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A Novel Relay Station Deployment Scheme for beyond 4G Multi-hop Network

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Abstract

In Long Term Evolution-Advanced (LTE-A) and Worldwide interoperability for microwave access (WiMAX) systems, the coverage area, signal strength and transmission quality are affected by white Gaussian noise, shadowing, wireless interference etc. This effect can be decreased by using more number of evolved NodeBs (eNB), but problem is that eNBs are expensive and it will increase network cost. Relay Stations (RS) are less expensive than eNBs, hence we go for RS deployment instead of eNBs. Thus this paper proposes a cost effective deployment of RSs using dynamic cost based deployment of RS (DCDR) approach. This approach first analyse the impact parameters and then finds the dynamic weighting and network cost for different deployment combination. Simulation result shows that DCDR approach gives a cost effective solution for the deployment of RSs.

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Keywords: Adaptive modudulation scheme (AMC); DCDR; Dynamic Weighting; Impact parameters; RS deployment.

1. Introduction

In mobile communication, if a Mobile station (MS) is within the service coverage area of eNB, then MS can communicate with eNB. In 4G and beyond 4G, the open issue is that to provide a continuous connection for the MSs which are not in the coverage area of eNB. One of the possible solutions is increasing the number of eNB. But the increase in number of eNB, increases the network cost. More number of eNB deployments will introduce intercell interference and spectrum allocation problems [1]. To overcome this, we go for Multihop Relay (MHR) station based deployment schemes. The LTE-A and WiMAX suffers from white Gaussian noise, reduction in wireless

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service coverage, shadow fading, wireless interference, and degradation in signal quality. One of the solution for above problem is MHR networks. MHR network addresses the coverage and throughput requirements of the cell edge users. Since the deployment cost of RS is much lower than eNB, it is widely used in LTE-A, WiMAX IEEE 802.16m and IEEE 802.16j. In IEEE 802.16j and LTE-A standards, two type of RSs are defined namely transparent and non-transparent [2]. The difference between transparent and non-transparent is given in Table 1 [3].

Nomenclature

L	Total number of tiers.
V	Total number of RS types.
R_v^l	Number of RSs of type v in tier l .
T^l	RSs transmission quality.
C	Total number of RS deployment combination for the given eNB capacity.
P_v	Price of deployment of v type RS.
A_v	Coverage area of v type RS
D^l	Deployed RS population density.
N_c	Network cost

Table 1.Transparent and Non-Transparent RS

	Transparent RSs	Non Transparent RS
Scheduling	Centralized	Distributed
Performance	High	Low
Coverage extension	No	Yes
Cost	Low	High
Number of Hops	2	2 or more

In transparent RS, there is no handover because MS and RS gets information from eNB. It is mainly used to increase network capacity. The system throughput is high for transparent RS. In non-transparent RS, the information to RS is from eNB and MS gets from RS.It is mainly used for coverage extension. In non-transparent RS throughput is less. Transparent mode and non-transparent mode can co-exist in one network. According to method of operation, RS is divided into two namely Type I and Type II. The Type I Relay node operates as half duplex relay.It controls cells, and each one has its own physical ID, synchronization channel, and reference symbols. Two type of Type I relay node is Type Ia and Type Ib. Type II relay node is inband relay and it does not create its own cells so there is no separate physical ID.

In LTE-A, the deployment of RS is an open issue. The improper deployment of RS will leads to increased delay and decreased throughput. It also increases the network cost. The critical challenge facing in LTE-A and WiMAX is efficient deployment of RS with limited resource and deployment cost. Many studies have been proposed for deploying RS. In [3], an RS deployment scheme for highly populated areas is proposed. RSs are deployed in such a way that RS and MS should be in line of sight (LOS) and RS and other interfering RS should be in non-line of sight (NLOS).The scheme proposed in [3],takes shadowing as advantage. But the problems like throughput improvement, network cost reduction are not addressed in this work. In [4], Yu, Y. et al. proposed an eNB and relay node deployment scheme based on the objective of minimizing the cost function. Again there are no special considerations about coverage and throughput improvement in this work.

