to asynchronous operation of the adjacent sectors on the boundary of areas where different CP length values apply. In TDD, the same CP length will be used across the entire contiguous deployment on the same frequency. Hence, the main purpose of multiple CP length values is to provide flexibility of CP per deployment, although different CP values are possible within the same deployment in FDD.

3. What is the mandatory number of antennas on the FL?

   Response: There is no “mandatory number of antennas on the FL”, beyond the general assumption of at least 1 TX/RX antenna.

4. As the mobile user (AT) chooses the sequence randomly, what happens when two AT choose the same sequence? How is the contention resolved?

   Response: First of all, the set of random sequences has been designed to keep collision probability very low. Random access collisions can be resolved at different levels. First, the AP can detect a collision based on the time of arrival of different paths. In this case, AP will not grant access until the next access attempt, since access sequence changes every attempt. In the event that the AP can not resolve collision based on the time of arrival, AP will assign the same MACID and channel to the colliding ATs. In this case, there is a chance that the initial RL payload (containing AT's unique ID: UATI) will not be demodulated from all or all but one colliding ATs. In this case, all ATs that don't get their initial payload through will time-out and hence lose their MACID. Note that given the large number of access sequences, unresolved collisions happen very seldom.

5. How is the access latency affected as the number of users is increased?

   Response: Access latencies reported earlier (22 ms for 90% tail and 30 ms for 99% tail) correspond to a very high access load of about 90 initial access attempts per second. We saw little degradation when this number was doubled.

6. As described in the proposal, there are two hopping modes on the FL data channel, how and when does the system switch between the two modes? When is subband scheduling used?

   Response: The two hopping modes are defined deployment-wide and are not supposed to be changed often. Information about the FL hopping mode used is an overhead parameter carried on pBCH0 channel of the superframe preamble. Subband scheduling can be used in both modes when FLDiversityHoppingMode is set to '0'.

7. Is the subband bandwidth of 1.25 MHz the smallest granularity of scheduling grant? What is the assumption on the smallest packet size?

   Response: Minimum granularity of scheduling grant is 16 tones (16 * 9.6 kHz), irrespective of subband scheduling. There is no assumption on the smallest packet size.

8. Slide 58 of contribution 05/64, the maximum C/I is shown to be less than 20 dB, has this plot already included fast fading? Which channel model is used?

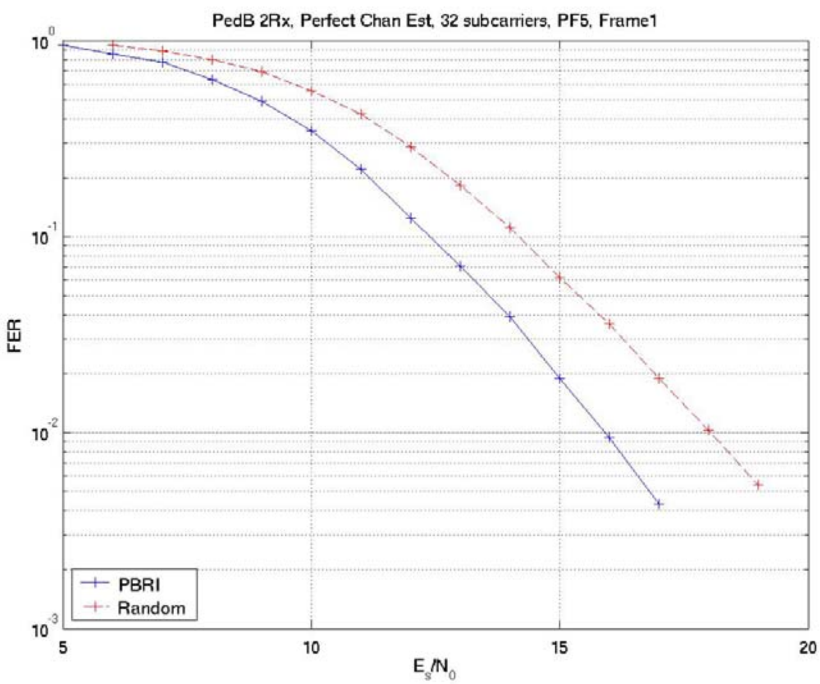
   Response: This plot doesn't include fast fading, hence, no specific channel is used.

