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Transmit Antenna Selection for Dual Polarized Channel Using Singular Value Decision

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ABSTRACT

In this paper, we focus on the potential of dual polarized antennas in mobile system. Thus, this paper designs exact dual polarized channel with Spatial Channel Model (SCM) and investigates the performance for certain environment.

Using proposed the channel model; we know estimates of the channel capacity as a function of cross polarization discrimination (XPD) and spatial fading correlation. It is important that the MIMO channel matrix consists of Kronecker product dividable spatial and polarized channel. Through the channel characteristics, we propose an algorithm for the adaptation of transmit antenna configuration to time varying propagation environments. The optimal active transmit antenna subset is determined with equal power allocated to the active transmit antennas, assuming no feedback information on types of the selected antennas.

We first consider a heuristic decision strategy in which the optimal active transmit antenna subset and its system capacity are determined such that the transmission data rate is maximized among all possible types. This paper then proposes singular values decision procedure consisting of Kronecker product with spatial and polarize channel. This method of singular value decision, which the first channel environments is determined using singular values of spatial channel part which is made of environment parameters and distance between antennas, level of correlation. Then we will select antenna which have various polarization type. After spatial channel structure is decided, we contact polarization types which have considerable cases

It is note that the proposed algorithms and analysis of dual polarized channel using SCM (Spatial Channel Model) optimize channel capacity and reduce the number of transmit antenna selection compare to heuristic method which has considerable 100 cases.

Key Words : MIMO system, dual polarization, SCM, singular values, Kronecker product, transmit antenna selection, channel capacity

Ⅰ. Introduction

Spatial multiplexing achieves the best performance in rich scattering MIMO channel in which transmit and receive antennas are subject to uncorrelated fading. In many practical situations, however, MIMO channels exhibit correlation due to small antenna spacing and poor scattering conditions. Previous studies have shown that the performance of spatial multiplexing(SM) can be substantially degraded depending on the level of correlation. But SM with dual polarized antennas as performing better than spatial multiplexing such as dense urban, high correlation existed environments. Therefore, we should be aware that we have to select antennas including only SM or with dual polarization to maximize data transmission rate for varying channel conditions.

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This paper is organized as follows. We outline the channel model for an SM system with dual polarized antennas, channel characteristics are expressed using dual polarized channel in certain environments, a heuristic decision strategy and a singular value decision procedure using system capacity with MMSE receiver are proposed to select the active transmit antenna configuration in Section ?. Section ? simulation method and conditions are represented. In Section ?we use this measure to show proper antenna types and selection via simulations. Section ?concludes the paper.

Ⅱ. Channel model

2.1 SCM Channel Model

Recently, due to the increased interest in intelligent antennas and space time coding techniques, the spatial dimension of the wireless channel has received more attention. Antenna performance prediction requires modeling the spatial dimension of the mobile channel, new spatial models have been formed which add the effect of angular spreading [2]. The various parameters are represented in Table 1.

Table 1. SCM Parameters

Ω	Antenna array orientation
$\theta_{AoD,AoA}$	LOS Angle of Departure & Arrival direction
$\theta_{n,m}$	Absolute Angle for m sub-path of n path
δ_n	Angle for n path
$\Delta_{n,m}$	Offset for m sub-path of n path
V	Velocity vector
θ_V	Angle of velocity vector

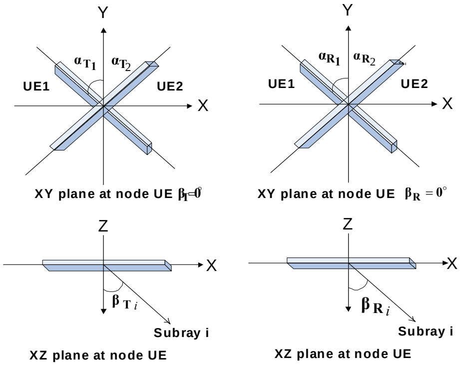

Fig. 1. Dual-polarized antennas

2.2 Daul polarization channel model

The dual-polarization channel model essentially extends thesingle-polarization model by allowing each ray to be depolarization by the scattering environment. This is illustrated in Figure 1, where the rays generated in the typical single-polarization scenario are reflected at different polarization than they were originally transmitted.It is considered that the dual-polarized system illustrated in Figure 1. It consists of MS array consists of a pair of antenna elements installed in the XY plane slantwise relative to the vertical direction at angles of α_{T1} and α_{T2} , respectively. Some examples of typical dual-polarized antennas are the slant 45° configuration ($\alpha_{T1}=-45°$ vertical pol and $\alpha_{T2}=45°$ horizontal pol). For sub-ray k that is transmitted from the jth transmit antenna via the transmitting polarization ($h_{ij,k}$), the contribution at the kth receive antenna is computed by first decomposing the sub-ray into its vertical and horizontal components as follows:

