RESEARCH ON THROUGHPUT MAXIMIZATION OF WIRELESS POWERED COMMUNICATION NETWORK BASED ON A RETRO DIRECTIVE MATRIX

Bo Li[1, 2] and Hong Tang[1, 2]

[1]School of Communication and Information Engineering, Chongqing University of Posts and Telecommunications, Chongqing 400065, China;
[2]Chongqing Key Laboratory of Mobile Communications Technology, Chongqing 400065, China

ABSTRACT

Aiming at the problem of limited system throughput caused by double near-far effect in wireless power communication network. In this paper, a retro directive matrix method based on phase conjugation is proposed. In the method, energy base stations and information base stations are depolyed separately, energy base station uses large-scale multiple input multiple output (MIMO) system, when system running point equipment firstly to send a beacon signal to energy base station, the energy base station amplifies its conjugate to form a directional beam to achieve multi-input and multi-output energy gains, thus improving the throughput of information transmission of node devices. Through the optimizated and allocated the time of beacon signal, the time of energy transmission, the time of information transmission and some power parameters, a convex optimization problem is proposed. And it has been solved by Lagrange generalized multiplier method and golden section method. Simulation results show that the proposed method has better performance than others projects.

KEYWORDS

Wireless Powered Communication Network, Matrix Retrodirective Array, Energy Transmision, Information Transmision, System Throughput.

1. INTRODUCTION

Conventional wireless sensor networks, such as those that detect earthquakes, temperature, humidity and noise, are powered by batteries. Battery power comes with a number of pitfalls, such as limited available time. If the replacement is delayed, communication is interrupted and service quality is affected [1]. Wireless power communication network (WPCN)is a new type of network which combines energy transmission and traditional information transmission. Energy transmitter uses Radio frequency (RF) transmission mode to transmit energy, and sensor node equipment can realize self-sustainable information transmission after acquiring these energy [2].

In literature [3], a classical WPCN is studied for the first time and a "acquisition first, transmission later" protocol is proposed, in which the user (device) first obtains energy from the Downlink (DL, Downlink) through mixed node H-AP broadcast. The obtained energy is then used to send information to the hybrid node H-AP on the UL (Uplink).H-AP here refers to the deployment of energy nodes and information nodes together, which results in limited information

David C. Wyld et al. (Eds): NATP, ACSTY, CCCIOT, MLSC, ITCSS - 2022
pp. 51-63, 2022. CS & IT - CSCP 2022 DOI: 10.5121/csit.2022.120104

transmission distance and double near-far effect. Firstly, the limited information transmission distance is due to the difference in the scope of energy transmission and information transmission. Energy transmission is different from the structure and antenna system of information transmission, and has high requirements on the sensitivity of the receiver. Usually, the effective range is about 15 meters. Secondly, "double near and far effect" means that users who are far away from H-AP receive less energy on DL than those who are close to H-AP. However, due to signal attenuation caused by double distance on DL and UL, remote users need to transmit signals at higher power on UL to ensure service quality. Taken together, these problems can result in low system coverage and limited throughput. In order to solve the problem of limited throughput of wireless power supply network, time inversion technology is added in the information transmission stage in literature [4] to increase system capacity by resisting multipath effect. Literature [5] studies the problem of throughput maximization of wireless power supply network based on NOMA technology. All node devices are equipped with multiple antennas, and NOMA technology is adopted for transmission in the information transmission stage to increase system throughput through beamforming. Literature [6] and [7] studied the maximization of wireless power supply network throughput of UAV as node device. Energy transmission is also particularly important in the wireless power supply network. Node devices need to obtain enough energy to ensure good service quality.

Therefore, in order to overcome the problem of reduced system throughput caused by the limited energy of node devices due to significant power loss over long distances in rf wireless energy transmission, Multi-antenna directional transmission of energy or energy beamforming (EB) can be a good solution [8]. However, the practical implementation of EB requires obtaining the perfect CSI in the energy emitter. In order to obtain CSI, literature [9] uses forward link training with CSI feedback of receiver, and literature [10] uses reverse link training with channel reciprocity, as well as training based on energy feedback. However, prior to link training and training methods based on energy feedback and feedback overhead actually is very high, especially in the equipment has a large number of nodes or has a large-scale multiple input multiple output system, but as this article proposed a reverse link training method based on phase conjugate feedback because they don't need node equipment, and the length of training has nothing to do with the number of transmit antennas, This has huge advantages for large-scale MIMO systems[11]. Back in the direction of the array is on the basis of the principle of phase conjugate reverse link training method, has proven to be an effective way of wireless power transmission (WPT), able to position the target under the condition of unknown, automatic back entrance to the direction of the wave, and there's no need to through complex digital signal processing algorithm, this method has been widely used in radio frequency identification, microwave imaging, Radar anti-collision system and other identification systems.

