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Dual Triggering for Improvement of Handover in Mobile WiMax

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ABSTRACT
Mobile WiMax (Worldwide Interoperability Microwave Access) is a wireless system based on IEEE 802.16e standard which provides the support for handovers between the cells. However in this handovers between the cells handover delay is introduced due to excessive scanning of frequencies by the Mobile Station (MS) in order to select a Target Base Station (TBS) as well as during the actual handover from the serving Base Station (SBS) to the TBS. In this paper two mechanisms are proposed, one to decrease the excessive scanning involved for selection of TBS using GPS system and other for the actual handover decision using distance as an added parameter for effective handover which changes dynamically depending on the velocity of the vehicle. This mechanism provides an effective improvement over the handover delay involved. Dual triggering is initiated to resolve the handover deficiency and provide an effective handover with reduction in handover delay.

General Terms
Mobile WiMax, GPS

Keywords
Handover, Delay, Excessive scanning, Signal Strength, Packet loss, Velocity

1. INTRODUCTION
Currently in Mobile WiMax two major types of Handovers (HO) are defined [1]. They are: Hard Handover (HHO) and Soft Handover (SHO). HHO is set as mandatory for MS with low speed while SHO is optional particularly in case of MS with High speed. HHO is characterized by "break before make" connection which implies that MS releases its connection from the SBS before establishing a new connection to the TBS (see Figure 1). In this type of handover the MS can be connected to only one Base Station (BS) at a time from which the handover should be decided and initiated. During the handover since the MS has to disconnect from the current SBS before connecting to new TBS there is a service interruption and handover delay that is being introduced which has a negative impact on the delay sensitive applications.

SHO [2] is characterized by "make before break" connection in which the MS can be connected to different BS at a given point of time and do not have to disconnect its current connection before establishing a new connection. SHO is divided into two types: Macro-Diversity Handover (MDHO) and Fast Base Station Switching Handover (FBSS).

In both the types of soft handover a Diversity Set is maintained by the MS and BS. Diversity set is a list of all Base Stations that are involved in the handover procedure. In MDHO MS communicates with all the BS's in the diversity set (see Figure 2). For downlink in MDHO two or more BS's transmit data to MS such that diversity combining can be performed at the MS. For uplink in MDHO, MS transmission is received by multiple BS's where selection diversity is of the received information is performed. The BS, which can receive communications among MS's but the level of signal strength is not sufficient enough is noted as the Neighbor BS's by the current serving BS and MS.

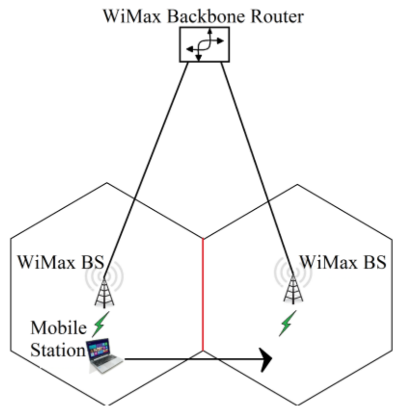

Figure 1: Hard Handover

In FBSS, the MS continuously monitors the BS's in the diversity set and defines an "Anchor BS". Anchor BS is only one BS of the diversity set that the MS communicates with for all uplink and downlink traffic (see Figure 3). This is the BS where the MS is registered, synchronized, performs ranging and there is monitored downlink channel for control information. The Anchor BS can be changed from frame to frame depending on BS selection scheme which means that every frame can be sent via different BS in the diversity set. This Anchor BS is chosen depending on the signal strength of all the BS's in the diversity set i.e. the BS having the strongest signal is noted as Anchor BS.

Mobile WiMax users have the characteristics of mobility which allows users to move anywhere at any time and be served as long as there is network coverage in the region. When the MS wishes to join a new network, it must follow the network entry procedure which involves scanning for a frequency on a particular BS. The MS has to do a repeated scanning in order to maintain connectivity to the network while moving from one cell area to another. Handover is executed when the mobile station receives signal strength from the Neighboring Base Station (NBS) stronger than that of the current SBS. The MS has to scan a number of frequencies in order to select a particular BS as TBS for the actual handover process which introduces a handover delay in the handover.

