Proposed Algorithms for Downlink LTE-A network performance Evolution

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Abstract— Fourth Generation (4G) cellular networks are foreseeable to provide maximum data rates to follow the rapid increase in applications and number of subscribers. It can execute in LTE-A Network using some technologies such as Relays, Synchronous Direct and Multi-hop Transmission (SDMT), low complexity resource allocation algorithms are proposed, Adaptive MIMO, Modulation, and Coding switching (AMMCS) scheme. This paper introduces some solutions for LTE-A Downlink Performance Improvement. It will be done via four parts are studied. In the first part of the study: 4x4MIMO and AMMCS were proposed for low BER and maximum throughput. The second part proposed lower resource allocation algorithms named Optimum Time Fair Work Conserving (OTFWC) based on SDMT. The third part of the study is deciding the optimum number of RSS. And the fourth part optimum location estimated for n-fixed RSS.

Index Terms. downlink LTE-A, AMMCS, SDMT, OTFWC.

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1 INTRODUCTION

Relaying in LTE-A downlink performance have many considered studies. In [1], the author's presented study studied the effect of co-channel interference with the relay position problem in an LTE-A. In [2], the authors presented the uplink performance of MIMO multi-hop LTE-A based on link adaptation. In [3], the authors presented Optimal Capacity Relay Node Placement in a Multi-hop Wireless Network. In [4], the authors presented Multi-Hop Relays for LTE Public Network. In [5], the authors presented Performance modeling and analysis for LTE, which studied the impact of RS positioning on the LTE uplink performance. In [6,7], the authors presented the LTE Downlink RB scheduling algorithm. And in [8], the authors presented FWC scheduling using a relay station.

In this paper: There are three main objectives for the present work. The first one is to discuss Downlink Scheduling Scheme Optimum Time Fair Work Conserving (OTFWC) is proposed for zero multi-hop links overflow based on SDMT for LTE-A Network Downlink performance improvement. The second objective is to study the impact of the number of RSS on the Downlink LTE-A performance. And the third objective is to study the effect of utilizing high-order adaptive MIMO on performance. The total and user data rates are improved using these three Ideas.

This paper is structured as follows. The system model for LTE-A downlink is present in Section 2. The model description of the performance model used is present in Section 3. The simulation results are shown and discussed in Section 4. The optimum location estimates for n-fixed RSS were presented in section 5. Finally, the conclusion of this paper is in section 6.

2 SYSTEM MODEL

LTE-A Downlink Channel Capacity for the maximum channel capacity, equation 1 obtained mathematical formula of Shannon capacity, where channel capacity C is proportional to the bandwidth B and signal to noise power ratio (SNR) of the logarithmic function [9]

$$C = B * \log_2 (1 + SNR) \quad (1)$$

Some parameters will be affected in LTE-A downlink channels, such as Bandwidth and SNR efficiencies. These parameters can be acquired in table 1 as a function of the number of transmitting antennas [10]

Table 1: SNR and BW efficiencies [10].

N_r of TX antennas, r	$\eta_{BW,r}$	$\eta_{SNR,r}$
1	0.80	0.91
2	0.76	1.05
3	0.75	1.11
4	0.72	1.24

2.1 Adaptive MIMO, Modulation, and Coding Switching Scheme

For getting maximum cell capacity with improved coverage better than standard 4x4MIMO. Adaptive MIMO, Modulation, and Coding switching (AMMCS) scheme is a scheme of Adaptive MIMO Switching (AMS) used parallel with AMC to enhance network performance with low BER [11].Figure1 shows the SNR threshold for downlink LTE-A using the network parameter as shown in table 2 . This figure shows that the SNR threshold for switching between 4×4 MIMO and 2×4 is 10 dB.

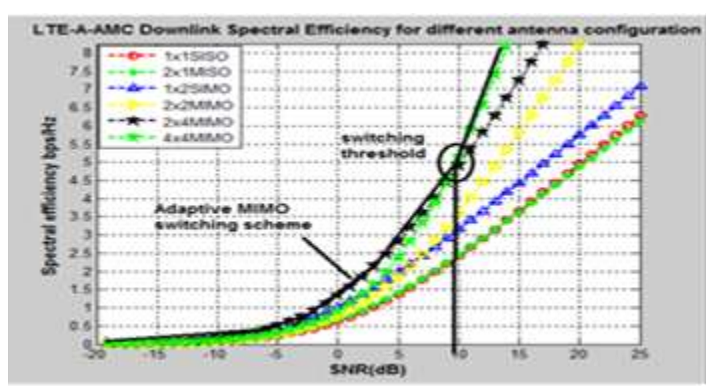


Fig .1. LTE-A Downlink AMMCS spectral efficiency.

Table 2: CQI switching thresholds for Proposed AMMCS

CQI	Max.SNR(dB)	modulation	MIMO mode	Code rate
0	-6	BPSK	2×4 MIMO	1
1	4-	BPSK	2×4 MIMO	1
2	-2	QPSK	2×4 MIMO	1/3
3	0	QPSK	2×4 MIMO	1/2
4	2.1	QPSK	2×4 MIMO	2/3
5	3.8	QPSK	2×4 MIMO	4/5
6	6	16QAM	2×4 MIMO	1/3
7	7.8	16QAM	2×4 MIMO	1/2
8	9.9	16QAM	2×4 MIMO	2/3
9	12.6	16QAM	4×4 MIMO	4/5
10	15	16QAM	4×4 MIMO	5/6
11	16.2	64QAM	4×4 MIMO	1/3
12	18.1	64QAM	4×4 MIMO	½
13	19.8	64QAM	4×4 MIMO	2/3
14	24	64QAM	4×4 MIMO	4/5
15	25	64QAM	4×4 MIMO	5/6

3 MODEL DESCRIPTION

This section presents the considered network scenario, cell model used in experiments.

3.1 Network Scenario

A single LTE-A cell in an urban area is supposed with network parameters given in table 3. This study will be executed for LTE-A downlink. The cell has N of RSS where N=1,2,3,4, and 5, whose work is in half-duplex relaying mode. It used the Cost 231 Hata path loss model [12]. The proposed scheduling scheme OTFWC based on SDMT is used in which the RS position is located at 50% of the cell radius towards the cell edge. This proposal will be made for different arrival rates of UEs at a random placement in the cell. Performance metrics used in this study, total throughput, average throughput in downlink LTE-A network, and RS service area, are defined.

