# Fast Handover Algorithm for IEEE 802.16e Broadband Wireless Access System

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**Abstract-- IEEE 802.16e wireless metropolitan area networks refers to the new standard for broadband wireless access (BWA), which targets to support wireless Internet service up to 2Mbps. Existing draft version of standard proposes OFDM(A)-based handover process system, which consists of network topology acquisition, scanning, initial ranging, authorization, and registration. Since various researcher groups and companies have done each part of standardization work, there exist some unclear parts and redundant processes, especially in HO process. For instance, HO initiation timing is not clearly defined and unnecessary neighboring base station (BS) scanning and association are performed before and during HO process. These redundant processes causes a long HO operation time, which makes severe degradation in system performance. In this paper, fast HO algorithm is proposed to reduce HO operation delay. Target BS estimation algorithm using mean CINR and arrival time difference reduces unnecessary neighboring BS scanning. And some redundant work during network topology acquisition and scanning process is abbreviated as well. The performance analysis validates the efficiency of the proposed algorithm.**

*Index terms--* **Handover, WirelessMAN, BWA, Ranging**

## I. INTRODUCTION

The IEEE 802.16e broadband wireless access (BWA) has drawn much attention at the moment. It is an evolved version of existing IEEE 802.16 wireless metropolitan area networks (WirelessMAN) and its standardization process is still ongoing by the IEEE 802.16e tasking group [1]. It aims to support the cellular-based BWA with the data transmission rate up to 2Mbps and the mobility up to 60km/h [2]. Because of its superb characteristics, it is regarded as one of candidates for the pre-stage wireless communication systems forward to beyond 3G or 4G systems.

To provide stable handover (HO), the IEEE 802.16e BWA defines several steps of HO [3]. Before HO initiation, network topology acquisition including network topology advertisement, neighboring base station (BS) scanning, and the target BS association are carried out helped by backbone network. Then, cell reselection, HO decision, HO initiation, downlink synchronization with the target BS, initial ranging, termination service with the serving BS, authorization, and registration are performed during the actual HO. However some parts such as HO initiation timing are still ambiguous, since it is not clearly defined yet. Furthermore, unnecessary neighboring BS scanning and association are conducted before and during HO process. Once HO process is initiated, data transmission is paused until the establishment of the new connection. It causes service disruption for some time. Thus, the IEEE 802.16e provides neighboring BS scanning opportunity before HO initiation. Since it is done before the actual HO, data transmission is not paused but interleaved with neighboring BS scanning. However, system throughput is degraded because they share the same wireless resources.

Up to now, several fast HO scheme had been proposed. In [4], fast HO scheme for real-time downlink services using Fast DL_MAP_IE is suggested. It proposed to allow forward data transmission before the establishment of the MS registration and authorization. However, it is not adopted as a standard while some fast HO schemes such as FAST-RNG_IE, soft handover, and fast BS switching are adopted. FAST_RNG_IE is suggested to reduce the ranging time. Neighoring BS allocates non-contention based ranging opportunity for MS and notify the allocation information to the serving BS through backbone network. Soft handover and fast BS switching scheme define the Active Set, which is a list of BSs. And the current serving BS is defined as Anchor BS. MS and BS shall maintains the Active Set and switch the Anchor BS from the Active Set if needed. Since MS and BS have to scan and modify the Active Set periodically , there still exists wireless resource waste with these scheme.

In this paper, enhanced fast HO algorithm is proposed to reduce the waste of the wireless channel resources and the HO latency. Target BS estimation using mean CINR and arrival time difference is proposed, which can reduce unnecessary neighboring BS scanning and association process. Moreover, some redundant processes existing in the current draft standard are analyzed and optimized HO algorithms are proposed to reduce HO latency.

The remainder of this paper organized as follow. Section Ⅱ provides a background of the IEEE 802.16e HO process and section Ⅲ describes the proposed HO algorithm. The performance analysis and conclusion are given in section Ⅳ and section Ⅴ, respectively.

