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Moving Hotspot Improvement Based on Adaptive Nomadic Relay Station Optimization Algorithm

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Abstract— The RS location optimization introduced in the most of reseaches were based on FRS location optimization. The optimum locations were estimated depending on uniform distribution assumption for UEs. However, in the practical network, the UEs distribution is randomly distributed and the hotspots positions are varying with the time. Moreover, the effect of the scheduling schemes was neglected in that study. Therefore, the results of the above study may not be considered as optimum placement of the RSs all over the simulation time. Stated in other words, in real networks the optimum location may vary according to the time varying parameters of the channel, number of RBs allocated to each UE, number of active UEs, and their locations.

In order to improve the performance of the network adopted in [8], Nomadic Relay Station (NRS) with adaptive optimized location is proposed in the current study. The NRSs can be a candidate solution for time varying parameters, and moving hotspots improvement. Hotspot Improvement (HI) can be considered as a feature of LTE-B (Rel.12, and 13) [1, 2].

Index Terms— LTE-A, Nomadic Relays, Optimization, Relay Stations, 4G, LTE-B, 5G, Troughput

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1 Introduction

LTE-B (Rel.12, and 13) can be considered as a second phase of LTE-A (Rel.10, and 11) as shown in Fig.1 [1]. It focuses on the network as long as UEs performance improvement to meet the new challenges in the coming few years. This can be achieved by increasing both system and network capacities up to 30 times higher than LTE Rel.8. On the other hand, CEUs performance has to be improved. General enhancement technologies may be added as, higher order MIMO transmission modes up to 4×4 in uplink and 8×8 in downlink, Hotspot Improvement (HI), and small cells using optimized relaying technologies, and Pico-cells [1].

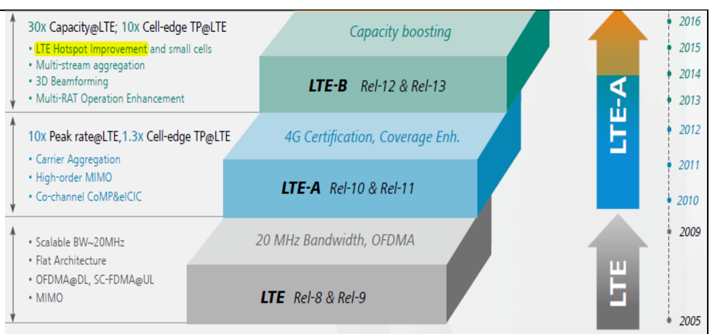

Fig. 1, LTE releases evolution [1]

Hotspot Improvement (HI) is adopted in LTE-B to improve the hotspot as long as the total network performance. This can be performed by focusing on small cell spectrum efficiency enhancements using Pico-cells or FRSs as shown in Fig.2 [3].

Moving hotspots has locations variant with time according to given network parameters and environments [1, 2]. In the case of moving hotspots the Pico-cells or FRSs is not efficient. According to this fact, NRSs were proposed in the current study.

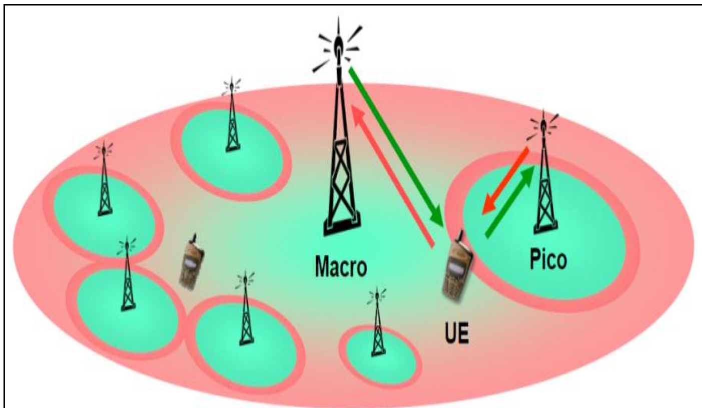

Fig. 2, HI using pico-cells and RSs in parallel with micro cells [3]

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2 Problem Statement

A practical example of moving hotspots is shown in Fig.3. This figure shows a map downloaded from Google earth for a part of Mansoura University with its nearby streets. A day time moving hotspot and its locations may be obtained in table.1 with regions shown in Fig.3. For the same network parameters and assumptions given in section 8.1, the main problem will be that the hotspot locations are not fixed. Therefore, the pico-cells and FRSs will not be efficient. This requires a proposed nomadic relay station with adaptive periodic optimized location update.