$$h_{ij,k,V}=h_{ij,k}\cos(\alpha_{Tj}) \tag{1}$$

$$h_{ij,k,H}=h_{ij,k}\sin(\alpha_{Tj}) \tag{2}$$

This is similarly done for the orthogonal polarization ($h_{ij,k,\perp}$) as follow:

$$h_{ij,k,\perp,V}=h_{ij,k}\cos(\alpha_{Tj}-\pi/2) \tag{3}$$

$$h_{ij,k,\perp,H}=h_{ij,k}\sin(\alpha_{Tj}-\pi/2) \tag{4}$$

where the $\perp$ indicates the contribution of the identical sub-ray in the orthogonal polarization to the transmit polarization. At the ith receive antenna, the contribution of this sub-ray to the composite channel between the antennas j and i is then added based on own receive orientation, and the impact of the angle of arrivals at MS and BS are included. This is performed as follows:

$$\begin{aligned} h_{ij,k,total} &= (h_{ij,k,V}+h_{ij,k,\perp,V})\cos(\alpha_{Ri}) \\ &+(h_{ij,k,H}+h_{ij,k,\perp,H})\sin(\alpha_{Ri})\cos(\beta_{Tk})\cos(\beta_{Rk}) \end{aligned} \tag{5}$$

2.3 Combined channel model with spatial and polarization

In this section we will see the combined channel model with polarization and spatial elements.

The fading behaviors between the cross polarized elements will be a function of the per-ray spreads and the Doppler. The fading between orthogonal polarizations has been observed to be independent and therefore the sub-rays phases are chosen randomly. The propagation characteristics of V-to-V paths are assumed to be equivalent to the propagation characteristics of H-to-H paths. The equations of channel coefficients add on polarization are described as and Figure 2 shows the effect of dual polarization extended from SCM.

$$
\begin{aligned}
h_{i,j}^{Pol}(t) = {} & \sum_{m=1}^{M} R_m e^{\left\{j2\pi(f_d \cos(\theta_{n,m,AoA}-\theta_v)t\right\}} \times \\
& e^{\left\{-f\tau_m - f d_{R_i} \sin(\theta_{n,m,AoA})/c - f\ d_{T_j} \sin(\theta_{n,m,AoD})/c\right\}} \times \\
& \left[\begin{array}{l}
\left(\cos(\alpha_{T_k}) + \cos(\alpha_{T_k} - \pi/2)\right)\cos(\alpha_{R_l}) \\
+\left(\cos(\alpha_{T_k}) + \cos(\alpha_{T_k} - \pi/2)\right)\sin(\alpha_{R_l})\cos(\theta_{n,m,AoA})\sqrt{r_1} \\
+\left(\sin(\alpha_{T_k}) + \sin(\alpha_{T_k} - \pi/2)\right)\sin(\alpha_{R_l})\cos(\theta_{n,m,AoD})\cos(\theta_{n,m,AoA}) \\
+\left(\sin(\alpha_{T_k}) + \sin(\alpha_{T_k} - \pi/2)\right)\cos(\alpha_{R_l})\cos(\theta_{n,m,AoD})\sqrt{r_2}
\end{array}\right]
\end{aligned}
\tag{7}
$$

i and j denote the index of MS and BS, k and l indicate Vertical or Horizontal/ Slant -45/+45 degree and r_1 and r_2 are related with the cross polarization discrimination (XPD), d_T, d_R distance between the antennas and f_d is Doppler frequency.

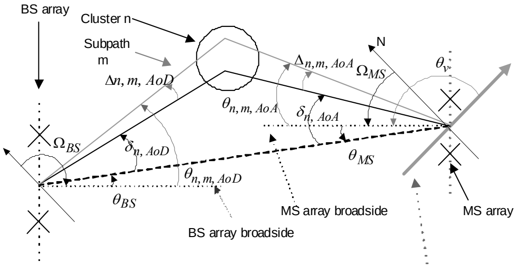

Fig. 2. SCM applied dual polarization

2.4 Capacity with MMSE receiver

The rate allocation method among transmit branches derived from [2] which achieves the capacity with MMSE receiver. Here we assume that transmit power devoted to each antenna $P_m = \frac{P_T}{M}$, is pre-determined. The capacity of the ith antenna can be expressed in terms of the channel matrix, the transmit power of each branch and instantaneous SNR for certain channel environments. The process is parameterized by a set of projection vectors $F_m (m=1,\ldots,M)$ and cancellation vectors $B_{m1}, B_{m2}, \ldots, B_{mm}$ $(m = 1,\ldots, M-1)$, all of them of dimension $N \times 1$. In decoding the mth transmit antenna signal, interference from the $m-1$ already decoded signals is subtracted from y by applying the proper cancellation vectors. The optimal cancellation vectors are given by $B_{(m-1)j} = h_j$ and the projection vectors admit the expression

