A Simplified Scheme of Group Vertical Handover Decision-Making for Multiple Mobile Nodes and Multiple Target Base Stations

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***Abstract*—This paper proposed a simplified scheme of Group Vertical Handover (GVHO) decision-making for multiple mobile nodes (MNs) and multiple target base stations (target networks). In the GVHO situation, there are multiple MNs and multiple target networks. Since there are so many cases of matching of MNs and target networks, high calculating load is required for determining the best case of matching. Our scheme is more efficient scheduling algorithm with reduction of calculating load. In addition, we proposed the algorithm of supporting fairness for MNs with handover failure.**

***Keywords*—GVHO; Calculating load; Scheduling algorithm; fairness**

I. Introduction

In the next generation network environment, size of the cell is getting smaller, networks of varying types exist, and number of mobile node in the cell are increase. Then, in case of vertical handover of mobile node is frequently, the specialized scheduling algorithm should be considered in Group Vertical Handover scenario, as Fig. 1.

The scheduling algorithm for GVHO has been considered as a drawback of traditional schemes [2], three decision-making algorithms discussed for GVHO from different points of view. The first proposed scheme is inspired by the idea of separating massive VHO requests in time sequence (scheme 1), while the second one is trying to distribute concurrent VHO requests into available networks according to the predefined probability (scheme 2), and the last scheme (scheme 3) is network assisted handover, because the network side can collect more information and nearly eliminate uncertainly of information, and then it makes coordination among VHO requests and multiple networks to achieve optimized decision results that can improve whole system performance. The scheme 3 is the algorithm with the best performance among three schemes. However, in the scheme 3, high calculating load is required for considering all cases of matching of multiple MNs and multiple target networks. In this paper, we proposed the scheme which is lower calculating load by using bandwidth sorting method. Moreover, in case of sum of required bandwidth is larger than the sum of available bandwidth, we proposed the algorithm of providing fairness for MNs with handover failure.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (NRF-2013R1A1A2011856).

This work was supported by the Sogang University Research Grant of 2013 (201321042).

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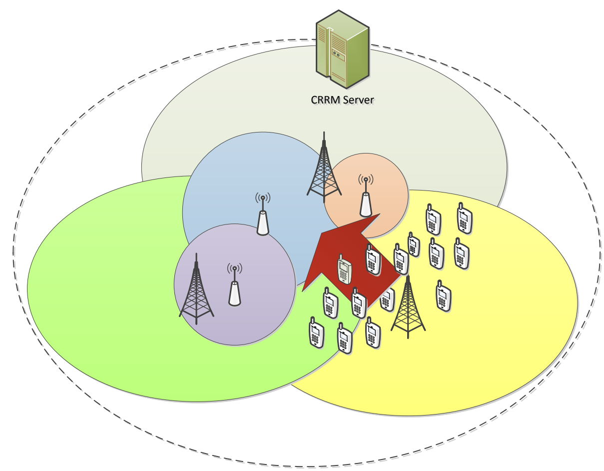

Fig. 1. Group Vertical Handover (GVHO) scenario

II. Realted Work

A. Problem Formulation

It is supported that the set N denotes the target networks. The target networks mean the available networks that can connect to MNs for vertical handover request. For each network $i \in N$ $(i = 1, 2, \ldots, n)$, the available resources are AR_i Mbps and the round trip time is RTT_i ms, and both parameters are various with time. Let the set V, denote users operating handover at a given time. For each user $j \in V$ $(j = 1, 2, \ldots, m)$, the required service bit rate is R_i Mbps, and it is assumed that $R_i \in R$, where R is the discrete set of allowable bit rate.

Various services have special characteristics. The real-time service is delay-sensitive, when it consider about the real-time service. For real-time service, its objective is to minimize the average transmission delay of whole system.

If the allocated rate approach the available resources, the transmission delay will increase due to network congestion. Therefore, a simple fraction function is given to approximate the non-linear increase of transmission delay with the allocated rate to user j and the available resources of network i [2], as

$$T_{ij} = \frac{R_j \times RTT_i}{2 \times AR_i^*} \qquad (1)$$

Where AR_i^* is the available resources of network i after the vertical handover.

B. Network Assisted GVHO decision-making

The two types of GVHO decision-making algorithm are the network-assisted GVHO decision-making algorithm (NETA) and MN-assisted GVHO decision-making algorithm (MNA).