Table 1- Daytime hotspots movement in Mansoura University

Beginning time	Ending time	Hotspot regions	Region description
7.30 am	8.30 am	2, 3, 4, 5, and 6	The streets around university
8.30 am	10 am	Uniform distribution between streets and university With hotspots in some colleges	
10 am	2 pm	1,3, and 6	University colleges and roads
2 pm	4 pm	2, 3, 4, 5, and 6	The streets around university
4 pm	7 pm	Absence of hotspots	
7 pm	1 am	2, and 4	Shopping streets
1 am	7.30 am	7, and 8	Students housing

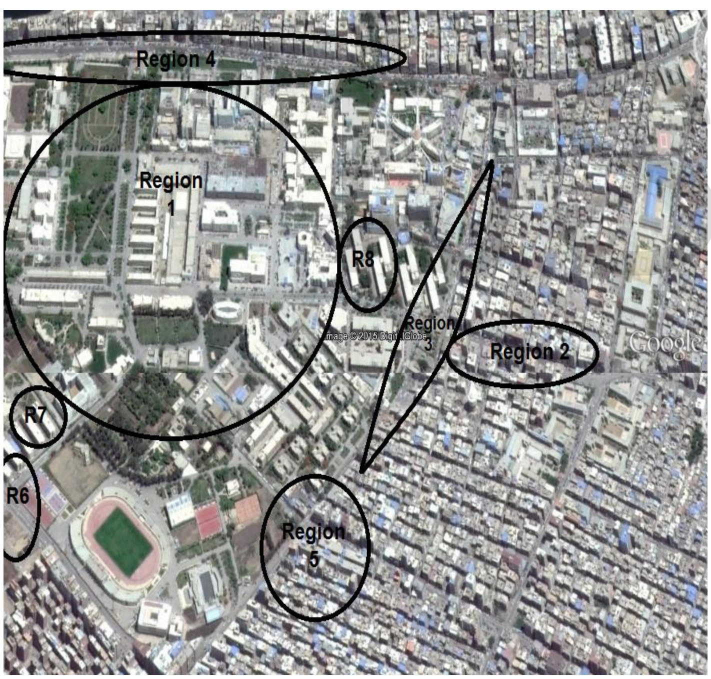

Fig.3, Mansoura university map with daytime hotspots

3 Related Works

In [4, 5] a moving relay station (MRS) was introduced to improve the performance of some of UEs traveling on a vehicle. It has the same characteristics as FRNs [6, 7], but it differs in the way it works while moving with the movement of the users as shown in Fig4. In this study the served user place is known to the MRS, and the MRS select whether to connect directly to eNB or via FRSs. From this fact it can be seen that this MRS works in a way different to the way required for this study.

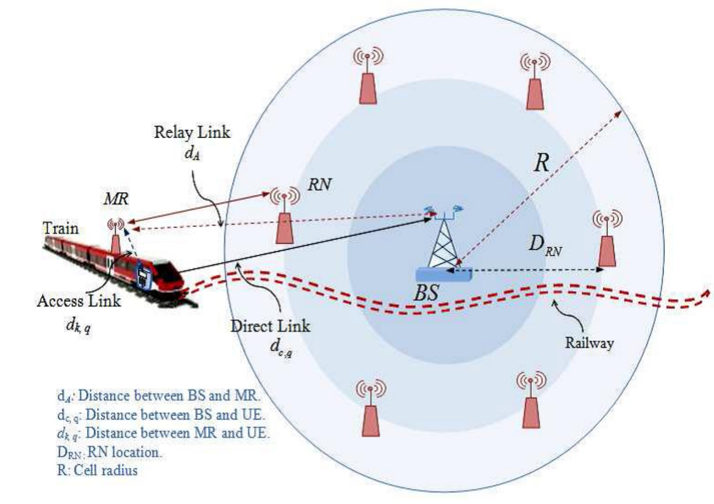

Fig.4, Train travelling across one cell with L-FRSs using MRS [36]