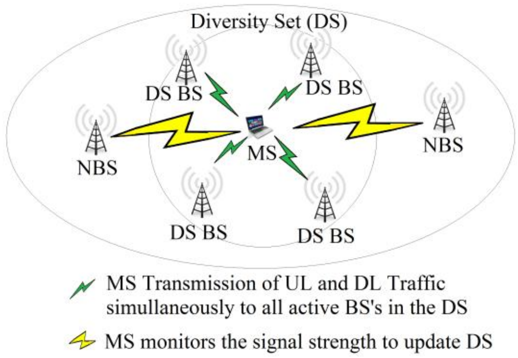

Figure 2: MDHO

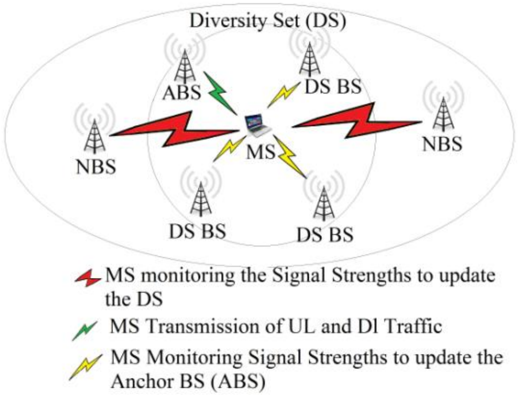

Figure 3: FBSS

Currently in Mobile WiMax, the Received Signal Strength Indicator (RSSI) is used to measure the signal strength of each BS. When the RSSI of SBS is lower than that of TBS the handover is executed. The MS scans the multiple BSs and selects the most suitable BS as the TBS. The TBS selected is the most appropriate because of its stronger signal strength when compared to other adjacent BSs. But in order to select this TBS excessive scanning of the NBS needs to be performed by the MS. In order to reduce the number of frequencies needs to be scanned the use of GPS for predicting of TBS has been proposed which will minimize the excessive scanning being involved. But even when the TBS is selected the handover initiation should be fast enough in order to reduce the handover delay so in order to cope up with this the proposed scheme considers both signal strength received by the MS and depending on the dynamic distance threshold which is set based on the velocity of the vehicle the Handover is executed.

The remainder of this paper is organized as follows: Section II describes the related work that is being carried out. Section III explains the HO process in IEEE 802.16e. Section IV describes the existing strategies for scanning and the handover initiation schemes used for the handover activity. Proposed scheme along with the algorithm and scenario description of output is provided in section V and finally Section VI concludes the paper.

2. RELATED WORK

2.1 Minimizing Excessive Scanning

There are many strategies proposed to minimize the number of frequencies to be scanned but only few are proposed to minimize the excessive scanning by predicting the TBS. The MS can scan some of the NBSs to be set as potential TBS candidates. However, the HO technique does not clearly say anything regarding the number of NBSs that a MS may need to scan before ultimately deciding a TBS. This may result in redundant scanning of NBSs [3] leading to unnecessary wastage of channel resources and degrading the overall performance. Recently Prashant shinde has introduced an implementable enhanced handover target cell selection algorithm for WiMax network based on the effective capacity estimation and neighbour advertisement for prediction of the TBS [4].

Sayan K. Ray has introduced Mobility management in IEEE 802.16e based wireless Metropolitan Area Network [5]. In this paper to minimize the excessive scanning the prediction of the TBS is being done using two databases, one maintained by the MS and other by the Base stations. The one maintained by the MS contains the BSIDs of the visited BSs and interval between each hop and the one maintained by the BS contains BSIDs, location info of all other BS's, coverage info and load. On the bases of these two databases the prediction for a particular TBS is being done. However Use of GPS in selection of a TBS which will further minimize the excessive scanning has not been taken into count. In this paper a new technique has been proposed for the prediction of a TBS by using GPS system in order to find the current location of the MS from which the trajectory of motion of the MS is found which helps in minimizing the excessive scanning of NBS that is being involved in existing scanning strategy. The proposed scheme minimizes the excessive scanning by predicting only some NBS that the MS is heading towards and scans only those NBS from which the TBS can be selected and continuity of signal could be maintained by MS while moving from one BS area to another.

