Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Multihop System Evaluation Methodology – Performance Metrics {Harmonized}**
Date Submitted	**2006-07-20**
Source:	Gamini Senarath, Wen Tong, Peiying Zhu, Hang Zhang, David Steer, Derek Yu, Mark Naden, Dean Kitchener Nortel 3500 Carling Avenue Ottawa, On, K2H 8E9 Canada Roger Peterson Eugene Visotsky Motorola 1301 E. Algonquin Road, Schaumburg, IL 60196 USA Gamini@nortel.com wentong@nortel.com r.peterson@motorola.com
Re:	Response to a call for contributions for the Relay TG
Abstract	This document provides performance metrics proposals to be included in the evaluation methodology document.
Purpose	To propose performance metrics for multi-hop systems.
Notice	
Release	
Patent Policy and Procedures	

Multi-hop System Evaluation Methodology: Performance Metrics

1 Introduction

This document provides input to Section 4 (Performance Metrics) of the "Multi-hop System Evaluation Methodology (Channel Model and Performance Metric) document (ref. C80216j-06_040.doc) . It is proposed to have two sections 4.1 and 4.2 for single-user and multi-user performance as mentioned below. The current Section 4.1 may move as Section 4.2.1.

2. Input Text

+++

{ Input Text for Section 4 }

The performance metrics are divided into two categories. They are:

Single-user performance; and

Multi-user performance.

Examples of single-user performance metrics are the link budget margins, C/I area coverage and data rate area coverage. These metrics are evaluated assuming that a single user is in a particular cell area utilizing all the resources in that cell while external interference may be evaluated assuming that at least a single active user is available in the external cell (for both forward and reverse link). These metrics are not end-to-end performance metrics and therefore, could be evaluated without modeling higher layer protocols and is independent of applications.

However, when multiple users are in the system the system resources have to be shared and a user's average data rate will be smaller than the single-user rate. Therefore, multi-user metrics are proposed which show how a system behaves under a multi-user environment.

In order to evaluate multi-user performance accurately, scheduling and higher layer traffic behaviors and protocols need to be modeled. However, simulation run times can be prohibitively large. Specially, in the case of multihop systems, each sector can have several relay stations and there are a large number of relay stations and relay to user and relay to base links need to be modeled sand simulated. Therefore, such simulations can be very CPU intensive. Therefore, we suggest that initial design validations be done using a simple but representative analysis using a full queue traffic without modeling higher layers. These are described under multi-user performance metrics.

4.1 Single-user performance Metrics

Note that the area coverage mentioned below is equivalent to the percentage of users meeting a given requirement when the users are uniformly distributed in the interested geographical area.

4.1.1 Link Budget and Coverage Range (Noise Limited) – single-cell consideration

Link budget evaluations is a well known method for initial system planning and this needs to be carried out for relay to base, relay to user and base to user links separately. The parameters to be used needs to be agreed upon after obtaining consensus. Using the margins in the link budget, the expected signal to noise ratio can be evaluated at given distances. Using these results, the noise limited range can be evaluated for the system when the relays are deployed. Link budget analysis are provided in detail in Section 5.

Since relays can be used to extend the range covered by a cell under noise limited environment (i.e. no interference from other cells but the limitation coming from the fact that the transmit power is not enough to provide a sufficient signal strength above thermal noise) coverage range is a metric of importance in such cases.

Coverage range is defined as the maximum radial distance to meet a certain percentage of area coverage (x%) with a signal to noise ratio above a certain threshold (target_snr) over y% of time, assuming no interference signals are present. It is proposed that x be 99 and y be 95.

4.1.2 C/I Coverage – interference limited multi-cell consideration

The C/I coverage is defined as the percentage area of a cell where the average C/I experienced by a stationary user is larger than a certain threshold (target_ci).

4.1.3 Data Rate Coverage – interference limited multi-cell consideration

The percentage area for which a user is able to transmit/receive successfully at a specified mean data rate using single-user analysis mentioned above. No delay requirement is considered here.

4.2 Multi-user Performance Metrics

4.2.1 Combined Coverage and Capacity Metric (cc)

There are three important aspects that need to be considered when the multi-user performance is evaluated for a multi-hop system.

Sharing the shared channel among users:

Taking into account the number of relays used by each user

Although a user may be covered for a certain percentage area (e.g. 99%) for a given service, when multiple users are in a sector/BS, the resources (time, frequency) are to be shared with other users. It can be expected that a user's average data rate may be reduced by a factor of N when there are N active users (assuming resources are equally shared and no multi-user diversity gain), compared to a single user rate.