4 The Main Proposal

The Nomadic Relay Station (NRS) can be defined as a Moving relay with location optimized and updated periodically with the time varying network parameters and moving hotspots. The location optimization is performed subjected to the total throughput maximization objective.

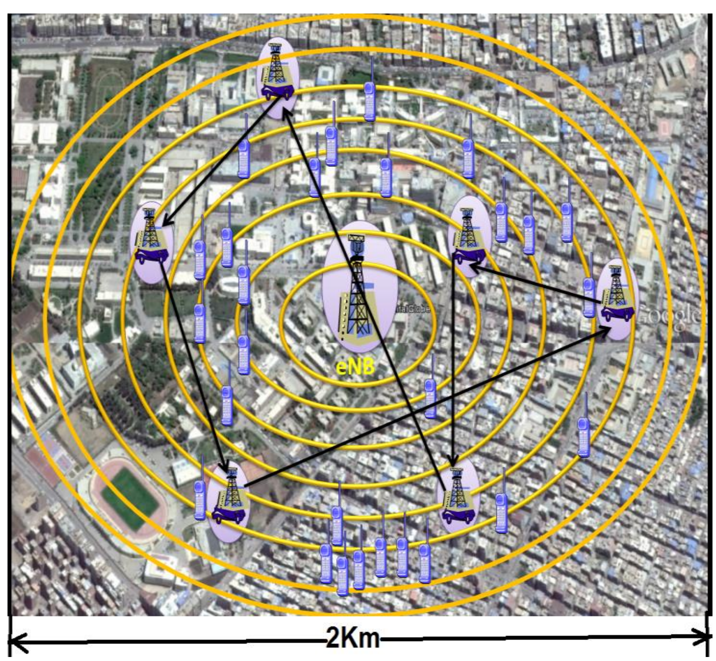

Fig.5, NRS with adaptive optimized location

In the study reported here, the hotspots assumed to be time varying and moving as shown in Fig. 3. The NRS have to make exhaustive search each particular period and updates its location to the new optimized location. Therefore, it will be adaptive with the time varying parameters and moving hotspots. This period must be multiple integers of the optimum transmission time calculated [8] and shown [9] according to OTFWC + SDMT schemes. In this case the RS will work as a hotspot follower in order to maximize the network performance.

The main objective of the study reported here, is to improve the multi-hop network performance using Nomadic RS (NRS). The NRS's location is optimized with total throughput objective, and adaptive with time varying parameters and moving hotspots in the network as shown in Fig.5. This proposed type of RSs will be heavy more complex than other types, and need faster processors to overcome the delay resulted from the adaptive feedback. However, it decreases the cost of L-FRSs, increases the system feasibility, and improves the network performance.

5 Performance Model

Assuming that the number of zones per cell Ň = {1, 2, …,i, …,N}, the number of sectors per cell ķ={1, 2, …,j, …,K}, and ℵ(z.T*)={1, 2, …,n, …, N} is the number of UEs in the cell at a certain time (z.T*), where T* is the minimum transmission time for UEn using OTFWC [8], and Z={0,1,2,…,z,…,Z} which is defined as an integer numbers with (Z=total simulation time/T*). For the UE located at distance r1 from the eNB (see Fig.6); the received data rate assuming 2×4MIMO [10] may be expressed as:

$$R(UE_n(i,j)) = C\left(SNR(r_{1n}(i,j))\right) = R_n(i,j)$$

$$= 0.38 \times 2 \times RB \times W$$

$$\times log_2(1 + 1.05 \times 1 \times SNR(i,j))$$

Where,

$$SNR(i,j) = \begin{cases} \left(\frac{P_{UE\_max}}{N_o \times W \times RBs \times L(i,j)}\right) & ; SNR < SNR_{max} \\ SNR_{max} & ; SNR \geq SNR_{max} \end{cases}$$

