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Initialization of Handover Procedure in WiMAX Networks

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Abstract: This paper introduces a new approach in the triggering of handover procedure in WiMAX networks. Mobile WiMAX, based on the IEEE 802.16e standard, supports a several types of handovers and allows full mobility of users. The originating IEEE 802.16j standard introduces new network entities called relay stations. A relay station enables either throughput enhancement in the selected area or enlargement of a coverage area of base station. Both IEEE 802.16e and IEEE 802.16j standards utilize downlink channel parameters to set up the initialization of a handover procedure. To increase the overall network throughput, the proposed method initializes a handover procedure based on evaluation of maximal network throughput in uplink or downlink direction. The evaluation and comparison of conventional and proposed approach are presented.

Keywords: Handover, Mobility, Network throughput, Relay station, WiMAX.

1. Introduction

WIMAX technology is a wireless networking standard that addresses interoperability across IEEE 802.16 standard-based products. So far, two standards have been already approved, the IEEE 802.16-2004 [1] intended for fixed scenarios and the IEEE 802.16e [2] implementing mobility features such as handover (HO) and power management modes to the former standard.

The HO mechanism implemented in WiMAX allows a movement of a Mobile Station (MS) from the air interface of one Base Station (BS) to the air interface provided by another BS. The IEEE802.16e standard defines HO only among BSs, but it does not consider Relay Stations (RS). The RSs are generally simplified BSs and may be used either to extend a coverage of a BS or to increase of a capacity in the specific area [3]. The RSs are connected to the network via radio interface, so there is no wired connection to the backbone network. The implementation of RSs into WiMAX networks is the target of currently specified standard IEEE 802.16j [4]. In the scope of paper, the relay stations designed for purpose of throughput enhancement are assumed.

The HO process is composed of several phases [1]: Network topology advertisement, MS scanning, Cell Reselection, HO decision and initiation and Network Re-entry. The paper focuses on the cell reselection and HO decision and initialization phases. In addition to conventional IEEE 802.16e handover, that use only downlink channel parameters to make a decision about HO [2] the proposed method take into account as well as the maximization of network throughput.

The rest of paper is organized as follows. The next section summarizes state of the art in the field of handover. The third section explains basic principles of conventional HO in WiMAX with the focus on the HO decision and initialization procedure. Section 4 proposes novel method of the HO decision and initialization. The fifth section describes simulation scenario and basic assumptions. The comparison of results obtained from the conventional

HO and proposed methods is presented in section 6. Following section presents the requirements to bring the proposal into market. The last section sums up the results and presents our conclusions.

2. Related Work

Two types of handover decision and initiation criteria are assumed by the IEEE 802.16 management messages. Those criteria are summarized in [5]. First, channel quality indicators, such as CINR (Carrier to Interference and Noise Ratio) or the signal strength, can be exchanged. Second, QoS is characterized by the service level prediction. The service level prediction indicates the level of service expected by MS from target BS. Depending on their availability, other criteria such as the bit error rate (BER), packet delay / jitter, service pricing [6], the MS velocity [7], and the MS location [8] can be used. If RSs are introduced into WiMAX system, new challenges for handover decision and initialization arise. General principle of handover in networks with RSs is introduced in [9]. Further, some studies deal with implementation of handover for mobile RSs (e.g. [10]).

So far, above mentioned papers do not consider the maximization of system throughput in downlink and uplink as a handover decision criterion. Hence, we propose a mechanism that initiate handover base on evaluation of maximal network throughput in uplink or downlink direction in networks with RSs.

3. Principle of Handover in WiMAX

The main target of HO in mobile broadband wireless networks is to provide the continuity of services during a MS travelling across the cell boundaries of BSs.

3.1 Handover types

Standard IEEE 802.16e [2] defines three types of HO. The first one is Hard Handover (HHO). Within HHO the MS communicates with just one BS at each time instance. It means all connections with the previous BS (called Serving BS) are broken before the connection with a new BS (noted as Target BS) is established. Hence, there is a very short time interval, when MS is not connected to any BS. HO is executed after the signal strength from neighbor's cell exceeds the signal level from the current cell. This type of HO is also called break-before-make.