## II. HANDOVER PROCESS OF THE IEEE 802.16E

Fig. 1 shows overal MAC layer HO procedure of the IEEE 802.16e BWA. Firstly, network topology acquisition is carried out before HO request. Then,the actual HO process including HO decision, initiation, ranging and network re-entry process is performed. To our best knowledge, the detailed explanation of HO procedure has not referred in the literature yet. Thus, we state a brief explanation of each HO stage as follows.

### A. Network Topology Acquisition

MS and the serving BS conduct network topology acquisition helped by backbone network before HO initiation. Fig. 2 describes the network topology acquisition procedure based on the MAC message transmission. BS periodically broadcasts the network topology information using MOB_NBR-ADV message, which includes channel information of neighboring BSs. Then, MS is able to synchronize with neighboring BSs without listening their DCD / UCD broadcast messages. Next step is scanning of neighboring BSs. MS selects some neighboring BSs as a candidate BS for HO through scanning. Using MOB_SCN-REQ / RSP message, MS may carry out downlink synchronization with each neighboring BS. To obtain more completely evaluated PHY channel characteristics, contention or non-contention based ranging is conducted as well. During this MS scanning process, incoming data to MS is buffered by the serving BS. Last step of network topology acquisition is association procedure between MS and candidate target BSs. It is optional initial ranging process performed during MS's scanning interval. By setting and recording initial ranging values of associated BS, MS is able to reuse those informations for the future HO.

There exist some inefficient factors in this stage. Firstly, MS scans and synchronizes with two or three neighboring BSs as a candidate of the target BS. Redundant neighboring BS scanning processes could be conducted. Secondly, since downlink data transmission is paused and interleaved when MS conducts the neighboring BS scanning, system throughout is degraded. Lastly, the timing of MS scanning of neighboring BSs is ambiguous. If it is not done with appropriate timing, channel condition of neighboring BSs would be changed. That would make scanning process results useless.

### B. Handover Process

When MS migrates from the serving BS to the target BS HO process is performed as follows. Firstly MS conducts cell reselection with information obtained from network topology acquisition stage. Since it refers the same operation with network topology acquisition, this stage can be abbreviated. Then, HO decision & initiation is followed, which can be originated by both MS and BS using MOB_MSHO-REQ / MOB_BSHO-REQ message. However, there exists another ambiguity regarding the timing of HO initiation. When the HO target BS is decided, MS send MOB_HO-IND message to the serving BS and actual HO process begins as illustrated in Fig. 3.

Another ranging process is followed after HO initiation. MS may synchronize to downlink of the target BS and obtain downlink and uplink parameters with DCD / UCD message. Then RNG_REG / RSP messages are exchanged to complete the initial ranging process. It may be done contention-based operation or non-contention based.

If RNG_REG contains the serving BSID, the target BS may obtain MS information from the serving BS through backbone network. And if MS is already associated with the target BS at the previous stage, some process may be abbreviated. Therefore neighboring BS scanning and association should be done enough close to HO initiation timing to utilize pre-obtained information before channel condition changes.

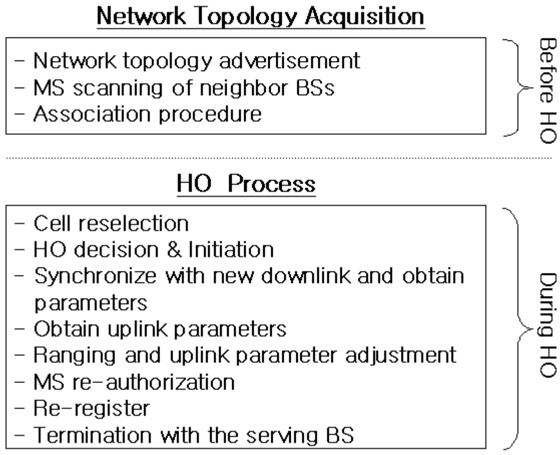


Fig. 1. Mac layer handover procedure.