This article introduced in the traditional wireless network reverse beamforming is a kind of low complexity, in this kind of technology, all nodes to equipment energy transmitter launch a public beacon signals at the same time, all energy transmitter antenna on the conjugate amplifier, and on all the nodes radio equipment energy, node equipment using its energy to the base station to send information. The work of this paper is as follows:

1. Improve the traditional wireless power supply network model, deploy energy nodes and information nodes separately, so as to increase the coverage of the system
2. By using channel reciprocity, the directional backtracking matrix method based on phase conjugate is added in the energy transmission stage, and large-scale MIMO system is adopted in the energy base station to make the node equipment obtain energy gain, so as to increase the throughput in the information transmission stage.
3. Considering the quality of service of node equipment, the time allocation and power control of beacon signal, energy transmission and information transmission are jointly

optimized, and the problem model is planned, and the maximum throughput is solved by using Lagrange duality method combined with golden Section algorithm.

4. Other classical wireless power supply network schemes are compared and analyzed by simulation to prove the effectiveness of the proposed scheme.

2. SYSTEM MODEL

As shown in Figure 1, we have studied the multi-user wireless power communication network under a large-scale antenna array. The energy transmitter ET has M_t transmitting antenna, and there are k node device (ER), each node device has an antenna, and the information receiver IR has a receiving antenna. The transmission matrix from ET to ER is represented by H .

$$H = \begin{bmatrix} h_{11} \; h_{12} \; \dots \; h_{1M_t} \\ h_{21} \; h_{22} \; \dots \; h_{2M_t} \\ \vdots \quad \vdots \qquad \vdots \\ h_{K1} \; h_{K2} \; \dots \; h_{KM_t} \end{bmatrix} \tag{1}$$

Among them, h_{ij} =($i=1,2,...,K; j=1,2,...M_t$)represents the channel transmission coefficient from the j th energy transmitter antenna to the i th receiver antenna. Assume that all transmitted signals are narrowband signals:

$$h_{ij} = \sqrt{\beta_{ij}} S_{ij} \tag{2}$$

β_i and g_i represents the large-scale fading coefficient of the channel, and S_{ij} represents the small-scale fading coefficient of the channel. The large-scale fading coefficient is related to the distance between equipment and energy transmitter ET and information receiver IR. The large-scale fading coefficient of each node device and all ET antennas is the same, which can be expressed as:

$$\beta_i = c_0 (r_i / r_0)^{-\alpha} \tag{3}$$

The large scale fading coefficient from each node device to the IR of the information receiver is also the same, g_i can be expressed as:

$$g_i = c_0 (d_i / r_0)^{-\alpha} \tag{4}$$

Where $c_0 = -30dB$ is the constant attenuation factor of path loss at the reference distance $r_0 = 1m$. α is the path loss index, r_i is the distance from the i th antenna of the terminal device to the energy transmitter, d_i represents the distance between the i th antenna of the terminal device and the information receiver. The fading coefficient of small scale S_{ij} independent from antenna of different energy transmitter to antenna of different receiver. It is a complex Gaussian random variable with zero mean unit variance, $S_{ij} \sim CN(0, 1)$. The channel from ET to ER_k is represented by $h_k^* \triangleq [h_{k1}......h_{kM_t}]^T$, $a*, a^T$ represents the conjugate and transpose of the copy vector. It is assumed that the channels from the energy transmitter ET to the node device are reciprocal and that the information receiver IR has perfect CSI for all node devices, so the channel from ER_k to ET can be represented by h_k^H , a^H represents the conjugate transpose of the vector a .

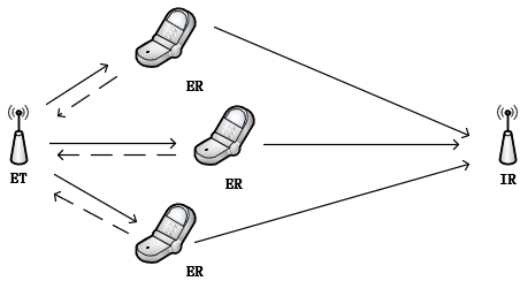

Figure 1. The system model diagram

3. SYSTEM SOLUTION

Based on the reciprocity of channel, a wireless power supply network scheme with low complexity based on phase conjugate directional backtracking array is proposed. Each time transmission block is composed of three time slots. In first time slot τ_1, the node device transmits a beacon signal to the energy transmitter ET. In second time slot τ_2 , the energy transmitter ET transmits energy to the node equipment. In third time slot τ_3, the node device sends information to the information receiver IR. And each node device has a certain amount of energy before the system starts to ensure that the node device can send beacon signals to the energy transmitter ET. In the following time block, the energy transmitted by the acquired energy transmitter ET is used to transmit information to the information receiver IR, so as to realize the self-sustainability of node equipment. Figure 2 is the slot allocation diagram of the system model in this paper.

