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Interference Analysis and Simulation for Moving Network

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Abstract. In order to meet the needs of enjoying mobile data services at anytime and anywhere, we created the Moving Network (MN), which means that the "exclusive" mobile base station is carried by the vehicle carrying. The Vehicular Penetration Loss(VPL) of the signal transmission is reduced by the moving network, also, it can improve the signal to noise ratio (SNR), but due to the mobility of MN, the inter cell interference will be enhanced, which can seriously affect the signal interference to noise ratio (SINR) of the network, reduce the Quality of Service (QoS) of users. In this paper we focuses on the research of the interference management of moving network and put forward a coordination method that based on a threshold of the mobile network backhaul link interference. The simulation results show that the proposed method is beneficial to improve the performance of MN network.

Keywords: interference coordination, interference management, moving network

1 Introduction

As reliance on smart phones, tablet PCs and other portable intelligent devices increases, the demand for wireless network services is not just for voice services. Wireless network is becoming a kind of necessity in human's daily life. Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) do researches on the demand for wireless network services at different times, as shown in Table 1. It can be learned from the table that the demand for network services from users in cars is far greater than other users, so improving the QoS of vehicle user equipment (VUE) is a research topic of important value in the field of wireless research. It also has important research significance. Among the various researches of improving the quality of service of the users, the MN can effectively reduce the VPL, which is considered to be the most effective method to improve the quality of VUE service.

Table 1. The demand for wireless networks in different countries in different countries

	Home access Internet	Office access Internet	On-road access Internet
USA	3 7.8%	19.6%	42.6%
UK	45.6%	17.85%	36.6%
Germany	43.4%	15.3%	41.3%
France	33.1%	21.7%	45.2%
Italy	39.6%	21.4%	39%
China	30.1%	32.7%	37.2%

In 2006, Makela and his research team put forward the concept of moving network in the second International Conference on network development. MN is a moving network, which can also be called moving base station. Current research shows that the service area through the access links of MN for car users. Macro base station or micro base station do not directly provide services for car users. MN uses the full duplex mode. The MN network's backhaul link and access link work in different frequency bands.

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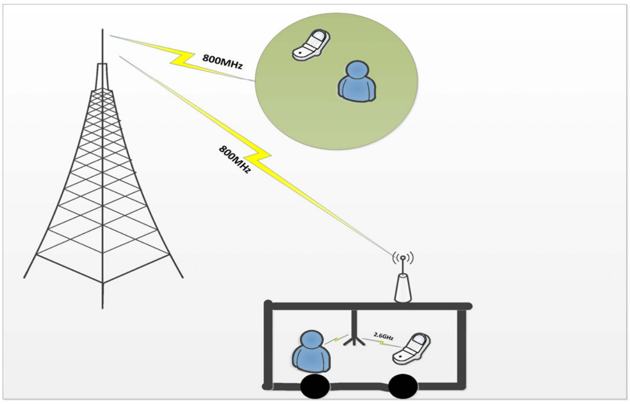

Fig. 1. The concept of moving network

MNs is the most effective way to improve the quality of service of the users in the car. When the working frequency is 2.4GHz, both macro base station and micro base station direct service users in the automobile VPL as high as 25 dB and with the increase of working frequency [1], VPL will increase, which will cause a very big impact of the vehicle user QoS. The cumulative distribution function is given [2] in the use of MN and does not use the MN backhaul link SINR/SNR and user directly service stations in Acer SINR/SNR (CDF). From Fig. 2 that, due to the existence of SNR MN significantly improved.