Table 3: LTE-A Network parameters used in this study.

Parameter	Value
Cell radius	2000m
Transmit power (P_t)	46dBm
RS maximum Transmitted power ($P_{RS\ max}$)	46dBm
Thermal noise power spectral density (N_0)	-174dBm/HZ
Max received SNR (SNR_{max}) for downlink LTE-A	25dB
The average height of UE (hm) or (X)	1.5m
The average height of the building($_{roof}$)	25m
Average separation between building (W)	15m
The average height of eNB ($_{CBS}$)or ($_{RX}$)	30m
Reference distance (d_0)	100m
Number of RB	50 B

3.2 Cell Modeling

The cell surface is divided into the number of zones (N), and the number of sectors (K). the intersection between a zone and a sector is known as a geometrical sector (segments). In geometrical sectors, each MSs have a position. Therefore, each segment would have an equal surface as shown in Figure 2 [7]. To calculate the surface per zone, A_{zone}, see Eq.2

$$A_{zone} = \frac{\pi r_{cell}^2}{Ztotal} \quad (2)$$

To determine data rate, the data rate is a function of distance, so it should be calculated the separation distance between BS, RS, and MS is shown in Fig 3 [2]. the distance among RS and MS [d] can be calculated by Eq 3:

$$d^2 = r_1^2 + r_2^2 - 2 \times r_1 \times r_2 \times cos\emptyset \quad (3)$$

Where r_1 distance between eNB and MS, r_2 distance between eNB and RS can be calculated by Eq 4:

$$r_2 = \sqrt{\frac{Azone}{\pi} - r_1^2} \quad (4)$$

To calculate the downlink data rate. There are two types of users: some UEs are scheduling to receive data from BS (direct link) this type of user is called cell-center (CCU), and also there are some UEs that have bad channel conditions, the data rate will be low too, it used Relay Station to help deliver data from the BS to the destination UEs (Relay link) this type of US is called (CEU) [2]. The received data rate for CCU, whose UEs have high SNR located at distance r1 from the eNB can be calculated by Eq 5 :

$$R = C(SNR(r1)) = \mu_{BW}.RB.w \log_2 (1+\mu_{SNR} .SNR(r_1)) \quad (5)$$

Where SNR can be expressed as :

$$SNR(r_1) = \frac{P_{UE\_max}}{No \times W \times RBs \times L(r1)} \quad (6)$$

Where P_{UE_max} is transmitted power of eNB, $L(r_1)$ path loss. The second type is the CEUs, the received data rate for CEU via RS can be calculated by :

$$R(CEU) = \frac{1}{2} \min[C(SNR(r_2)), C(SNR(d))] \quad (7)$$

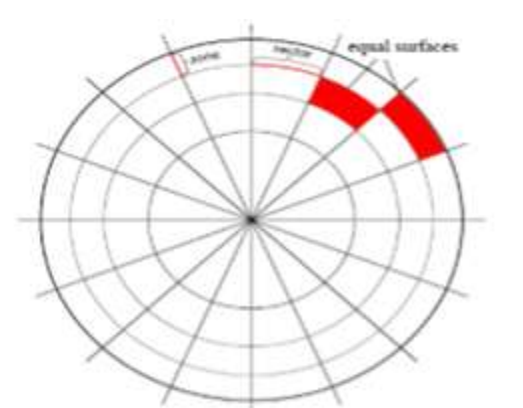


Fig. 2. Model of the cell [7].

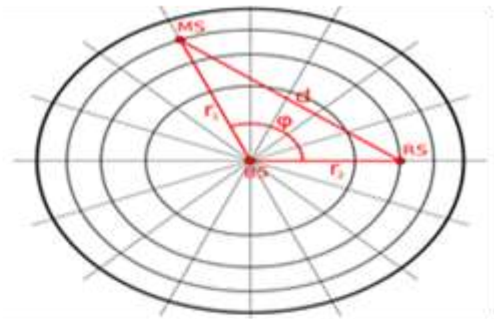


Fig. 3. Distance from BS to RS and MS [2].

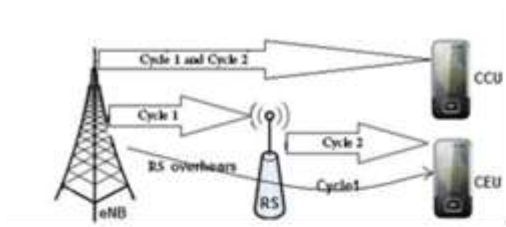
3.3 Synchronous Direct and Multi-hop Transmission (SDMT)

CEUs have to improve their performance to make better use of available scheduled RBs and then improve CCUs and total cell capacity. This can be performed by increasing their data rate which can be done by increasing SNR. The proposed transmission scheme is called (SDMT) [1] as shown in Fig 4 [6]. The RSS is used in half-duplex relaying. The transmission of CEU's data from eNB to UE via RS can be performed over two-time slots. In 1st time slot, eNB transfer the data to the call center, and the RS overhears the transferred data to cell edge UEs. In the 2nd timeslot, the eNB and RS transfer the data to the cell center and cell edge UEs. The received SNR at UE can be calculated by the sum of the received from RS (Multi-hope SNR) and the overheard from eNB (direct SNR). The maximum achievable data rate for CEU is calculated by Eq 8:

$$R(CEU)=\min[C(SNR((r_2), C(SNR(r_1)+SNR(d))] \quad (8)$$

The maximum data rate, for cell center users (CCU), connected directly to the eNB is:

$$R(CCU)=C(SNR(r_1)) \quad (9)$$



Timeslot 1st	Timeslot 2nd
eNB transmits to cell-center and cell-edge, RS overhears	eNB transmits to MS(CCU), RS transmits

Fig. 4. Downlink Synchronous Direct and Multi-hop Transmission [12].