The other two types, Macro Diversity handover (MDHO) and Fast Base Station Switching (FBSS) are so called "soft handovers" (or make-before-break). Within MDHO and FBSS, the list of BSs involved in the HO procedure is maintained by the MS and BSs. This list is called Diversity set. If the MDHO is processed, the MS communicates with all BSs in the diversity set. For downlink, all BSs included in the diversity set transmit data to the MS such the MS performs the diversity combining. For uplink, MS transmission is received by multiple BSs where selection diversity of received information is performed. In case of FBSS, the MS communicates only with so called Anchor BS. Anchor BS is a BS from diversity set to which the MS is currently synchronized and registered. Moreover, the MS performs ranging with anchor BS and monitors anchor BS downlink channel for control information. The anchor BS can be switched among all BSs in diversity set on frame by frame basis. It means that the HO procedure is reduced to switching of anchor BSs.

The HO in emerging IEEE 802.16j is assumed to be based on the similar principles like in IEEE 802.16e; furthermore the support of RSs will be implemented (see e.g. [11], [12]) in addition to IEEE 802.16e.

3.2 Handover stages

According to [2], the HO procedure can be separated into several stages (Figure 1).

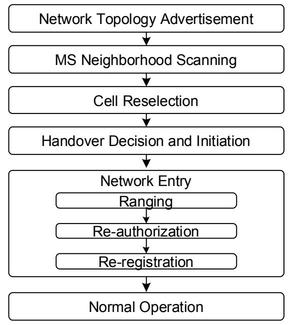

Figure 1: Decomposition of the HO procedure into stages.

In the Network Topology Advertisement and during MS Neighborhood scanning phases, the MS collects information about BSs in its neighborhood.

During the scanning procedure, the MS seeks for a suitable target BS or BSs that are appropriate to be added into the diversity set. The scanning of neighborhood is done in the "scanning intervals" that interleave a normal operation of the MS. The results of scanning procedure are reported back to the serving BS. Two types of reporting are distinguished: event triggered reporting and periodic reporting. In the event triggered reporting the MS sends reports after each measurement of channel parameters, i.e. CINR, RSSI (Receive Signal Strength Indicator), Relative delay and Round Trip Delay (RTD). In the periodic reporting, the reports are sent in the periodic intervals. The spacing of individual reports is indicated in a number of frames (between 1 and 255 (2^8).

The target BS is selected in the cell reselection procedure based on the channel parameters (usually CINR metric is used as a HO trigger) and QoS provided by the possible target BSs.

For the initialization of a HO procedure in MDHO and FBSS two thresholds are defined: Add Threshold (T_Add) and Delete Threshold (T_Delete) (see Figure 2). While the former threshold defines absolute signal level for adding of the BS into the diversity set, the latter threshold defines absolute level of the signal for removing of the BS from the diversity set. When one of these thresholds is met by the neighboring BS, the HO procedure can start.

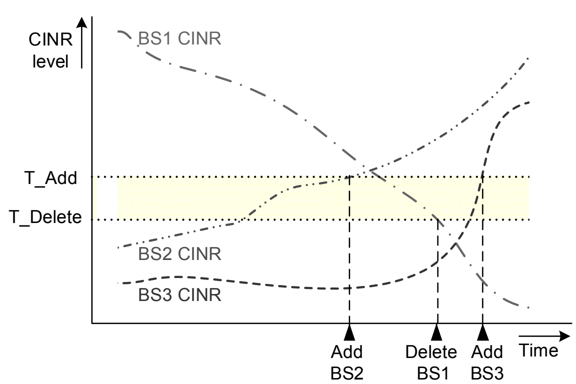

Figure 2: Principle of HO initialization in MDHO and FBSS. Black arrows present the time instance of initialization of HO.

In case of HHO, “Hysteresis margin” is used by the MS to include a neighbor BS to a list of possible target BSs. The neighbor BS is included in the list of possible target BSs if its CINR is larger than the sum of the CINR of the current serving BS and the hysteresis margin. The HHO is initialized based on the comparison of signal level of the current serving BS and the possible target BS (see Figure 3).

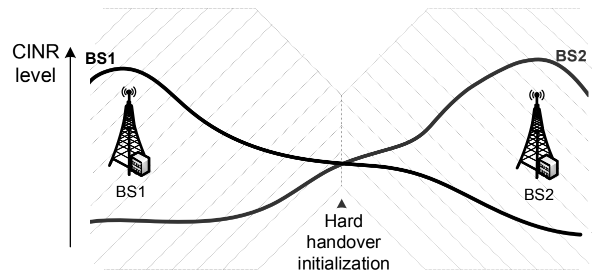

Figure 3: Principle of hard HO initialization. The HO is initialized when the signal level from BS2 cross the signal level of BS2.