5.1 RS Assisted Channel Capacity

Assuming that ɱ={1, 2, …,m, …,M} is the candidate positions (CPs). ℵ(z.T*)={1, 2, …,n, …, N} is assumed to be the number of UEs in the cell at a certain time (z.T*), where ℵccu(z.T*)={1, 2, …,nccu, …, Nccu} is the number of CCUs in the cell at (z.T*), ℵCEU(z.T*)={1, 2, …,nCEU, …, NCEU} is the number of CEUs in the cell at (z.T*), and

$$N_{CEUs}(z.T^*) \cup N_{CCUs}(z.T^*) = N(z.T^*) .$$

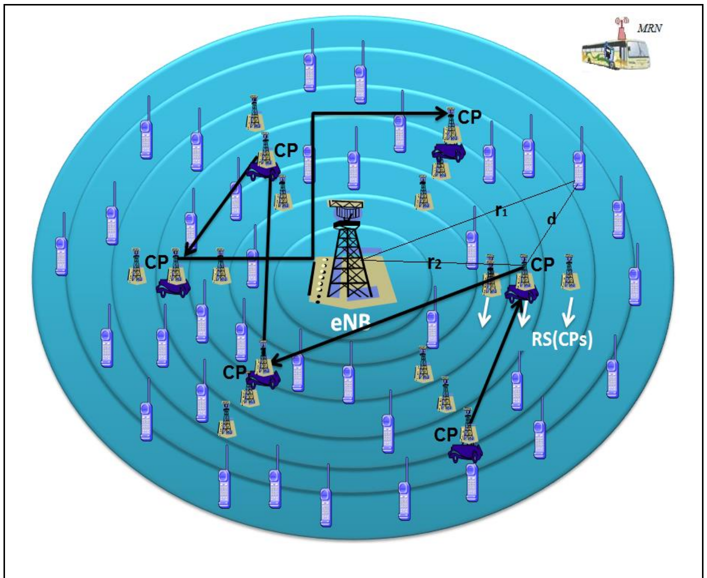

Fig.6, NRS CPs in the N-zones cell model

For the CCU number n which is located at distance r1 from the eNB (see Fig.6) based on 2×4MIMO [10] , the received data rate may be expressed as:

$$R(CCU_n) = C(SNR(r_{1n})) = R_n = 0.38 \times 2 \times RB \times W \times \log_2(1 + 1.05 \times 1 \times SNR(r_{1n}))$$

Where, n∈N_{CCUs} (z.T*). Assuming OTFWC RB scheduling [8] scheme, SNR is improved using SDMT scheme. The data rate of CEUs can be defined as,

$$R(CEU_{m,n}) = \left[\frac{C(SNR(r_{2m}) + SNR(r_{1n})) \times C\left(SNR(d_{m,n})\right)}{C(SNR(r_{2m}) + SNR(r_{1n})) + C\left(SNR(d_{m,n})\right)}\right] = R_{m,n}$$

Where,

$$C(SNR(r_{1n})), C(SNR(r_{2m})), \text{and } C\left(SNR(d_{m,n})\right)$$

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Can be estimated from equations 1, and 2, $n \in N_{CEUs}(\text{z.T}*), and\ m \in M$. The data rate of the UE located at zone i, and sector j can be defined as:

$$R(UE_{m,n}(i,j)) = \max\left(R_n(i,j), R_{m,n}(i,j)\right)$$

5.2. One-NRS Placement Optimization Problem Formulation

The optimum location of the NRS in the cell at a certain time (z.Tmin) can be calculated using the Capacity Maximization Nonlinear Integer Problem (CMNIP). It may be expressed as [11, 8]:

$$\max_{X,SNR} \sum_{\substack{n\in N_{CEUs}(z.T*) \\ m\in \mu}} R_{m,n} + \sum_{n\in N_{CCUs}(z.T*)} R_{n,z}$$