3.4 Proposed OTFWC Scheme for Zero Link Overflow

There are two problems: In radio interface RS-UE multi-hop networks (wasting RBs and data overflow in two-hop links). To avoid this problem, the amount of data transported from eNB to RS has to be equal to the data transported from RS to MS, this can be achieved by using a modified FWC RB scheduling scheme by adding a time-domain scheduling algorithm is known as Optimum Time Fair Work Conserving (OTFWC) was Proposed. This can be made by exchanging the equal time-sharing(T/2) among two phases (eNB-RS, RS-MS) with optimum time-sharing values ψ*, and (1- ψ*) [13] as seen in Fig 5. Assuming SDMT is used with the OTFWC as shown in Fig 6, equation (8) can be modified as:

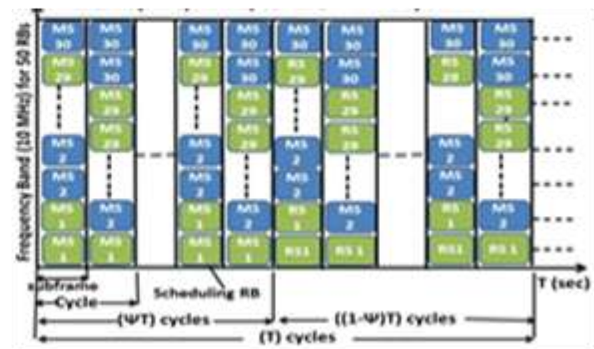


Fig.5. OTFWC transmission using RS [6].

$$R(CEU)=\min[\psi\, C(SNR(r_2), (1-\psi)\, C(SNR(r_1)+SNR(d))] \quad (10)$$

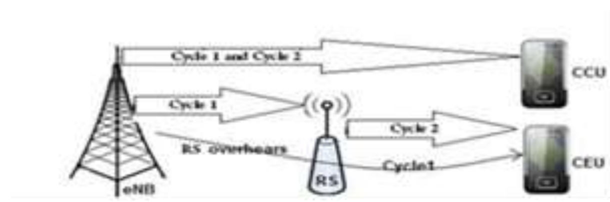
the total data rate for CEU using the proposed optimum time scheduling scheme can be expressed as:

$$R(CEU)=\left[\frac{C(SNR(r_2))\times C(SNR(r_1)+SNR(d))}{C(SNR(r_2))+C(SNR(r_1)+SNR(d))}\right]=\left[\frac{C_1\times C_2}{C_1+C_2}\right] \quad (11)$$

$$R^{*}_{modified}(CEU)=MAX\begin{pmatrix} \min\left[\frac{[\psi^{*}\times T^{*}]}{T^{*}}\times C_1 \frac{[(1-\psi^{*})\times T^{*}]}{T^{*}}\times C_2\right] \\ \min\left[\frac{[\psi^{*}\times T^{*}]}{T^{*}}\times C_1 \frac{[(1-\psi^{*})\times T^{*}]}{T^{*}}\times C_2\right]\end{pmatrix} \quad (12)$$

Where the optimum value of Ψ* for zero link overflow will be

$$\psi^{*}=\left(\frac{C(SNR(r_1)+SNR(d))}{C(SNR(r_2)+C(SNR(r_1)+SNR(d))}\right) \quad (13)$$



Cycle 1, eNB transmits to cell-center and cell-edge, RS overhears	Cycle 2, eNB transmits to MS(CCU), RS transmits
Ψ T cycles	(1- ψ) T cycles

Fig. 6. Multi-hop LTE-A downlink proposed OTFWC scheduling with SDMT.

4 RESULT AND ANALYSIS

This section describes and permission the simulations and experiments performed in this study, The cell model and network parameters were assumed as shown in section 3. The RS position has located at 50% of the cell. The simulations were made using 4×4MIMO and AMMCS respectively based on OTFWC with SDMT. In this section, there are three experiments. Total downlink throughput and cell capacity for 4×4MIMO, AMMCS based on OTFWC scheduling scheme with SDMT scheme and RS service area is estimated.

4.1 Experiment 1; Total throughput and cell capacity for 4×4MIMO

In this experiment, we used 500 Zone and 499 Sector to investigate the total downlink throughput and the capacity of the system. This experiment can be achieved for each arrival rate (λ) value varying from 1 to 30 with steps of λ=0.25.

Result and discussions

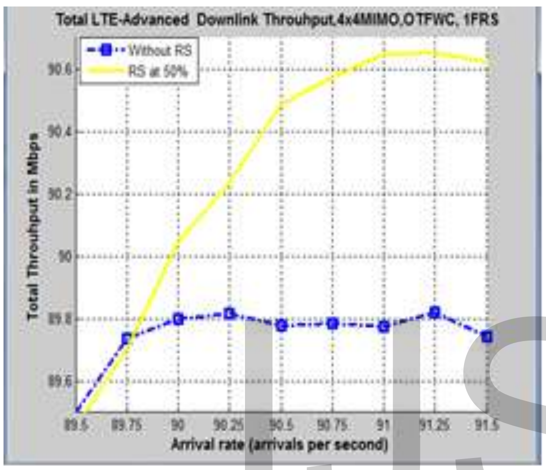


Fig. 7. total throughput 4×4MIMO, OTFWC.

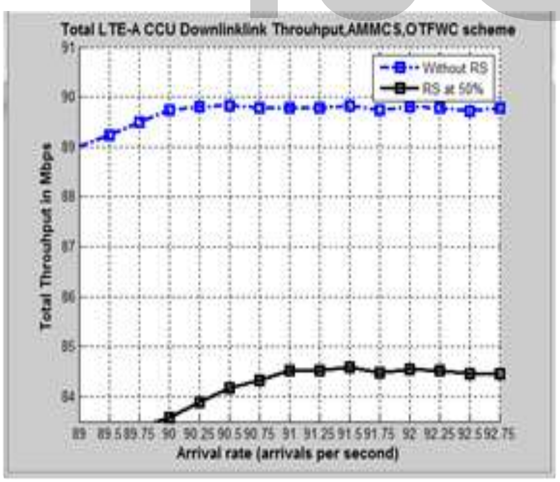


Fig. 8. total CCU throughput 4×4MIMO, OTFWC.

