Performance evaluation using reduced neighbor lists in cellular based multi-hop relay network

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Extended Abstract

I. A BRIEF INTRODUCTION

In multi-hop wireless networks, communication between two end nodes is carried out through a number of intermediate nodes whose function is to relay information from one point to another. There have been many research works [1]- [4] about multi-hop communication, in which cellular networks employ multi-hop wireless forwarding. The standard community IEEE 802.16 [6] has the most active work in progress about relay infrastructure-based network. The relay task group of IEEE 802.16 was approved at May 2006 and they published draft document of 802.16j at Aug. 2007 [7]. Fig. 1 shows two kinds of relaying usage model of IEEE 802.16 relay task group, throughput enhancement and coverage extension. Considered RS types are fixed, nomadic, and mobile RS.

Neighbor lists advertised by BS(Base Station) help MS(Mobile Subscriber) to prepare and decide where to handover. Based on these neighbor lists in the neighbor advertisement, MS performs scanning the signal strength between target neighbors and itself, cell re-selection, handover decision and so on. In single hop cellular networks, such as 802.16e Mobile WiMAX, neighbor lists are delivered via periodic MoB_NBR-ADV messages and organized statically in first network deploying stage. And also it doesn't change until a BS is added in or deleted from the network because BS rarely moves, appears and disappears temporarily. However, in multi-hop environment such as 802.16j, neighbor lists are required to be organized dynamically reflecting movement, appearance and disappearance of RSs(Relay Station) which are recognized as BS by MS. Moreover, MS performs handover not only BS to BS but also BS to RS, to BS and RS of another cell directly, the number of neighbors would be increased significantly. If BS contains the information of all BSs and RSs in the MoB_NBR-ADV message, unnecessary wireless information would be broadcasted while transmitting neighbor information to MSs.

In this paper, we introduce a neighbor list composition scheme that organizes small numbers of adjacent neighbors for cellular based multi-hop networks so that reduced number
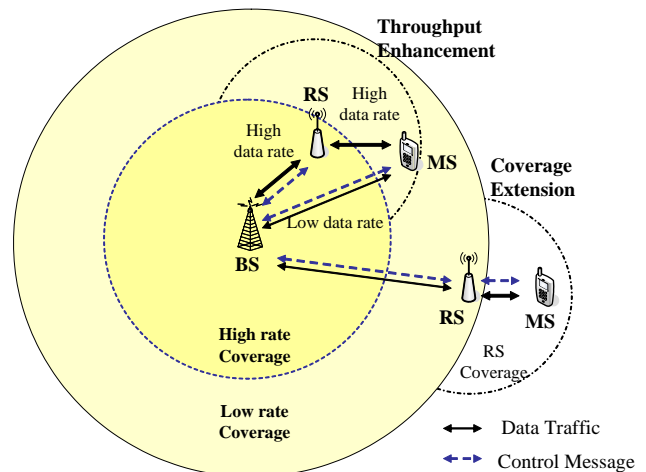

Fig. 1. Relaying usage models

of neighbors could increase average transmission rate of MR networks.

II. NEIGHBOR LISTS REDUCING ALGORITHM

Neighbor lists composition algorithm, proposed in this paper, are based on the location information of BSs and RSs. Although, the acquisition method of location information is not the scope of this paper, we assumed that BSs and RSs have the GPS module. Considering the location of the serving BS and its adjacent neighbors, we could reduce the number of neighbor candidates to the appropriate quantities for avoiding resource wastage and deciding the correct target BS in handover situation. Fig. 2 shows exaggerated neighbor lists delivery in multi-hop networks. BS_1 serves the MS which is preparing handover via RS_{13}. Although the MS needs only list of 5 neighbors (BS_1, BS_2, RS_{23}, BS_3, BS_{31}) considering its movement direction, BS broadcasts neighbor information including all lists of the BSs and RSs in the network if BS doesn't have any neighbor list composition algorithm because BS only knows the logical link connectivity not the geographical position of stations. This un-reduced neighbor list information makes the length of MoB_NBR-ADV message longer, wasting wireless resources while transmitting unessential information. In addition, considering the movement and
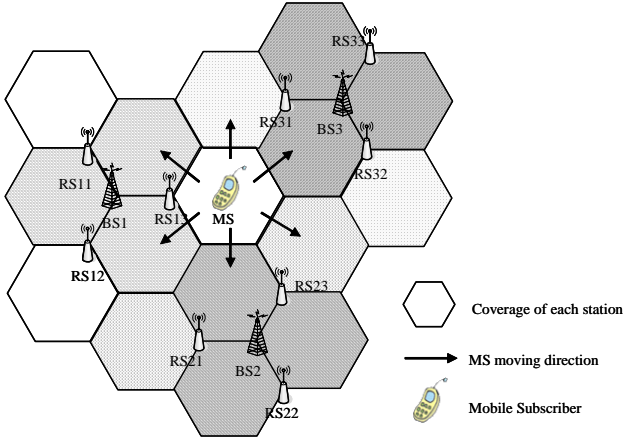
Fig. 2. neighbor lists in 802.16j MR network

Fig. 3. neighbor selection from RS_{13}

temporality of RS, it is required that dynamic organizing algorithm of neighbor lists in multi-hop system.