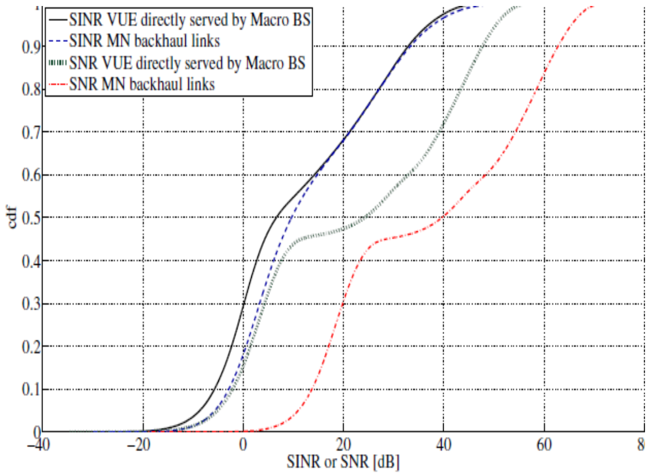

Fig. 2. SNR and SINR plot of VUEs

However, due to the mobility of MN, it has a serious inter cell interference among multiple cells, resulting in SINR the performance of MN has not been significantly improved. In order to inhibit the interference between inter MN cells, the ABS time domain interference coordination, MIMO system and other interference inhibition methods are proposed, which can improve the performance of MN [3].

2 MNs System Model and Interference Analysis

2.1 System Model for Moving Networks

In order to facilitate the research, this paper adopts the METIS project proposed a simplified abstraction of MN system model, shown in Fig. 3: model for the urban environment, carrying MN vehicles traveling in the streets, the transmission channel for the Rayleigh fading channel. Acer station is located above the building, has three sectors, for ordinary users and MN backhaul service network. The micro base station is located on the ground, there are two sectors, and the access link of the MN has the same operating frequency. Maintaining the integrity of the specifications.

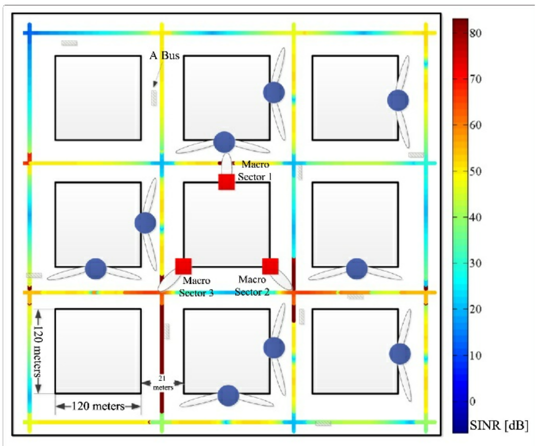

Fig. 3. MN system Model

2.2 Interference Analysis for MNs

With the increasing complexity of mobile communication technology and the increasing demand for communication services, the wireless resources become increasingly tense and scarce. In order to improve the utilization of wireless resources, the current TD-LTE system uses a network with 20MHz bandwidth of the same frequency group [4, 7]. The same frequency network means that a number of cells within a certain range of uses the same frequency spectrum resources for their users in the area for communication services. These cells which use the same frequency are called the same frequency cell. However, the use of the same frequency in different cells will lead to co-channel interference.

According to the provisions of the 3GPP meetings, we call communication links between MN and macro base station for the backhaul link. we call communication links between MN and VUE for the access link. Because of the MN backhaul links and basic station (BS) working in the same frequency of 800MHz and bandwidth of 20MHz, access links of MN and micro base stations working in the same frequency of 2.6GHz and bandwidth of 80MHz. Due to the mobility of MN will generate the same frequency interference between the residential area with complex, thereby greatly reducing receiving signal drying than SINR, resulting in reduced performance of MN. As shown in Fig. 4 [8]: when MN establish connection with BS through the backhaul link, in the other cell is a regular user at the same time serviced by macro BS .due to the MN backhaul links and macro BS use the same frequency and bandwidth, between MN backhaul link and ordinary users will form a complicated inter cell interference. When the MN access link service the VUE and a user serviced by the micro base station. Because the micro base station and MN access link using the same frequency and bandwidth, VUEs will be interfered by the micro base station of two sectors. At the same time, due to the ordinary users are serviced by the micro base station, they will be affected by the interference of MN access link. When two vehicles use the same spectrum resource at the same time, the access link of the two MN can also form inter cell interference.

