Push-Pull Distributed Movement Algorithm for An Optimized Coverage of Mobile Base Station in Topology-less Wireless Networks

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Abstract: Much recent attention on wireless technologies is put on topology-less wireless network, in which all nodes can be mobile and can communicate over wireless links, due to its ease of deployment, high flexibility and low expenses. One key in topology-less wireless network is mobile base stations (MBSs), which provides access points for mobile terminals (MTs) to wireless backbone network. MBSs can move to anywhere in accordance with changes in geographical distribution of MTs. They serve as dynamic nodes. However, in order to utilize network resources and take full advantage of this topology-less network, MBSs must move to suitable position according to the current state of network use. Moreover, MBSs have to consider the distance among them to avoid the crash and gap area of MBSs. Therefore, this paper proposes MBS movement algorithm by implementing push-pull method to fulfill the corporation of MBSs and considering the center of covered MTs or centroid to satisfy the MT coverage. From the simulation results, the proposed algorithm increases the performance of system when comparing with the centroid-based algorithm[7], such as coverage area, MT coverage and call drops rate.

1. Introduction

The traditional wireless networks can be divided into two main types. One is the topology-fixed network, known as cellular network. This network relies on a fixed backbone infrastructure, which interconnects all fixed based stations (FBSs). However, the nature of Mobile Terminals (MTs) dynamically moves while all FBSs are fixed. Thus, this model introduces a probability of non-effective usage of FBS [1-2]. The other is a topology-less network initially known as ad-hoc network. In this model, each node provides services such as routing, self-organized topology to their own network. Therefore, this model is flexible enough to allow communication anywhere. However, this mode may be appropriate to be implemented with in intra-group communication due to its complexities in routing and management [3-4].

In order to overcome such limitations of the above two models, some researchers proposed another type of topology-less network that possesses the mobile base station (MBS) system as its component. This model combines the advantages of cellular network in having base stations, with the flexibility of ad hoc network to adjust to current state of network [5-7]. The examples of MBS are proposed and tested in [8-11]. These MBSs will rely on the semi-topology-less network where FBSs and MBSs coexist in the same network. So the tendency of the communication network planning in the future will be the topology-less network because the resources should be used more efficiently.

To take advantage of topology-less wireless cellular network, one critical point is how MBS can move according to change of network state and stop at the most suitable position. Some works proposed the channel allocation algorithm of MBS for cellular network [6]. However, there is no work that focuses on the MBS movement algorithm for realizing higher coverage of MT. Ref. [7] initially presented such algorithm called "centroid-based". This algorithm will find a center of covered MTs that seems to be the suitable position for MBS and then move towards that position, independent to one another. However, this algorithm is designed without considering the distance and corporations among MBSs. This leads to the oversupply MBS problem in which an excessive number of MBSs exist in small area with high MT density. Hence this paper proposes a novel MBS movement algorithm that considers the movement of other MBSs in order to maximize the coverage area. The proposed algorithm applies a push-pull model employing in [12]. Furthermore, the centroid of edging MTs is another factor for making decision in the MBS movement in order to maximize the MT coverage and minimize call drops. Based on the simulation results, the proposed algorithm has more efficient than the centroid-based algorithm such as the lower call drops and the higher coverage area and MT. The detail of this method and MBS movement algorithm are described in section 2 and 3 respectively. Simulations and results are presented in Section 4. Section 5 concludes the paper.

2. Push-pull method for MBS Movement

The push-pull method has related with the MBS motion as follows:

2.1 The repulsion

The push influences over short distance, i.e. as two MBSs are too close, each MBS will try to move away each together. The reason is that they try to find an appropriate separation in order to avoid the too excessive or useless cell overlap. The repulsion of MBSs is shown in fig.1. This method is known as "collision avoidance".

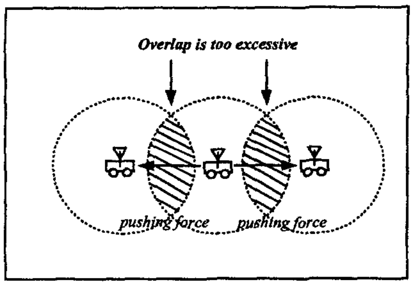

Figure.1 Pushing force between MBSs

2.2 The attraction

The pull dominates over long distance and is divided two types as follows.

2.2.1 The pull between MBSs.

As two MBSs are far away, they will come close each other depicted in fig.2. This is because they attempt to reduce a scattering probability of resources but to guarantee a minimum of cell overlap, which leads the smooth teı minal handoffs. Note that: since scattering of resources introduces a usage of MBS to be not efficient.