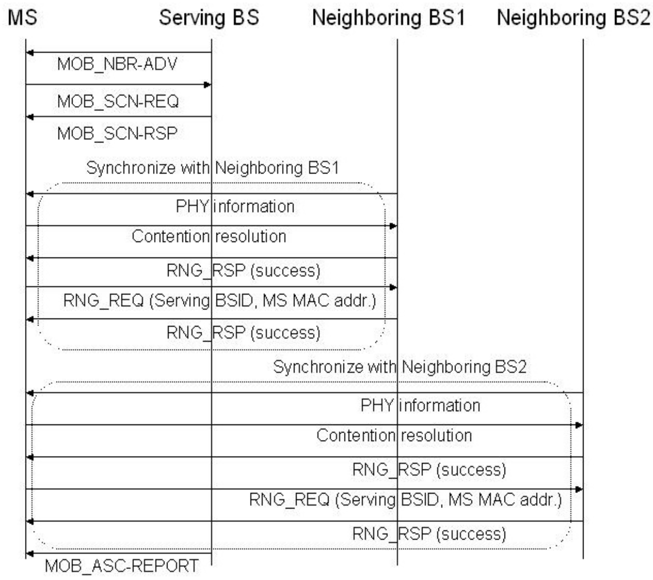


Fig. 2. Network topology acquisition**.**

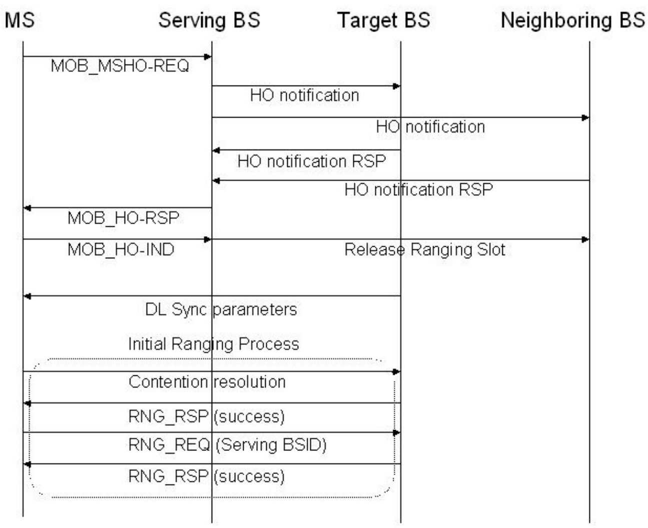


Fig. 3. HO decision, initiation, and ranging procedure.

If all physical parameter adjustments are done successfully, network re-entry process is initiated. Fig. 4. shows this procedure. It includes MS authorization and new BS registration. The target BS requests MS authorization information to Authorization server via backbone network. And new BS registration is performed with REG-REQ / RSP message. Processes including capabilities negotiation, MS authorization, key change, and registration can be abbreviated based on the association level. Details regarding association level and private security support are beyond the context of this paper. Thus, detailes are not stated in this paper. After successful registration with the target BS, MS sends MOB_HO-IND message to the serving BS to notify HO is completed.

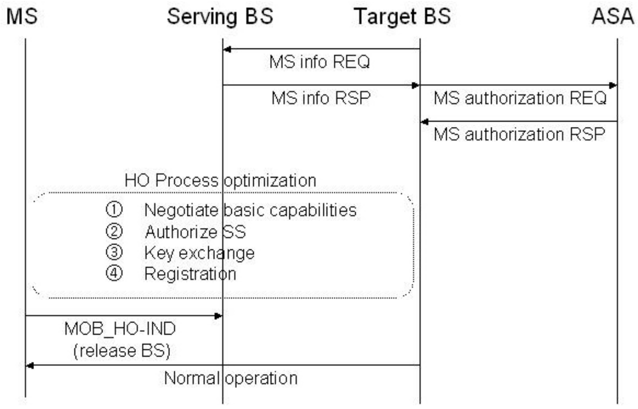


Fig. 4. Authorization and registration procedure.