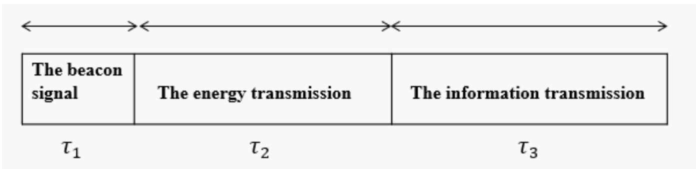

Figure 2. The timeslot allocation diagram of this paper model

3.1. Solution Steps

1) Beacon signal stage: dotted arrow in the system model figure in Figure 1, K node devices simultaneously send beacon signals to the energy transmitter ET when the system is running, which can be expressed as:

$$\Phi_k(t) = \sqrt{2P_k}\cos(2\pi f_c t) \qquad (5)$$

P_k is the power of the node device to send beacon signals, $0 \le P_k \le P_{\max}$, $P_{\max}$ is the maximum transmitting power of beacon signal, f_c is carrier frequency, beacon signal duration is τ_1. So the system bandwidth is $w = 1/\tau_1$. The equivalent baseband signal received by ET is expressed as:

$$y(t) = \sum_{k=1}^{K}\sqrt{P_k}h_k^* + z(t) \qquad (6)$$

$$= g + z(t) \quad (7)$$

$z(t) \triangleq [z_1(t),......z_{M_t}(t)]^T$ represents additive White Gaussian noise (AWGN) with mean value zero and power spectral density is N_0 .At the same time, $g \triangleq \sum_{k=1}^{K} \sqrt{P_k} h_k^*$ represents the effective weighted linear combination signal received by the energy transmitter ET sent by K nodal devices. Then the energy transmitter ET performs matching filtering operation on the received signal $y(t)$. The result of that is $\hat{g}$, can be expressed as:

$$\hat{g} = \frac{1}{\tau}\int_0^{\tau} y(t)dt = g + \tilde{g} \quad (8)$$

Among them, $\tilde{g} \triangleq \frac{1}{\tau}\int_0^{\tau} z(t)dt \sim CN(0, \frac{N_0}{\tau} I)$, ***0***, ***I***, represents the all zero vector of size $M_t \times 1$, and the identity matrix of size $M_t \times M_t$ .At this point, the energy consumed by node equipment ER_k at this stage can be expressed as:

$$E_k^c = P_k * \tau_1 \quad (9)$$

2) Energy transfer stage: as shown in the left straight arrow in Figure 1, the energy transmitter ET sends energy to K node device ER, Specifically, $\hat{g}$ is conjugated at the receiving end of the energy transmitter. Each antenna sends a sinusoidal signal using the same carrier f_c as the beacon signal. The transmitted power is P_t . At this time, equivalent baseband transmitting signal of energy transmitter can be expressed as:

$$x = \sqrt{P_t} \frac{\hat{g}^*}{\|\hat{g}\|} \quad (10)$$

Then the signal received by each node device can be expressed as:

$$r_k = h_k^H x \quad (11)$$

$k = 1,...,K$, accordingly, the energy received by each node device is E_k , can be expressed as:

$$E_k = |r_k|^2 * \tau_2 = \frac{P_t}{\|\hat{g}\|^2} \left| \sum_{l=1}^{K} \sqrt{P_l} h_k^H h_l + h_k^H \tilde{g}^* \right|^2 \tau_2 \quad (12)$$

In this phase, the energy transfer time is τ_2 , For the sake of simplicity, we ignore the power lost by the circuit during the actual transmission.

3) Information transmission stage: as shown in the straight arrow on the right in Figure 1, the node device ER adopts the mode of air division multiple access to simultaneously send information to the information receiver IR, and the transmission time is τ_3 . It is assumed that each node device consumes its acquired energy during the information transmission phase, leaving only the next time block for the node device to transmit the energy E_k^c of the detection signal. At this point, the transmitted power ER_k of each node device can be expressed as:

$$P_k^S = \frac{E_k - E_k^c}{\tau_3} \tag{13}$$

At this point, each node device transmits data to the information receiver within the unit time transmission block. In this process, the throughput that a single node device can achieve can be expressed as follows:

$$R_k = W\tau_3 \log_2(1 + \frac{P_k^S g_k}{N_0}) \tag{14}$$

Combined with (9),(12),(13) and (14), it can be further concluded that:

$$R_k = W\tau_3 \log_2(1 + \frac{(\frac{P_t}{\|\hat{g}\|^2}\left|\sum_{l=1}^{K}\sqrt{P_l}h_k^H h_l + h_k^H \tilde{g}^*\right|^2 \tau_2 - P_k * \tau_1)g_k}{\tau_3 N_0}) \tag{15}$$