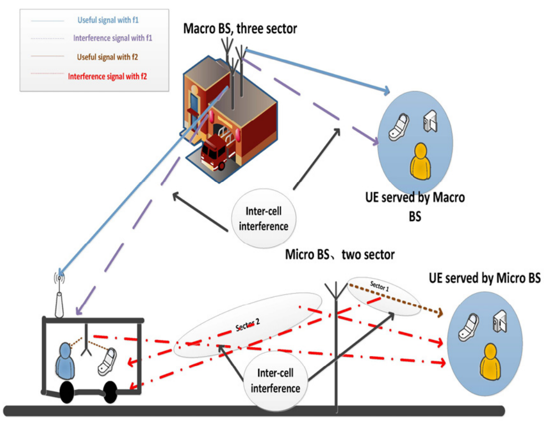

Fig. 4. The inter-cell interference of MNs

3 Related Studies

There are three main methods of interference management:
Interference randomization. Seeing interference signal as noise and adding a new "interference" to interference signal so that the interference signal is transformed into white noise or close to Gauss white noise, in order to achieve the purpose of interference suppression.
Interference. When the interference signal intensity is large, even larger than the available signal at the recipient, the interference signal needs to be demodulated, decoded, analyzed and then deleted.
Interference coordination. Through controlling spectrum resources to a certain limit to carry out a certain number of coordination mechanism.

But these three methods are only to reduce the inter cell interference. They cannot be used to avoid inter cell interference completely. The performance of the system to enhance is limited. To effectively solve inter cell interference of LTE-A, 3GPP proposed enhanced type inter cell interference coordination technology in 2010, mainly including power control, frequency enhancement type inter cell interference coordination and time domain enhance the coordination.
Inter cell coordination power control. 3GPPR8 proposed an important alternative to the power control scheme ICIC. Because of the backward compatibility and support for the duplex communication mode, the power control scheme is widely accepted. It mainly includes under the line power control technology, uplink ah power control technology, dynamic power control technology, etc. In the heterogeneous network, home network only need to cover in a small range while micro base station needs to cover a lot of home network community, so inter cell coordination control power is suitable to heterogeneous networks. However, in MN, MN backhaul links need to communicate with Acer station. So power control method is not suitable in MN backhaul links. The access link in the MN only needs to cover the user group in the MN cars, so low power can be considered. So the cell coordination power control technology can be taken into account.
Frequency domain enhanced inter cell interference coordination limits the wireless spectrum resource in order to achieve the purpose of interference suppression. Enhancement in the frequency domain type inter cell interference coordination technology, mainly use the orthogonality of the interference serious regional "staggered", in order to achieve the purpose to suppress the interference. However, due to the mobility of vehicles, vehicles in a number of cells, so the paper considers the use of frequency domain enhanced inter cell interference coordination.
Time domain interference coordination. The time domain interference coordination technology is mainly based on the interference signal in the time dimension to achieve the purpose of reducing the interference of the receiver. It is suitable to certain spectrum resources. Time domain interference control coordination technology is mainly divided into two categories: sub frame alignment scheme and sub frame migration scheme. The Almost Blank Subframe (ABS) is adopted by the sub frame. ABS sub frame is a special sub frame that does not contain the control and data signal. It contains reference signal only. When disturbed, ABS adjusts the transmission time of the user from the time dimension to achieve the purpose of interference suppression. The sub frame migration scheme is also called the OFDM symbol scheduling scheme, in order to avoid the overlapping of the control signal. It translates the sub frame of the control signal into several OFDM symbols to achieve the purpose of interference suppression. Because the OFDM symbol scheduling scheme has a high demand for time synchronization, it has a certain effect on the user's throughput.