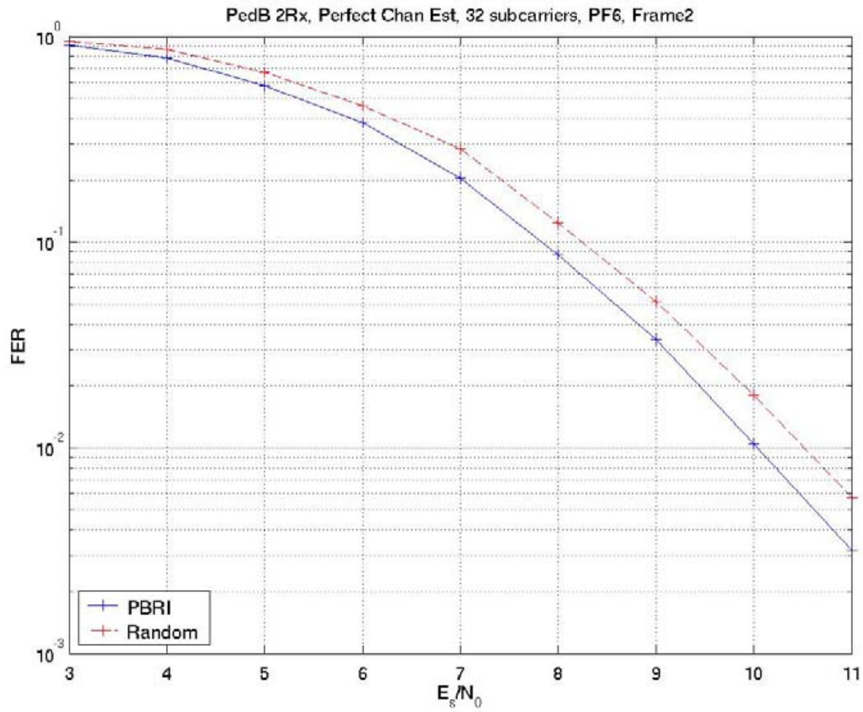
9. Why are the CP length and number of guard subcarriers requirement different for the superframe preamble than the PHY frame?

   Response: Superframe preamble needs to use a single setting for CP, so that the terminal is not required to search over multiple hypotheses during initial acquisition. Also, it is desirable to keep the number of guard carrier possibilities in the superframe preamble to a small number for the same reason. The value of CP length and number of guard carriers used for FL/RL PHY Frames are overhead parameters contained in pBCH0 which is a channel within superframe preamble.

10. What is the performance for channel interleaving based on the PRBI, especially for the smallest data block size? What is the test result on the randomness of PRBI?

Response: The PBRI-based channel interleaver is not a random interleaver. It is based on bit-reversal. This provides for good spreading properties and regular puncturing patterns at all data rates, thereby giving a significant improvement in performance over a random interleaver. The figures given below show the improvement of the PBRI-based channel interleaver over a random interleaver for a 32-subcarrier assignment on a pedB, 2Rx channel with perfect channel estimation at two different spectral efficiencies (PF5, Frame 1 and PF6, Frame 2).





11. Have the simulation results for system capacity (throughput) included power control? If so, what are the assumptions on power control delay and error probability?

    Response: FL simulations did not take advantage of power control. RL simulations model both control channel power control and data channel power control. The control channel power control interval is 6 frames for full-buffer simulations. Power control command error is modeled with 10% error rate. Data channel power control is also modeled in simulations based on OSICH interval.

12. Which set of simulation results indicate the performance of block hopping mode?

    Response: All system level simulations assume block hopping.

13. In the block hopping mode, a dedicated pilot is required as specified in the proposal, what is the additional overhead? Has this been excluded from the performance simulation results?