In [5], Kim et al. proposed a cost effective coverage extension by using different topology, sectored eNB and MHR networks. The main drawback of this work is, not considering the concept of AMC. This work also assumes uniform traffic and no interference, which is not practical. In [6], Wang et al. proposes a cost efficient RS deployment scheme for LTE-A. The main drawback is, the algorithm fails to consider other requirements. In [7], a cost function is defined based on various impact factors like Transmission Quality index (TQI), Price of deployed RSs Index (PRI), Service Coverage Index without consideration of Population (SCI), Service Coverage Index with consideration of Population (SCI_P), RS Overlay index (ROI).The objective of this algorithm is to minimize the cost function and to go for corresponding RS deployment combination. The obtained simulation results prove that, this scheme offer better performance over the RANDom deployment approach (RAND) [8], the static average weighting approach (SWA) [9] schemes. Hence in this work, we have adopted this algorithm as the base and tried to improve its performance by considering interference and link overloading issues.

The main objective for a wireless network is to satisfy the Quality of service (QoS) requirements of the requested clients and to maximize the network revenue by decreasing the network cost. The above objectives are mainly affected by service coverage, cost of different types of RSs, etc. Hence, this paper gives an optimal solution for effective deployment of RS by using different impact parameters, and then goes for a DCDR approach. The proposed algorithm has three phases. The main objective of the proposed algorithm is to reduce the deployment cost and increase the service coverage area.

The remaining section in the paper described as follows: In section 2, system model is discussed. DCDR approach is discussed in section 3 and in section 4 simulation parameters and results are discussed. Section 5 concludes the paper.

2. System Model

In this section, the necessity of MHR network, different types of RS and important impact parameters are discussed. MHR network is used to extend the eNB coverage area. The RS deployment helps to reduce site acquisition and backhaul cost. The RS helps to forward user information from MS to eNB and vice versa. The different types of RS are Fixed RS (FRS), Mobile RS (MRS), and Nomadic RS (NRS). The FRS helps to increase network capacity and coverage. It can operate in LOS and NLOS. MRS is usually deployed in transport system to increase the throughput and capacity. NRS is deployed for temporary coverage, where more number of MS are present for a short time period. NRS can be used as a temporary eNB, if the eNB has any problem.

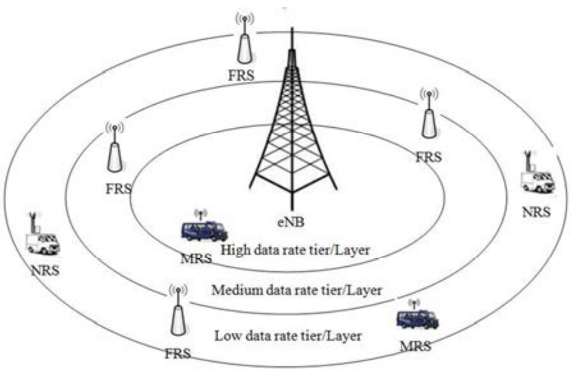


Fig. 1. Various types of RS Deployment.

LTE-A and WiMAX uses the concept of AMC. In AMC, the eNB service area is divided into tiers or layers [11]. The tiers nearer to eNB have good signal strength when compared to the tiers far from eNB. It is assumed that all the MSs within one tier will use same modulation and coding scheme. In this paper, we are going for five impact parameters to analyse the effective deployment of RS. The five important parameters are Signal Transmission Index (STI), RS Deployment Price Index (RPI), Coverage Area Index without Population (CAI), Coverage Area Index with Population (CAI_P) and Overlapping index (OI).