The research content of the article is related to the ABS interference coordination method. ABS is one of the effective methods to protect the disturbed users from excessive and serious interference. ABS can be deployed at different densities and levels in the micro cell or macro cell to protect the users from interference.

There are three sectors in MNs model of macro base station. In different locations, the degree of interference is also different. As shown in Fig. 5 the users are divided into three user groups, the first types of users: users in the community center in the region from the adjacent cell interference or by interference is very low, does not affect the normal user quality of service. Second types of users are subjected to one of the adjacent. Cell interference is more serious. Third types of users are also affected by the inter cell interference of two adjacent cells. Therefore, we can learn from the classification above, the third type of user groups need to be protected most. The second groups of users follow behind. the first type of user groups can be least protected. As shown in the Fig. 6, ABS interference coordination method will divide radio resources into three regions to provide services for the interference level of three different levels of user.

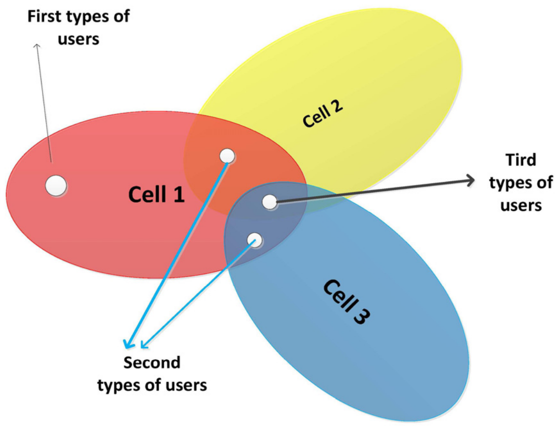

Fig. 5. Different types of users of ABS

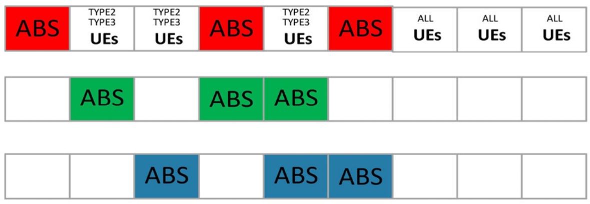

Fig. 6. An example of frames with ABS configurations

The simulation diagram of performance of ABS is shown in the Fig. 7. From the graph, we can learn that the performance of MN is improved by ABS. But according to the graph ABS is not the best method of interference suppression. IRC is the greatest improvement in MN performance. But in practical applications, because the IRC need to find out the antenna coefficient of the multi antenna system, the antenna coefficient is very difficult to get in the actual situation.