    Response: Roughly 14% overhead for most cases on both FL and RL. Exception 1: when rank 4 MIMO transmission is used for a particular transmission, the pilot overhead is close to 19%. Exception 2: VehB channels also require close to 19% pilot overhead. All overheads have been subtracted from simulation results.

14. Timing Uncertainty in Uplink - MS (mobile stations) will have different round-trip delay to the BS (base station) based on location. If multiple MS transmit in the uplink using multiple sub-channels, then the subcarriers may be non-orthogonal to adjacent or near subcarriers from other CPE. In addition they may not be synchronized to the BS receiver. Is this timing issue handled by:

    a) CP (cyclic prefix) large enough to accommodate the maximum delay uncertainty?

    b) Guard sub-carriers between sub-channels?

    c) BS measures delay from MS and sends timing adjustment to MS?

    Response: BS tracks RL channel (based on RL control channels) and sends SLP timing adjustment commands to the AT.

15. Doppler Shift - Has the effect of Doppler shift been taken into account in the simulations with the following considerations:

    a) Under maximum vehicle B velocity using minimum subcarrier width AND

    b) Maximum # CPE sharing uplink with maximum allowed sub-channels WITH RESPECT TO

    c) Total channel throughput?

    Response: The effect of mobility is modeled by Jakes Doppler spectrum with the corresponding speed. Doppler spread is accounted for in link curves used for system simulation, through realistic channel estimation. A separate link level study has shown that the overall effect of Doppler spread is dominated by the effect on channel estimation while the effect of inter-carrier interference is low for speeds of interest and the allowed power spectral density (p.s.d.) distribution.

16. Doppler Shift - If Doppler shift has been modeled, how are uplink sub-channels from multiple CPE demodulated at the BS receiver without loss of orthogonality?

    Response: See the previous answer.

3. List of questions on 802.20 proposals (from C802.20-06/10)

3.1 MBFDD

3.1.1 OFDM signaling parameters

1. When the shortest CP length, i.e., 6.51us is supported, the overhead is about 9%. What could be the worst case overhead percentage, i.e., when CP length is 4 times longer at 26.04us?

   Response: For the CP length of 6.51us, the total overhead of CP and windowing is about 8.57%. With 26.04us CP, the total CP and windowing overhead is about 21.95%.

2. In Table 6-1, the guard subcarriers are said to be functions of bandwidth. What is the mathematical representation of the function?

   Response: Guard subcarriers are allocated in units of 32 subcarriers (16 on each side of the band) according to the total bandwidth available and the amount of guard band needed to meet spectrum mask. There is no general rule or restriction on the number of guard subcarriers.

3. In Table 6-1, the bandwidth of operation for 2048 pt FFT is used for BW of operation <= 20 MHz, what other configuration parameters would be changed when the BW is 15 MHz, as compared to 20 MHz?

   Response: A bandwidth of 15 MHz would be generated by using a 2048 point FFT with the appropriate number of guard carriers. Other system parameters may change in a dependent manner based on this change, e.g., the hopping pattern and the size of a subband. Dependency of various system parameters on the system bandwidth is captured in the specification.

3.1.2 Acquisition and synchronization

4. Could you explain the details of cell acquisition and synchronization procedure employing the preamble channel? In your scheme, what is the mean acquisition time? What is the mean acquisition time for a user located at the cell edge?

   Response: Details of acquisition and synchronization procedure are described in section 10 of the technology overview document. In a synchronous deployment, we seen an average acquisition time of about 50 ms for C/I around -10 dB, for Ped.A channel with dual RX, and for a false alarm rate of under 1%.

5. Would there be more detail description on the asynchronous mode and the semi-synchronous mode? How to determine which mode is to be used?

   Response: Details on semi-synchronous and asynchronous modes are provided in section 10 of the technology overview document. Semi-synchronous mode can be used in the networks where superframe level synchronization (e.g., synchronization accuracy less than half superframe duration) is achieved. Asynchronous mode should be used otherwise.