$$F_m = \left(\mathbf{H(m+1)P(m+1)H(m+1)^H} + \boldsymbol{\sigma}^2 I\right)^{-1} \mathbf{h_m} \tag{8}$$

Furthermore, the transmit rate of the mth antenna can be expressed as

$$C_m = \log_2\left(1 + \mathbf{P_m h_m^H} \cdot (\mathbf{H}(m+1)\mathbf{P}(m+1)\mathbf{H}(m+1)^H + \sigma^2 \mathbf{I_N})^{-1}\mathbf{h_m}\right) \tag{9}$$

and it was proved in [3],[4] that

$$\sum_{m=1}^{M} C_m = \log_2 \det\left(\sigma^2 \mathbf{I_N} + \mathbf{HE[xx^H]H^H}\right) \tag{10}$$

2.5 Antenna selection algorithm

Transmit antenna selection actually correspond to propagation environment. For environment, the change of channel can be performed by decomposing into spatial and polarization part. The state of channel is determined by singular value decomposition (SVD) of instantaneous varying channel. In this section we can show that four reasons to select transmit antenna with maximum capacity. First, channel is divided spatial and polarized channel. Second, the relation of two channels is Kronecker product. Third, each singular values product of spatial channel and polarized channel represent origin channel state. In the last, the structure of transmit antenna determine the quantity of channel capacity.

A, B, C and D are denoted polarization properties with slanted $+45^\circ/-45^\circ$

$$A = -\sqrt{2}\cos(-45^\circ)\cos(\theta_{AoD})\sqrt{r_{n2}}\,e^{j\Phi^{(v,h)}} + $$
$$-\sqrt{2}\sin(-45^\circ)\cos(\theta_{AoD})\cos(\theta_{AoA})e^{j\Phi^{(h,h)}}$$
$$B = \sqrt{2}\cos(-45^\circ)e^{j\Phi^{(v,v)}} + \sqrt{2}\sin(-45^\circ)\cos(\theta_{AoA})\sqrt{r_{n1}}\,e^{j\Phi^{(h,v)}}$$
$$C = -\sqrt{2}\cos(+45^\circ)\cos(\theta_{AoD})\sqrt{r_{n2}}\,e^{j\Phi^{(v,h)}} + $$
$$-\sqrt{2}\sin(+45^\circ)\cos(\theta_{AoD})\cos(\theta_{AoA})e^{j\Phi^{(h,h)}}$$
$$D = \sqrt{2}\cos(+45^\circ)e^{j\Phi^{(v,v)}} + \sqrt{2}\sin(+45^\circ)\cos(\theta_{AoA})\sqrt{r_{n1}}\,e^{j\Phi^{(h,v)}} \tag{11}$$

$$h_{vv\_11} = A$$
$$h_{vv\_12} = A \times e^{jkd_T \sin(\theta_{AoD})} \times e^{jk\|v\|\cos(\theta_{AoA}-\theta_v)t}$$
$$h_{vv\_21} = A \times e^{jkd_R \sin(\theta_{AoA})} \times e^{jk\|v\|\cos(\theta_{AoA}-\theta_v)t}$$
$$h_{vv\_22} = A \times e^{jkd_T \sin(\theta_{AoD})} \times e^{jkd_R \sin(\theta_{AoA})}$$
$$\times e^{jk\|v\|\cos(\theta_{AoA}-\theta_v)t} \tag{12}$$

h_{11}, h_{12}, h_{21}, h_{22} are expressed spatial properties with referenced position and Φ denotes the phase offsets. Thus, we can represent the Kronecker product of spatial part and polarized part.

$$\mathbf{H_P} \otimes \mathbf{H_S} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \otimes \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \tag{13}$$