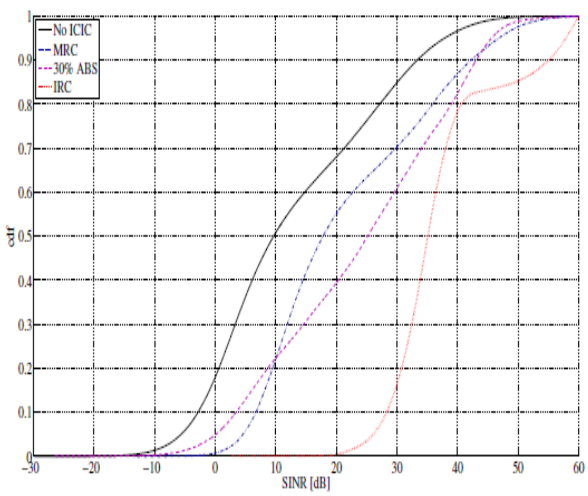

Fig. 7. The simulation diagram of performance of ABS

4 Interference Coordination Method Based on Threshold

ABSs inter cell time domain interference is the main idea of the method of coordination, the limited wireless spectrum resource is divided into three different protection level of the wireless spectrum resource area, different grades of by interfering users assigned to different spectrum resource area in. Relatively speaking, the ABS by interfering with the user's resource is limited, so as far as possible users if to be in "all users" of resources in the region is the best, more users in the "all users" resource area, namely that reduces the interference source of interference and show that limited spectrum resource is fully used. Therefore, the "threshold based MN backhaul link inter cell interference coordination method" is proposed, in which the threshold value is MN can withstand the minimum signal to dry ratio SINRmin [9]. When the user receives the received signal, the first step is to confirm whether the receiver of the receiver is lower than the threshold SINRmin. If less than SINRmin then indicates that the user is affected, if not less than SINRmin then indicates that the user is not affected by inter cell interference or adjacent cells caused by the interference will not affect the normal communication of MN. Interference coordination in case of less than SINRmin. The total power of the interfering signal corresponding to the SINRmin is calculated, and the average power of the current N interference source is obtained, and the interference signal which is larger than the average power value in the interference signal is eliminated. The way to eliminate the interference signal is to inform the power reduction. When the power to reduce the average user's communication if not affected by the end of the coordination, if the user communication, such as the interruption of the case, the user will be moved to the ABSs protected area. So the interference coordination method is feasible, and the resource "re utilization" is realized, and the interference is reduced.

4.1 Theoretical Analysis

The SINR of the MNs backhaul link can be expressed as below:

$$SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \quad SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{1}$$

Where P0——the power of useful signal

L0——path loss of useful signal

Pi, j——the transmit power of interference signal

Li, j——the path loss of interference signal

N0——noise power

The channel obeys the Rayleigh distribution channel, As the signal x(t) transmit in the channel with power Pt, the received signal can be expressed as below:

$$y(t) = h(t)x(t)l(t) + n(t) \quad SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{2}$$

where, n(t) represent the WGN. l(t)=d(-c/2) is Amplitude attenuation coefficient. α is in the range of 2-4. h (t) obey the Rayleigh distribution. Its probability density function is:

$$P_h(x) = \frac{x}{\sigma^2} e^{\frac{-x^2}{2\sigma^2}} \quad SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{3}$$

Eventually the received power:

$$P_r(t) = \frac{\gamma(t) P_t}{d^{\alpha}} = \frac{(h(t))^2 P_t}{d^{\alpha}} \quad SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{4}$$

the probability density of γ(t) function is expressed as:

$$P_h(x) = \frac{1}{2\alpha^2} e^{\frac{-x^2}{2\sigma^2}} \quad SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n}\sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{5}$$

4.2 Interference Coordination Step

- Setp1, MN and basic station MN communicate to determine the SINRmin in the small area.;
- Step2, MN calculates of the SINR under current case;
- Step3, Determine whether the SINR is less than SINRmin;
- Step4, When SINR is less than SINRmin, the total interference power is calculated;
- Step5,Calculate the average power of N interference;
- Step6, Eliminate the interference signal source which is greater than the average power value;
- Step7, back to step 2.