The acquired location information of BS and RS is reconstructed into distances and angles from the origin which is the location of serving BS or RS. Although, the acquisition method of location information is not the scope of this paper, however, we assumed that BSs and RSs have the GPS module. Distances are calculated on 3-dimensional cartesian coordinates(width, length, height), coordination transform of GPS(longitude, latitude, height) to cartesian is carried out from the following equation.

$$(x, y, z)_{cartesian} = (2\pi r \cos b \times \frac{a}{360}, 2\pi r \times \frac{b}{360}, c) \quad (1)$$

Where (x, y, z) is defined as the cartesian coordinates, (a, b, c) as the GPS and r denotes the radius of the earth. The distance and the angle from the origin, serving BS, to the another BS or RS is calculated by

$$d_{01} = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2} \quad (2)$$

$$\omega_{01} = \tan^{-1} \frac{y_1 - y_0}{x_1 - x_0} \quad (3)$$

According to the information of distances and angles, a BS sorts neighbor candidates along the zone(θ) and distance. For each station, zones are created by dividing angles with specific θ values, after that, BS selects the nearest neighbor candidates in each zone as a member of neighbor list set. Following equations explain the selection of neighbor members.

$$\sum_i \theta_i = 2\pi$$

$$N_{CA_{\theta i}} = \{N_{\theta_{ik}} | \arg min[d_k]\}$$

where $N_{\theta_{ik}}$ are neighbor BSs and RSs in zone θ_i, d_k means the distance between serving BS or RS and $N_{\theta_{ik}}$. As a result of above operation, the number of neighbors in MoB_NBR-ADV message are decreased to about the numbers that BS
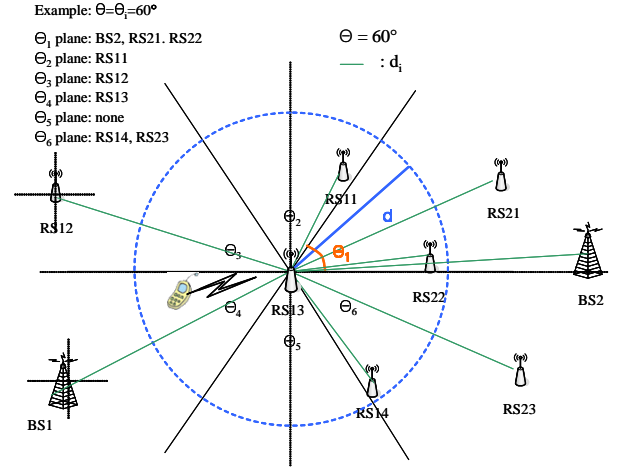
chooses in each zone. Fig. 3 illustrates that RS_{13} select and organize neighbor lists using the zone and distance. RS_{13} would divides its coverage into 6-zones and selects the nearest stations in each zone as a member of neighbor list. In the θ_1, RS_{13} would select the nearest station, RS_{22}, as the neighbor in θ_1, while excluding remaining two stations, BS_2 and RS_{21}. From the θ_2 to θ_4, there is only one station in each zone, and no neighbor member in θ_5. In θ_6, RS_{13} selects RS_{14} excluding RS_{23}. RS_{13} finally selects 5 neighbor members to organize neighbor list for MoB_NBR-ADV excluding 3 neighbors in this situation. We've suggested a new MAC management message, MMR_LOC-REQ/RSP and MoB_NBR-INFO, to deliver the location information from RSs to the serving BS. Using this message RSs would report its location information periodically or as the response of a information request [7].

Fig. 4 illustrates the handover process using reduced neighbor lists. MMR_NBR-INFO message contains customized neighbor lists and its location information, and RS creates MoB_NBR-ADV message based on the received MMR_NBR-INFO. BS and RSs broadcasts its own MoB_NBR-ADV message to its coverage. In this operation, no modification is required except MoB_NBR-INFO exchanged between BS and RS.