6. Synchronization is an important issue for a system to work. What is the performance of the synchronization design? For example, what are the probabilities for detection and false alarm? Where is the analysis or simulation data for acquisition time? What is the performance versus jitter, phase noise and offset? What are recommended jitter, phase noise and offset requirements?

   Response: Simulation results for system acquisition are not required by the evaluation methodology and therefore have not been presented. In a synchronous deployment, our simulations show a mean acquisition time of around 50 ms for a -10 dB geometry, for Ped.A channel with dual RX and false alarm rate of 1%. At such a low C/I, the effect of jitter and phase noise is negligible, Hence, the stated average acquisition time is insensitive to jitter and phase noise, for the practical levels of these impairments.

7. What is the advantage of placing the primary broadcast channels before the TDM pilots in the superframe?

   Response: This placement allows for extra demodulation and decoding time of these broadcast channels (especially pBCH1) at the AT.

3.1.3 Multicarrier operation

8. How much guard band is required between 5 MHz, 10 MHz and 20 MHz for feasible scenario of multi-carrier mode?

   Response: The amount of guard band allocated at the edges of the total occupied band depends on the spectrum emission mask and is no different from a single carrier operation. The amount of quasi-guard band is defined by the adequate level of inter-carrier interference. For typical spectrum emission masks, requirements for the number of guard subcarriers is more stringent than requirements for the number of quasi-guard subcarriers. In the specification, the number of quasi-guard subcarriers is equal to the number of guard subcarriers.

9. What is a whole operation scenario of multi-carrier mode I and II?

   Response: There is no multicarrier modes I and II. Specification defines MultiCarrierModeOn or MultiCarrierModeOff. Details on multi-carrier operation are provided in section 24 of the technology overview document.

10. What are the differences between guard and quasi-guard subcarriers, as specified in section 9 of 05/69? How many of these are used when Multicarrier mode is turned on?

    Response: Guard subcarriers are allocated at the edges of the total system band while quasi-guard subcarriers are allocated between carriers in the multi-carrier mode. The number of quasi-guard subcarriers equals the number of guard subcarriers.

3.1.4 MIMO schemes

11. How are the mapping between the effective antennas and physical antennas done in SCW and MCW modes?

    Response: The mapping is beyond the scope of the specification. However, we present in this answer a way of doing that.

    If we have Mt transmit antennas but only want to transmit on M effective antennas a data vector **x** of size M x 1, then we first construct a random unitary Mt x Mt matrix **U**. We then choose **D** to be a sub-matrix of **U** constructed by the first M columns, i.e. **D** is an Mt x M. Now the data that are transmitted on the physical antennas are **y**=**Dx.** A different random matrix **U** is generated for every tile.

    There is no difference between SCW and MCW in his regard.

12. It seems that more sophisticated receiver is required to support the proposed multi-code word (MCW) modes. What is the complexity of the simulated receiver?

    Response: The simulated receiver is based on successive interference cancellation. Basically, the MIMO layers are ordered in ascending order. Once the first layer is decoded, the receiver reconstructs the data transmitted on this layer, cancels the reconstructed version from the received signal, proceed to decode the second layer, and so on.

13. How was the multiuser MCW mode with rank adaptation supported?

    Response: The reader should first review the response to question 16, since this provides background information regarding SDMA operation. .

    In SDMA, two or more users who are spatially distant are overlapped on the same resources. The data transmitted to each user could be SIMO or MIMO. The AT is unaware of whether or not somebody else is assigned the same resources, i.e., the interfering user(s) is treated as noise. Now if one or more users are in the MIMO MCW mode, the receiver operation is similar to the non-SDMA mode. That is, the rank is captured through assigning the null packet format for the layers that are not used.

14. In the MCW mode the streams are periodically circulated over the effective antennas. Then, why is it necessary to have different CQI for different effective antennas?

    Response: The CQI values are different for different layers because they are computed post detection/cancellation. For instance the CQI value for the first layer will potentially be worse than that of the second since it experiences interference form layers 2 to the total number of layers while the second layer experiences interference from layers 3 to the total number of layers.