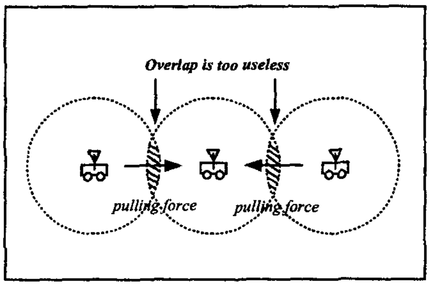

Figure.2 Pulling force between MBSs

2.2.2 A unilateral pull from MBSs towards the MTs.

This allows MBS to follow MTs, which are approaching the periphery of supportive range by giving the weight to them. Then MBS will compute the center 'c_{cen}' of MTs and try to move towards that position. This enables MBS to cover all MTs, which are its range as long as possible (fig.3).

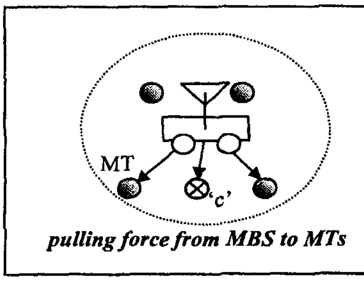

Figure.3 Pulling force from MBS to MTs

Hence, an individual MBS's motion is controlled by the above resultant.

3. MBS Movement Algorithm

The steps of movement algorithm illustrated in fig.4 (a-e) are the following:

Step 1: a unilateral pull from MBS towards the MTs:

- Each MBS will calculate the center ('c_{cen}') of covered MTs approaching its cell edge. At this step, MBS will get the direction and distance vector of movement, which is the attraction from itself to MTs. This step is shown in fig.4a.

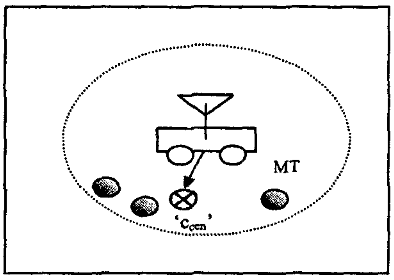

Figure.4a) The direction and distance of MBS movement that results from MTs.

Step 2: the push-pull between MBSs

- Then, MBS finds the other MBSs, which are in its cut-off distance and computes the distance 'D' between them.
- At this step, MBS will know that which the neighboring MBS is too close or far away by comparing the distance 'D' with the equilibrium distance 'd' where is defined as equation (1). See fig. 4b.

$$d = \sqrt{3}\,R \qquad \text{........... (1)}$$

Here R is radius of cell, 'd' is the suitable distance among base stations in the cellular network, which arrange their cells to be hexagon [13].

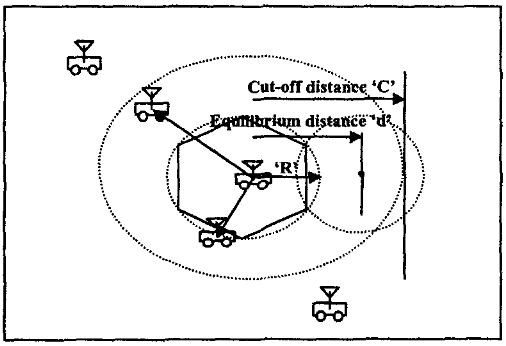

Figure 4b) The environment of an MBS

- When the distance 'D' is less than the equilibrium distance 'd', MBS has to move away from neighboring MBS with distance => |D-d|.
- On the other hand, when the distance 'D' is more than the equilibrium distance 'd', MBS has to come close to MBS neighbor with distance => |D-d|. The push-pull algorithm is depicted in fig. 4c-d.

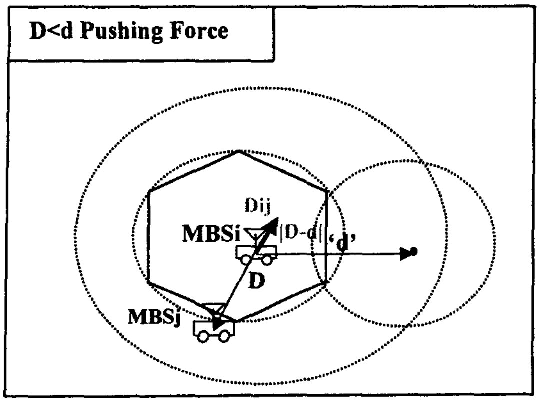

Figure 4c) The movement vector of MBSs is caused from the repulsion

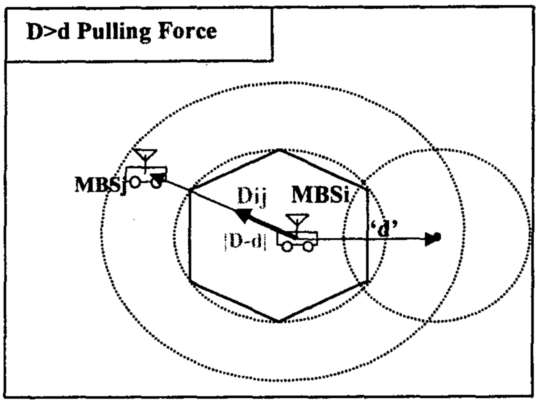

Figure 4d) The movement vector of MBSs is caused from the attraction

Step 3: the direction of MBS movement

- A sum of all distance and direction vectors from step 1 and 2 defined as equation (2) will be evaluated to make decision which direction that MBS should be moved and which position that MBS should stop (fig.4e).

$$\vec{D}_i = \Sigma \vec{D}_{i,j}(X_i,X_j) + \vec{c}_{cetroid}(X_i, X_n) \text{ .... (2)}$$

Here $\vec{D}_i$ is the movement force of MBS_i

$D_{i,j}$ is the direction and distance vector from MBS_i to MBS_j

$\vec{c}_{cetroid}$ is the centroid of MT_n

X_i, X_j, X_n is the position of MBS_j, MBS_j and MT_n in a fixed Euclidean space at a fixed time.