As soon as the HO is initialized, the MS can start the next stage of HO – Network Re-entry procedure. Network re-entry consists of three substages i.e. Ranging, Re-authorization and Re-registration. In the ranging process the MS obtains information about uplink channel. Ranging is followed by authorization and registration of the MS to the target BS. After successful authorization and registration to the target BS, the MS can start with the normal operation.

4. Proposed method of handover initialization

The conventional HO and its decision and initialization are based on downlink channel parameters, typically on downlink CINR (DL CINR). Besides DL CINR, other additional parameters such as RSSI, relative delay or RTD can be used for make a HO decision. However, a decision according parameters listed above is absolutely inadequate when RSs are introduced into the system. The reason may be following:

The path between the BS and the MS through the RS involves two or more hops (for the sake of the simplicity and better understanding, the paper is focused only on two hops communication). Hence, the connection via RS may provide lower performance than the direct link to the BS despite of the fact that RS signal in downlink is received with better quality.

The performance in uplink and downlink direction is completely different since MSs are limited by factors such as battery power or antenna type. Thus attachment through the RS may be the only way how to send data to the BS in uplink direct connection. Consequently, an uplink should be taken into consideration during a HO decision.

To save valuable radio resources, reuse of the RS may be implemented at the cost of interference increase. As a result, an attachment through the RS may be better even though that signal from the BS is received with better quality.

Hence is feasible to initialize a HO according other parameters such as downlink or uplink performance instead of DL CINR. To allow BS/MS decides which point of attachment is more suitable, a metric for calculation of minimum radio resource cost (RRC) is implemented. The RRC between individual stations is obtained from 1) number of bits carried per one subcarrier *Nob* (derived from modulation), 2) coding rate *CR* and amount of data *D* sent within one burst to the destination station and can be expressed as:

$$RRC = \frac{D}{Nob * CR} \qquad (1)$$

The example of RRC derivation from CINR for D = 100 bits is shown in Table 1 (CINR thresholds are taken from [2]).

TABLE 1: Derivation of RRC metric

Modulation	*Nob*	*CR*	CINR (dBm)	RRC
BPSK	1	1/2	>3 and <6	200
QPSK	2	1/2	>6 and <8.5	100
		3/4	>8.5 and <11.5	66.7
16QAM	4	1/2	>11.5 and <15	50
		3/4	>15 and <19	33.3
64QAM	6	2/3	>19 and <21	25
		3/4	>21	22.2

To decide which point of attachment is the best for system performance, the RRC of all available routes from (to) the BS is compared and determination how much system resources have to be spent is accomplished. The principle may be explained by the next example (see Figure 4). Let assume simple scenario where a MS is in the range of one BS and one RS. The RRC_{BS-MS}, RRC_{BS-RS} and RRC_{RS-MS} correspond to RRC between individual stations. For the time being, the MS is attached to the RS since summation of RRC_{BS-RS} and RRC_{RS-MS} is smaller than RRC_{BS-MS}. While this statement is true, MS stays connected to that particular RS. However, as soon as RRC_{BS-MS} becomes smaller than summation of RRC_{BS-RS} and RRC_{RS-MS}, the MS should initiate HO to the BS in order to guarantee the best system overall throughput. To perform this evaluation, the BS needs to know RRC_{BS-RS}, RRC_{RS-MS} and finally RRC_{BS-MS}. While RRC_{RS-MS} and RRC_{BS-MS} could be simply derived by the BS through CINR received in MOB_SCN-REP management message, RRC_{BS-RS} is known to the BS as RS is supposed to be fixed. Thus, the proposed method does not introduce any additional signalling overhead. However, as already stated RRC in UL direction has to be taken into account. Additionally, the RRC metric may be adapted to cases where reuse of RSs resources is enabled and thus cope well with that kind of scenarios. Detail description o RRC metric may be found in [13]).