15. In the FDD mode operation, it is unclear how the codebook based closed loop MIMO schemes obtain the CSI. Could you provide more details on this?

    Response: In the closed loop MIMO mode, the AT sends back an index of a matrix to be used in the FL transmission. This matrix is chosen from some codebook that is known to the AP and AT. The matrix is meant to be the closest one to the channel eigen vector matrix seen by the AT. With that approach, sending back the matrix index to AP substitutes the need to send back the full CSI.

16. The support for SDMA is not very clear. Could you provide us with some more details?

    Response: Let us assume a case when only two users can be in SDMA. In this case, part of the codebook will be dedicated to SDMA transmission. This part, if we only have 2 SDMA users, will be divided into two clusters. The matrices in a given cluster correspond to one part of the spatial domain. If the AT finds out that the best beam index lies in one of those clusters, the user also feeds back SDMADeltaCQI which captures the effect of intra cell interference. Now, if users a and b report beam indices that lie in clusters A and B respectively, the AP recognizes that users a and b are spatially distant and then have the option of overlapping both users on the same resources. In doing so, the packet format assigned to each user should capture the rate degradation due to intra cell interference. That can be achieved by utilizing the SDMADeltaCQI.

17. On one of the presentation slides (35), different antennas have to use different codes, what type of codes is used here?

    Response: Different antennas use orthogonal codes for pilot transmission. This is so that the receiver can distinguish the different antennas, and accurately estimate the separate channels from each of them.

3.1.5 Reverse link design

18. What is the distribution of the ratio of instantaneous signal power to average signal power for the reverse link transmit waveform?

    Response: PAPR depends on the assigned number of assigned subcarriers and modulation order.

19. How much backoff is necessary for a typical power amplifier?

    Response: The backoff required is dependent on the exact PA characteristics, on the number of guard carriers allocated, and on the out-of-band emission requirements. The out-of-band emissions for an example situation can be found in C802.20-05-61R1.

20. Slide 39 of 05/59 shows that the access latency with power ramping is within 22ms for 90 percentile of users, what was the number of simultaneous access users simulated?

    Response: Initial access arrival process was modeled as Poisson process with the average number 0.5. This corresponds to around 90 initial access attempts per second.

21. Maximum power control update rate is only 180 Hz for the RL control channel (CDMA), would this be sufficient for different mobility classes? How much is the performance degradation when the update rate is even slower, also taking into consideration the intra-sector interference that exists in the CDMA control segment?

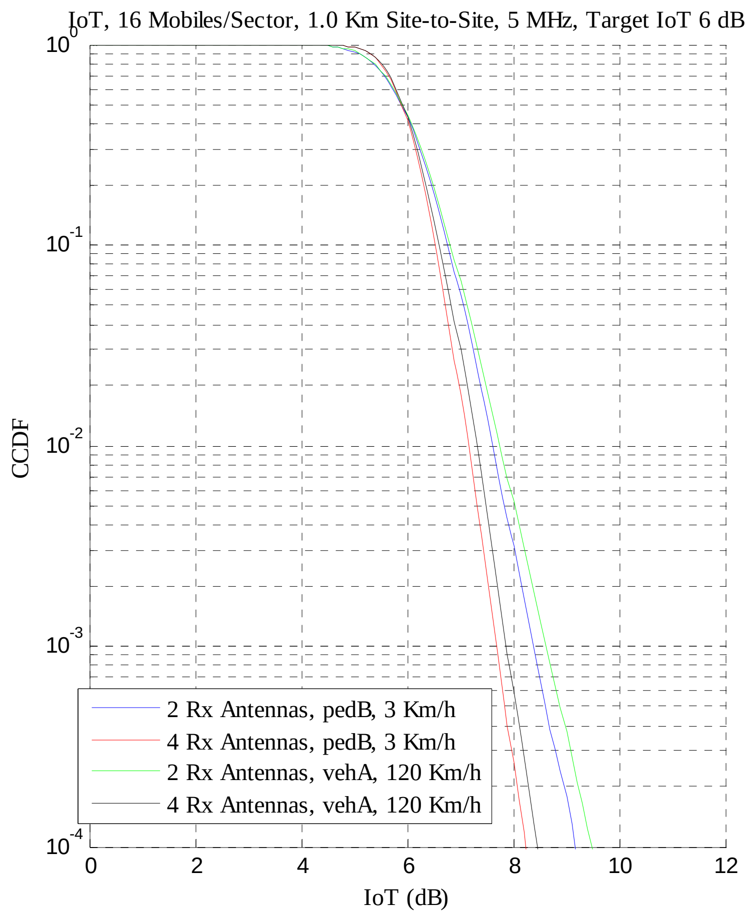
    Response: The control channel power control is not intended to follow the fast fade component for all mobility classes. For high mobility users, it will result in only path loss and log-normal shadowing inversion, with a sufficient back off to guarantee the required performance (e.g., erasure rate) for the control channels. For low mobility users, further slowing down the update rate will result in wider C/I distribution, however, the performance will still be better than the lower bound obtained by a power control scheme based on path loss and shadowing inversion (as in the case of high mobility users).