Therefore, the total system throughput achieved by all nodes within the unit time transmission block is:

$$R = \sum_{k=1}^{K} W\tau_3 \log_2(1 + \frac{(\frac{P_t}{\|\hat{g}\|^2}\left|\sum_{l=1}^{K}\sqrt{P_l}h_k^H h_l + h_k^H \tilde{g}^*\right|^2 \tau_2 - P_k * \tau_1)g_k}{\tau_3 N_0}) \tag{16}$$

4. PROGRAMMING PROBLEM

In order to maximize the system throughput R, we need to allocate time for beacon signal time τ_1, energy transmission time τ_2 and information transmission time τ_3. Without loss of generality, the sum of single transmission fast time is 1. Considering the service quality of single node equipment, the following problems are planned:

$$Max \qquad R = \sum_{k=1}^{K} W\tau_3 \log_2(1 + \frac{(\frac{P_t}{\|\hat{g}\|^2}\left|\sum_{l=1}^{K}\sqrt{P_l}h_k^H h_l + h_k^H \tilde{g}^*\right|^2 \tau_2 - P_k * \tau_1)g_k}{\tau_3 N_0}) \tag{17}$$

$$S.t \ \ \tau_1 + \tau_2 + \tau_3 = 1 \tag{18}$$

$$R_k \geq R_{\min} \ \ (k = 1......K) \tag{19}$$

$$\tau_1, \tau_2, \tau_3, P_t, P_k, P_k^S > 0 \tag{20}$$

$R_{\min}$ represents the minimum throughput of node devices. (19) Constraints indicate that the throughput of any node device in the system must be greater than or equal to the minimum throughput requirements to ensure the service quality of node devices.

4.1. Analysis and solution of optimal solution

In order to solve make it easier to solve, we let $\tau_2 + \tau_3 = m$. According to the convex optimization theory, it can be concluded that the system throughput R is a strictly concave function about τ_2 in the domain $[0,1]$. And it has a maximum in its domain. The simulation assistant is set here to prove this conclusion. Simulation parameters are set as： M_t =120, Power of beacon signal emitted by node device P_k =0.2W, The transmitted power of ET is P_t =2W. τ_1 =0.1s, α =3. Noise power spectral density is N_0 =-55 dBm/Hz.

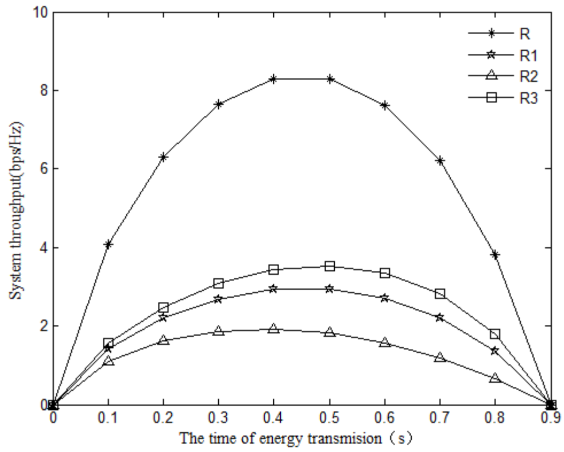

Figure 3. The relationship diagram of energy transfer time and system throughput

Here, nine node devices are set up in the simulation, which are divided into three groups R_1, R_2, R_3 .There are three nodes in each group. R_3 is 4-6 meters away from the energy base station and 100 meters away from the information base station. R_1 is 9~11 meters away from the energy base station and 95 meters away from the information base station. R_2 is 13~15 meters away from the energy base station and 90 meters away from the information base station. According to Figure 3, it can be proved that the system throughput is a concave function of τ_2 and has a maximum value. Therefore, the original problem can be transformed into a standard convex optimization problem, and the objective function becomes:

$$Min \qquad R = -\sum_{k=1}^{K} W\tau_3 \log_2(1+\frac{A_k\tau_2 - B_k\tau_1}{C_k\tau_3}) \; (21)$$

$$S.t \qquad \tau_1+\tau_2+\tau_3-1=0 \; (22)$$

$$R_{\min} - W\tau_3 \log_2(1+\frac{A_k\tau_2 - B_k\tau_1}{C_k\tau_3}) \le 0 \; (23)$$

