Power Control For Wireless Communication Systems

Vahid Behtaji Siahkal Mahalleh, Chan Hui Ting, Loh Mun Wei

Abstract— efficient power control for signals related with randomly dispersed users that are using a single channel which is important in order to conserve the operating life of the battery as well as improving the overall systems capacity. Efficient power control is done by controlling the transmitted power at a given node so that the signal to interference ratio (SIR) of the system does not go above a certain threshold. Hence, channel reuse can be maximized. The distributed power control (DPC) can be used to implement this function as it does not require extensive computational power such as centralized power control methods. The DPC method adjusts the power of each transmitting signal by using local measurements which results in all users maintaining a reasonable SIR. In this paper, we review the DPC method for a wireless network with a single transmitter with random users or receiver nodes via different channels.

Index Terms— Efficient power control, signal to interference ratio (SIR), distributed power control (DPC), wireless network, Random nodes.

1 INTRODUCTION

For any wireless system, power control is an essential element. This is because one of the most crucial issues in most wireless networks are the fact that they have to work in limited energy environments [1]. The control on the transmitted power allows communication links to be developed in a channel with a signal to interference ratio (SIR) which is within the given quality of service (QoS). The reduction of interference increases the network capacity through higher channel reuse. Path loss is experienced by electromagnetic waves as they propagate between transmitter and receivers. This becomes a problem when many receivers are trying to communicate with one transmitter because the closest receiver will overpower all other receivers [7].

Previous studies have focused on balancing the SIRs on all radio links by centralized power control. However, this model was too complex and is only used for theoretical analysis. Later, a distributed power control algorithm was developed [2][3][7][8][9]. The distributed algorithm uses local measurements and is simpler to design and it ensures that eventually all users meet the SIR requirements. Besides that, several studies were also done on multicast and broadcast communications such as [1][2][3][4][5][6].

In this paper, we focus on the power control of the transmitter to various receiver nodes of different channels. In the following sections, we study the Power Control Concept (Section A), Wireless Communication Model (Section B), Distributed Power Control (Section C), Simulations (Section 5), and Conclusions (Section 4).

2. LITERATURE REVIEW

2.1 THE POWER CONTROL CONCEPT

The main parts of network control in any networked communication environment are the communication links as well as the user required quality of service (QoS). In wireless networking these functions are heavily dependent on transmitter power control. In power control, several aspects have to be optimized such as transmitter power minimization, network capacity maximization as well as optimal resource allocation. In a nutshell, by adjusting its transmitter power, a communication link interacts with the rest of the network and can get feedback information by monitoring the interference induced on its receiver by the other reacting links. Hence, power control can be used as a vehicle for performing several key dynamic network operations online, such as admission control, link QoS maintenance, channel probing, resource allocation, and handoffs.

In order to design a functional power control system, several aspects must be taken into consideration. Firstly, the algorithms should be from well justified assumptions. Besides that, the model should be distributed sufficiently so that it allows autonomous execution at the node which requires minimal usage of network communication resources. Moreover, it should be simple and scalable so that it is suitable for real-time applications and can maintain high performance at various networks scales and so on.

A good power control network will ensure that there will be less interference on other users sharing the same channel or transmitter [2]. The signal to interference ratio (SIR) is often used to design the power control network where the SIR is maintained at a certain threshold. The SIR is a measure of the quality of the received signal. A higher SIR contributes to a better received signal [7].

2.2 WIRELESS COMMUNICATION MODEL

In a wireless communication system, a node can be established between any pair of nodes as long as the SIR at the receiver node is higher than the threshold [1]. The connectivity of the nodes is determined by the transmitter power, distance between the transmitter node and receiver node, error-control schemes, other user interference as well as the background noise.

The transmitter power that is controlled should not exceed a maximum value power which is denoted as Pmax. The transmitter power is denoted as Pi and the received power between the transmitter node i and receiver node j is denoted as Pij.

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We assume that the receiver signal power varies with r-α, where α is a parameter between 2 and 4 is depending on the characteristics of the communication medium [1][3][7][8][9]. The goal of this study is to maintain a required SIR threshold, denoted as γ, for each transmitter-receiver node pair by adjusting the transmitter power so that the interference at nodes that are too far away from the transmitter can be reduced.