## III. Proposed Algorithm

### A. Target BS Selection

Main purpose of this paper is to reduce wireless channel resource waste and latency during HO. Most of resource waste arises from neighboring BSs scanning and contention-based ranging operation. When scanning process begins, the serving BS provides neighboring BSs' information and MS shall pause its transmission for scanning operation. Thus, total amount of time spent to scanning process causes throughput degradation and it is especially significant for real time services. Moreover, MS performs neighboring BSs synchronization and association work not simultaneously but one by one, scanning time increases as the number of scanned neighboring BS. Therefore, we proposed to associate only one neighboring BS, most likely to be the target BS.

Fig. 5 shows our proposed network topology acquisition algorithm. Main idea is to prove preambles of neighboring BSs and select the target BS before synchronization and association. Since BS provides PHY information of neighboring BSs using MOB_NBR-ADV message, MS is able to prove the neighboring BSs' preambles without association. Then, MS acquires mean CINR and arrival time difference (ATD) of each neighboring BS and selects the most likely target BS. Mean CINR is measured by MS from –16.0 dB to 47.5 dB and ATD indicates the delay of downlink signal relative to the serving BS. A negative value indicates that the signal of the neighboring BS arrived earlier that of the serving BS [3]. Our algorithm assumes that the neighboring BS with bigger mean CINR and smaller the ATD is more likely to be the target BS.

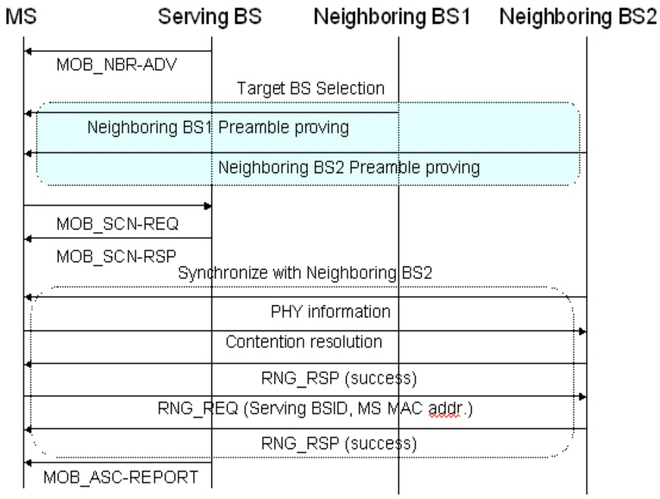


Fig. 5. Proposed Network Topology Acquisition.

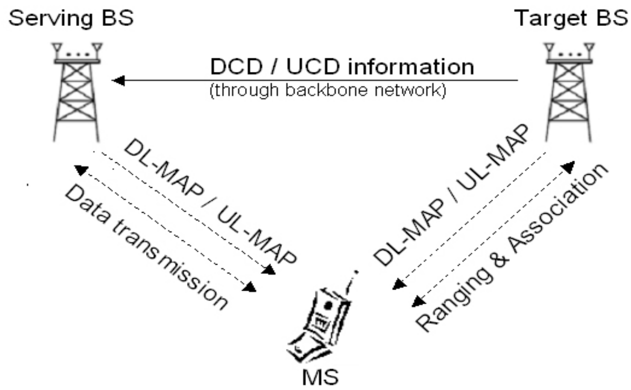


Fig. 6. Fast Association model.

If the target BS is decided, MS requests synchronization and association opportunity to BS using MOB_SCN-REQ message. And MS needs to conduct this process only with one selected target BS not several neighboring BSs. It can reduce redundant synchronization and association processes.

### B. Fast Synchronization and Association

Network topology acquisition process consists of scanning neighboring BSs and association. The former refers to obtain DCD / UCD and DL-MAP / UL-MAP information of the neighboring BSs. The latter indicates to synchronize and associate with the neighboring BSs. According to the existing draft standard, data transmission and reception is paused, which degrades system throughput. To cope with this problem, we proposed the fast synchronization and association method.