Subjected to:

$$\sum_{m=1}^{M} X_m = 1, m \in \mu \quad ,X_m \in \{0,1\}$$

$$SNR \le SNR_{max}$$

Equation (6) represents the objective function referred to the maximization of the total uplink throughput in the cell. The constraints of equation 6 are expressed in equations 7, 8, and Constraint (7) means that the total number of used RS in the cell is one RS. Constraint (8) means that the decision variable is binary 0 if the RS is not at CP, and equals to 1 if the RS was at CP. According to this fact,

$$\sum_{m=1}^{M} X_m$$

means the total number of RSs assigned to CP. Constraint (9) means that the received SNR cannot be more than the maximum acceptable SNR in the uplink LTE-A. This condition is achieved using power control algorithms. Using exhaustive search [69, 8], the optimum CP in which maximum total uplink throughput is achieved will be known in each Time step (z.T*). Note that it is not needed to do the exhaustive search each z step=1. The step can be calculated according to the expected time in which the hotspots will be moved from place to another.

6 Performance Evaluation Model

A single LTE-A/E-UTRAN cell in urban area with cell model described in section 3.4 is considered. The number of zones N=500, and sectors K=49 Study is carried out for Uplink. Half-duplex decode and forward Nomadic RS is considered with CPs μ={1, 2, …,m, …,M}, where M assumed to be 60 CPs. These CPs has a uniform distribution of r2m=U(300,1000m), φm= U(0,2π). The RS optimum position in the cell is evaluated for higher total Throughput.

The results are compared with fixed RS positions studied in [12]. Proposed OTFWC scheduling scheme is considered in the RS with SDMT scheme [8, 10]. New file transfers from random users at random locations in the cell are initiated. In addition, new file transfers from additional random users at random locations in a range of a given hotspot with radius 100m in the cell. The hotspot location will be changed randomly each 5% of the total simulation time. The overall file transfers in the cell will be initiated according to a given wide range of arrival rates λ. 2×4MIMO transmission modes are used in simulations.