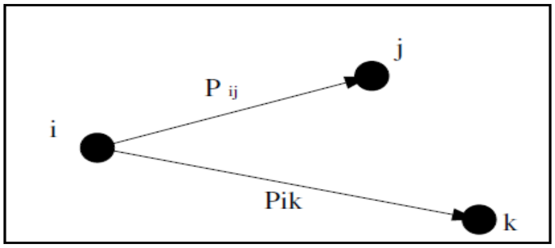

Fig. 1: The Wireless Network [1].

2.3 DISTRIBUTED POWER CONTROL

The SIR, Ri at the ith node of the system is evaluated as follows:

$$R_i = \frac{G_{ii} * P_i}{\sum_{j \neq i} G_{ij} * P_j + \eta_i} \quad (1)$$

Where i, j = {1, 2, 3… n} and ηi>0. ηi is the thermal noise at the receiver node.

Gii is the power gain of the transmitter and can be obtained by the following equation:

$$G_{ii} = \frac{g}{r_{ij}^{\alpha}} \quad (2)$$

Gij is the power loss from the transmitter node to the receiver node. This loss is due to the free space loss, multi path fading, shadowing, other radio wave propagation effects as well as the spreading or processing gain of the transmission. Hence, we need:

$$R_i \geq \gamma \quad (3)$$

For every i=1, 2, 3… n.

The SIR threshold, γ should be same for every node. The value of γ reflects a certain QoS that the node has to maintain in order to operate correctly.

If the Ri obtained is below the γ, the following formula is used in order to increase the transmitted power.

$$P_i(k+1) = \frac{\gamma P_{ik}}{R_{ik}} \quad (4)$$

Where k=1, 2, 3… n.

If Pi(k+1) > Pmax, then the new node is not added into the network. Hence a node is only established into the communication network if and only if the new state of the system is stable. In a nutshell, the transmitter power increases independently when its current SIR to a node is below ã [2][3][7][8][9][10].

The transmitting power is then chosen from:

$$P_{ijk} = \max\{P_{ij}, P_{ik}\} \quad (5)$$

Where P*ij* and P*ik* are the power transmitted to the *j*th node and *k*th node respectively.

3. RESULTS AND DISCUSSION

3.1 SIMULATION MODEL

The setup for the simulation experiments is using Matlab R2008a. The distributed power control method is presented in this section. In order to simplify the interference scenario, several assumptions has been made in this study. First and foremost, in this paper we assume one base station and two random users (receiving nodes) in the CDMA environment. Besides that, interference occurred due to the users does not employ completely orthogonal spreading code. Hence, multiple access interference (MAI) occurred in this CDMA environment.

In this paper, the interference occurred only within the cell that covered by the particular base station which is at the coordinate (0,0). Thus, the users are not interfering with other base station. Besides, broadcast link is not created and State Space-based Control Design (SSCD) is not included in our scope.

Apart from that, the users' received signal power is assumed decreases logarithmically with the distance only.

Hence, both transmissions were done via different channels which á was taken as 2 (Free Space Path Loss model) and 4 (Plane Earth Path Loss model) for receiving node 1 and 2 respectively. In reality, more complicated channel model should be used with taken into account of different correction factor.

Furthermore, the transmitter power, Pi is set to 0.05W, while ã was set to 5dbmW according to [1]. The thermal noise, çi was set to 3.972 x 10-17W as in [8]. In this paper we assume the worst case interference scenario which Gij*Pj will be 120, and the g is set to 1.The performance is measured by adjust the transmitter power. The transmitter power is increased whenever the SIR is below γ. Hence the SIR is maintained just above the target γ.