4.3 Flow Diagram of Interference Coordination (Fig. 8)

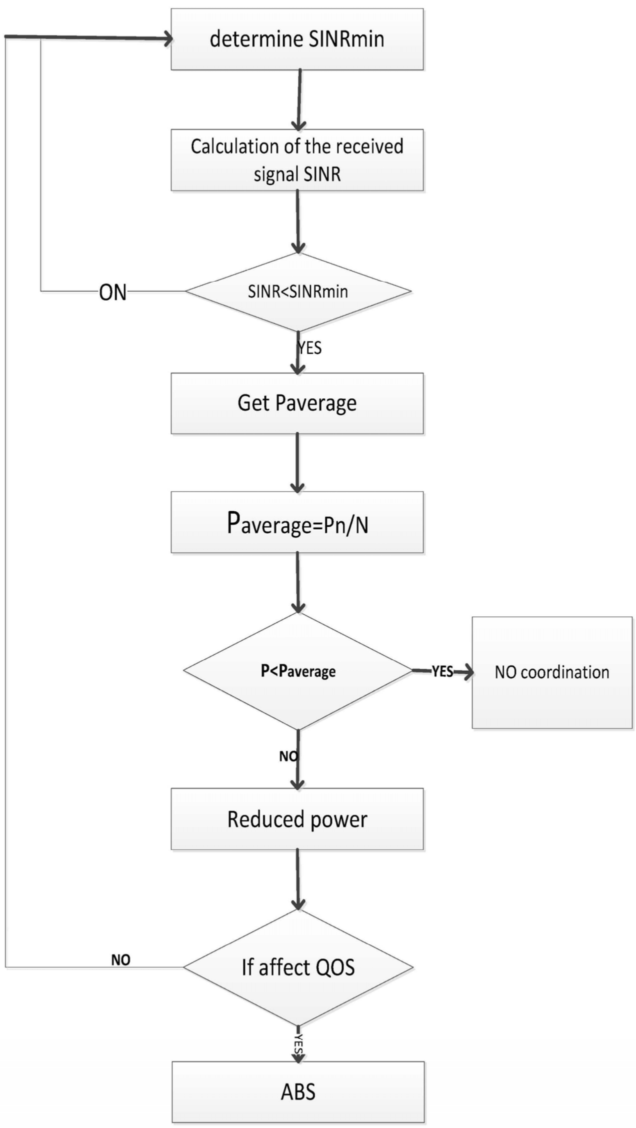

Fig. 8. Flow diagram of interference coordination

5 Simulations and Comparisons

On the basis of the concept and the implementation steps of the inter cell interference coordination method based on threshold, the Matlab performance simulation is carried out in this section. The model uses the MN model, and the parameters are given in Table 2.

Table 2. Simulation parameters

Model section	Parameters
Buildings and streets	120m*120m *3.5m with 6 floors Width of the street: 21 meters
Macro BS	Height: 5 meters Located on the top of buildings The maximum transmission power: 43dBm/10MHz working frequency: 800MHz bandwidth: 20Mhz Three sector
Micro BS	Height: 10 meters, Located on the ground The maximum transmission power: 43dBm/10MHz working frequency: 2.6GHz bandwidth: 80Mhz Two sector
Moving network	Speed: 50km/h Height: 3.5 meters Backhaul link: 800MHz bandwidth: 20Mhz Access link: 2.6GHz bandwidth: 80Mhz
UE	Random distribution within the cell
Number of sources of interference	1-30 randomly selected, the source of interference randomly assigned in two other adjacent cells

Matlab simulation of the inter cell interference coordination scheme based on threshold. The cumulative distribution function (CDF) curve of the SINR letter drying ratio is obtained, as shown in Fig. 9 below.

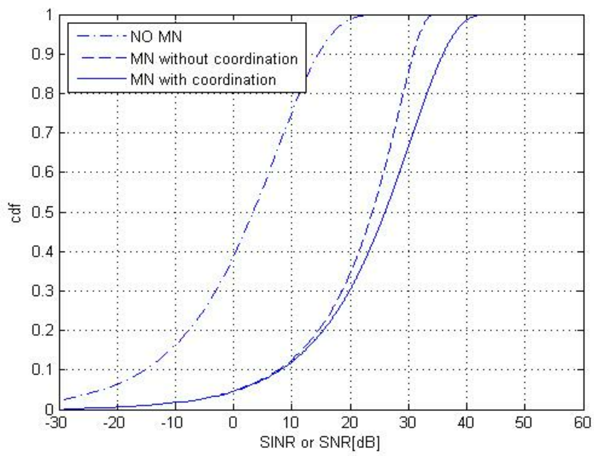

Fig. 9. Simulation results

The cumulative function of the SINR distribution diagram, it can be concluded that in the use of based on threshold of inter cell interference coordination case, and without the use of coordination methods of comparison, under low signal to dry ratio had no significant effect, but in the area with high SINR, improve the effect becomes more obvious. Therefore, the inter cell interference coordination scheme based on threshold plays a role in reducing the interference. With the increase of SINR, the effect of interference suppression is more obvious. Due to the inter cell interference coordination method based on threshold, the interference between the cells in the MN is put forward according to the threshold of the interference source, which can achieve the goal of inter cell interference suppression. Therefore, the inter cell interference coordination method based on threshold is able to improve the MN network's letter to dry ratio, and improve the QoS of MN.