$$\tau_1,\tau_2,\tau_3,P_t,P_k,P_k^S > 0 \; (24)$$

$$(k=1......K)$$

These variables including $A_k = \frac{P_t}{\|\hat{g}\|^2}\left|\sum_{l=1}^{K}\sqrt{P_l}h_k^H h_l + h_k^H \tilde{g}^*\right|^2 g_k$, $B_k = P_x * g_k$, $C_k = N_0$. The maximum problem is transformed into a minimum standard convex optimization problem with constraints. In order to further solve, the constraint condition (22) is changed to

$$\tau_2 = m - \tau_3 \qquad (25)$$

Here $m = 1-\tau_1$ is a constant, Substitute (25) into (21) to obtain the new objective function:

$$Min \qquad R = -\sum_{k=1}^{K} W\tau_3 \log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3}) \qquad (26)$$

$$S.t \quad R_{\min} - W\tau_3 \log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3}) \le 0 \qquad (27)$$

$$\tau_1, \tau_2, \tau_3, P_t, P_k, P_k^S > 0 \qquad (28)$$

Lagrange multipliers $\lambda_k (k = 1......K)$ are introduced to solve the above convex optimization, then the Lagrange form of the objective function is as follows problems:

$$L(\tau_3, \lambda_k) = \sum_{k=1}^{K} W\tau_3 \log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3}) + \lambda_k (R_{\min} - W\tau_3 \log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3})) \, (29)$$

This paper adopts Lagrange duality method to solve the problem, so the dual function is:

$$g(\lambda_k) = \min \; L(\tau_3, \lambda_k) \qquad (30)$$

The dual problem is:

$$\max \quad g(\lambda_k) = \sum_{k=1}^{K} W\tau_3 \log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3}) + \lambda_k (R_{\min} - W\tau_3 \log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3})) \, (31)$$

According to the convex optimization theory, (26) and (27) are convex functions, and the dual gap is zero, which meets the strong dual condition. Therefore, the solution of the original function is the solution of the dual function. The duality function is solved below. According to the Karloch-Kuhn-Tucker (KKT) condition, the partial derivative of τ_3 is obtained:

$$\frac{\partial L(\tau_3, \lambda_k)}{\partial \tau_3} = \sum_{k=1}^{K} W[\log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3}) - \frac{A_k m + B_k\tau_1}{(A_k(m-\tau_3) - B_k\tau_1 + C_k\tau_3)In2}]$$

$$+\lambda_k W[\log_2(1 + \frac{A_k(m-\tau_3) - B_k\tau_1}{C_k\tau_3}) - \frac{A_k m + B_k\tau_1}{(A_k(m-\tau_3) - B_k\tau_1 + C_k\tau_3)In2}] \qquad (32)$$

Let $\frac{\partial L(\tau_3, \lambda_0, \lambda_k)}{\partial \tau_3} = 0$, get out:

$$\lambda_k^* = \frac{\sum_{k=1}^{K} [\log_2(1 + \frac{A_k(m-\tau_3^*) - B_k\tau_1}{C_k\tau_3^*}) - \frac{A_k m + B_k\tau_1}{(A_k(m-\tau_3^*) - B_k\tau_1 + C_k\tau_3^*)In2}]}{[\log_2(1 + \frac{A_k(m-\tau_3^*) - B_k\tau_1}{C_k\tau_3^*}) - \frac{A_k m + B_k\tau_1}{(A_k(m-\tau_3^*) - B_k\tau_1 + C_k\tau_3^*)In2}]} \qquad (33)$$

τ_3^* and λ_k^* are the optimal solutions of the original problem and the dual problem. On this basis, the maximum value of $g(\lambda_k)$ can be calculated by combining the golden section method. That is to calculate the maximum throughput of the system, the algorithm table for solving the maximum throughput of the system is proposed here.

Table 1. Table of time allocation and throughput algorithms

1）Calculate m with given τ_1 ,
2）Initialize $\tau^{low}=0, \tau^{up}=m$,
1. $\tau_3^a=\tau^{low}+0.382*(\tau^{up}-\tau^{low})$
2. $\tau_3^b=\tau^{low}+0.618*(\tau^{up}-\tau^{low})$
3.Compute $\bar{\lambda}_{k1}, \bar{\lambda}_{k2}$ by substituting τ_3^a and τ_3^b into (33)
4.Compute $\bar{g}_1$ by substituting τ_3^a and $\bar{\lambda}_{k1}$ into (31)
5.Compute $\bar{g}_2$ by substituting τ_3^b and $\bar{\lambda}_{k2}$ into (31)
6.if $\bar{g}_1<\bar{g}_2$, let $\tau^{up}=\tau_3^b$, else $\tau^{low}=\tau_3^a$ 。
3)if $\tau^{up}-\tau^{low}\le\varepsilon$, let $g(\lambda_k)=(\bar{g}_1+\bar{g}_2)/2$, $\tau_3^*=(\tau^{up}+\tau^{low})/2$, otherwise go to step 1, until $\tau^{up}-\tau^{low}\le\varepsilon$