First and foremost, random nodes were generated. Fig. 2 shows 2 receiver nodes generated randomly and the transmitter node is placed at coordinate (0, 0). (See Appendix for the other states)

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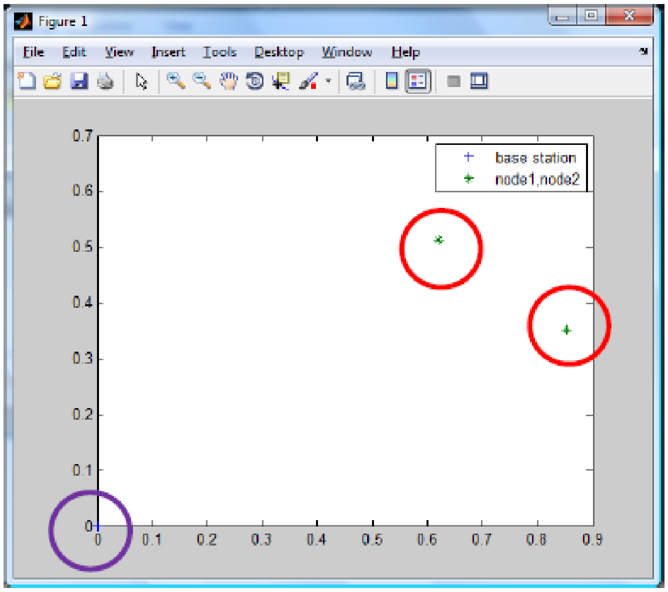

Fig. 2: Random Node Placement.

The distance of each node was first tabulated and the SIRs were computed. Then, both SIRs were checked and if anyone was less than the threshold, the transmitted power was automatically recalculated in order to maintain the SIR above the threshold. Fig. 3 and Fig. 4 shows the SIRs and power obtained for the two nodes generated above.

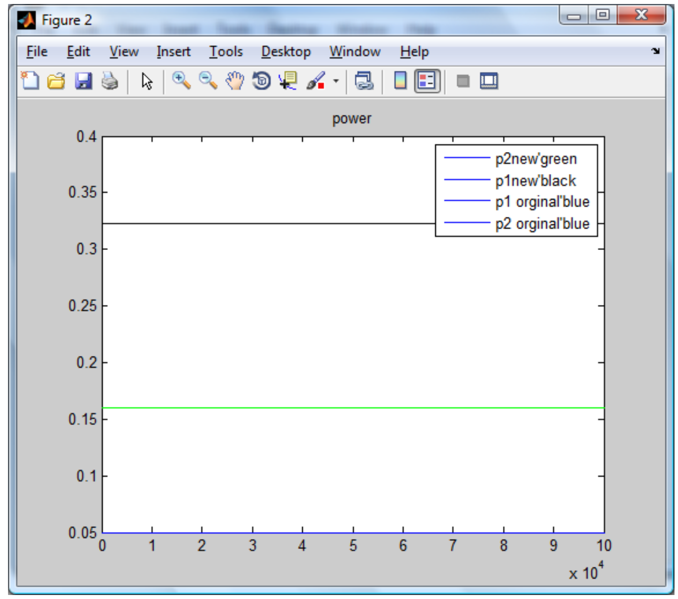

Fig. 4: Transmitted power for both nodes.

From Fig. 4, it can be seen that the initial transmitted power is the blue line (0.05W). However, in Fig. 3 it has been seen that both SIRs were below the threshold which called for an increase of transmitter power which is denoted as the green line and the black line. Fig. 5 and Fig. 6 show the variation of the SIR with random distance and how much the power increases for those random distances.