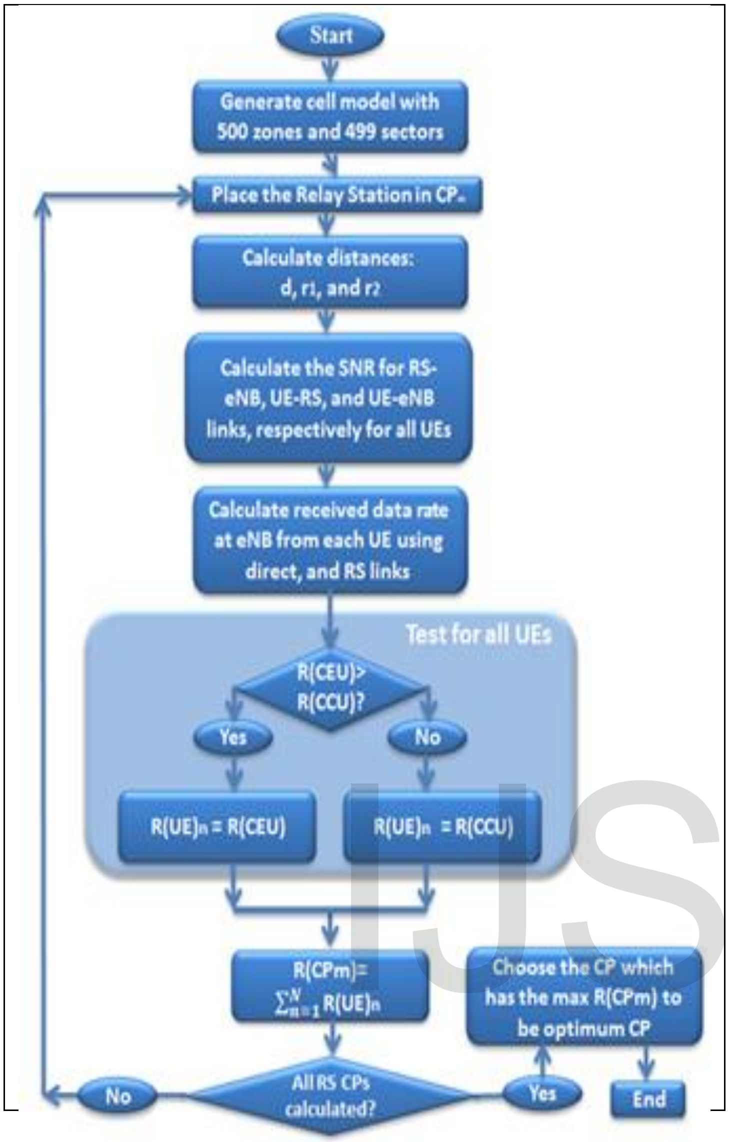
6.1. Simulations Setup

In the beginning of simulation time, the optimum location was chosen according to the flowchart shown in Fig. 7 for total throughput maximization based on exhaustive search. This optimum location will be estimated to one of the assumed 60 CPs each 5%, and 10% of the total simulation time using the same flowchart. The simulations will be repeated using FRS optimized location, and the results will be compared in order to compare the performance of NRS and FRS.

In the simulation environment, the cell model with 500 zones and 499 sectors is used and the hotspot with a given placement. After that, a loop is entered with one new iteration for each time step among all of simulation time. For each time step a random number of new UEs are assigned to random segment within the cell and added to a queue.

At the same time, a random number of new UEs are assigned to random segment within the hotspot region and added to the queue also. The total number of added UEs will be assigned according to a given arrival rate. All UEs were classified whether there are cell edge users (CEU) or cell center users (CCU).

According to the OTFWC scheduling scheme, each UE begins to transmit file directly to eNB if it's CCU or via RS if it's CEU. When the file is completely transmitted; the UE is removed from the queue. The hotspot placement will be changed randomly each 5% of the total simulation time. The optimized RS position will be updated each given time step, and the NRS will move to the new position.



At the end of the simulation time the total cell throughput is obtained according to the total transmitted files size and total required time for transmission. From these results the throughput results are obtained, and compared with the simulation results obtained using FRS results.

7 Results and Discussions

A matlab program was designed to simulate the model reported in section 6, with a randomly moving hotspots using four RS scenarios. The scenarios simulated were: 1-FRS with position optimized with total throughput objective, 4-FRSs with positions optimized with total throughput objective, Adaptive NRS with location optimized and updated each hotspot moving time, and Adaptive NRS with location optimized and updated each time period twice as the hotspot moving time. The results were found, and compared. Fig. 8 illustrate the simulation results for the LTE-A total uplink throughput versus their arrival rates using 2 × 4MIMO transmission mode with moving hotspot. Both OTFWC and SDMT schemes were considered.

From Fig. 8, it can be seen that for the given network parameters and assumptions, the one fixed relay station has lower performance as compared to all other RS scenarios. It has channel capacity 11.1Mbps and maximum system capacity 11.25 average user arrivals per second before system saturation. On contrary, the 4-FRSs have the best performance allover all RS scenarios with channel capacity 13.4Mbps, and system capacity 13.5 arrivals per second. This is because using four FRSs at their optimum values will cover most of the cell with a high SNR on the expense of high cost of using 4-RSs in each cell.