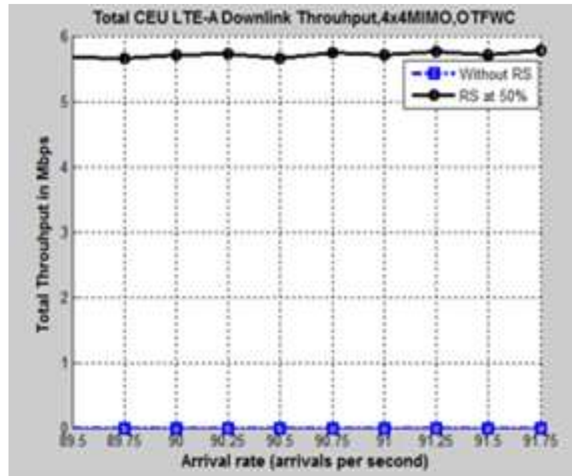


Fig. 9. total CEU throughput 4×4MIMO, OTFWC.

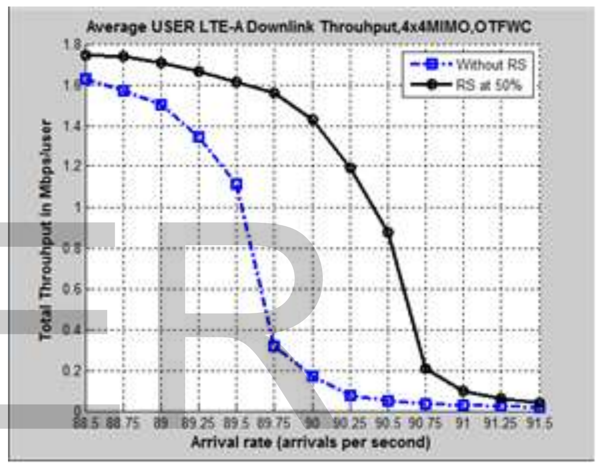


Fig. 10. average user throughput 4×4MIMO, OTFWC.

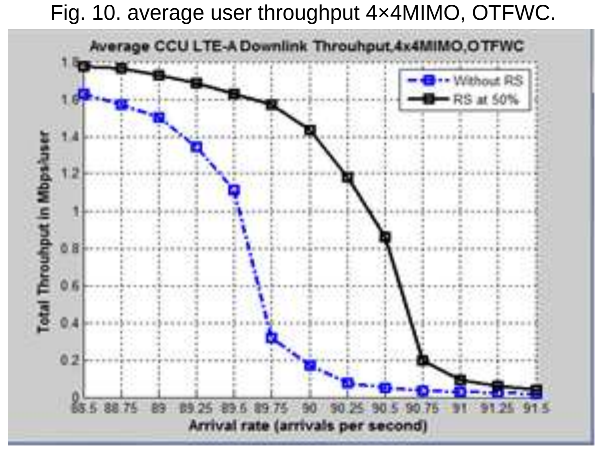


Fig. 11. average CCU throughput 4×4 MIMO, OTFWC.

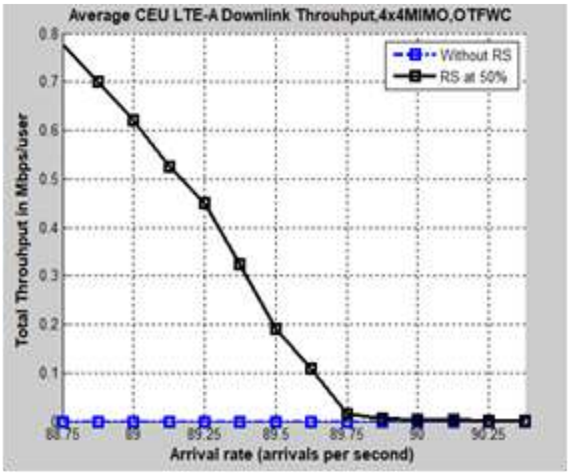


Fig. 12. average CEU throughput, 4×4MIMO, OTFWC.

Figure 7, Offer total downlink throughput versus arrival rate for using 4×4MIMO with OTFWC when RS is located at 50 % of the cell. This figure shows that the maximum channel capacity that can be achieved at an arrival rate of 91 arrivals per second is 90.65 Mbps when using RS. Therefore, the maximum channel capacity was achieved using RS at 50% of the cell radius. Figures 8 and 9 are represented the total DL CCU and total DL CEU throughput versus arrival rate for using 4×4MIMO with OTFWC respectively. From these figures, it notes that, improving the system performance by using RS, where an increasing number of users served by RS and getting high their data rate while reducing the number of users is using eNB directly. this means CEU will achieve full use of available scheduled RBs. Figures 10,11, and 12, offer average user, average CCU, and average CEU LTE-A downlink throughput versus arrival rate for using 4×4MIMO with OTFWC respectively. From these figures, it can be seen the average throughput is more accurate than total throughput. Also, the user data rate is reduced up to reached zero whereas the arrival rate increases.

4.2. Experiment 2; Total throughput and cell capacity for AMMCS

Result and discussions

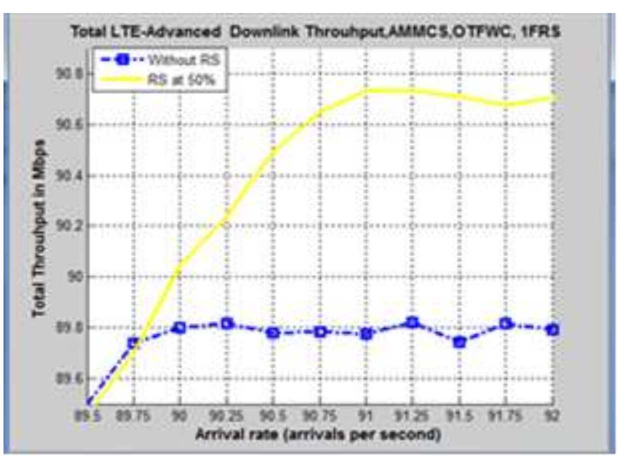


Fig. 13. total throughput, AMMCS, OTFWC.