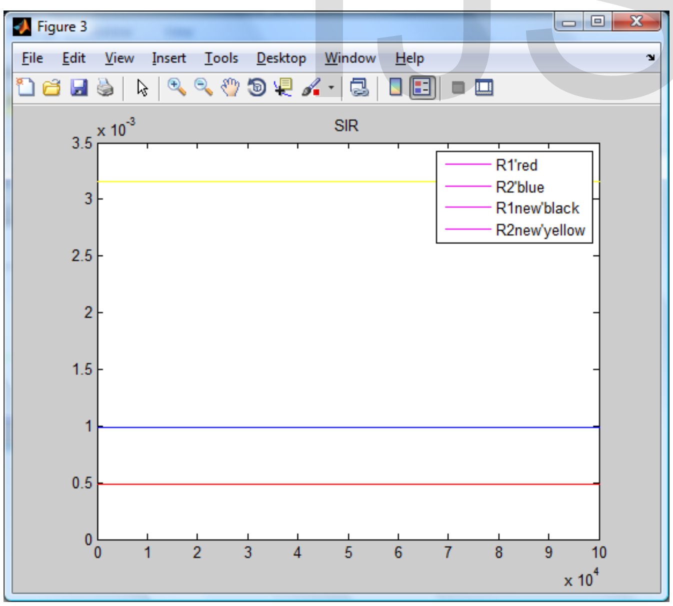

Fig. 3: Simulated results of SIR for both nodes

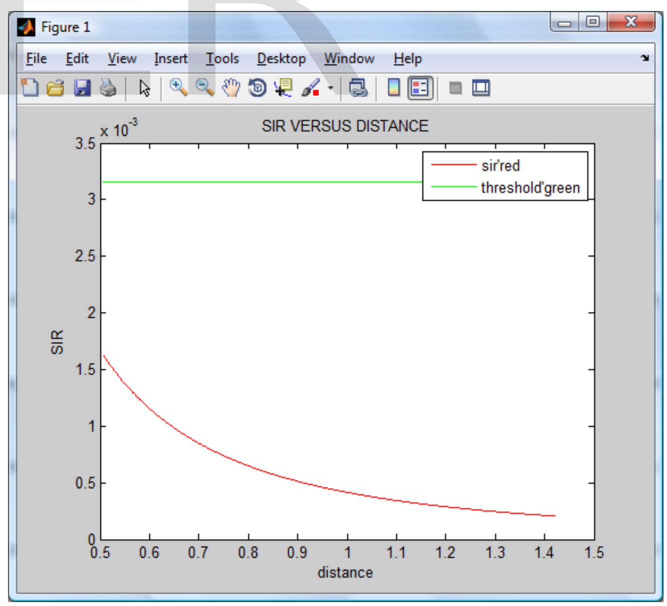

Fig. 5: Simulated SIR for Several Distances.

The red and blue lines denote the SIR obtained before power control. Both SIRs are below threshold. After power control, the SIR has increased to the yellow line and black line (3.5 x 10-3).

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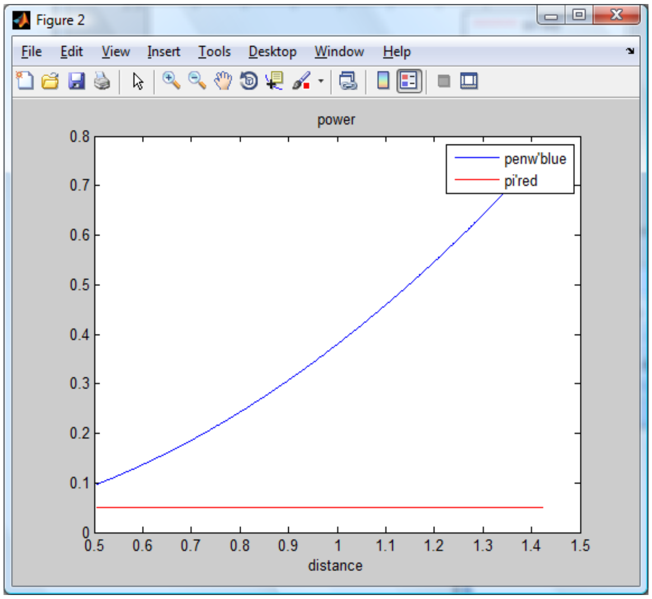


Fig.6: Power Transmitted for Several Distances.

In Fig. 5, since the SIR (red line) is below threshold (green line) for the distances generated randomly, hence the transmitted power will be automatically increased as shown in Fig. 6 where the red line shows the initially transmitted power and the blue line denotes the controlled power.