The basic concept is to conduct synchronization and association process and data transmission simultaneously as illustrated in Fig. 6. MS shall obtain DCD / UCD information from the serving BS using the MOB_NBR-ADV message. And MS is able to obtain DL-MAP / UL-MAP of the serving and neighboring BS simultaneously. Because every BS is distinguished by 48-bit BSID. Thus MS is able to obtain synchronization parameters for both BSs at the same time. Originally, neighboring BS scanning interval is allocated after the negotiation between BSs. The neighboring BS shall notify the ranging opportunity for MS to the serving BS during this negotiation. The serving BS should adjust its resource allocation for MS in the DL-MAP / UL-MAP message not to collide with given ranging slot. If the neighboring BS provides dedicated ranging slot, the serving BS should avoid the contention between downlink transmission and RNG-RSP slot and between uplink transmission and RNG-REQ slot. If dedicate ranging slot is not supported, the serving BS should assign MS's uplink transmission slot and contention-based CDMA ranging slot at different slot. Then MS can conduct neighboring topology acquisition process without pausing its data transmission to the current serving BS.

### *C. Optimized HO Initiation Timing*

When network topology acquisition is performed, MS request actual HO to the serving BS using MOB-MSHO-REQ message. Then the serving BS responds to this request after the negotiation with the neighboring BSs through backbone network. Candidate neighboring BSs shall allocate ranging slot for MS. If MS decide the target BS, it informs to the serving BS using MOB_HO-IND and HO is initiated. Other neighboring BSs, except the target BS, release its prepared raging slot. These ranging slots were waste of resources since that were actually not used during HO. However if MS select only one target BS this waste will be reduced.

If MS priory conducted ranging process and association with the target BS before HO, the target BS may allocate basic / primary CID for ranging and registration. Then MS can use that information during actual HO. If HO is initiated too early, allocated ranging slot is not utilized for some time. Otherwise HO is initiated too late, the target BS doesn't have enough time to allocate ranging slot, which means MS should conduct the contention-based ranging process. Thus, HO initiation should be performed with the appropriate timing. The most important factor to initiate HO is received signal strength and MS mobility. However, the draft standard considers only the former. It defines HO initiation timing when the received signal strength of the serving BS is lower than threshold. Thus, the threshold should be set differently according to the MS mobility. This will be considered at the performance analysis.

## IV. PERFORMANCE ANALYSIS

To validate the performance of proposed scheme, HO operation time is studied with the IEEE 802.16e OFDMA PHY model. It is TDD system with frame length 5ms. And one OFDMA symbol length is 115.2 usec including cyclic prefix. The cell size is assumed to be 1 km.

### *A. Required time of each stage*

We define some parameters for the analysis as follows:

T1 = required time for one neighboring BS scanning;
T2 = required time for obtaining parameters;
T3 = required time for contention based ranging;
T4 = required time for non-contention based ranging;
T5 = required time for registration;
T6 = required time for HO decision & initiation;
T7 = required time for authorization;

Since BS assigns scanning slots after negotiation with BSs through backbone network, T1 depends on the traffic condition of the backbone network. Assuming no channel error, T2 can be done within 2 frames. Because DCD / UCD information is already obtained and DL-MAP / UL-MAP is broadcasted in the every frame. And contention resolution should be performed for contention based ranging. It includes some process such as CDMA ranging detection and random backoff. Thus T3 depends on the CINR and cell loading. Since CINR is relatively low at the cell boarder, CDMA ranging detection may be failed to arise random backoff [5]. And the ranging collision probability is higher as cell-loading rate grows. Considering these, T3 is set to 75 ms and 150 ms with cell loading rate 0 % and 50 % respectively. T4 depends on cell loading rate as well because neighboring BS should assign dedicated ranging opportunity to MS. Thus, T4 is set to 25 ms and 50 ms with cell loading rate 0 % and 50 % respectively. T5 is not the main concern in this analysis and it is set to 35 ms. T6 is depends on the usage of proposed optimized HO initiation timing algorithm and it is set to 50 ms when the algorithm is used and 100ms in other case. T7 is also depends on the backbone network traffic because it is done by authorization server.

