Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
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Re:	Call for contributions regarding P802.16m project, 1/22/2007
Abstract	This document provides definition of output metrics for IEEE 802.16m evaluation methodology document.
Purpose	For discussion and approval by TGm
Notice	
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Patent Policy and Procedures	

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References

[1] Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000, “Recommendation ITU-R M.1225,” 1997

[2] 3GPP2 C.R1002-0 1.0, “CDMA2000 Evaluation Methodology”, January 2005.

1 Simulation Outputs and Performance Metrics

Statistics will be collected from sectors belonging to the test cell(s) of the 19-cell deployment scenario. Collected statistics will be traffic-type (thus traffic mix) dependent.

In this section, we provide a definition for various metrics collected in simulation runs. For a simulation run, we assume:

1] Simulation time per drop = T_{sim}
2] Number of simulation drops = D
3] Total number of users in sector(s) of interest= N_{sub}
4] Number of packet calls for user u = p_u
5] Number of packets in i^{th} packet call = $q_{i,u}$

Throughput Performance Metrics

For evaluating downlink (uplink) throughput, only packets on the downlink(uplink) are considered in the calculations. Downlink and uplink throughputs are denoted by upper case DL and UL respectively (example: R_u^{DL}, R_u^{UL}). The current metrics are given per a single simulation drop.

The throughput metrics below shall be measured at the following layers:

PHY Layer
MAC Layer
TCP Layer

The throughput for those layers is measured at the points identified in Figure 1-1; where the throughput refers to the payload throughput without the overhead.

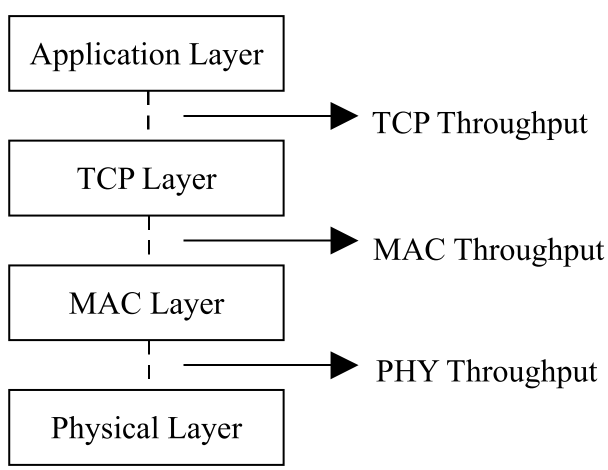

Figure 1-1: Throughput Metrics Measurement Points

Average Throughput for User *u*

To evaluate downlink (uplink) average user throughput; assuming a simulation time T_{sim}, user u has $p_u^{DL(UL)}$ downlink (uplink) packet calls , with $q_{i,u}^{DL(UL)}$ packets for the i[th] downlink (uplink) packet call, and $b_{j,i,u}$ bits for the j^{th} packet; then

Data throughput for user u: $$R_u^{DL(UL)} = \frac{\sum_{i=1}^{p_u^{DL(UL)}} \sum_{j=1}^{q_{i,u}^{DL(UL)}} b_{j,i,u}}{T_{sim}} \qquad (1.1\text{-}1)$$

Sector Data Throughput

Assuming N_{sub} users in sector(s) of interest, and u^{th} user where u N_{sub} has throughput $R_u^{DL(UL)}$, then:

Sector(s) Data Throughput: $$R_{\sec}^{DL(UL)} = \frac{\sum_{u=1}^{N_{sub}} \sum_{i=1}^{p_u^{DL(UL)}} \sum_{j=1}^{q_{i,u}^{DL(UL)}} b_{j,i,u}}{T_{sim}} \qquad (1.1\text{-}2)$$

The histogram of users' data throughput

The histogram will display the distribution of the downlink (uplink) throughput observed at the MS (BS) for the subscribed users assuming that the scheduler is work conserving; i.e. users with sufficient SINR to support the lowest MCS are scheduled. To obtain the histogram, the data throughput for each user needs to be calculated according to equation (1.1-1).

Throughput Outage

Throughput outage ($O_{thpt}(R_{min})$) is defined as the number of users with data rate R_u^{DL}, less than a predefined minimum rate R_{min} (TBD). This can be computed identifying the number of users with R_u^{DL} less than R_{min} from , and dividing it by the total number of users.