2.2 Minimizing Handover Delay using Distance Parameter

Many of the algorithms have been proposed in past with respect to handover initiation. The initiation of handover takes place depending on the RSSI signals of the BS i.e. the handover is executed when the signal strength of NBS exceeds that of the current SBS. Recently Mary Alatise, Mjumo Mzyece and Anish Kurien have proposed a combined method of signal strength and distance to initiate fast handover [6]. In this scheme they have considered the distance as a parameter in initiating the potential handover activity i.e. depending on the distance between the BS and MS the handover is executed. In this scheme if the distance between the MS and NBS exceeds the distance between the MS and current SBS then the handover will be initiated from the current SBS to the NBS that is set as TBS. But this handover does not depend on the velocity of the vehicle and hence for fast moving MS it would be inconvenient since the MS may overrun the boundary of NBS to much extent in terms of distance and then the initiation of handover will be done. So in order to reduce this handover delay in case of fast moving MS a dynamic distance handover scheme is proposed in second part of proposed scheme. The distance parameter is set depending on the velocity [7] of the vehicle which will decrease the handover delay occurring in case of fast moving MS as well as reduce the packet loss incurred in the existing handover scheme.

3. HANDOVER PROCESS

3.1 Stages of Handover Process

Handover is a process which helps to maintain the continuity in the service of MS even when the MS is moving from one BS area to another. Handover in mobile WiMax can be divided into two major phases: the Network Topology Acquisition phase (NTAP) and the Actual HO process (AHOP) [2]. The Network Topology phase precedes the actual HO process which includes handover decision and initiation, synchronization and ranging process, cell reselection and termination context. The breakdown of the handover process is shown in Figure 4.

3.1.1 Network Topology Acquisition Phase: -

During the NTAP, the MS and SBS, along with the help of the backhaul network, try to gather information about the underlying network topology before the actual handover decision is being taken into count. This is done so that the lists of potential NBSs are identified, out of which one particular TBS is to be chosen for the potential handover activity.

The major tasks involved in this phase are as follows:-

1) Network Topology Advertisements**:** - Using MOB_NBR-ADV message i.e. Mobile Neighboring Advertisement, the SBS periodically broadcasts information about the state of the NBSs, preparing for the potential handover activities. The SBS with the help of backbone network keeps on gathering these channel information in order to help MS in the potential handover activity.

2) Scanning of advertised neighboring BSs by MS: - The MS scans the advertised BSs obtained from the NBS advertisements list within specified time frames in order to select a suitable candidate BSs for the potential handover from which the list of potential TBS is maintained. This procedure is carried out with the help of MOB SCN-REQ and MOB SCN-RSP i.e. Scanning Interval Allocation request and response messages respectively, sent by the MS and the SBS. In the end, scanning result report summarizes all the scanning activities.

3) Cell Reselection: - The scanning of NBS is followed by contention/non-contention ranging activities from which the MS gathers further information about the physical channel related to selected TBSs which makes use of Ranging Request (RNG REQ) and Ranging Response (RNG RSP) messages. Ranging may be followed by optional association activities through which the MS gets associated with the potential target BS candidates. Association Result Reports (MOB ASC-REP) can be used for this purpose.

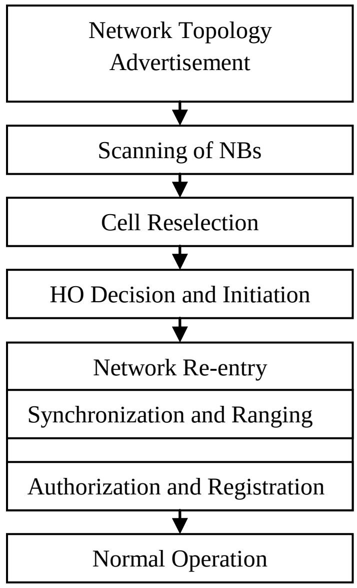

Figure 4: IEEE 802.16e HO Stages

3.1.2 Actual Handover Phase: -

During the AHOP, the MS selects a TBS for the handover and switches location from the SBS to the selected TBS i.e. the actual handover takes place from SBS to selected TBS. The major tasks involved are as follows:

1) Deciding on the TBS: - Here the MS selects the final TBS for the handover, out of the multiple TBSs selected from the scanning activities. The decision of this handover arises at the MS, the current SBS or at the network associated. If the decision arises at the MS, it communicates with the MOB_MSHO-REQ message containing the list of selected TBSs to the SBS and the SBS replies back with the MOB_BSHO-RSP message. On the other hand, if the decision arises at the SBS, the MOB_BSHO-REQ message is used. However the preference is always given for the handover decision and initiation messages from the MS.

2) Initiating the Handover:-Depending on the above mentioned messages, once a particular TBS is selected from the list of the suitable candidate TBSs, the MS informs the current SBS about the beginning of the HO activity by sending a MOB_HO-IND i.e. Mobile Handover Indication message.

3) TBS synchronization and Ranging Process: - Appropriate synchronization and ranging activities take place once again with the TBS in order to resume the Uplink and downlink retransmission.