2.1 Signal Transmission Index (STI):-

AMC helps to obtain an optimal data rate. The STI is mainly related to the transmission quality. In AMC scheme, the inner tier uses 64-Quadrature Amplitude Modulation (QAM) (high data rate) and outer tier uses Binary Phase Shift Keying (BPSK) (low data rate). Hence the RSs and MSs in higher tier achieves higher capacity .STI is given by,

$$STI = \sum_{l=1}^{L}\sum_{v=1}^{V}\left(R_v^l T^l\right)_c, \forall c \in C \qquad 1 \le v \le 3 \tag{1}$$

where L is total number of tiers, l is tier index, v is type of RS which is 1, 2 and 3 for FRS, MRS and NRS respectively, V is total number of RSs types, R_v^l is number of RSs of type v in tier l , T^l is RSs transmission quality (i.e. Signal to Noise Ratio), C is the total number of RS deployment combination for the given eNB capacity.

2.2 RS Deployment Price Index (RPI):-

The price of FRS, MRS and NRS are different. In this paper, we have checked total price for deployment. The RPI depends on the price of individual RS. The RPI is given by,

$$RPI = \sum_{l=1}^{L}\sum_{v=1}^{V}\left(R_v^l P_v\right)_c, \forall c \in C \tag{2}$$

where P_v is price of deployment of v type RS. The different deployment price for various RSs are discussed in section 4.

2.3 Coverage Area Index without Population (CAI) and with Population (CAI_P):-

In CAI, we are not considering the distribution of population. Here we are assuming that there are unlimited resources. Hence, we place all RSs in entire coverage of eNB. In CAI, we are not considering population distribution but in CAI_P we are considering population distribution. The CAI and CAI_P can be obtained using

$$CAI = \left(\frac{\sum_{l=1}^{L}\sum_{v=1}^{V} R_v^l A_v}{\sum_{l=1}^{L} N_{v=1}^{l} A_{v=1}}\right)_c \forall c \in C \tag{3}$$

$$CAI\_P = \left(\frac{\sum_{l=1}^{L}\sum_{v=1}^{V} R_v^l A_v D^l}{\sum_{l=1}^{L} N_{v=1}^{t} A_{v=1} D^l}\right)_c \forall c \in C \tag{4}$$

where A_v is the coverage area, $N_{v=1}^{l}$ is the FRSs which are non-overlapping, D^l deployed RS population density and $A_{v=1}$ is the FRS coverage area.

2.4 Overlapping Index (OI):-

The overlapping index depends on the overlapping area of RSs. The overlapped area of RSs has both advantage and disadvantage. The advantage is it offers a MS multiple uplink relay links to the eNB and increases the network reliability. The disadvantages are in terms of reduced coverage and increased network cost. The OI is defined as,

$$OI = \left(\frac{\sum_{l=1}^{L} O^{l}}{\sum_{l=1}^{L} N_{v=1}^{l} A_{v=1}} \right)_{c} \forall c \in C \tag{5}$$

where O^l is overlap area.

3. Dynamic Cost Based deployment of RS Approach (DCDR)

The MMR network uses different types of RS to improve the service coverage and transmission quality without increasing the deployment cost. The factors affecting the deployment of RS are RS deployment price, RS type, RS service range, RS channel transmission quality and RS reliability. For solving this problem, a cost based deployment scheme is proposed.

Some of the assumptions are made before starting the DCDR approach. They are:

- Every FRS has its own frequency.
- In order to increase the transmission quality, FRS is deployed in eNB coverage.
- MRS and NRS can move randomly in the network.
- Different RS types have different cost.

The steps in DCDR approach is

1. Analysing of impact parameters phase.
2. DCDR approach phase.
   a. Defining optimal solution for the issues of RS Deployment.
   b. Changing the impact parameters into accordant parameters.
   c. Normalizing and Dynamic Weighting is applied to the accordant parameters.
   d. Finding the minimum Network cost for Deployment of RS.

3.1 Defining optimal solution for the issues of RS deployment: The optimal solution for RS deployment is to minimize RPI, OI and maximize CAI and STI.