### *B. Required time for various scenarios*

Four different HO types are analyzed as follows:

Type1 = contention based ranging with pre-association;
Type2 = contention based ranging without pre-association;
Type3 = non-contention based ranging with pre-association;
Type4 = non-contention based ranging without pre-association;

Pre-association refers the case when MS conducts association with the neighboring BS before HO.

When conventional scheme is adopted, total needed time for each type is analyzed as follows:

Type1: (T1 + T2 + T3 + T5) * n + T6 + T7;
Type2: (T1 + T2 + T3) * n + T5 + T6 + T7;
Type3: (T1 + T2 + T4 + T5) * n + T6 + T7;
Type4: (T1 + T2 + T4) * n + T5 + T6 + T7;

The number of the neighboring BSs to scan is indicated as 'n' above and set to 3 in this paper.

When the target BS selection is adopted, HO operation time is analyzed as follows:

Type1: T1` + T2 + T3 + T5 + T6 + T7;
Type2: T1` + T2 + T3 + T5 + T6 + T7;
Type3: T1` + T2 + T4 + T5 + T6 + T7;
Type4: T1` + T2 + T4 + T5 + T6 + T7;

When the target BS is decided before HO, the parameter 'n' is 1. However T1 has to add the time amount for proving the preamble to adopt this algorithm in this case. Thus T1 is shown as T1`. If each preamble is distinguished perfectly from others using some orthogonal code, T1` equals T1. It depends on system implementation. For simplicity T1` is assumed to T1 in this analysis.

And when the fast synchronization and association is adopted, HO operation time is analyzed as follows:

Type1: (T1 + T2 + T3 + T5) * n * c + T6 + T7;
Type2: (T1 + T2 + T3) * n * c + T5 + T6 + T7;
Type3: (T1 + T2 + T4 + T5) * n * c + T6 + T7;
Type4: (T1 + T2 + T4) * n * c + T5 + T6 + T7;

If fast synchronization and association is adopted, MS conducts the network topology acquisition and its data transmission at the same time. However as the cell-loading rate grows, the probability of contention between those two operations also increases. Thus, the cell-loading rate should be considered and it is expressed with parameter 'c' above. When the cell-loading rate is zero, 'c' is zero. And it is set to 0.5 with cell loading rate 50 %. 'n' refers the number of neighboring BSs as well and if fast synchronization and association is adopted with the target BS selection simultaneously 'n' would be one.

Finally, when optimized HO initiation timing scheme is adopted HO operation time is analyzed as follows:

Type1: (T1 + T2 + T3 + T5) * n + T6 + T7;
Type2: (T1 + T2 + T3) * n + T5 + T6 + T7;
Type3: (T1 + T2 + T4 + T5) * n + T6 + T7;
Type4: (T1 + T2 + T4) * n + T5 + T6 + T7;

Although this analysis apparently shows the same results with the analysis of the conventional scheme, T6 is different as stated before.

### *C. HO operation time analysis*

Fig.7. and Fig. 8. shows the HO operation time analysis with cell loading 0% and 50% respectively. Target BS selection (TBS), fast and synchronization and association (FSA), and Optimized HO Initiation Timing (OHIT) algorithms are analyzed alone and combined with four different HO types. And table 1. indicates the amount of saved HO operation time when each algorithm is used. For instance, when TBS is adopted for the type1 HO with the cell-loading rate 50 %, it saves 450 ms.