4.2. Complexity Analysis

In this paper, the maximum throughput and the allocation of each time slot per unit time block are obtained by Lagrange duality method combined with golden Section algorithm, namely the algorithm in Table 2, whose complexity is approximately $O(n\log N)$.Under the condition of maintaining the same accuracy, compared with references [4], [5]($O(n\wedge k)$) and [3]($O(n^2)$), the complexity of the algorithm in this paper is greatly reduced, and the convergence effect can be achieved more quickly, so as to quickly calculate the beacon signal detection time, energy transmission time and the allocation of information transmission time, thus improving the system performance.

5. SIMULATION RESULTS

Simulation results demonstrate the excellent performance of the proposed retrodirective matrix method based on phase conjugation in wireless power communication networks. In order to better highlight the performance of the proposed scheme, a comparative analysis is made with the traditional wireless power supply network scheme [3], the scheme based on time inversion [4] and the scheme based on NOMA [5]. As shown in Figure 4, the simulation analyzes the influence of the energy transmitter ET transmitting power on the system throughput, where the simulation parameter is set as,

$M_t=40$, $P_k=P_{\max}=0.1W$, $\tau_1=0.05s$, $f_c=910MHz$, $W=20kHz$,

$N_0=-55\,\mathrm{dBm/Hz}$, $\alpha=3$,

The system contains nine nodes. Their relative positions are as follows:

$r_1=d_1$ ranges from 4 to 6 meters. $r_2=d_2$ ranges from 9 to 11 meters. $r_3=d_3$ is in the range of 13 to 15 meters. Three nodes are randomly placed in each range. In order to compare simulation parameters uniformly, energy transmitter and information receiver are placed together. It can be seen from the figure that as the power of the energy transmitter increases, the system throughput of the retrospective matrix method based on phase conjugate and all other schemes increases accordingly. However, when the power of energy transmitter is the same, the throughput of the backtracking array based on phase conjugate is greater than that of other schemes, and the throughput of the scheme in this paper, the scheme based on time inversion and the scheme based on NOMA are all greater than that of the traditional scheme. It is proved that the system throughput can be improved by increasing ER transmitting power in practical application.

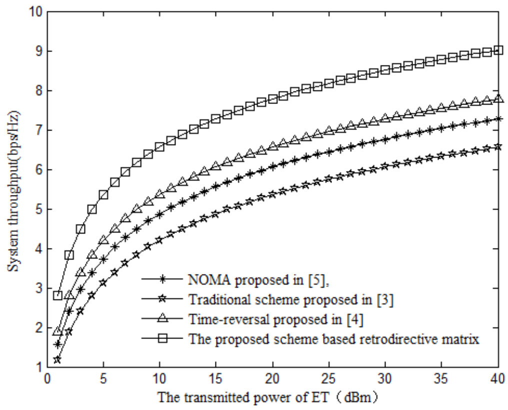

Figure 4. The relationship diagram of transmitted power and system throughput

As shown in Figure 5, the simulation studies the influence of different positions of node equipment on system throughput. It should be noted that node equipment is between energy transmitter and information receiver. $P_t = 30dBm$, A node device is set up in the simulation, and the energy transmitter and the information receiver are placed separately. $d_1 = 80$. As can be seen from the figure, when the distance from the energy transmitter is less than 4 meters, the throughput of the transmission scheme based on NOMA is slightly higher than that of the proposed scheme and other schemes at the same distance. When the distance is beyond 4 meters, the throughput of the proposed scheme is greater than that of other schemes with the increase of the distance. It is proved that the proposed scheme has a wider coverage and better robustness.