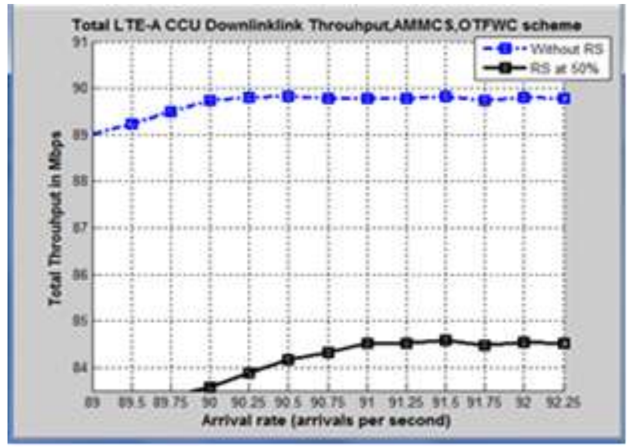


Fig. 14. total CCU throughput, AMMCS, OTFWC.

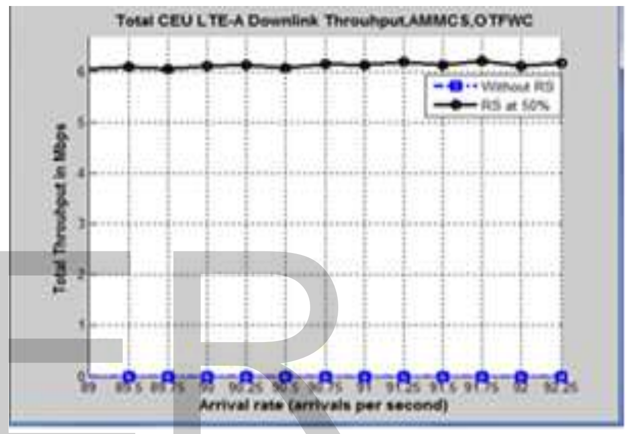


Fig. 15. total CEU throughput, AMMCS, OTFWC.

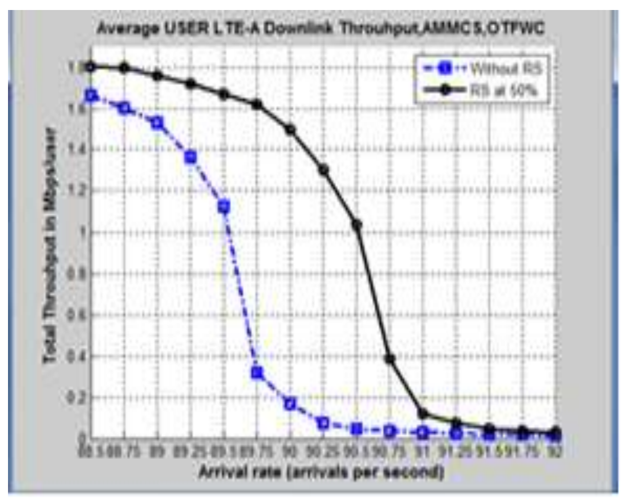


Fig. 16. average user throughput, AMMCS, OTFWC.

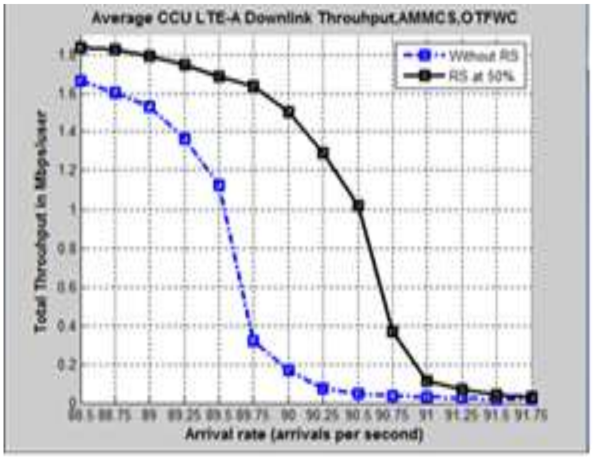


Fig. 17. average CCU throughput, AMMCS, OTFWC.

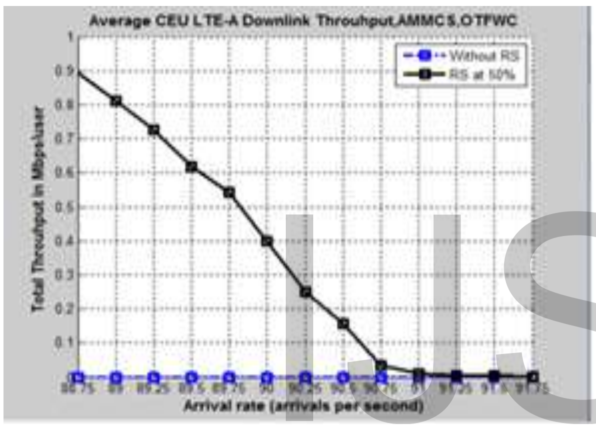


Fig. 18. average CEU throughput, AMMCS, OTFWC.

From Figure 13 to figure 18, note that the AMMCS with OT-FWC based on SDMT has better performance than 4x4MIMO with OTFWC based on the SDMT scheduling scheme.

4.3. Experiment 3; service area of the Relay Station

In this experiment, RS has located at 50% of the cell, and its assignment the amount of RBs to the MS, the RS coverage area is evaluated via calculation of the data rate for each MS position using equations 8,10. In this simulation the cell model and network parameters were assumed as shown in section 3. it used N _Zone =1000, and K_ sector =999.

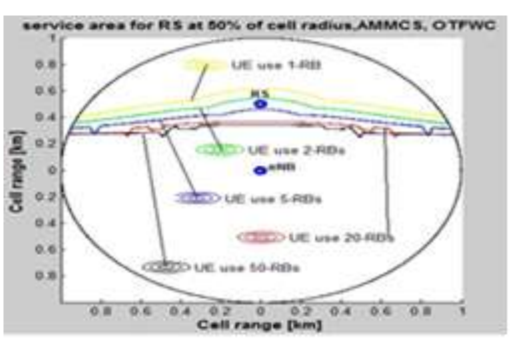


Fig. 19. The show service area for RS at 50%, AMMCS, OTFWC.