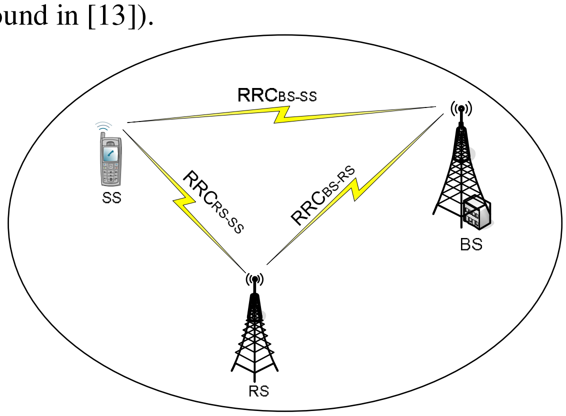

Figure 4: Principle of RRC metric

5. Model of simulation

The simplified description of simulator developed in MATLAB is depicted in Figure 5. The whole simulation may be separated into several individual parts which interact between themselves. At the very beginning, all parameters necessary for evaluation (e.g. OFDM parameters, channel model and its parameters, BS and RS position, etc.) are specified (the most important parameters are shown in Table 2). The simulation model consists of one BS and 6 fixed RSs deployed symmetrically along the BS in distance of 1470m.

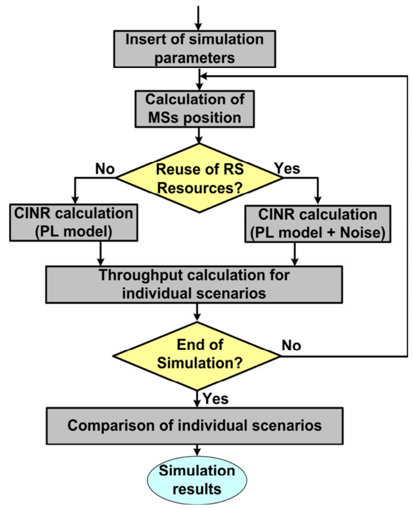

Figure 5: Simulator description.

After that the main simulator loop is initiated. Firstly, initial position of each MS is randomly chosen in such a manner, that MS has to be located within defined range from the BS (between 0 to 2600m). All MSs in the system are assumed to be moving along straight line (like in [14]) until the distance from the BS is equal or larger than defined BS cell area. In such a circumstance new direction of MS is established. This mechanism guarantees, that no MS roam out of BS range during the simulation process.

Subsequently, in every step of simulation (length of frame), CINR calculation between BS-MSs (respectively MSs-BS) and between RSs-MSs (respectively MSs-RSs) is evaluated. Path loss channel model applied in the simulations was developed by Stanford University and its definition may be found in [15].

Finally, according to the chosen scenario (see more detail below) current overall system throughput is determined and individual cases are finally compared. Throughput evaluated in the paper represents rough system WiMAX capacity obtained on the MAC layer. By rough capacity is meant that overhead introduced by protocols of OSI higher layers (e.g. network, transport, etc.) is not considered. Nevertheless, the impact of such an overhead is the same for all compared scenarios so the final results are not influenced by that fact. How individual bit rates per channel are calculated is shown in [16].

During evaluation process, two basic scenarios are considered; 1) reuse of RSs radio resources is not enabled or 2) reuse of RSs resources is enabled. In the first case is considered that RS transmission is separated in time domain. On the other hand in the second case, all RSs are supposed to be transmitting simultaneously during intervals scheduled on the 2nd hop between the MSs and RS. Anyway, on the 1st hop individual RS are sending/receiving data in consecutive sequences in order to avoid collisions.

The length of one simulation cycle is 1000s. The whole simulation is composed from 50 cycles which are finally averaged.

TABLE 2 : Simulation Parameters

Parameter	Value
BS range radius (m)	2600
RS range radius (m)	1000
BS-RS distance (m)	1470
Frequency band (GHz)	5
Channel bandwidth (MHz)	20
Frame duration (ms)	20
Number of data sub-carriers	192
Number of RS	6
Number of MS	50
MS velocity [$m.s^{-1}$]	20
Symbol useful time t_b (µs)	11.64
t_g/t_b	¼
CP time t_g (µs)	2.91
Symbol time t_s (µs)	15.55
BS transmit power P_t (dBm)/height (m)	30/30
RS transmit power P_t (dBm)/height (m)	27/25
SS transmit power P_t (dBm)/height (m)	25/2
a	3.6
b (m^{-1})	0.005
c (m)	20
Noise (dBm)	-100.97

6. Results

Within every scenario (with and without reuse), several cases are taken into account considering the different condition for HO triggering: 1) HO based on the received DL CINR, 2) HO based on better performance in DL and finally 3) HO based on better performance in UL.