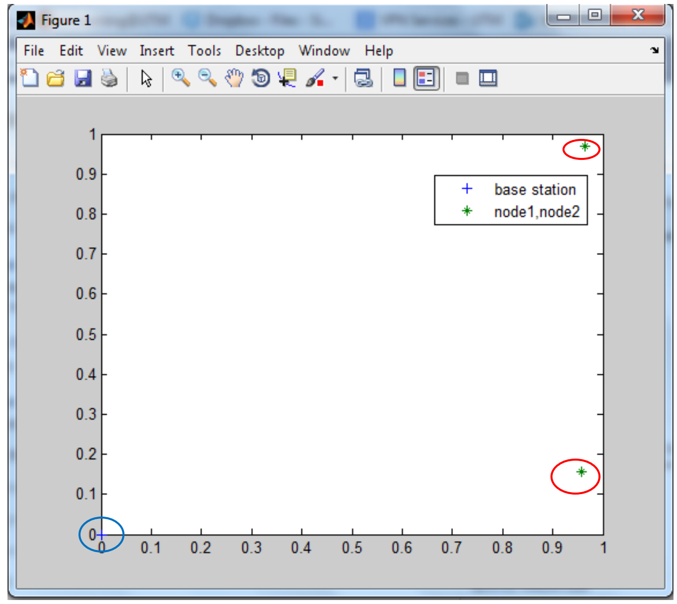
4. CONCLUSION

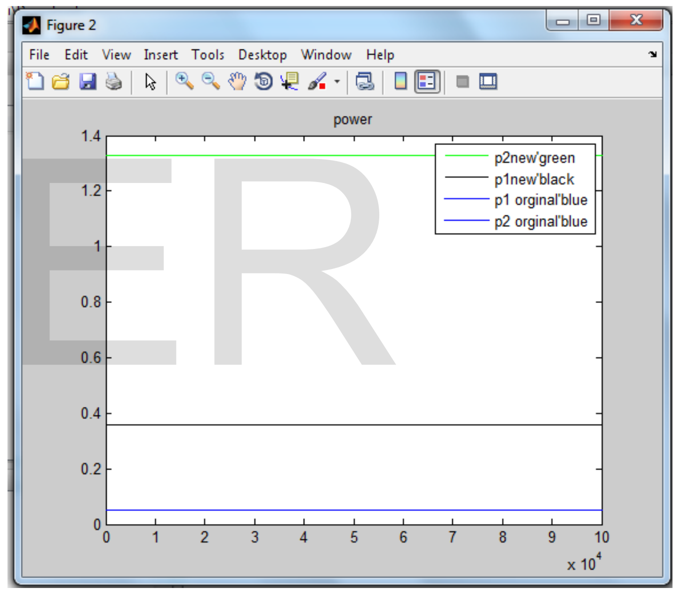
From this study, we have investigated and simulated a power control system using the distributed power control (DPC) approach for wireless networks. We have shown that when the SIR for a receiver signal is below the threshold value, the transmitter power will automatically increase in order to maintain the SIR above the threshold.