4) Authorization and Registration Phases: - Ranging Process is followed by lengthy authorization and registration processes of the MS with the TBS that marks the onset of the network re-entry phase of the MS.

4. EXISTING STRATEGIES

4.1 Scanning of Base Stations

Scanning in IEEE 802/16e [8] is a continuous activity that is conducted by a MS in order to scan the frequencies from NBSs. The goal of this scanning is to acquire a downlink signal from a BS. Scanning is done by monitoring each possible frequency until a downlink signal is received from a particular BS which may be set as TBS. Scanning is performed during the initial network entry procedure of the handover process and continues periodically to aid the MS in order to select a suitable TBS for a handover so that the network connectivity could be maintained even when the MS is in motion.

Current IEEE 802.16e [9] specifications provide support for network assisted handovers where the Current SBS can obtain the information of neighbouring BSs over the network. The SBS periodically sends using broadcast this information as a MOB_NBR-ADV message to the MS. Through this information obtained MS tries to only scan the frequencies which are present in the list of NBS broadcasted by SBS. So the NBSs of the current SBS will be scanned by the MS before the handover is being executed.

4.1.1 IEEE 802.16e/WiMax Handovers

As a MS moves throughout the coverage area, connectivity is maintained via performing handovers between neighbouring BSs. An example is shown in Figure 5, where a MS must choose one of six neighbouring BSs. Selection of the best handover target can be complex since the MS must scan for neighbouring BSs to find a suitable target based on a number of criteria such as RSSI signal measurement etc. Since a handover is an important function, a MS should perform the scanning and determine a TBS before beginning the handover. In Figure 5 NBS 6 is chosen depending on the result of scanning of the list of NBS.

The IEEE 802.16e standard supports temporarily suspending the uplink and downlink communication between the MS and BS in order to allow the MS to perform scanning for NBSs. While communication is suspended, the data streams must be buffered on either side. This delay involved before establishing a new connection could be reduced if the number of frequencies that need to be scanned by MS is reduced by predicting the TBS which will further reduce the time for temporary suspension of communication.

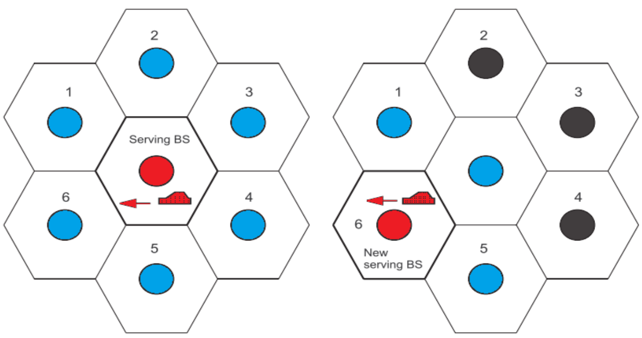

Figure 5: Scanning in 802.16e WiMax

4.2 Conventional Handover Schemes

The HO process is initiated based on receiving the RSSI of the SBS and TBS, measured and reported by the MS[11] This section outlines a number of conventional HO decision initiation algorithms that has been proposed and currently used. They are as follows:-

4.2.1 *Relative signal strength:* - In this algorithm, the HO decision is based on the average measurement of the received signals. MS is allowed to handover if the RSS of a TBS exceeds that of SBS. The scheme can be expressed as:

$$RSS_{TBS} > RSS_{SBS}$$

4.2.2 *Relative signal strength with threshold:* - The MS is allowed to handover only if the RSS of the TBS exceeds that of the SBS and the signal strength of the SBS is below a threshold, TH. The performance of this method is dependent on the value of threshold chosen. The scheme can be expressed as:

$$RSS_{TBS} > RSS_{SBS} \text{ and } RSS_{SBS} < TH \text{ or}$$
$$RSS_{TBS} > RSS_{SBS} \text{ and } RSS_{TBS} > TH$$

4.2.3 *Relative signal strength with hysteresis:* **-** The MS is allowed to handover if the RSS of the TBS is stronger than that of the SBS by a hysteresis margin, HYS. The scheme can be expressed as:

$$RSS_{TBS} > RSS_{SBS} \text{ and } RSS_{SBS} + HYS$$

4.2.4 *Relative signal strength with hysteresis and threshold:-* The MS is allowed to handover to the TBS, except if the current signal level of the SBS drops below a threshold and the signal level of the TBS is capable of supporting the current BS by a given hysteresis margin. The scheme can be expressed as:

$$RSS_{TBS} > RSS_{SBS} + HYS \text{ and } RSS_{SBS} < TH \text{ or}$$
$$RSS_{TBS} > RSS_{SBS} + HYS \text{ and } RSS_{SBS} > TH$$

The relative signal strength with hysteresis and threshold scheme is considered the best algorithm to initiate the HO process because it incorporates the advantages of the other algorithms and helps in handover process with eliminating some unnecessary handover stages.