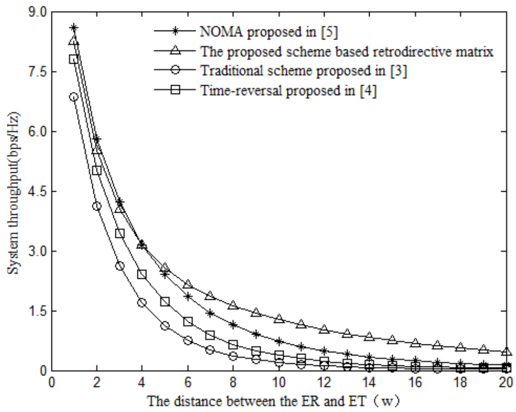

Figure 5. The relationship diagram of the location of node devices and system throughput

As shown in figure 6, the simulation research of antenna number influence on system throughput, because this article scheme and is based on NOMA scheme adopts large-scale MIMO antenna array, the traditional solutions and based on the time reversal USES a single antenna, so it can be seen in the picture increase number of traditional antenna scheme and had no effect on the solution of inversion based on time, Here, 9 node devices are set, and the relative positions of nodes are the same as in simulation figure 5.As can be seen from the figure, it can be noted that,

$P_t = 30dBm$, when the number of antennas is the same and both are greater than 10, the system throughput of the scheme proposed in this paper is greater than that of other schemes. As the number of antennas increases, the throughput of both the proposed scheme and the NOMA scheme increases, but the growth rate gradually slows down. Therefore, the throughput of the system can be increased by increasing the number of antennas of the energy transmitter, and the appropriate number of antennas can be selected considering the cost.

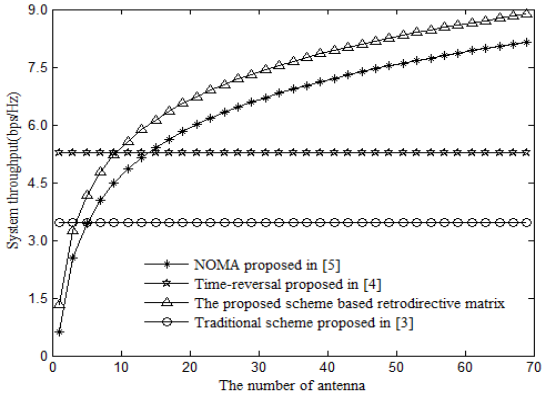

Figure 6. The relationship diagram of the number of antennas and system throughput

As shown in Figure 7, the simulation studies the relationship between beacon signal power transmitted by node equipment and the respective throughput of each node. Consider nine node devices, of which three are in a group, and the first group is in a relative position: r_1 ranges from 4 to 6 meters, $d_1 = 80$. The second group of relative positions: r_2 ranges from 9 to 11 meters, $d_2 = 75$. The relative position of the third group: r_3 is in the range of 13 to 15 meters, $d_3 = 70$.

As can be seen from the figure, under the same beacon signal power, the throughput of the node device close to the energy transmitter is higher. With the increase of beacon signal power, the throughput of all three node devices increases, but the increase of R_1 is obviously larger than that of R_2 and R_3, that is to say, the node device closer to the energy transmitter is more sensitive to beacon signal power transmitted by the node device. Therefore, the throughput of the system can be increased by increasing beacon signal power as much as possible.

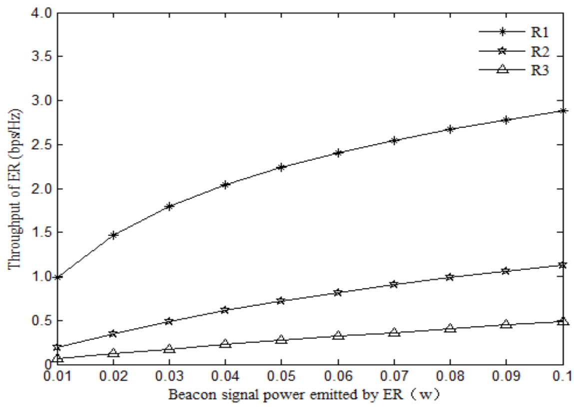

Figure 7. The relationship diagram of the node device transmits beacon signal power and the node harvests energy

As shown in figure 8, the simulation research is the influence of channel attenuation index of system throughput, can see from the picture, with the increase of channel fading index, all solutions achieve throughput decreases, on the same channel fading coefficient, based on the time inversion scheme to realize the throughput of the plan and this article is higher than other schemes, At the same time, the scheme based on time inversion is higher than the scheme in this paper, because the scheme based on time inversion adopts the time inversion technology, uses the channel reciprocity to focus the signal and restrains the interference in the information transmission stage at the same time, showing good adaptability in different environments. As the channel fading index increases, the system throughput decreases in all schemes. When $\alpha \geq 5$, as the channel attenuation index continues to increase, the throughput gap achieved by the scheme in this paper, the scheme based on time inversion and the scheme based on NOMA is not obvious. As the channel attenuation index continues to increase, the throughput decreases sharply, which can no longer meet the service demand. Therefore, in the area of low signal attenuation, the proposed scheme can achieve higher throughput than other schemes based on time inversion.