In the GVHO environment, a MN collects information and it cannot know the handover decision results of other MNs. Therefore, many MNs may send handover requests to a certain target network condition and inefficient scheduling.

When it comes to scheduling, the NETA is more efficient than MNA. It is because NETA uses base station or access point for collecting information, and it can collect more information than MN.

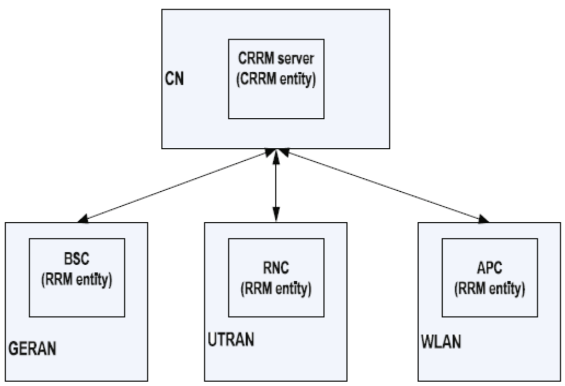

Fig. 2. CRRM Functional Model [3]

The existing NETA uses CRRM (Common Radio Resource Management) functional model. Fig. 2 shows CRRM architecture. The CRRM concept is based on a two-tier RRM model [3], consisting of CRRM and RRM entities. The RRM entity is located at the lower tier and manages RRUs (Radio Remote Units) within a RAT (Radio Access Technology). The CRRM entity and can communicate with other CRRM entities. Based on the information gathered from its controlling RRM entities, the CRRM entity is able to know the RRU availability of multiple RATs and allocate a user to the most suitable RAT [3].

The CRRM allocates MNs, which requested for handover, to available target networks (i.e. BS, eNB, AP). The allocation results are generated in sets. Each allocation set has average transmission delay, and the set with minimum average transmission delay (ma-delay) is selected. Then, the CRRM allows handovers according to the chosen set.

The procedure of selecting allocation set with ma-delay follows [2] :

1) All cases of allocation set are transformed into matrix D_k format, where d_{ij} indicates whether the user $j \in$ *{MN user}* selects the network $i \in$ *{target network}*.

$$D_k = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mn} \end{bmatrix} \qquad (2)$$

2) $d_{ij} \in \{0, 1\}$. If d_{ij} is *"1"*, it means that the selected result is positive; otherwise, the selected result is negative. The objective of decision-making for MNs is to select the set with minimize the average tranmission delay, which is described as

$$D_{k.select} = \arg\min \frac{1}{m} \sum_{i \in N} \sum_{j \in V} T_{ij} \qquad (3)$$

3) The CRRM gives the decision results to the corresponding network and then each network update the available resources and inform the corresponding VHO users for data transmission. Above matrix each MN chooses one target network.

III. A Scheduling Algorithm for GVHO

A. A Low Calculation Load GVHO decision-making algorithm

To facilitate description, the compared VHO scheme is named as "scheme 3" [2]. It is possible for the scheme 3 to find the allocation set with ma-delay because it considers average transmission delay of all allocation sets. However, performing such mechanism requires massive calculating load for finding the ma-delay decreases handover performance.

The proposed algorithm is designed to find an allocation set with nearly ma-delay by using a single allocation set. This algorithm allows networks to be optimized by reducing calculating load. MNs must be allocated to target networks properly in order to maintain nearly equal level of remaining resources among target networks. As a result, calculating load reduces dramatically.

The following shows the procedure of MNs allocation to target networks for calculating load diminution:

Step 1. Each source network, which is connected to MN, collects information about required bandwidths of MNs for VHO request.

Step 2. Each source network send collected information to CRRM server. And CRRM server collects information from the source networks.

Step 3. CRRM server arrays MNs in order of required bandwidths from largest to smallest.

Step 4. CRRM server arrays target networks in order of available bandwidths from largest to smallest, and allocates the MN with the largest required bandwidth to target network with the largest available bandwidth.

Step 5. CRRM server arrays target networks, and the only required bandwidths of remaining MNs after allocated are sorted.

Step 6. Step 4 and Step 5 are repeated.

Step 7. If the last MN, which has the smallest required bandwidth, is allocated, the GVHO scheduling is complete.