III. PERFORMANCE EVALUATION

As mentioned above, longer neighbor list wastes wireless resources and it causes the degradation of network performance in the view of transmission rate. As fewer as the neighbor members we organize, BS could allocate more resources to transmit data payload. The correct neighbor station selection in handover process also effects the network performance because neighbor selection is carried out according to the received signal strength between MS and stations. Therefore, a trade-off relation exists between the numbers of neighbors in MoB_NBR-ADV and data transmission allocation time. Following equations express the network overhead, average
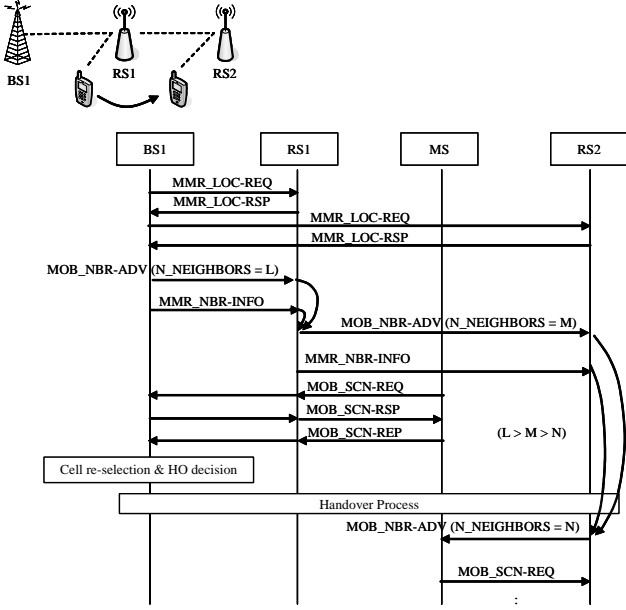
Fig. 4. Handover process using neighbor information

TABLE I

RECEIVER MINIMUM SENSITIVITY LEVEL

Modulation	Coding rate	Receiver SNR(db)
QPSK	1/12	-3
	1/2	5
	3/4	10.5
16-QAM	1/2	10.5
	3/4	14
64-QAM	1/2	16
	2/3	17
	3/4	20

TABLE II

SIMULATION PREFERENCE

Parameters	Values	Notes
Cell radius	$1\ km$	
P_b	2	2 Watts power for BS
P_r	1	1 Watt power for RS
BW	$10\ Mhz$	Bandwidth
Freq	2400	$2.4Ghz$
PLE	4	For urban area
MS Speed	$10 \sim 35$	$36km/h \sim 126km/h$
Simulation time/number	$7200\ sec\ /\ 100$	100 repetition

transmission rates with number of neighbor lists.

$$R_{ss} = \frac{P_{tx} \cdot g_{link}}{N_0 W} \quad (4)$$

$$tx(n) = \left[1 - \frac{T_{tx\_time} \times overhead(n)}{T_{NBR}}\right] \cdot \max_j[g_j(n)] \quad (5)$$

$$T_{tx\_time} = \frac{1}{K/coding\_rate}t_s, \quad where \quad t_s = 22\frac{146}{357}\mu s \quad (6)$$

$$Average\ tx\_rate = \sum_n tx(n)/T \quad (7)$$

Where $tx(n)$ denotes the transmission rate on a certain interval n, and the degradation which is caused by broadcasting neighbor lists is simplified by the normalized subtraction of overhead transmission time from the neighbor list broadcasting period. T_{tx_time} denotes the time that is spent to transmit a single-bit, is concerned with the modulation type and coding rate. Modulation type and coding rate is listed in the table I and these values are decided according to the received signal strength of equation(4) . And g_j is the link gain between MS and stations(BSs and RSs), t_s represent the symbol time, T is the neighbor advertisement period and $overhead(n)$ is the difference between full-neighbor lists and reduced neighbor lists in bits. We could obtain average transmission rate based on the table I and time period n in which stations transmit payloads. All these values are come from WirelessMAN-OFDMA parameters [5], [6].

We perform simulations to examine the effect of neighbor lists reduction to the transmission rate with various mobile speed, direction and number of relay stations. A single MS is traverse the network of 7 BSs in which have 6 RSs each. The

MS performs handover based on full-neighbor lists and reduced neighbor lists from the stations. Simulation preferences are listed in the table II.