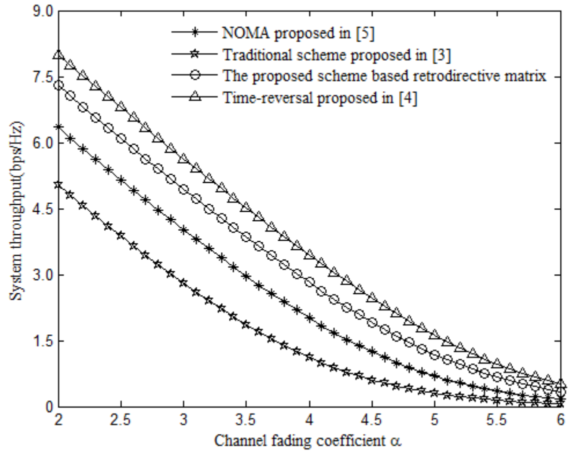

Figure 8. The relationship diagram of channel fading coefficient and system throughput

6. CONCLUSION

Improve traditional wireless power supply network model, this paper studied on the basis of the principle of phase conjugate wireless power supply network, adopt the way of energy transmitter and receiver information segregated, increases the system coverage, transmitter using MIMO antenna arrays, and the energy in the energy transfer process to generate directional beam, node equipment node equipment gain energy gain, This increases node device and system throughput. This paper also studies the maximization of system throughput under the condition of ensuring the minimum throughput of each node device, and uses the generalized Lagrange multiplier method combined with the golden section algorithm to solve the value of maximum throughput and the time allocation of each slot. This scheme has the advantages of flexible installation and low complexity of equipment. Various wireless sensor networks are suitable for indoor wireless charging in the future, such as sensors used to monitor temperature, humidity, pressure, soil ph and other data in agricultural greenhouse planting, and sensors used to monitor noise in industrial indoor. At the same time, the system energy efficiency is also an important indicator of wireless power supply network, which needs further research in the future.

ACKNOWLEDGEMENTS

This work is supported by Program for Changjiang Scholars and Innovative Research Team in University (IRT_16R72).

REFERENCE

[1] BI Suzhi, ZENG Yong, ZHANG Rui. "Wireless powered communication networks: An overview. IEEE Wireless Communications", 2016, 23(2): 10-18.

[2] BI Suzhi, HO C K, ZHANG Rui. "Wireless powered communication: Opportunities and challenges". IEEE Communications Magazine, 2015, 53(4): 117-125.

[3] JU H, ZHANG Rui. "Throughput maximization in wireless powered communication networks". IEEE Transactions on Wireless Communications, 2014, 13(1): 418-428.

[4] LI Fangwei, WU Yue, NIE Yifang, et al. "Time allocation and optimization in time-reversal wireless powered communication networks". International Journal of Antennas and Propagation, 2020, 2020: 1-8.

[5] SONG D, SHIN W, LEE J, et al. "Sum-throughput maximization in NOMA-based WPCN: A cluster-specific beamforming approach". IEEE Internet of Things Journal, 2021, 8(13): 10543-10556.

[6] MIAO Jiansong, WANG Pengjie, ZHANG Qian, et al. "Throughput maximization for multi-UAV enabled millimeter wave WPCN: Joint time and power allocation". China Communications, 2020, 17(10): 142-156.

[7] PARK J, LEE H, EOM S, et al. "UAV-aided wireless powered communication networks: Trajectory optimization and resource allocation for minimum throughput maximization". IEEE Access, 2019, 7: 134978-134991.

[8] ZENG Yong, CLERCKX B, ZHANG Rui. "Communications and signals design for wireless power transmission". IEEE Transactions on Communications, 2017, 65(5): 2264-2290.

[9] YANG Gang, HO C K, GUAN Yong liang. Dynamic resource allocation for multiple-antenna wireless power transfer. IEEE Transactions on Signal Processing, 2014, 62(14): 3565-3577.

[10] ZENG Yong, ZHANG Rui. "Optimized training design for wireless energy transfer. IEEE Transactions on Communications", 2015, 63(2): 536-550.

[11] KASHYAP S, BJÖRNSON E, LARSSON E G. "On the feasibility of wireless energy transfer using massive antenna arrays". IEEE Transactions on Wireless Communications, 2016, 15(5): 3466-3480.

AUTHORS

Bo Li received the B.S. degree from Shanxi Institute of Engineering and Technology, China, in 2018. Currently studying for a master's degree in Chongqing University of Posts and Telecommunication. His major is information and communication engineering. His research interest covers Internet of Things and wireless power communication network.

Hong Tang received the B.S.degree from Sichuan University, China, in 1990 and Dr. degree from Chongqing University, China ,in 2003. He is currently a professor at Chongqing University of Posts and Telecommunications. His research interests include key technologies and implementation of mobile Internet.