3.2 Changing impact parameters into accordant parameters: The impact parameter is changed into another parameter, where all new parameter increases when performance increases.

$$\left.\begin{aligned} STI^{\#} &= \frac{1}{STI} \\ RPI^{\#} &= \frac{RPI}{\sum_{l=1}^{L} Y_{FRS}.P_{v=1}} \\ CAI^{\#} &= \frac{1}{CAI} \\ CAI\_P^{\#} &= \frac{1}{CAI\_P} \\ OI^{\#} &= OI \end{aligned}\right\} \tag{6}$$

3.3 Normalizing and Dynamic Weighting is applied to the accordant parameters:

- Normalizing: - To make all values in same range, normalization is done. Here all parameters is normalized to $STI^{\#}$

$$w_{STI^{\#}} : w_{RPI^{\#}} : w_{CAI\_P^{\#}} : w_{OI^{\#}} = \frac{STI^{\#}}{STI} : \frac{STI^{\#}}{RPI^{\#}} : \frac{STI^{\#}}{CAI\_P^{\#}} : \frac{STI^{\#}}{OL^{\#}} \quad (7)$$

- Dynamic Weighting is done after normalization:-By using the proportional formula dynamic parameters weight calculated

$$x_j = \frac{w_j}{w_t}, \quad where \quad w_t = \sum_{j=1}^{J} w_j \quad and \quad \sum_{j=1}^{J} x_j = 1 \quad (8)$$

3.4 Finding the minimum network cost for deployment of RS:

For deploying the RS, the network cost for combination c is given by

$$N_c = \left(x_{STI^{\#}}.STI^{\#} + x_{RPI^{\#}}.RPI^{\#} + x_{CAI\_P^{\#}}.CAI\_P^{\#} + x_{OI^{\#}}.OL^{\#} \right)_c, \forall c \in C \quad (9)$$

For understanding clearly we can take some index values as an example. Let STI=18, RPI=2.25, CAI_P=0.184, OL=0.48.

Using (6), we get the following accordant parameters.

$$STI^{\#} = \frac{1}{18} = 0.055$$

$$RPI^{\#} = \frac{2.25}{25} = 0.090$$

$$CAI\_P^{\#} = \frac{1}{0.184} = 5.434$$

$$OI^{\#} = 0.48$$

Using equation (7), (8), (9), we get minimum network cost.

$$w_{STI^{\#}} : w_{RPI^{\#}} : w_{CAI\_P^{\#}} : w_{OI^{\#}} = \frac{0.055}{0.055} : \frac{0.055}{0.090} : \frac{0.055}{5.434} : \frac{0.055}{0.480}$$

$$w_{STI^{\#}} : w_{RPI^{\#}} : w_{CAI\_P^{\#}} : w_{OI^{\#}} = 1 : 0.611 : 0.01012 : 0.114$$