5. PROPOSED SCHEMES

5.1 Minimizing Excessive Scanning Using GPS

The proposed scheme for minimizing of the excessive scheme makes use of GPS system in order to select a TBS for the potential handover activity to perform. In the existing handover strategy for scanning the MS scans all the BSs neighbouring to that of current SBS depending on the NBS advertisement sent by the SBS therefore the delay involved depends on the number of NBS that is required to scan by MS. If the number of NBS that is required to be scanned is minimized so the delay will be reduced. So the proposed scheme makes use of GPS in order to find the position of the MS and thereby determines the nearest BS to which the MS heading to and list out only those BSs which will be more probable TBS. The proposed scheme algorithm and scenario description is discussed as follows:-

5.1.1 Algorithm Steps:-

Step1) BS keeps the information in the database containing the (a) BSID (b) Location info all base station (c) coverage info (d) Load. This information is obtained by the SBS from the backhaul network.

Step2) MS maintains a database containing (a) MSID (b) location info which is updated from time to time using the GPS system.

Step3) In the NTAP zone, with a drop in SBS's received signal strength, MS communicates the updated database containing MSID and location info to SBS, initiating a potential HO activity.

Step4) Depending on the location information of MS, the SBS finds the trajectory of motion of MS that is whether it is moving towards which BS and then SBS will check across the database for the coverage info, location info of all BSIDs and selects the most appropriate BSID that can be set as TBS.

Step5) Scanning is to be performed by the MS for the selected BSID to make decision regarding setting it as TBS.

Step6) Once Decision is being taken for the TBS the handover will be made from the SBS to TBS.

5.1.2 Scenario Description

For the proposed scheme GPS system is used in order to find the position of MS and BS and accordingly the information is being put in the database for BS and MS.

Table 1. Base Station Information

BSID	Location Info	Coverage Info	Load
1	20.234	30kms	100
2	80.254	30kms	100

Table 2. Mobile Station Information through GPS

MSID	Location Info
1	25.267
1	45.245
1	50.280

The base Stores the information about BS ID, Its location information, Coverage information and the total connections it can support i.e. load. This information is obtained by the BS from the backhaul network to which it is connected to. The MS stores the information about its ID and its location information obtained from the GPS system. When the Mobile Station moves from one base station area to another base station area and when there is reduce in signal strength of current SBS the MS sends its location information to current SBS. The SBS will check the location information of MS corresponding to the database maintained by the SBS and will predict a most probable TBS for the MSID. With respect to Table 1 and Table 2, the MS is moving towards BSID 2. Since the coverage information of BSID 2 is 30kms and location information is 80.254 and for MSID 1 the location information is 50.284 i.e. it is moving towards base station with BSID 2.

Thus the MS have to scan only one frequency in order to maintain its continuity from one coverage area to another. The proposed scheme makes use of only the effective BS for the handover depending on the trajectory of motion of the MS which minimizes the number of frequencies that was needed to be scanned by MS in the existing strategy for handover.

5.2 Minimizing Handover Delay

In this section, new scheme for the initiation of the handover has been proposed in order to reduce the handover delay occurred during the normal handover procedure. This scheme makes use of distance as a parameter for the potential handover which is set depending on the velocity of the vehicle. The existing standard takes only RSSI into consideration when deciding handover. In the signal strength algorithm, the MS handover is done from one BS to another BS i.e. If signal strength of a SBS exceeds that of NBS by a hysteresis margin and the signal strength of the SBS is below a certain threshold. In this scheme Distance needs to be also considered in deciding for the handover in order to minimize the handover delay. So in this section a control measure scheme called dynamic distance handover scheme is being proposed. This scheme makes use of dynamic distance threshold for the handover which is set depending on the velocity of the MS on when exactly handover should begin in order to reduce the delay incurred in deciding handover.

5.2.1 Algorithm Steps:-

Step1) The distance between the MS and BS can be calculated by

$$D_{MS\text{-}BS} = V_{MS} \times T_{MS}$$

where $D_{MS\text{-}BS}$ is the distance between the MS and the BS, V_{MS} and T_{MS} are the speed and the travel time of the MS as respectively.