22. The uplink interference indicators are transmitted through the OSICH only once per superframe, which imply the PC loop for traffic channel update rate is less than 50 Hz. Would this be sufficient especially for high mobility users?

    Response: The IoT distribution provided in response to question 23 shows good system stability for both low and high mobility scenarios. In addition, the Fast OSI segment of the SSCH may be transmitted as often as every FL PHY Frame (~ every 0.9 ms) to provide loading indication for nearby sectors. However, note that the IoT distribution shown in the response to question 23 shows system stability even without taking advantage of this feature.

23. In contribution 05/61, CCDF of IoT is simulated for Pedestrian B, 3 km/h channel model case only, how about the performance at higher mobility cases?

    Response: The IoT distribution for the case of Vehicular A channel at 120 Km/h is presented in the figure below, and is compared to the corresponding distribution with Pedestrian B channel at 3 Km/h.



24. For the case of 0.866 km cell radius, 2 Antennas, the 1% tail of the IoT CCDF is at 1.6 dB away from the target of 6 dB, i.e., 60% higher than the value in the text description.

    Response: The text description of tail being 1 dB away from mean IOT is only meant for 4 antennas. For the 2 antennas case, 1% tail IOT being 1.6 dB away from mean IOT is an indication of good system stability.

25. Can the stability of the algorithm be maintained? Tail shown for 1% only, could there be a few users 0.1 or 0.001% of users with much higher noise rise?

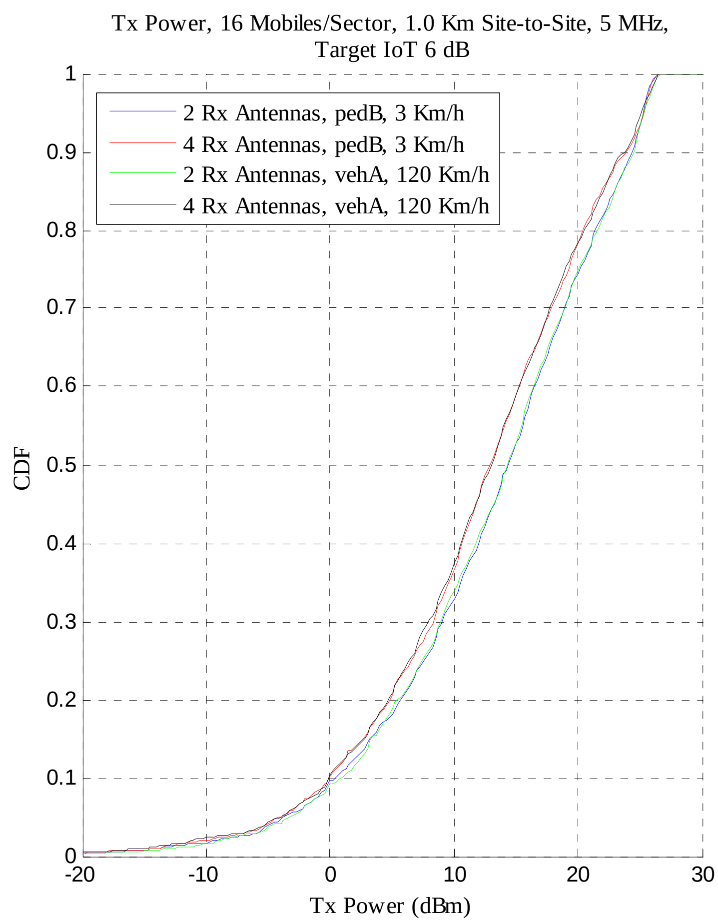
    Response: The IoT distribution provided in response to question 23 includes the tail distribution up to 0.01%, and shows good system stability for both low and high mobility scenarios.