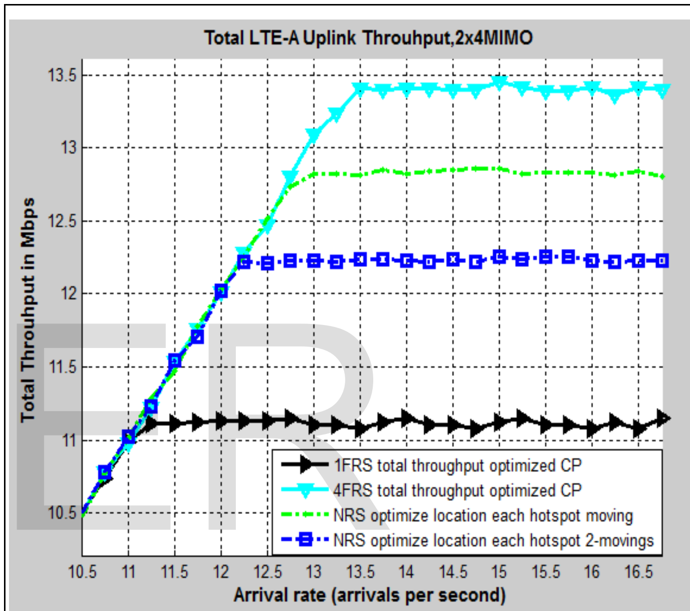


Fig.8, Total uplink throughput for LTE- A network with moving hotspots effect based on OTFWC, SDMT, and 2×4 MIMO transmission mode

Moreover, it was noticed that using NRS with optimized adaptive periodic location update in a network has varying UEs locations, and moving hotspots will give performance better than one FRS. The throughput gain will be 10.36% in case of adaptive NRS with time step 10% of total simulation time (twice av. Hotspot movement time), and 15.37% in case of adaptive NRS with time step 5% of total simulation time (av. Hotspot movement time). This gain value can be considered the maximum gain value achieved using this proposed RS scenario. In other words, decreasing the location update time step than the hotspot movement time will not be useful. However, this gain means significant improvement in CCUs, CEUs. It may also cause hotspot improvement which can be considered one of LTE-B features.

On the other hand, comparing the performance of 4-FRSs with NRS with adaptive location it can be seen that 4-FRSs provides heavy higher gain compared to its complexity. Another problem solved by the adaptive NRS that using 1-RS will save power, cost, and connections complexity than using 4-RSs. Note that the capacity enhancement using 4-FRSs comes from the fact that the average power transmitted per RB will be more than this using one NRS. This is because each RS transmitted power will be divided among the RBs used for its CEUs transmission.

8 Conclusion

In this paper, a Nomadic Relay Station with optimized location Adaptive with the time varying parameters in the network was proposed. The LTE-A uplink network performance was evaluated using this RS strategy. A time varying hotspot that randomly moved from location to another during the daytime was added to the network to study the effect of the proposed NRS. The network performance using the proposed adaptive NRS was compared with the fixed relay station with location optimized assuming uniform user distribution for 1-FRS, and 4-FRSs, respectively. 2×4MIMO, OTFWC scheduling, and SDMT schemes were considered in the current study for performance enhancement.

The main idea of the adaptive NRS is that, it can estimate its optimized location periodically each a particular time using exhaustive search. Note that the time period for periodically exhaustive research must be multiple integer of the minimum transmission time obtained in the proposed OTFWC scheme for dependent scheduled UEs.

The simulation results showed that there was significant improvement of the network performance containing moving hotspots using the proposed adaptive NRS compared to using 1-FRS with maximum throughput gain 17.37%. This throughput gain is achieved when the RS adapts its location periodically with the hotspot movement. From this fact it can be concluded that, no improvement will be achieved using location update period less than this period. On the other hand, increasing the location update period will decreased the number of movements of the RS leading to less complexity and cost, but with less throughput gain

Another conclusion was that, the performance of 4-FRSs is compared with NRS with adaptive location is better with heavy gain compared to its complexity. Another problem solved by the adaptive NRS that using 1-RS will save power, cost, and connections complexity than using 4-RSs. It may also cause hotspot improvement which can be considered one of LTE-B features.

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