Step2) In order to reflect the dynamic distance threshold $th_{d\ is}$ calculated

$$th_d = \log_2(v+1)/10$$

where v is the velocity of the vehicle. Through this we can see for slow moving vehicle the value of threshold distance will be set low and as the vehicle speed will increase so does the distance threshold will increase.

Step3) Initiation of handover depending on the conditions given below:-

i) If the $RSS_{TBS} > RSS_{SBS} + HYS$ and $RSS_{SBS} < TH$ or $RSS_{TBS} > RSS_{SBS} + HYS$ and $RSS_{SBS} > TH$

ii) If the calculated distance of the MS from the SBS exceeds that of the TBS by reducing the threshold distance, the handover will be decided which can be given by:

$$D_{MS\text{-}SBS} \geq D_{MS\text{-}TBS} - 2\times th_d$$

The handover will be initiated depending on the velocity of the vehicle.

Step4) Normal Process with the new TBS and data transfer from this TBS which will be set as SBS.

In this case the handover will be decided depending on the velocity of the MS i.e. if the MS is moving at very low speed then the decision of the handover will be made just before entering into the new cell region, so by the time the MS reaches into the new cell the handover process would be completed. This scheme is much more necessary in the case of MS with high speed in which the handover decision would be made much before entering into the new cell region, so by the time the MS reaches into the new cell the handover process would be completed and the normal operation of the MS will be done using new TBS. This dynamic distance threshold used takes into count the velocity of the MS because in high speed MS the distance covered is much faster than that of the slow moving vehicles and does not require much time in entering the new cell region. So in order to take handover decision with reduction in handover delay this scheme is proposed which reduces the handover delay in the existing handover scheme.

5.2.2 Scenario Description

The existing strategy takes into count only the RSSI for the handover process and hence handover delay is dependent entirely on the time that is required for the MS to connect to new TBS. However by adding one more parameter i.e. distance the handover delay that is being involved is reduced since the handover initiation will start before the MS overruns the boundary of next BS area. In the scenario description when the MS moves in very low speed , whenever there is reduce in signal strength the MS has to scan the next BS it can connect to . So by the time it connects to next BS it must have overrun the boundary to certain extent during which it remains disconnected while in case of MS with high speed whenever there is reduce in signal strength the MS scans for new base station and then the handover process starts. So by the time it connects to next TBS, the MS overruns the boundary to a greater extent and hence remain disconnected during that time.

The proposed scheme takes into count the decision of handover depending on the velocity of the MS i.e. if the MS is moving in very low speed, the handover decision is taken 200-300 meters before it overruns the boundary and in case of high speed MS, the handover decision is taken 500 meters before it overruns the boundary, so by the time the MS reaches to the boundary the handover decision is already made and the MS can maintain its continuity with next BS which is set as TBS. The handover delay in this case is thus reduced since the MS connection to the TBS is being done before there is reduce in signal strength of the current SBS.

6. CONCLUSION

Mobile WiMax supports the handover between the two cells and hence the MS can maintain the continuity in the service to the BS. However the delay involved due to scanning of NBS by the MS in order to select a particular TBS is dependent on the number of NBS required to be scanned by the MS. Handover delay is also introduced depending on the velocity of the vehicle. The existing technique only focuses on the RSSI signal for the handover and does not considers distance as a parameter.

In this paper two new schemes have been proposed, one for the minimization of the excessive scanning involved in the selection of a TBS and second for reducing the handover delay involved for the actual handover initiation. The minimization is being done by predicting Target base station from the information provided by the GPS system. This prediction helps in the number of frequencies of channel to be scanned by the MS thereby decreasing the delay involved in the handover. Since the MS has to remain disconnected with the SBS till the scanning is being done the delay is introduced which is reduced by minimizing the number of frequencies needed to be scanned and hence reducing the delay. For the minimization of handover delay a dynamic distance handover scheme is proposed. According to the existing draft version of 802.16e standard, the HO initiation is performed if the RSSI of the serving BS is lower than the RSSI of TBS. However, it does not consider the distance between the MS and BS in the HO process, so there is a handover delay involved. To cope with this problem the proposed scheme makes use of dynamic distance threshold which allows handover between the two BSs depending on the velocity of the MS and establishes the connection before the MS overruns the boundary of NBS to a much extent in terms of distance thereby decreasing the handover delay involved.

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