$$w_t = 1.7357$$

$$x_{STI^{\#}} = \frac{w_{STI^{\#}}}{w_t} = \frac{1}{1.7357} = 0.5767$$

$$x_{RPI^{\#}} = 0.3587$$

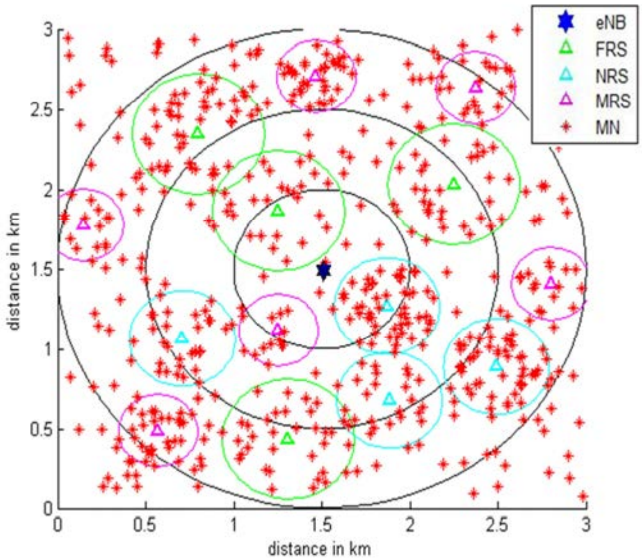
$$x_{CAI^{\#}} = 0.00516$$

$$x_{OI^{\#}} = 0.0587$$

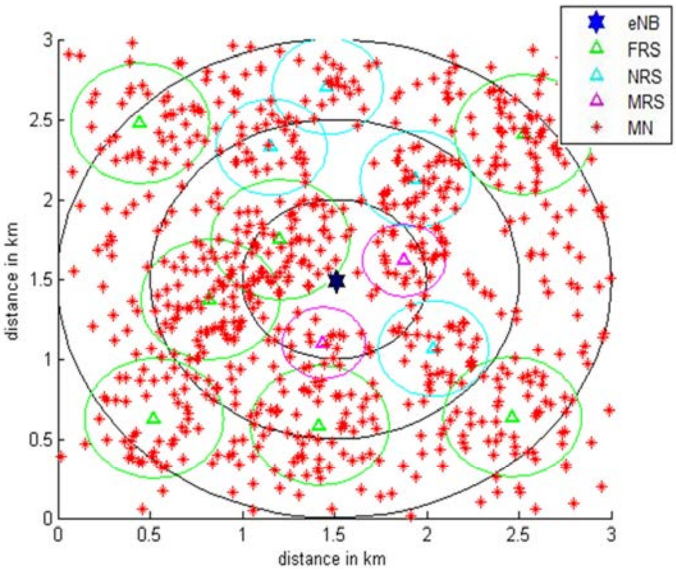
$$N_c = (0.5767) \cdot 0.055 + (0.3587) \cdot 0.090 + (0.00516) \cdot 5.434 + (0.0587) \cdot 0.48 = 0.1202$$

4. Simulation parameters and Results

The performance of DCDR approach is evaluated in this section. In this paper, we consider free space propagation model [12]. Here all the impact parameters and DCDR approach is analysed using Matlab and showed that the proposed scheme is better than the existing algorithms.



(a)



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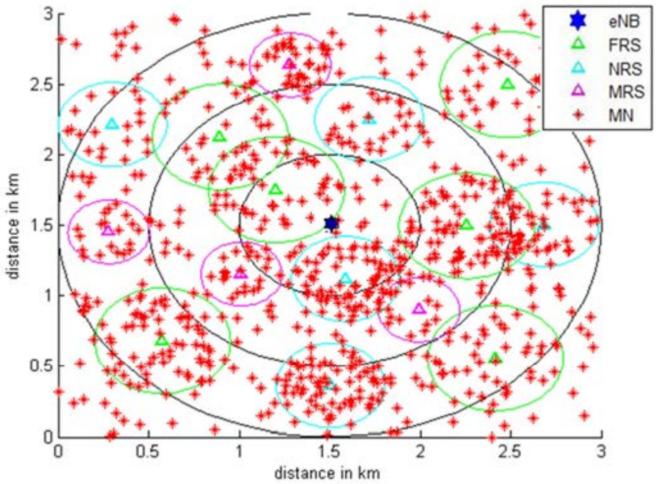
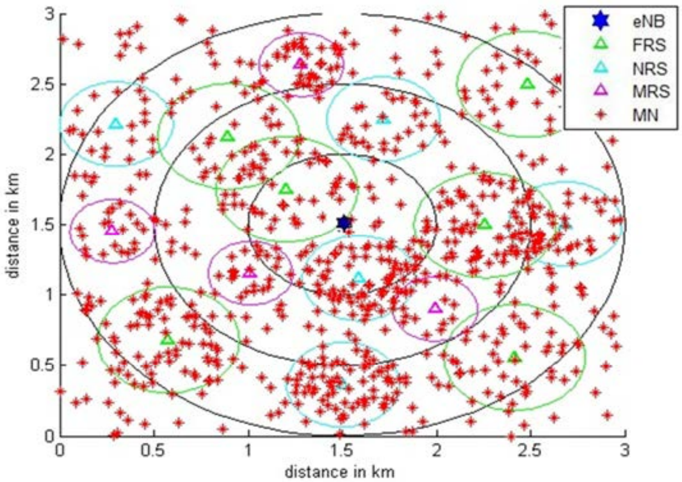