Fig 19 shows the service area for RS located at 50% for the cell radius, AMMCS, OTFWC. It used the Cost-231hata model. From this figure, it can be noticed that more than RBs to UE led to a large service area for RS. Because the SNR received was decreased when used a large number of RB where the total transmitted power will be split between more RB. Also displaying the RS service area covers around a quarter of the cell, so to get maximum improvement by adding nearly three or four RSS.

4.4. Making the Decision about the Optimum Number of RSS

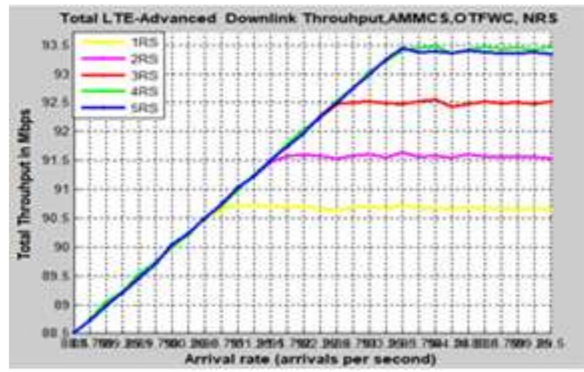


Fig. 20. Compare total throughput between NRS, AMMCS, OTFWC, for LTE-A DL.

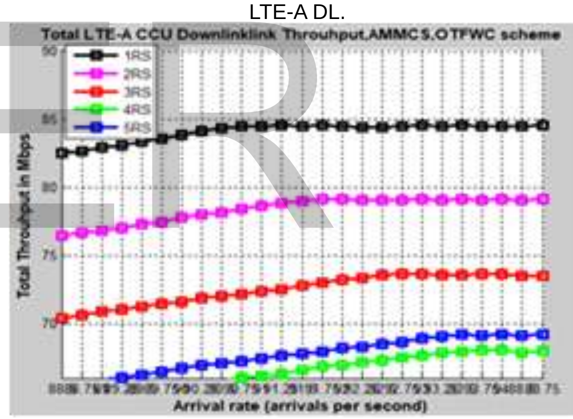


Fig. 21. compare Total CCU throughput, between NRS, AMMCS, OTFWC, for LTE-A DL.

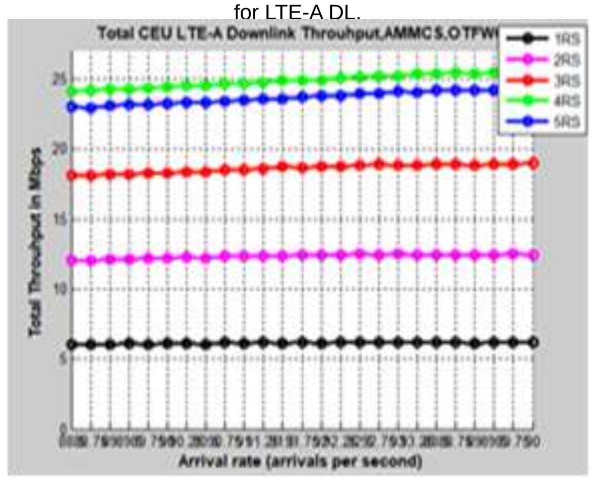


Fig. 22. compare Total CEU throughput, between NRS, AMMCS, OTFWC, for LTE-A DL.

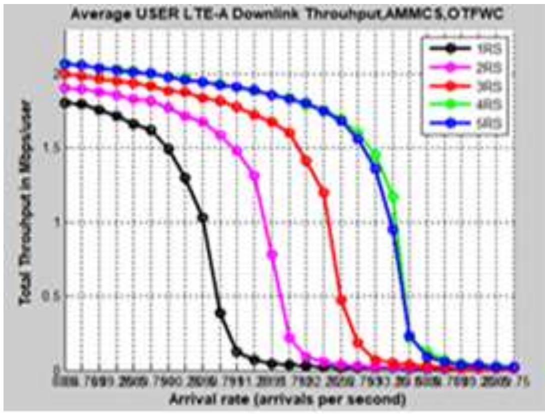


Fig. 23. compare Average user throughput, between NRS, AMMCS, OT-FWC, for LTE-A DL.

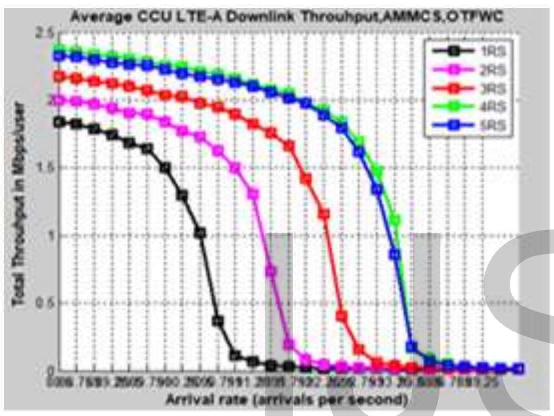


Fig. 24. compare Average CCU throughput, between NRS, AMMCS, OT-FWC for LTE-A DL.

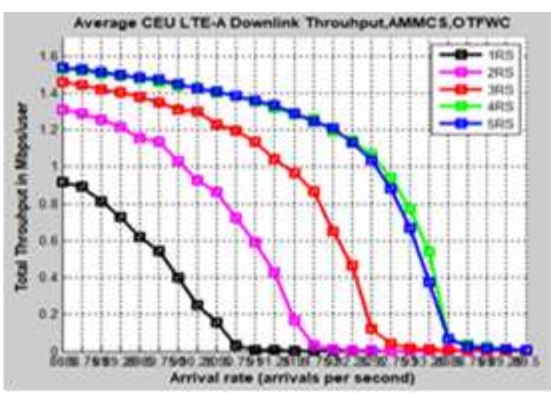


Fig. 25. compare Average CEU throughput, between NRS, AMMCS, OT-FWC for LTE-A DL.

From these figures, it is observed that using 4RS enhanced the total throughput by increasing the number of UE served by RSS (have a maximum data rate than 5RS 3RS,2RS,1RS).