The simulation analysis above shows that the method of inter cell interference coordination based on threshold is feasible. It can improve the signal to noise ratio of MN, so it can improve the user's QoS, but there are two deficiencies in the method of inter cell interference coordination based on threshold:

Over coordination and under coordination. The inter cell interference coordination method based on threshold is to eliminate all of the interference power values which are larger than the average interference power. When the power of the interference signal sources has a maximum or minimum, the average power value would be greatly affected. The average value of the power is greatly increased when there is a maximum value. Eliminating the power may still be unable to meet the MN letter dry ratio which is demanded to be less than the threshold value of the requirements, at this time will appear under the coordination of the phenomenon. When the interference signal power of all the interference sources is very small, the average interference power value will be greatly reduced. At this time the amount of MN removed interference source is too much, that is, to reduce the number of power interference source too much. It is very likely that there will be no interference signal from the main source in the reduced power source. But in practical application in the power of the transmitted signal is controllable, really within a certain range, so in a set of interference signal power under normal circumstances rarely have maxima and minima, so coordination and less probability of the emergence of coordination is very low and can be controlled.

Signaling cost increases. The cell interference coordination method based on threshold need to confirm where each interference signal comes from for the coordination with large noise interference source. In this paper, the source of each interference signal is determined by the resource block, so the signaling cost is more.

6 Application in High Speed Railway Environment

6.1 A Railway System Model

With the model above, the analysis model of the railway is simpler than that of the model. The railway model is a linear model, as shown in Fig. 10. In the railway model, the communication between the various base stations makes the advance preparation of the list of the cells train to get through and to know the allocation of resources in each district become possible. In such a scenario, the coordination of the railway environment is much easier than the traditional bus environment. But the disadvantage of the railway model is that the speed of trains is fast, and the switching frequency is high. Therefore, we need to ensure that the coordination cycle of the inter cell interference coordination technology based on threshold is less than the cycle of the train cell switching.

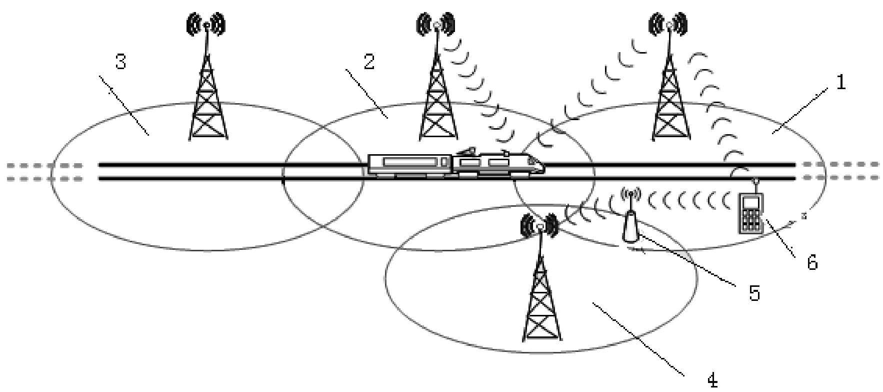

Fig. 10. Railway system model

6.2 Simulation Results

In the linear model, the trains are mainly affected by the neighboring cells. Assuming a total of L interference sources, we express the signal to noise ratio as the following formula:

$$SINR = \frac{d^{-\gamma_D} P_D}{N + \sum_{J=1}^{2} \sum_{i=1}^{L} d_{j,i} - d_{j,i}^{-\gamma_D} P_{j,i}} \quad SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{6}$$

Where P_D——Transmission power of transmitter for wireless link

γ ——Loss coefficient equals to 3.5

Pi,j——Interference transmit power of the j interference source in the i cell.

di,j——Interference path length of the j interference source in the i cell.