Geographical Distribution of Data Throughput per User.

The plot will show the geographical distribution of the throughput observed on the downlink (uplink) by the MS (BS). It provides insight into the throughput variation as a function of distance from the BS. This allows for easy comparison between different reuse scenarios, network loading conditions, smart antenna algorithms, etc.

Geographical Distribution of Throughput Outage

The plot will show the geographical distribution of the users experiencing throughput outage; providing insight into the outage probability as a function of distance from the BS.

Delay Sensitive Applications Performance Metrics

For evaluating downlink (uplink) delay, only packets on the downlink (uplink) are considered in the calculations. Downlink and uplink delays are denoted by upper case DL and UL respectively (example: D_u^{DL}, D_u^{UL})

User Average Packet Delay

Assuming the *j*

$$D_u^{avg,DL(UL)} = \frac{\sum_{i=1}^{p_u}\sum_{j=1}^{q_{i,u}}\left(T_{j,i,u}^{dep,DL(UL)} - T_{j,i,u}^{arr,DL(UL)}\right)}{\sum_{i=1}^{p_u} q_{i,u}} \quad (1.2\text{-}3)$$

CDF of Users' Average Packet Delay

The CDF will reflect the cumulative distribution of the average delays observed by the users.

Sector Average Packet Delay

For the application of interest, assume N_{sub} users in sector(s) under consideration. If the application for the u^{th} user, where $u \in N_{sub}$ has average packet delay $D_u^{avg,DL(UL)}$, then:

$$D_{\sec}^{avg,DL(UL)} = \frac{\sum_{u=1}^{N_{sub}}\sum_{i=1}^{p_u}\sum_{j=1}^{q_{i,u}}\left(T_{j,i,u}^{dep,DL(UL)} - T_{j,i,u}^{arr,DL(UL)}\right)}{\sum_{u=1}^{N_{sub}}\sum_{i=1}^{p_u} q_{i,u}} \quad (1.2\text{-}4)$$

Sector Packet Delay Variance

For the application of interest, assume N_{sub} users in sector(s) under consideration. If the application for the *u*th user where $u \le N_{sub}$ has average packet delay $D_u^{avg,DL(UL)}$, then the delay variance, $D_{\sec}^{\mathrm{var},DL(UL)}$ observed in the sector for the application is given by:

$$D_{\sec}^{\mathrm{var},DL(UL)} = \frac{\sum_{u=1}^{N_{sub}}\sum_{i=1}^{p_u}\sum_{j=1}^{q_{i,u}}\left(T_{j,i,u}^{arr,DL(UL)} - T_{j,i,u}^{dep,DL(UL)} - D_{\sec}^{avg,DL(UL)}\right)^2}{\sum_{u=1}^{N_{sub}}\sum_{i=1}^{p_u} q_{i,u}} \qquad (1.2\text{-}5)$$

User Average Packet Delay Jitter

For the application of interest, we define delay jitter $J_u^{avg,DL(UL)}$ as the variation in the packet delay times for consecutive packets observed at the receiver by user *u*.

$$J_u^{avg,DL(UL)} = \frac{\sum_{i=1}^{p_u}\sum_{j=2}^{q_{i,u}}\left|\left(T_{j,i,u}^{arr,DL(UL)} - T_{j,i,u}^{dep,DL(UL)}\right) - \left(T_{j-1,i,u}^{arr,DL(UL)} - T_{j-1,i,u}^{dep,DL(UL)}\right)\right|}{\sum_{i=1}^{p_u} q_{i,u}} \qquad (1.2\text{-}6)$$

CDF of Average Packet Delay Jitter

The cumulative distribution function (CDF) for the average packet jitter experienced by the users for the application of interest. The CDF's allow for an easy comparison between different reuse scenarios, network loading conditions, and evaluating the percentage of users experiencing excessive jitter.

Geographical Distribution of Average Packet Delay per User

The plot will show the geographical distribution of the packet delay for the application of interest observed on the uplink by the BS. It provides insight into the packet delay variation as a function of distance from the BS.