26. When the OSICH indicator is “2”, a faster PC rate is applied. How exactly would the PC rate be increased, and is there simulation or analytical results that guaranteed stability?

Response: For OSICH indicator “2”, the PC rate is not increased, instead, the user response to the OSICH indicator is changed (from a probabilistic decision used for OSICH “1”) to a deterministic step down decision. Furthermore, subsequent OSICH “2” indicators from the same sector (if such sector is the strongest non-serving sector of the AT), result in larger step sizes, and hence a faster decrease in the user’s transmit PSD. Simulation studies in C802.20-05/61r1 and C802.20-05/66r1 indicate the stability of IOT.

27. What does the distribution of user transmit power in the RL look like?

Response: The CDF of the mean user transmit powers for an example situation is shown in the figure below. This is for the case of a full-buffer simulation, with the parameters provided in the legend.



28. RL control segment is described as occupying a subband of 1.25 MHz (?), and hops over the whole band, what is the hopping frequency and sequence? How many codes (Walsh codes?) are accommodated?

Response: RL control segment occupies a multiple of 1.25 MHz (128 subcarrier) subbands. It hops every control segment occurrence (typically every 5.5 ms), according to a random hopping pattern which is synchronized across deployment. The maximum number of Walsh codes is 1024 (maximum 10 bits carried by channels within RL control segment).

29. What are the modulation schemes used for the control channels, PCB, CQICH, ACQCH and F-OSICH etc.?

Response: We assume that PCB refers to the FL power control bits sent by the AP. Power control bits use BPSK modulation. R-CQICH is a RL control channel within RL control segment, hence makes use of DS-CDMA modulation. F-ACQCH consists of three pilots: TDM1, TDM2 and TDM3. All these pilots are sector specific PN sequences in the frequency domain. F-OSICH is modulated as a constant modulus tri-state complex value applied to TDM3.

3.1.6 Forward link, multiple access, scheduling issues

30. What is the distribution of the ratio of instantaneous signal power to average signal power for the forward link transmit waveform, including the multicarrier modes?

Response: PAPR distribution depends on the total number of populated subcarriers, their distribution across system bandwidth and modulation orders used.

31. How is the proposed fractional frequency reuse scheme operated? In addition, could you show the adequate performance results displaying the relative advantage when compared to fixed frequency reuse scheme (1 or 3)?

Response: FFR operation is described in C802.20-05/68. Please refer to C802.20-05/88r1 and C802.20-05/86r1 for FFR performance results.

3.1.7 Performance issues

32. How can the spectral efficiency of 11 be calculated without MIMO support? Could you clarify the calculation method and assumptions?

Response: In the draft specification, spectral efficiency is defined as the number of bits in a packet divided by the number of modulation symbols at the first H-ARQ transmission.. For the case when the packet size is 11 times the number of modulation symbols in the first HARQ transmission, spectral efficiency under this definition would turn out to be 11b/s/Hz. Such a packet is not decodable at the first transmission, it becomes decodable at the second transmission. Note that the spectral efficiency calculated by using a non-decodable packet format is not used in peak rate or throughput calculations.

33. What is exactly the average retransmission interval? In the system simulation, what is the distribution of retransmission interval?