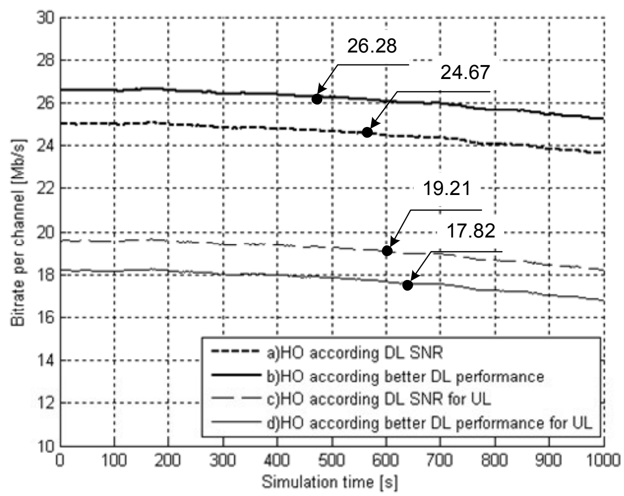

Figure 6: System throughput in DL direction without reuse of RSs radio resources.

In Figure 6 is shown overall bit rate for whole radio channel when reuse of RS is not taken into consideration. The black dots show the average bit rate throughput for all considered scenarios. The first case (in Figure 6 marked as a) represents scenario when the HO is always initiated with a respect to CINR in DL with a disregard to UL direction. Thus HO triggering mechanism corresponds to IEEE 802.16e conventional HO. The second case reflects the fact when decision algorithm takes into accounts RSs and RRC metric is considered. It is apparent that overall system has been slightly increased approximately by 1.6 Mb/s.

However, in UL direction is more convenient to initialize HO according conventional DL CINR metric. This could be observed in c) and d) scenarios. The first one corresponds to the situation when MSs performs HO according original HO procedure. On the contrary if HO initiation is based on better performance in DL (case d) in Figure 6) capacity decrease in UL direction may be observed (roughly by 1,4 Mb/s).

It is clear that gain in the downlink direction is at the cost of capacity reduction in the opposite direction from the MS to the BS. Consequently, some trade-off has to be done to maximize the system performance depending on the amount of the downlink and uplink transmission of separate users. For example, in case of broadcasted service is better to make the decision with respect to downlink conditions. On the other hand, when user is supposed to send large file, e.g. via FTP service, uplink link quality should be prioritized.

So far, the estimations were based on the fact that a reuse of RS resources is disabled. If the reuse of scarce radio resources is actually enabled (RSs are transmitting simultaneously), the results are quite different as it shown in Figure 7 (for downlink direction) and Figure 8 (for uplink direction). Since the overall interference is increased, bit rate per channel is significantly diminished when HO initialization is based only on DL CINR (see case a) in Figure 7). More than that, if standard RRC metric (does not take into account reuse) which calculates maximum downlink performance is utilized no notably improvement can be actually observed (approximately by 0.5 Mb/s).The reason is that the received signal from individual RSs is disturbed by the other RSs in the transmit range. Consequently it is assumed that a connection to the BS is more appropriate in most of the cases. However, reuse of RSs resources (only on 2nd hop) brings ultimate advantage of two hop communication over a direct one. This is also reflected in c) scenario where modified RRC metric (considers RS reuse) is employed and allows increase the overall system throughput nearly by 7 Mb/s.

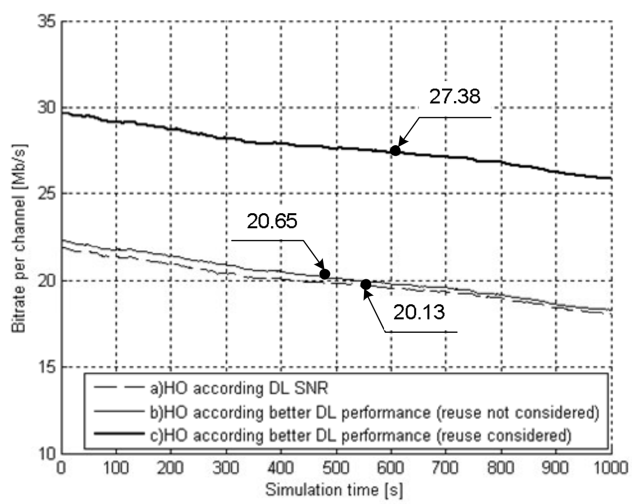

Figure 7: System throughput in DL direction with reuse of RSs radio resources.