(c)



(d)

Fig. 2. (a), (b), (c) & (d) Sample simulation scenarios of RS deployment for eNB capacity of 120 Mbps

The following assumptions and parameters are taken for simulation study:

- It is assumed that eNB is deployed in an optimum location.
- The geographic area of size 3×3 km^2 is considered.
- The network consists of eNB, RSs and MSs.
- The total system capacity of eNB is between 30-120 Mbps.
- The eNB has three tiers. The capacity of tier 1, 2 and 3 are 15 Mbps, 9 Mbps and 6 Mbps respectively.
- The maximum service range of eNB is 3 Km.
- The maximum service range of FRS, NRS and MRS are 375 m, 300 m and 225 m respectively.
- The deployment cost of FRS, NRS and MRS are 1 unit, 0.75 unit and 0.5 unit respectively.
- The maximum number of MSs in the geographic area is 200.

A sample RS deployment scenario is shown in Fig. 2 for a eNB capacity of 120 Mbps. For a eNB capacity of 120 Mbps, 34 combinations are possible. Four of them are displayed in Fig. 2 respectively. In Fig. 2. (a), there exist 1, 5 and 10 RSs in tier 1, 2 and 3 respectively. The number of FRS in tier 1 is 1. The number of FRS, NRS and MRS in tier 2 is 1, 3 and 1 respectively. The number of FRS, NRS and MRS in tier 3 are 3, 2 and 5 respectively.

The Fig. 3 shows the comparison of proposed algorithm for eNB capacity 120 Mbps with RANDom deployment approach (RAND) [8] and static average weighting approach (SWA) [9]. The comparison shows that DCDR approach is better than the SWA and RAND. In DCDR approach STI and CAI_P is high and the RPI and OI is low, than the other approaches.

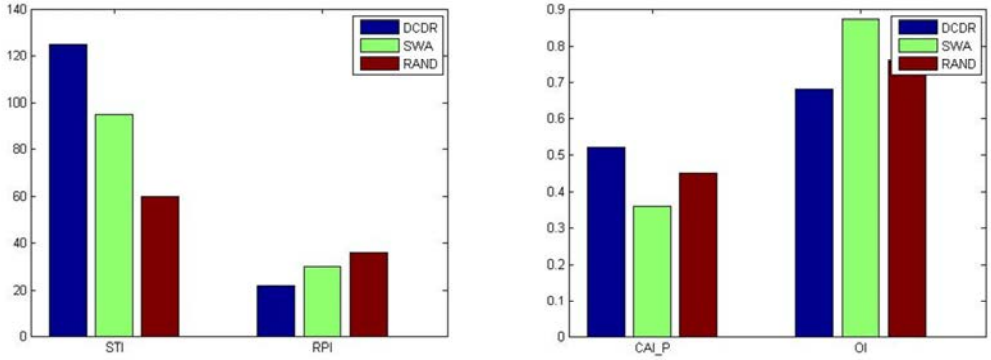


Fig. 3. Performance comparison of DCDR approach with RAND and SWA for 120 Mbps

5. Conclusion

The eNB transmission quality and coverage area is improved using the RS deployment. But cost effective deployment of RS is an issue. DCDR approach gives a cost effective RS deployment by considering the different impact parameters such as STI, RPI, CAI, and OI. The simulation result shows that DCDR approach gives a cost effective deployment of RS than SWA and RAND approach. The promising results pave path for further investigations on link overloading and inter RS interference issues. These issues may reduce the system capacity. Our future work is to modify and test the DCDR approach under the link overloading and co-channel interference conditions.

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