    Response: Retransmission interval is six FL/RL PHY Frames in FDD and three FL+RL PHY Frames in TDD 1:1. The actual retransmission time is about 5.5ms in FDD and about 5.8ms in TDD 1:1, it is longer when interrupted by a superframe preamble (~1 ms every ~22 ms in FDD and ~23 ms in TDD1:1).

34. What are the performance targets for the QoS classes and the mappings between these and the DiffServ classes?

    Response: The QoS classes in the draft specification do not have predefined performance targets. These targets can be configured through over-the-air negotiation. Some of the QoS classes can be mapped to predefined DiffServ classes through over-the-air negotiation. In our simulations, a total of three QoS classes have been used: expedited forwarding for VoIP, assured forwarding for NRTV, best effort for HTTP/FTP. More details on performance targets corresponding to each class are given in section 1.4 of the Performance Report II.

35. What are the requirements for frequency error, timing error, phase noise characteristics?

    Response: The draft standard does not include requirements on receiver performance. The draft specification is intended for many and diverse regulatory environments and applications, and the performance requirements for each of these environments and applications could be different.

36. Any simulation data or analysis to show that the handoff delay is about 8 ms? What are the channel models and mobile speed?

    Response: Please refer to Section 2.1.4 in C802.20-05/88r1 and C802.20-05/86r1 for detailed handoff delay analysis.

37. What is the performance on fairness criteria for the GoS scheduling algorithm? Is this a fairness standard as defined by the proponent?

    Response: We assume that GoS schedule algorithm is referring to EGoS fairness, which stands for equal grade of service. The resulting fairness is shown in C802.20-05/61r1 and C802.20-05/66r1.

38. Is there a plot showing the calibration for the reverse link simulator?

    Response: The same simulator is used for FL and RL simulations, and hence the same calibration data applies.

39. About the link budget, what is the assumption on the interference margin?

    Response: Please refer to C802.20-05/61r1 and C802.20-05/66r1.

40. As the PCB, OSICH and ACK bits are not encoded, what could be the bit error rate performance of these channels, especially in high mobility situation?

Response: For power control commands, we target error rate on the order of 5-10%. For ACK bits, false NACK rate of 1% and false ACK rate of 0.1% is the target. F-OSICH is designed to operate at within 10% error rate. The targeted error rates can be achieved by power controlling these commands using CQI reports from the terminals.

41. How much degradation in performance would be incurred because of errors in these channels as stated in the above question?

Response: The effect of the above error events is presented in C802.20-05-86r1 and C802.20-05-88r1.

42. What is the total overhead in the system? For example, superframe header, PHY frame header, guard and pilot tones etc. What is the increase in overhead after CRC is extended from 16 to 24 bits in the updated proposals?

Response: The overhead in the system can be found in Section 4.2 of contributions C802.20-05-61r1 and C802.20-05-66r1. The CRC overhead depends on the packet size, which differs from application to application. The application-level results provided in the performance reports take the CRC overhead into account.

43. What is the assumption on backhaul delay in the mobility simulations?

Response: A 10 ms one-way backhaul delay is used in our handoff performance analysis.

3.2 MBTDD

3.2.1 Wideband mode (Some of the FDD questions are valid for this mode)

44. For the values of guard time between transmit and receive frame supported, what is the assumption on the largest cell size?

Response: The guard times (FL to RL and RL to FL) are designed to accommodate up to about 15 us of RF warm-up time and about 60us of roundtrip time. The latter roundtrip time corresponds to cell radius of 9 km. Note that shorter RF warm-up time will allow for more roundtrip time, hence larger cells.

45. In the TDD proposal, it is described that CQI reporting is less than or equal to 150 Hz, does that imply PC rate of RL control channel has the similar value?

Response: First, a clarification: The CQI reporting rate is less than or equal to 180 Hz, not 150 Hz.

While the draft specification does allow for power control bits to be transmitted at a higher rate than the CQI reporting interval, we anticipate that the power control rate in practice would be less than or equal to 180 Hz. As explained in the response to question 21, we believe this power control rate to be sufficient.