For example, assume that there is a system, where a shared channel with a peak rate of 2 Mbps can serve 99% of the area. If a user wants to obtain a video streaming service at 2 Mbps, that particular user will be able to obtain the service, but no other user will be able to get any service during the whole video session (which may extend for more than an hour). Therefore, in this example although 99% area is covered for the video service, this service is not a viable service for the operator and performance of coverage need to be coupled with the capacity in order to reflect viable service solutions..

The low rate users can be provided more resources so that they would get equal service from the cellular operator but that would impact capacity. Thus, there is a trade-off between coverage and capacity and any measure of capacity should be provided with the associated coverage. .

Since an operator should be able to provide the service to multiple users in the same time, an increase in the area coverage itself does not give an operator the ability to offer a given service

Therefore, the number of users that can be supported under a given coverage captures actual coverage performance of a given service from a viability point of view.

{ Editor's note on harmonizsed proposal: The following definition in the original 071 submission is to be replaced by the improved definition provided below}

{This para is to be deleted}

The combined coverage and capacity index (*CC*) is defined as the maximum number of simultaneous users (N) that can be supported for a given service, with a specified level of area coverage.

{this para from 084 is included}

Combined Coverage and Capacity Index (*CC*): The number *N* of simultaneous users per cell (e.g. MMR-cell or legacy cell) that can be supported achieving a target information throughput $R\min$ with a specified coverage reliability.

{This para is deleted}

~~This metric can also be evaluated approximately without modeling higher layer protocols and without modeling application traffic (under the full queue assumption) for delay tolerant services. Due to its simplicity and its ability to compare two coverage enhancement systems quickly at the initial system concept development stage, this is included below to be used for system evaluation. The person providing results should mention which method is used in his/her evaluation.~~

{This para is included}

This performance metric can be approximated using either a simplified approximate evaluation methodology or a more detailed simulation as described below. Both methods are useful since the approximation methodology can be used to quickly compare two coverage enhancement techniques at the initial system concept development stage. The detailed simulations are useful to evaluate more carefully the most promising concepts. When results are presented the evaluation method used should be reported.

{ Editor's note on harmonizsed proposal: The methodology included in 084 is to be included as Methodology 2, an alternative detailed evaluation methodology}

Method 1:

This is a Simplified Methodology to evaluate Combined Coverage and Capacity Index (cc) using only the rate capability of each user. This can be evaluated without modeling higher layer protocols.

{This para is to be deleted}

~~A delay tolerant service can be satisfactorily served if a minimum data rate requirement is provided by a~~

~~system. If the operator can provide this minimum rate to a user the user can provide the specified service satisfactorily with the required level of per user outage for that service.~~

Assume, in a simulation that number of users are dropped uniformly in the service area. Let the required coverage for a given service is x% and the required information rate for that service is Rmin. The first step in evaluating *cc* is to take out the lowest (100-x)% of users out of the evaluation. Assume the number of users in the remaining group is *k*, and the average effective data rate that can be supported by the ith user is r_i (i = 1 to N).

Then,

if the min(r_i) < Rmin, $cc = 0$ (i.e. the service cannot be provided with the required coverage).

Else, $$cc = \frac{k}{\sum_{i=1}^{k} \frac{R\min}{r_i}},$$

this is the maximum # of users that can be supported by the system for that service with the given coverage (i.e. x%).

If a user communicates directly with BS, r is its effective rate to BS.

Method 2:

The following is a more detailed methodology to evaluate combined coverage and capacity metric.

{Editor's note: Inclusion from 084: Comment by Roger Peterson and Eugene Visotsky Motorola }

Coverage reliability for a particular system (cell radius, shadow fading environment, relay station placement, and so on) with a particular number of users n each requiring information throughput $R\min$ is calculated using a static system simulator. The static simulator shall model all other-user interference affects using appropriate path loss models and power control models (if any). The static simulator shall model a scheduler and resource manager that allocates resources to as many users as possible and all relays supporting those users such that the target information throughput is $R\min$ achieved. The static system simulator is run repeatedly with each run modeling a different instance of random drops of n mobile stations. Each simulator run results in $n_{s,i}$ mobile stations being served with the required information throughput and $n_{b,i}$ mobile stations being blocked due to insufficient carrier to interference plus noise ratio and/or insufficient time-frequency resources. $n = n_{b,i} + n_{s,i}$. In this equation, i is an index identifying a particular simulation run. Coverage reliability is a function of n and is:

$$\frac{1}{M \cdot n} \sum_{i=1}^{M} n_{s,i}$$

where M is the total number of simulation runs. The Combined Coverage and Capacity Index N is the largest n for which

$$\frac{1}{M \cdot n} \sum_{i=1}^{M} n_{s,i} \geq x$$