5. Location optimization for L-Fixed Relays

The aim of the study performed in this section is: to estimate the optimum position where L-Fixed Relay Stations (L-FRS) can be located in the LTE-Advanced cell to maximize both total downlink throughput and CEU throughput. The optimum location is required to secure fair capacity distribution over the cell. This optimum position of the RSS is calculated using the Capacity Maximization Nonlinear Integer Problem (CMNIP). The optimum RS position problem is formulated to select the optimum RS location over a discrete area when the UEs are uniformly distributed in the cell. This is performed by suggesting several candidate positions (CPs) for RS positions that are considered to be appropriate for RS placement as shown in Fig26 [14], each FRS will assign to one CP of (M/L) CPs to enhance the network realizations, depending on section 4, results concluded that the RS covers approximately a quarter of the cell. Where L can be Supposed to be 4-FRSs per cell, this gives an angle of 90 degrees for L=4. This means M CPs are split equally on the number of RSS giving (M/L) CPs for each FRS.

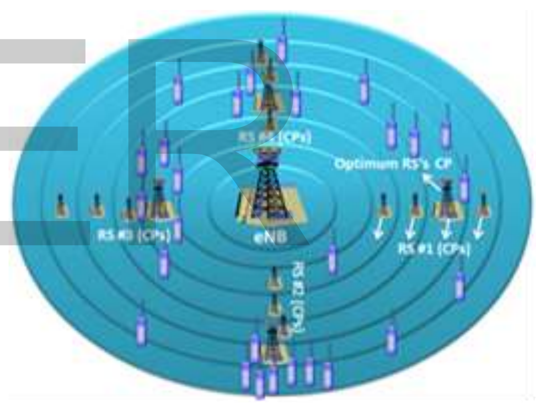


Figure 26. L-FRSs with m-Candidate Positions (m-CPs) in N-zones cell Model.

5.1. Performance Model

Suppose that the number of zones per cell Ň = {1, 2, …,i, …,N}, the number of sectors per cell ķ={1, 2, …,j, …,K}, ℵ={1, 2, …,n, …, N} is the number of UEs in the cell. For the UE located at distance r_2 from the eNB as shown in fig.3, ɱ={1, 2, …,m, …, M} is the total candidate positions (CPs) in the cell, and I={1, 2, …,l, …, L} is the number of used RSS in the cell. This gives an angle of 90 degrees for L=4 as in the previous section. The M CPs are split equally on the number of RSS giving (M/L) CPs for each FRS. The received data rate for CCUs, and CEUs, are expressed by equations 9, and 11 respectively.

5.2. Optimization Problem Formulation for L- FRS

The optimum position of L-RSS in the cell is calculated using the Capacity Maximization Nonlinear Integer Problem (CMNIP). It can be expressed as:

$$\max_{X,Y,SNR} \sum_{\substack{n\in \aleph_{CEUs} \\ m\in \mu}} Y_{m,n} \times R_{m,n} + \sum_{n\in \aleph_{CCUs}} R_n \quad (14)$$

$$\max_{X,Y,SNR} \sum_{\substack{n\in \aleph_{CEUs} \\ m\in \mu}} Y_{m,n} \times R_{m,n} \quad (15)$$

Subjected to

$$\sum_{m=1}^{M} X_m = L, m \in \mu \quad (16)$$

$$\sum_{m=1}^{M} Y_{m,n} = 1, m \in \mu, n \in \aleph_{CEUs} \quad (17)$$

$$Y_{m,n} \leq X_m \quad ,m \in \mu, n \in \aleph_{CEUs} \quad (18)$$

$$X_m, Y_{m,n} \in \{0,1\} \quad (19)$$

$$SNR \leq SNR_{max} \quad (20)$$

Equation (14) appear, the objective function referred to the maximization of the total downlink throughput in the cell. While equation (15) appears the objective function referred to the maximization of the CEUs downlink throughput. The limitation of equations 14, and 15 are expressed in equations 16, 17,18,19, and 20. Limitation (16) means that the total number of placed RSS in the cell is L. Limitation (17) means that each UEn will be assigned to only one RS from the L-FRSs in the cell. Limitation (18) assures that each RS has been positioned at CP before being assigned to UEn. In limitation (19) the decision variable X is binary 0 if the RS is not at CP, and binary 1 if the RS was at CP. This means that each RS of the L-RSS in the cell is assigned to only one CP. Furthermore, the decision variable Y is binary 0 if the UEn is not assigned to RS, and binary 1 if the UEn is assigned to RS. This means that each UEn in the cell can be assigned to only one RS. Limitation (20) means that the received SNR cannot be more than the maximum acceptable SNR in the downlink. This condition is by carried out power control algorithms. Solving this problem is considered an approximate preparatory solution obtained by exhaustive search [14,15]. The L-FRSs will be positioned at the optimum CPs in which maximum total downlink throughput or the maximum CEUs throughput is achieved.

5.3. Results And Discussion

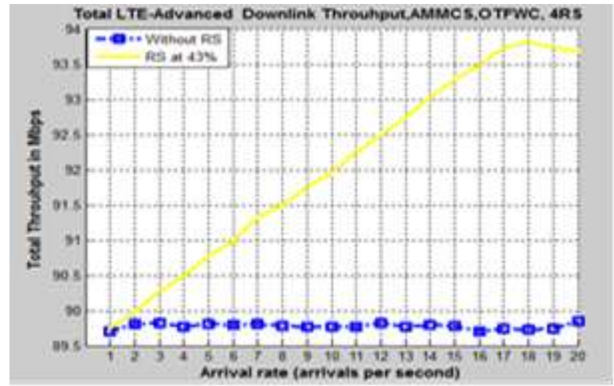


Fig.27. total throughput, AMMCS, OTFWC, L-FRS optimization for LTE-A DL.

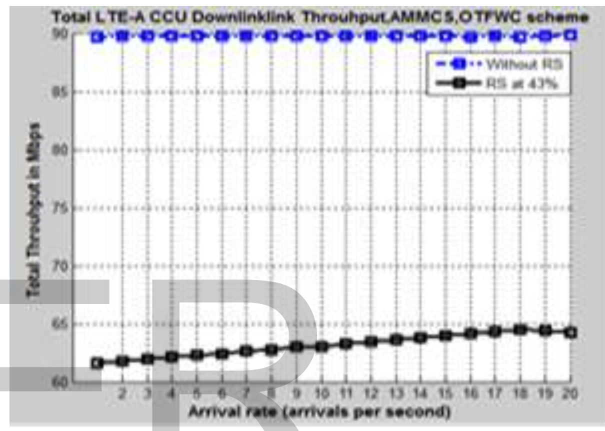


Fig.28. total CCU throughput, AMMCS, OTFWC. L-FRS optimization LTE-A DL.