Application Outage

Application outage *(O_{app})* occurs when:

A user experiences packet error rate (PER) exceeding a maximum allowable PER for a duration exceeding a certain percentage of the session time.

and/or

A user experiences an average delay exceeding the maximum allowable average packet delay. This delay is measured throughput the session time,

Voice applications are defined in output if session experiences in either direction a short term PER exceeding 15% more often than 1% of the time . As for gaming applications, outage is defined as having an average packet delay greater than 60msec; where dropped packets count as having an 180 ms delay.

System Level Metrics

Spectral Efficiency

Spectral efficiency *(SE)* is a key figure of merit for comparing different network configurations, and is defined as the data rate for all users served in a target cell normalized by total bandwidth required for deployment (BW_{TOT}).

$$SE = \frac{\sum_i \left(R_{SEC_i}^{DL} + R_{SEC_i}^{UL} \right)}{BW_{TOT}} \qquad 1.3\text{-}7)$$

The downlink and uplink spectral efficiencies are given by

$$SE_{DL} = \frac{1 + r_{DL/UL}}{r_{DL/UL}} \frac{\sum_i R_{SEC_i}^{DL}}{BW_{TOT}} \qquad 1.3\text{-}8)$$

$$SE_{UL} = \left(1 + r_{DL/UL}\right) \frac{\sum_i R_{SEC_i}^{UL}}{BW_{TOT}} \qquad 1.3\text{-}9)$$

where $r_{DL/UL}$ is the downlink to uplink ratio.

CDF of SINR

The cumulative distribution function (CDF) for the signal to interference and noise ratio (SINR) observed by the BS for each user on the uplink channel. The CDF's allow for an easy comparison between different reuse scenarios, network loading conditions, smart antenna algorithms, etc.

Histogram of MCS

The histogram will display the distribution of MCS for the subscribed users.

Geographical distribution of MCS

The plot will show the geographical distribution of the MCS used by the subscriber station on the uplink. It provides insight into the variation of MCS as a function of distance from the BS. This allows for easy comparison between different reuse scenarios, network loading conditions, smart antenna algorithms, etc.

Application Capacity

Application capacity *(C_{app})* is defined as the maximum number of application users that the system can support without exceeding the maximum allowed outage probability.

System Outage

System outage is defined as when the number of users experiencing outage exceeds k% of the total number of users. User outage is defined in (1.1-1) and ; where k is dependent on the application of interest (example: 3% for VoIP)

Fairness Criteria

1.1.1.1 Fairness Criterion with Normalized CDF of Users' Throughput

For baseline simulation with full-buffer traffic scheduled by proportional fair scheduler, we define fairness criteria to evaluate the fairness of the scheduler. It is assumed that the scheduling algorithm is known and does not change between simulation runs, and that the scheduler is not optimized for any particular mix of traffic.

The CDF of the normalized throughput for all users is plotted where the normalized throughput for user u is given by

$$R_{u,norm} = \frac{R_u}{R_{ave}} \qquad (1.3\text{-}10)$$

Fairness is said to be achieved if the CDF lies to the right of the y=x line for x= (0.1, 0.2, 0.5).

1.1.1.2 Fairness Criterion with Geometric Mean and Harmonic Mean

Optionally, geometric mean (GM) and harmonic mean (HM) calculated from the set of full-buffer throughputs can be used for full-buffer performance comparison [2]. Scheduler should optimize GM or HM if these metrics are used for performance comparison.

GM metric is calculated as in equation (1.1-12) and HM metric is calculated as in equation (1.1-13).

$$R_{GM} = \frac{1}{Ns}\sum_{k=1}^{Ns} N_{sub,k}\left(\prod_{u=1}^{N_{sub,k}} R_{k,u}\right)^{\frac{1}{N_{sub,k}}} \qquad 1.3\text{-}11)$$

$$R_{HM} = \frac{1}{Ns}\sum_{k=1}^{Ns} N_{sub,k} \frac{N_{sub,k}}{\sum_{u=1}^{N_{sub,k}} \frac{1}{R_{k,u}}} \qquad 1.3\text{-}12)$$

Where $R_{k,u}$ is the average throughput for user *u* in sector *k*, $N_{sub,k}$ is the number of users in sector *k,* and *Ns* is the total number of sectors in the network (57 in the standard layout).

To compare the throughput fairness across proposals, R_{GM} or R_{HM} shall be reported and compared. And no further criterion on throughput fairness is required.