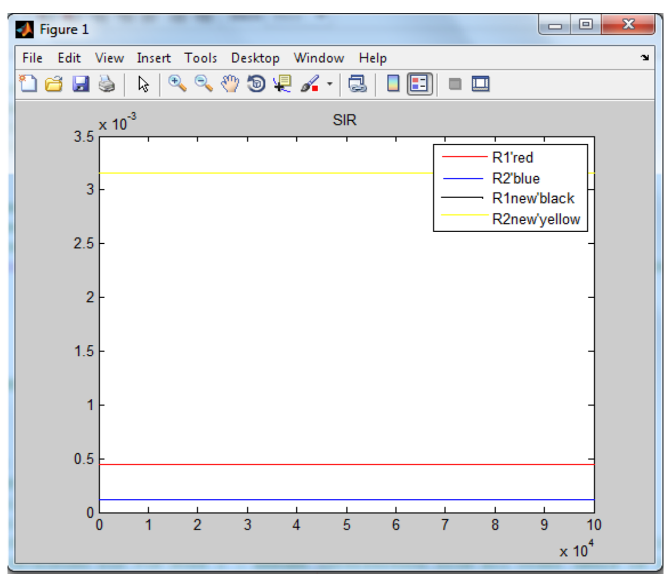
5 END SECTIONS

5.1Appendices

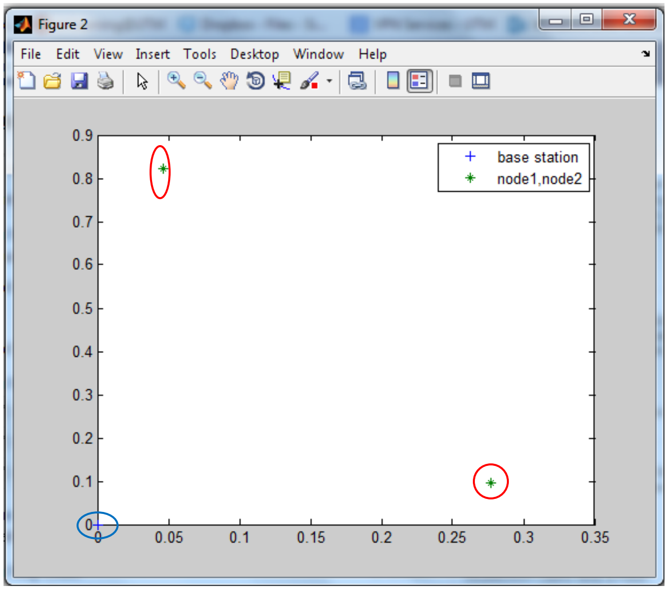
When both not satisfy the required SIR value:

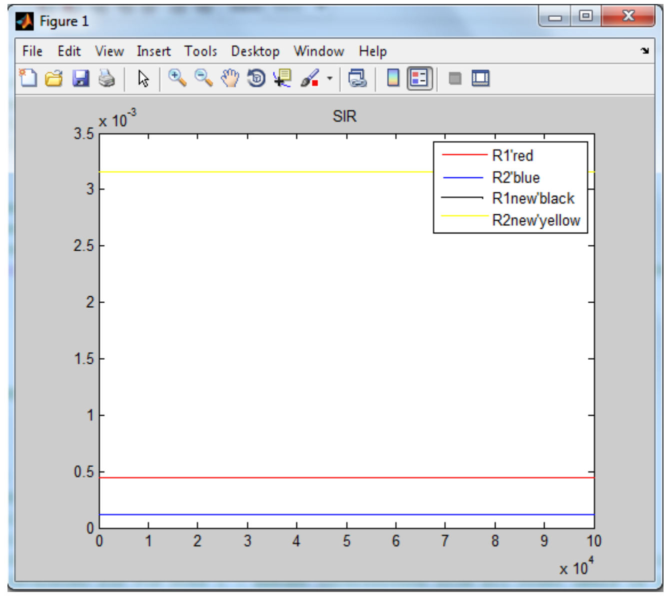


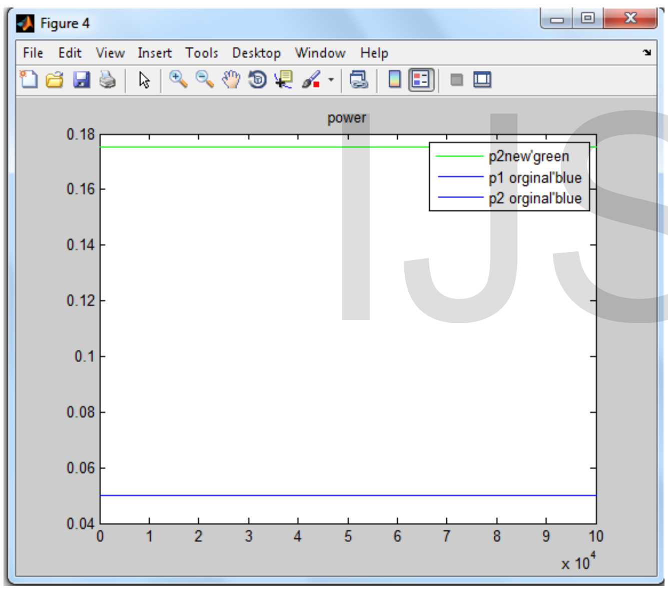




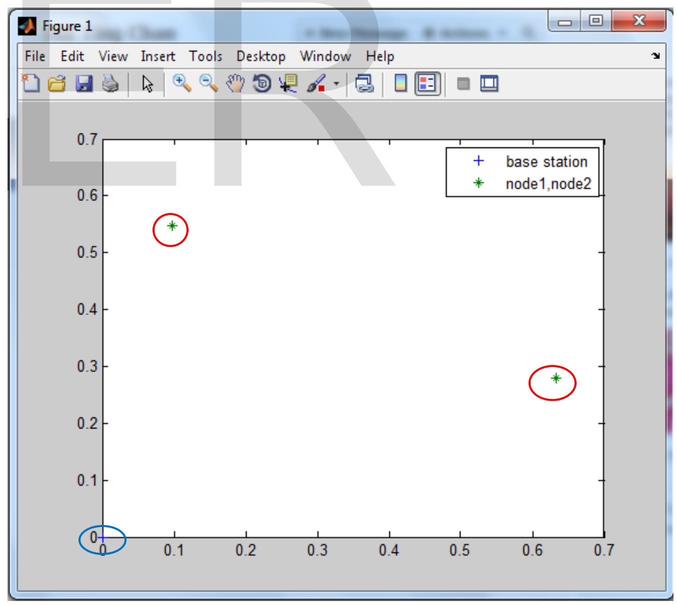
When R2 not satisfy the required SIR value:

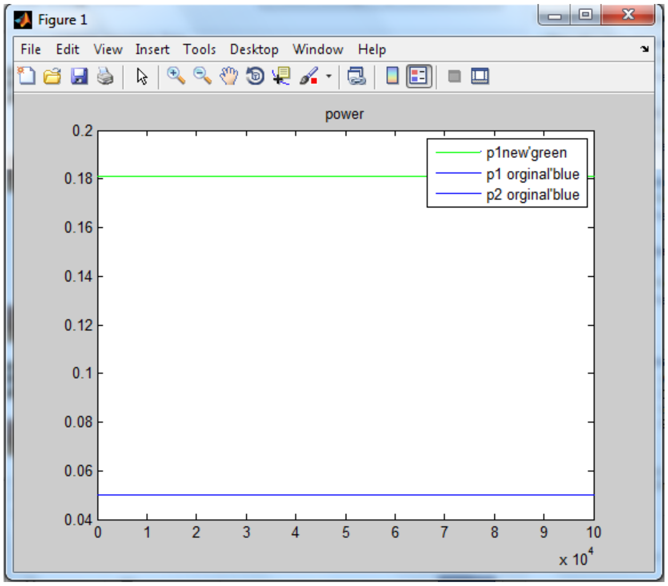


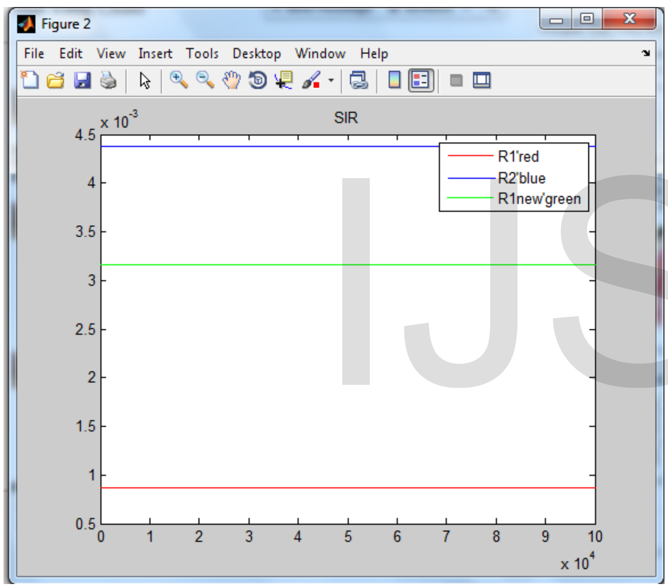




When R1 not satisfy the required SIR value:







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