Fig. 5, 6 show the simulation results about the average transmission rate of using full neighbor lists and reduced neighbor lists with the various mobile speed. The result graph of fig. 5-(a) and fig. 6 show propensity that the transmission rate is increased in low mobile speed with reduced neighbor lists than with full-neighbor lists. This is because that the reduced neighbor list could chase the actual moving direction of MS correctly so that MS could communicate with the station same as using full-neighbor lists, allocating more resources to transmit user data. And if MS has more neighbor lists, transmission rates will be enhanced to the relatively high mobile speed. The result says that as longer as the length of neighbor lists, MS could perform handover to the correct BS or RS compared to the short one. As shown in fig. 6, the improvement of transmission rate is relatively small and reduced-neighbor lists could not chase the correct neighbors for high speed mobile. This means that the suggested method is more suitable for the environment of lots of RS such as urban area. Fig. 5-(b) illustrates the time duration that MS communicates with different stations compared to the full neighbors receiving situation. MS selects wrong stations during approximately 2% of total simulation time in low mobile speed, and 13% in worst case, high mobile speed and small neighbors.

As a result, reducing neighbor lists in 802.16j multi-hop network could prevent wasting radio resources to transmit unnecessary control message and improve transmission rate between stations and mobile user of various moving speed. Despite the movement and impermanence of RS, BS could broadcast adequate neighbor lists using the location of stations. However, adequate management of operators, such as zone
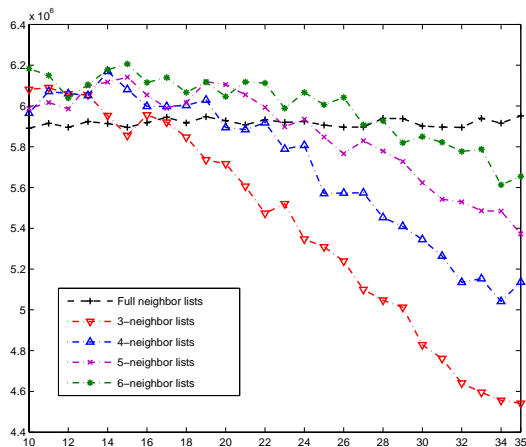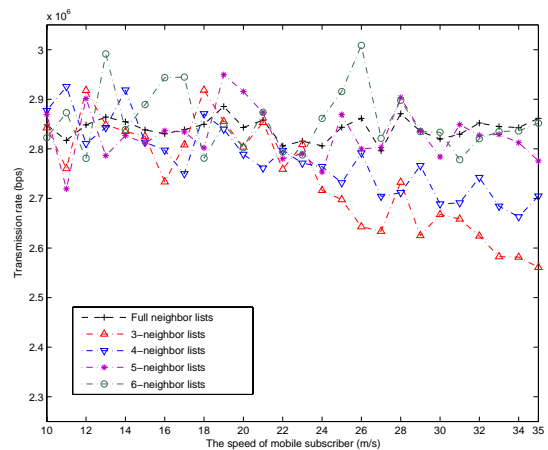
(a) Transmission rate-6RS
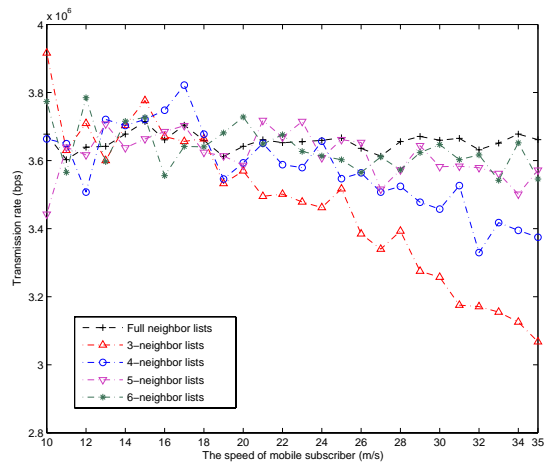
(a) Transmission rate-3RS
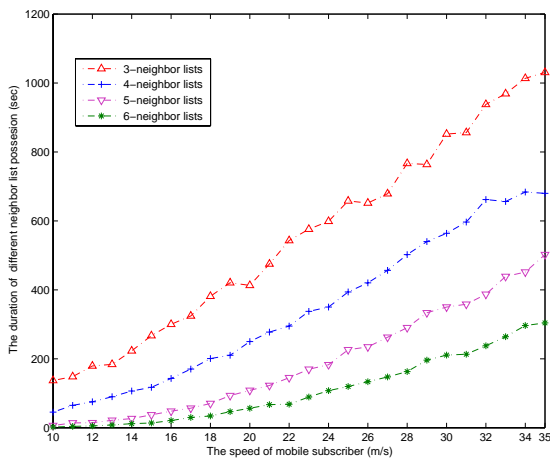
(b) Different duration-6RS

Fig. 5.   Simulation Results - 6RS

(b) Transmission rate-2RS

Fig. 6.   Simulation Results - 2RS and 3RS

dividing considering density of relay stations and the number of neighbors in MoB_NBR-ADV message, would be required for the efficient network operation.

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