For example, the target networks and MNs assume the set of target networks $N=\{2, 1.5, 2, 3\}$(Mbps), its $RTT=\{180, 190, 200, 200\}$(ms) and the set of MNs for VHO requests $V=\{0.1, 0.2, 0.3, 0.4, 0.5, 0.1, 0.2, 0.3, 0.4, 0.5\}$(Mbps). According to steps above, the MN with the maximum required bandwidth (0.5Mbps) is allocated to the target network with the maximum available bandwidth (3Mbps). When the allocating resource to the MN with the maximum required bandwidth is finished, the available bandwidth of the target network is 2.5Mbps. Because available bandwidths of target network are changed, target networks are re-sorted for finding the maximum available bandwidth. Then, the MN with the second maximum required bandwidth is allocated to the target network with the maximum available bandwidth.

The pseudo-code in Fig. 3 illustrates the procedure of proposed GVHO decision-making scheme for calculating load minimization.

1: define number of target networks, MNs for handover
let the target network $i \in N$ $(i = 1, 2, \ldots, n)$ and MN user $j \in V$ $(j = 1, 2, \ldots, m)$
let $1 \le i \le n$ and $1 \le j \le m$
2: sort required bandwidths of MN $j=\{R_1, R_2, R_3, \ldots, R_m\}$(Mbps); $R_1>R_2>\ldots>R_m$
3: sort available bandwidths of target network $i=\{AR_1, AR_2, AR_3, \ldots, AR_n\}$(Mbps); $AR_1>AR_2>\ldots>AR_n$
4: allocate R_1 to AR_1; AR_1-R_1
5: re-sort available bandwidths of
target network $i = \{AR_1-R_1, AR_2, AR_3, \ldots, AR_n\}$(Mbps);
if available bandwidth sorting is $AR_2>AR_1-R_1>\ldots>AR_n$
6: allocate R_2 to AR_2; AR_2-R_2
7: for($1 \le j \le m$) do

Fig. 3. Pseudo-code of the proposed scheme

B. Scheduling algotithm for GVHO failed MNs

In case of sum of required bandwidths is larger than the sum of available bandwidths, it occurs handover fail of some MNs because it cannot allocate available resource of target networks to every MNs. One GVHO scheduling procedure is called stage in the scheduling algorithm for GVHO failed MNs. At the second stage, it schedule MNs of the second stage and the handover failed MNs of the first stage together. At this time, it will be required bandwidth to the order of the MN based on the low calculation load GVHO decision-making algorithm, if required bandwidth of MN is small, there is a high probability that the handover fail again. Based on the scheduling algorithm, MNs for small required bandwidth failed handover repeatedly, when GVHO occurs continuously. Therefore, the weight factor to required bandwidth of handover failed MNs appropriate. It is possible to maintain fairness increase the priority of GVHO. For example, the required bandwidth of MNs with the failed 0.1Mbps, if weight factor is 0.3, when attempting the second handover request, the MN has a priority as 0.4Mbps, the resource allocated 0.1Mbps.

IV. Performance Evaluation

A. Simulation Modeling

It is used Complexity as calculating load. The complexity is calculated by quick sort algorithm.

1) Scheme 3

(1) delay of average transmission delay calculating = m
(2) number of total generated matrix = n^m
(3) SORT(n^m)

2) Proposed scheme

(1) SORT(m), SORT(n)
(2) UPDATE(n)

The calculating load of scheme 3 is consist of m : n^m : SORT(n^m) for delay of average transmission delay calculating : number of total generated matrix : determining the matrix with minimum average transmission delay. Meanwhile, as known from the description (from step 1 to step 7 above), proposed scheme is consist of SORT(m) : SORT(n) : UPDATE(n) for array of required bandwidths : determining the maximum available bandwidths : SORT(m) repeat m times.

TABLE I. Comparison the Calculating Load

	Calculating Load (Complexity)
Scheme 3	$O(m \times n^m + mlogn)$
Proposed Scheme	$O(logm + mlogn)$

TABLE I is shown to quantify the complexity of the calculating load of scheme 3 and proposed scheme. The complexity of scheme 3 is an exponential function, and proposed scheme is a log function. For example, when number of mobile nodes is 10 ($m=10$) and number of target networks is 4 ($n=4$), the calculating load of scheme 3 is $O(10485766.02)$ and the calculating load of proposed scheme is $O(7.021)$. Thus, we verify that the complexity of proposed scheme is greatly reduced compared to scheme 3.