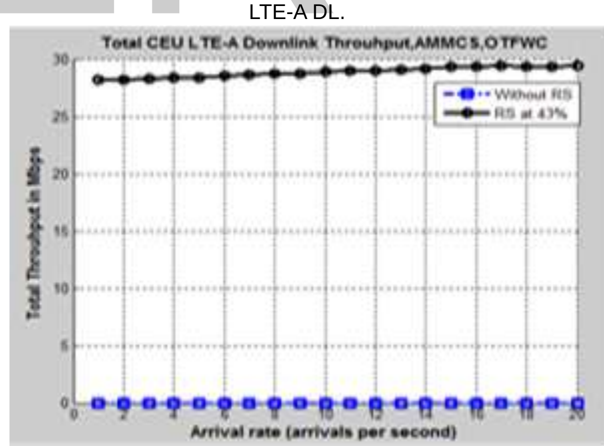


Fig.29.total CEU throughput, AMMCS, OTFWC L-FRS optimization LTE-A DL.

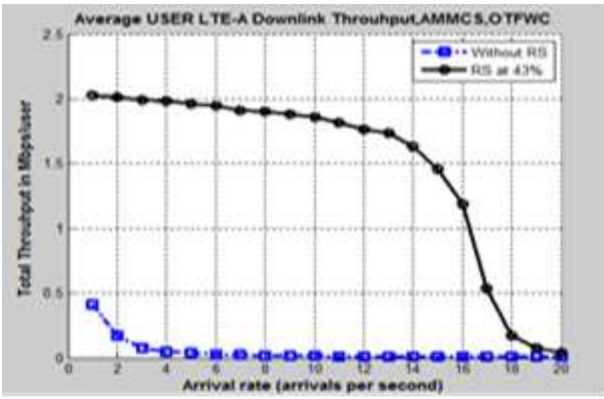


Fig.30. average user throughput, AMMCS, OTFWC. L-FRS optimization LTE-A DL.

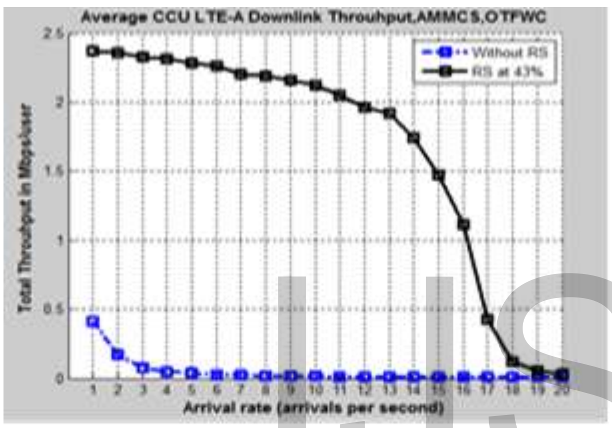


Fig.31. average CCU throughput, AMMCS, OTFWC L-FRS optimization LTE-A DL.

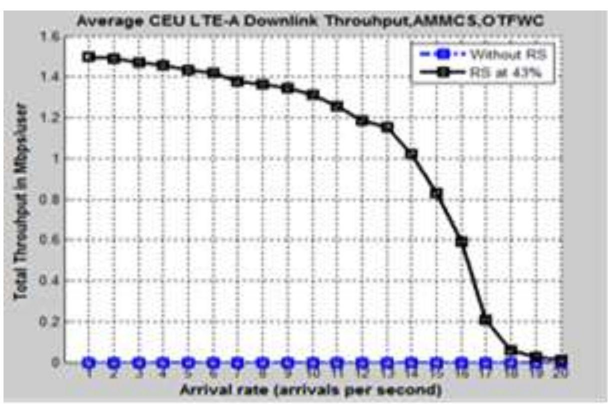


Fig.32. average CEU throughput, AMMCS, OTFWC, L-FRS optimization LTE-A DL.

From figure 27 to figure32 it may be concluded that the LTE-Advanced downlink throughput can be improved using 4-Relay stations with the optimized location at 43% with SDMT transmission scheme, OTFWC scheduling scheme, and AMMCS.

6. Conclusions

This paper has achieved improvement in the downlink LTE-A performance by using multi-hop relay technology with using 4×4MIMO, and AMMCS respectively based on scheduling scheme (OTFWC) with SDMT. This research has been discussing how to improve LTE-A downlink network performance this can be done by three scenarios; (a) to calculate the data rate of the UEs; 4×4MIMO, and AMMCS respectively based on scheduling scheme OTFWC with SDMT is considered. for this study, a model has been developed for an urban area a single LTE-A cell in which the cell is divided into equally sized segments. The performance metrics used for this study are: total and average throughput and system capacity were achieved as a function of arrival rate, from results, it can be concluded that using AMMCS with OTFWC based on SDMT has better performance than 4x4MIMO with OTFWC scheduling scheme based on SDMT. The RS service area shows that the RS covers around a quarter of the cell, so to enhance the data rate it uses more than one RS of the cell. (b) compare throughput between 1RS, 2RSs,3Rs, 4RSs, and 5RSs, it can be concluded that using 4RS enhanced the total throughput and system capacity by increasing the number of UE served by RSS, where CEU will achieve full use of available scheduled RBs (c) it can be concluded that the LTE-Advanced downlink throughput can be improved using 4-Relay stations with the optimized location at 43% with SDMT transmission scheme, OTFWC scheduling scheme. In a future study, a hybrid system of Li-Fi with LTE-A is proposed**.** Li-Fi networks can achieve maximum throughput with optical APs. to increase the system performance and to warrant equally high Quality of Service (QoS) among users, a hybrid Li-Fi-LTE network is capable of realizing the sum throughput of both Li-Fi and LTE stand-alone networks. Because of the different spectra used by Li-Fi and LTE, there is no interference between these systems.

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