TBS saves HO operation time since it reduces the number of neighboring BS to one. And it saves more time when non-contention based ranging is adopted. FSA reduces more HO operation time with low cell loading rate, however less time with high cell loading rate. FSA enables synchronization and association done without interfering current data transmission using unused slots. However it has to wait if unused slot is not found, thus it reduces less HO operation time with high cell loading rate. OHIT reduces the same amount with every HO type. It is because OHIT is not depends on the HO type, but MS mobility. Combinations of each algorithm are also studied. If all proposed algorithms are adopted, HO operation time is reduced about 300 ~ 400 ms and 300 ~ 600 ms with the cell loading rate 0 % and 50 % respectively.

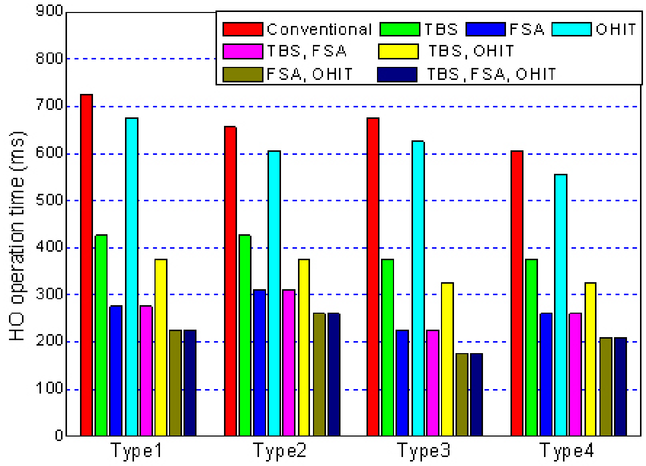

Fig. 7. HO operation time analysis (cell-loading 0%).

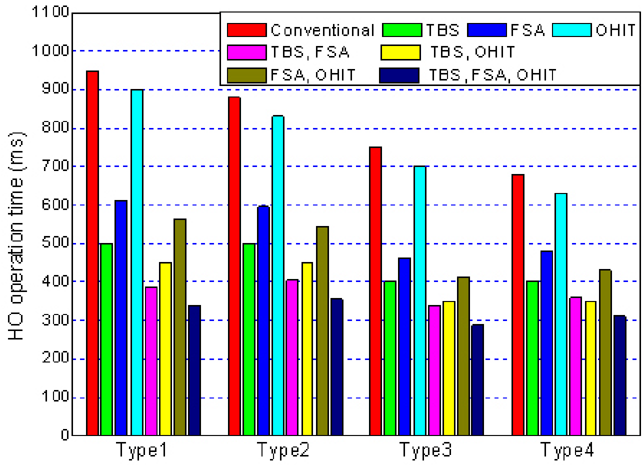

Fig. 8. HO operation time analysis (cell-loading 50%).

Table 1. Saved HO operation time (ms).

| Cell load | Scheme | Type1 | Type2 | Type3 | Type4 |
|---|---|---|---|---|---|
| 0% | TBS | 300 | 230 | 300 | 230 |
| | FSA | 450 | 345 | 450 | 345 |
| | OHIT | 50 | 50 | 50 | 50 |
| 50% | TBS | 450 | 380 | 350 | 280 |
| | FSA | 338 | 285 | 288 | 200 |
| | OHIT | 50 | 50 | 50 | 50 |

## V. CONCLUSION

In this paper, fast HO algorithm for IEEE 802.16e BWA is presented. According to existing draft version of standard, HO process consists of network topology acquisition, scanning, initial ranging, authorization, and registration. However there exists waste of channel resource and redundant work in the conventional algorithm. Therefore new algorithms including target BS selection, fast synchronization and association, and optimized HO initiation timing are suggested. And HO operation time is analyzed with four different HO scenarios. The performance analysis of proposed algorithms shows that HO operation time is reduced about from 300 ms to 600 ms depending on its usage. It will result to increase system throughput and validate the efficiency of the proposed algorithm. Some parameters of the algorithm are depends on backbone network traffic condition, cell-loading rate, user mobility, and CINR. Although they are assumed some fixed value for simplicity in this analysis, more precise study is needed in the future. Our future work considers these aspects.

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