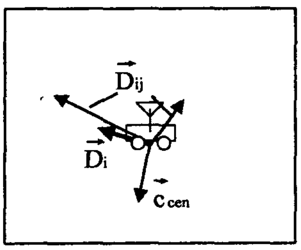

Figure.4e) The direction and distance of MBS movement

- Finally, MBS is moved to an appropriate position for an efficient usage of MBS. At the same time, other MBSs in the system also reckon their direction vectors in the same way and move to the suitable position.

Note that: In our system, MBSs will try to arrange their area to hexagon the same as the traditional cellular network. The arrangement of MBS is shown in fig.5.

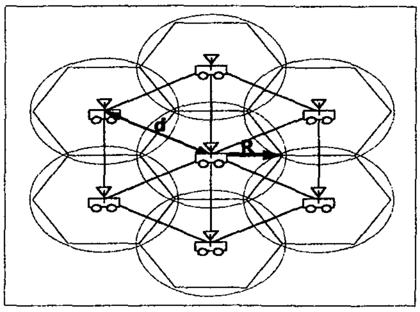

Figure 5. The arrangement of MBS cells

4. Simulation and Results

The following general behavior of MBSs and MTs are assumed for the simulation:

- Initially, MTs are randomly generated in MBS's range and numbers of MTs of each MBS are equal.
- Each MBS covers the circle area with the radius of 5 km.
- In our simulation, the cut-off distance is 3R where R is radius so the cut-off distance is 15 km.
- An MT can be serviced with by only single BS.
- MT can only be supported if it is inside the circle or received power (from MBS) is greater than or equal to a threshold value (γ = -100dBm)[13].
- MTs motion is randomly generated and independent of MBS.
- The speeds average of MT motion has range from 11 m/s (40 km/hr) up to 20 m/s (72 km/hr)[13].
- Maximum speed of MBS is 40 km/hr.

Three performances of measurement were considered in simulations: percentage of MT coverage, coverage area percentage, and call drop rate.

Figure 6 depicts the results of MT coverage percentage of the proposed algorithm, centroid-based [7] and fixed network. The proposed algorithm enables MBSs to increase the performance improvement of MT coverage approximately 6% and 17% over centroid-based algorithm and fixed network respectively.

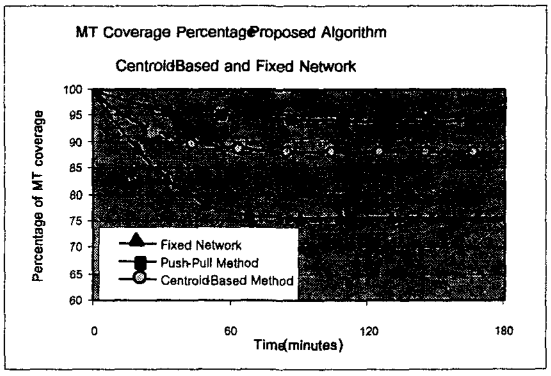

Figure 6. MT coverage percentage of the proposed algorithm, centroid-based and fixed network.

Besides, we observe that our MBS movement algorithm does not only increase the capability of coverage area up to 40 % but also can reduce the call drop rate approximately 25% compare with the centroid-based algorithm (figures not shown). The reason is that push-pull movement algorithm is designed with respect to attempt to arrange their cells to be hexagon in order to fulfill the high coverage area and the minimum overlap area. Moreover, the proposed algorithm still consider the center of covered MTs to be a factor of making decision so MBSs can fulfill in MT coverage and call drops. Subsequently, MBS can be used effectively.

5. Conclusion and Future Works

In this paper, we have proposed the algorithm of MBS movement, which applies the push-pull and centroid-based models to find the suitable position for MBS movement. Based on simulation results, it is convinced that this algorithm is not only appropriate to be applied in a full topology-less but also be convenient and flexible to be implemented in the semi-topology-less network where the existing network is extended by MBS. Since each MBS uses only its data to make decision to move towards the appropriate position. It does not use the whole information of the system.

In case of there is a high network usage in some cells e.g. festival, sport game etc. and then the demand of service exceeds the threshold of capacity of MBS, in order to alleviate this problem, MBS has to reduce equilibrium distance "d" value by considering a current load factor of each MBS to allow MBS neighbors to get into MBS for sharing loads. Therefore, equation (1) should be integrated the current load factor in our future work.

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