In Figure 8 is shown how system throughput is influenced by reusing of RSs resources in UL direction. Here, the second case actually significantly outperforms the conventional IEEE 802.16e HO by approximately of 2.5 Mb/s per channel. Additional gain (roughly 3.6 Mb/s) may be observed if modified RRC metric is applied.

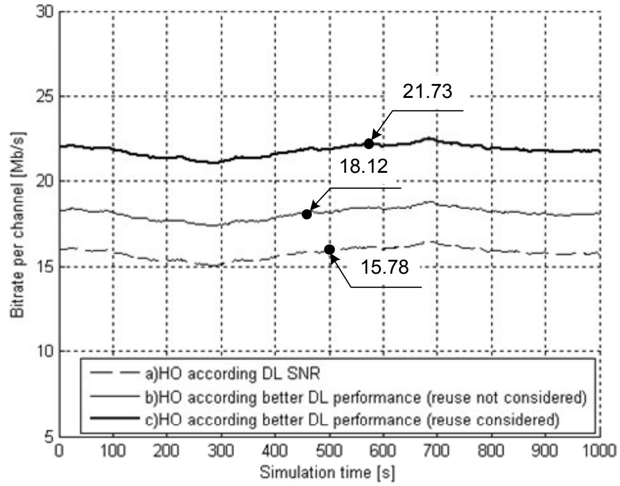

Figure 8: System throughput in UL direction with reuse of RSs radio resources.

7. Implementation of proposal

Currently, equipments for mobile WiMAX according to IEEE 802.16e standard are just on the market since it is the latest version of WiMAX. The RSs are not included in the IEEE 802.16e, however an upcoming standard, IEEE 802.16j, already take into account the RS deployment in the WiMAX networks. The conventional handover decision and initialization is based on downlink channel parameters (typically on DL CINR, RSSI, relative delay or RTD) that are not optimal when introducing RSs in networks. Therefore, a new metric, called RRC, is proposed for HO decision and initialization. This metric consider number of bits carried per one subcarrier (derived from modulation), coding rate and amount of data sent within one burst to the destination. All these parameters are already defined by MAC management messages and just are already known by MS or BS. Hence, only update of software controlling MAC layer must be done, no modifications of hardware are needed.

The implementation of proposed metric in commercial equipments brings important increase of channel throughput. Thus, more users can be simultaneously served or better QoS to currently served users can be provided in comparison to the conventional IEEE 802.16e networks.

8. Conclusions

This paper focuses on enhancement of handover procedure in WiMAX networks integrating fixed relay stations. Additionally, the paper shows the drawback in initialization of HO according to the existing IEEE 802.16e standard which mostly considers just downlink channel parameters. However, such solution is totally inadequate when introducing relay stations. Therefore this paper proposes a mechanism that triggers HO procedure according to the potential better performance either in downlink or uplink direction.

The simulation results confirm the enhancement and better performance of system when implementing the proposed technique. Especially if the reuse of RSs radio resources is enabled, significant improvement of overall system capacity may be obtained for both downlink and uplink directions. In the downlink direction, the overall system throughput is increased approximately by 1.6 Mb/s (6.5%) if the HO initialisation is based on the DL performance without reuse of RS resources and approximately by 7 Mb/s (36%) in case of the reuse of RSs radio resources.

On the other hand, in the uplink direction, it is better to initialize HO according to DL CINR where the overall system capacity decreases by roughly 1.4 Mb/s (7.8%) for the non-reuse scenario. However, if the reuse of RSs radio resources is enabled, the increase of system throughput is achieved even when the HO is initialized according to better DL performance and despite of the fact that the RRC metric does not take into consideration the reuse of RSs radio resources (gain per channel is approx. 2.5 Mb/s, i.e. by 14.8%). Additional gain (roughly 3.6 Mb/s, i.e. by 37.7%) may be observed if the RS resource reuse is considered in the uplink direction.

The advantage of proposed method is that no additional overhead is introduced since the RRC between individual stations can be directly derived from CINR obtained in the MOB_SCN-REP management message. Just software update of MSs, RSs and BSs is the only requirement to implement proposed techniques to the currently available equipments on the market.

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