B. Simulation Results

Results of the simulation, at the first, while reducing rapidly calculating load, we compared the minimum average transmission delay associated with it. Further, if the required bandwidths is greater than the available bandwidths by applying weight factor, it is compared the number of handover failure MNs.

TABLE II. Comparison the Minimum Average Transmission Delay

Number of VHO users (MNs)	Scheme 3 (ms)	Proposed Scheme (ms)
10	20.252	21.239
11	19.393	19.72
12	19.657	20.641
13	21.089	21.629
14	23.791	24.285

Number of VHO users (MNs)	Scheme 3 (ms)	Proposed Scheme (ms)
15	28.208	29.166
16	27.695	28.593
17	28.71	29.15
18	31.433	31.871
19	36.472	36.879
20	45.416	45.72

In the simulation of TABLE II, the target networks and MNs assumed the set of target networks *N={2, 1.5, 2, 3}*(Mbps), its *RTT={180, 190, 200, 200}*(ms) and the allowable required bandwidths of MNs for VHO requests *V={0.1, 0.2, 0.3, 0.4, 0.5}*(Mbps).

The large calculating load of scheme 3 is consumed in order to derive the minimum average transmission delay. However, the proposed scheme, while reducing calculating load significantly, transmission delay was to have a value close to nearly minimum average transmission delay of scheme 3 by using proposed algorithm. It is increased 2.41% of the minimum average transmission delay of scheme 3 as shown in TABLE II. Therefore, this result shows a significant improvement in tradeoff of transmission delay and calculating load.

TABLE III. COMPARISON THE NUBMER OF GVHO FAILED MNS ACCORDING TO WEIGHT FACTOR

Weight Factor	Single HO failed MNs	Multiple HO failed MNs	Total
0.1	80	97	177
0.2	98	32	130
0.3	94	20	114
0.4	98	2	100
0.5	100	1	101
0.6	111	3	114
0.7	102	2	104
0.8	105	0	105

If required bandwidths are greater than the available bandwidths, when applying the value of the weight factor. TABLE III shows a comparison the number of single and multiple GVHO failed MNs according to weight factor from stage 1 to 10. Stage means the procedure of allocating resource until the available resource of target networks is not exist. When the one stage is finished, resource of target networks is initialized, and the next stage is started, then HO failed MNs and new HO requested MNs are allocated target networks. In this simulation, the target networks *N={2, 1.5, 2, 3}*(Mbps), its *RTT={180, 190, 200, 200}*(ms) and the set of MNs for VHO requests *V={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}*(Mbps) and available bandwidths of each stage is initialized, the set *V* is added in each stage.

If it does not apply a weight factor, the number of handover failed MN is larger than the case of applying the weight factor. And it cannot support the fairness handover to handover failed MNs with small required bandwidths repeatedly.

In our simulation, we set the weight factor as from 0,1 to 0.8. Since the minimum required bandwidth of MN can be assigned the highest priority, the maximum weight factor is 0.8. As indicated from TABE III, when the low weight factor (0.1~0.4) is applied, number of MN with single handover failure is smaller than the high weight factor. Meanwhile, when the weight factor is applied from 0.1 to 0.4, number of MN with multiple handover failure is decrease rapidly. Otherwise, there is no significant difference about number of MN with multiple handover failure, and number of MN with multiple handover failure, and in this case, number of MN with multiple handover failure is smaller than former case. Thus, in order to support the fairness, 0.4 as optimal weight factor is appropriate. In this result, the optimal weight factor with the lowest number of multiple handover failed MNs and the lowest average transmission delay per each stage when weight factor is 0.4.

V. CONCLUSION

In this paper, the performance evaluation of scheme 3 and proposed scheme is presented by using simulation analysis. Scheme 3 suffers from some problems like calculating load and fairness. Simulation results have shown that proposed scheme performs better than scheme 3 in aspects at the expense of added complexity and fairness. It is shown that while reducing calculating load significantly, transmission delay was to have a value close to nearly minimum average transmission delay of scheme 3. In addition, we presented an analytical model in determining the optimal weight factor for maintaining fairness.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (NRF-2013R1A1A2011856).

This work was supported by the Sogang University Research Grant of 2013 (201321042).

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