N——Noise power

After the SINR is obtained, the throughput of the train C is obtained.

$$C = B \log_2 (1 + SINR) SINR_{MN} = \frac{P_0 L_0}{N + \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} L_{i,j}} \tag{7}$$

Where

B——total bandwidth.

The parameters are given in Table 3.

Table 3. Simulation parameters

Model section	Parameters
Macro BS	Height: 25 米, The maximum transmission power: 43dBm/10MHz working frequency: 800MHz bandwidth: 20Mhz
Micro BS	Height: 10 米, Located on the ground The maximum transmission power: 43dBm/10MHz working frequency: 2.6GHz bandwidth: 80Mhz
Moving network	Speed: 180km/h(fit with the speed of train) Backhaul link: 800MHz bandwidth: 20Mhz Access link: 2.6GHz bandwidth: 80Mhz Each train equipped with several MN to satisfy the passengers
UE	Random distribution within the cell
Number of sources of interference	1-30 randomly selected, the source of interference randomly assigned in two other adjacent cells

Simulation results are obtained as shown in Fig. 11. From the graph, we can learn that the network throughput is significantly improved when the inter cell interference coordination technology based on threshold is applied to the train. Therefore, the inter cell interference coordination technology based on threshold is also effective in high speed railway system.

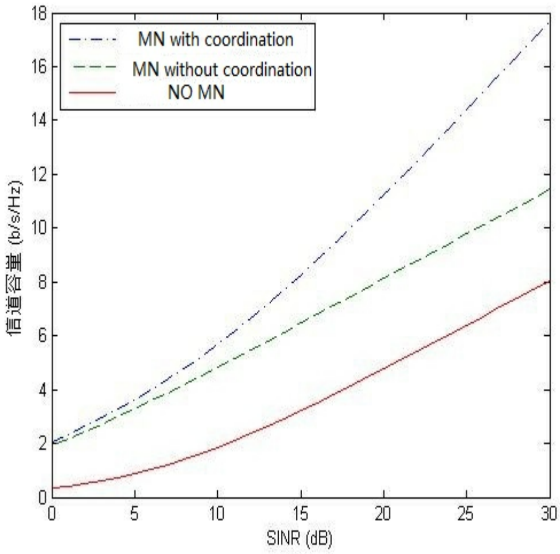

Fig. 11. Simulation result

7 Conclusions

In general, MNs can improve the throughput for the VUEs without significantly affecting the performance of outdoor UEs. This paper introduces the basic knowledge of MN network, and analyzes the inter cell interference in MN network. A threshold based inter cell interference coordination is proposed. The flow chart and implementation steps are given. Based on the analysis of MATLAB simulation, the results show that the inter cell interference coordination technology based on threshold can be improved by QoS. On this basis, the proposed method is applied to the high-speed railway environment and its simulation analysis shows that coordination method can improve the performance of MN in the high-speed railway scene.

There is very complex interference because of the mobility and randomness of MN. The paper mainly study the management method between same frequency cells. However, the performance of backhaul network of MN can further be enhanced. We also need a lot of interference management methods to improve the performance of MN. For example, the modulation scheme used in the current LTE-A system is 64-QAM. According to the literature [10], 256-QAM can be used in MN to improve the performance of MN backhaul link.

One of the biggest advantages of using MNs as they are less constrained by antenna space, power and transceiver complexities. Therefore, making full use of the advantage and combining with MIMO system can improve the performance of MN [11].

MN mobile network is a new technology that represents a new opportunity and challenge. In MN, due to movement of the vehicle, something like MN switching network between cells; resource allocation of common network and MN network; fairness between outdoor UEs and VUEs all require further research.

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