Let $\sigma_{P_1},\cdots,\sigma_{P_m}$ be the singular values of the $m \times m$ matrix $\mathbf{H_P}$, and let $\sigma_{S_1},\ldots,\sigma_{S_p}$ be the singular values of the $p \times p$ matrix $\mathbf{H_S}$. Then we have

$$|\mathbf{H_P}| = \prod_{i=1}^{m} \sigma_{P_i}, \quad |\mathbf{H_S}| = \prod_{j=1}^{p} \sigma_{S_j} \tag{14}$$

$$|\mathbf{H_P} \otimes \mathbf{H_S}| = \prod_{j=1}^{p}\prod_{i=1}^{m} \sigma_{P_i}\sigma_{S_j} = \prod_{i=1}^{m} \sigma_{P_i}^{p}\left(\prod_{j=1}^{p}\sigma_{S_j}\right)$$
$$= \prod_{i=1}^{m} \sigma_{P_i}^{p}|\mathbf{H_S}| = |\mathbf{H_S}|^m\left(\prod_{i=1}^{m}\sigma_{P_i}\right)^p$$
$$= |\mathbf{H_S}|^m|\mathbf{H_P}|^p \tag{15}$$

If we have considerable three cases, the equations are represented as

$$\textbf{(Selected k)}\left|H_{\mathbf{P_k}} \otimes H_{\mathbf{S_k}}\right| = \prod_{k=1}^{p}\prod_{k=1}^{m} \sigma_{P_k}\sigma_{S_k}$$
$$\textbf{max}\left\{|H_{\mathbf{S1}}|^{\mathbf{m}}|H_{\mathbf{P1}}|^{\mathbf{p}}, |H_{\mathbf{S2}}|^{\mathbf{m}}|H_{\mathbf{P2}}|^{\mathbf{p}}, |H_{\mathbf{S3}}|^{\mathbf{m}}|H_{\mathbf{P3}}|^{\mathbf{p}}\right\} \tag{16}$$

Therefore, considerable cases are shown Figure 3 and Figure 4. In thinkable cases, we can select maximum determinant value of Kronecker product for spatial and polarized channel.

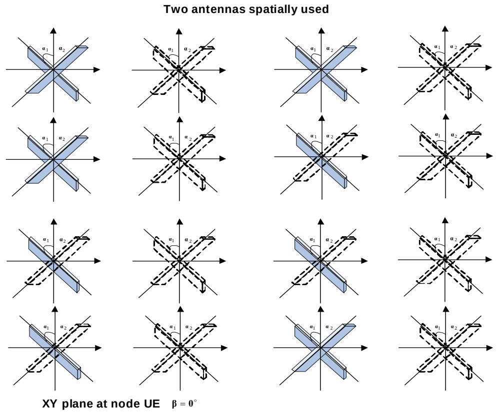

Fig. 3. Transmit antenna type used two antenna spatially

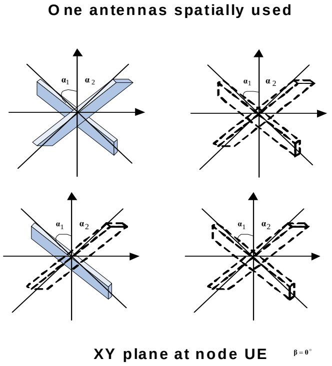

Fig. 4. Transmit antenna type used one antenna spatially

Ⅲ. Simulation setup

3.1 Environment setup

In this paper, it is set from different two environments: Urban-Micro line-of-sight (LOS), Urban-Micro non-line-of-sight (NLOS). Generally it is classified into the following conditions. Parameters are shown in [1].

3.2 Simulation

As a measure of performance, the average (ergodic) capacity is used. When the transmission of QPSK modulated signal is assumed and the transmitter has no knowledge for channel is applied. Also, Transmission system use spatial multiplexing (SM) scheme. For all examined propagation conditions, simulation results are presented for $M_T = M_R = 2$ spatially, if dual polarized antennas are considered the number of antennas is defined $M_T = M_R = 4$ and the time samples is 1000 seconds.

Ⅳ. Simulation results

4.1 Capacity for transmit antenna type

It is shown that graphs described in Figure 5-6are presented the types of proper transmit antennas are in better position for various time varying channel environments [5]. Where, Figures denotes S1 and S2 are used spatial multiplexing consist of one or two antenna configuration spatially. And SP1 and SP2 are applied spatial and polarized multiplexing schemes with dual polarized antennas.

Figure 5-6's second row are described that high XPD values have performance gain for capacity differently Figure 5-6's first row. Especially, For NLOS environments, Figure 6 expresses the pure spatial using two antennas spatially separated multiplexing has more gain compare to combine multiplexing using one antenna spatially. Namely, for Urban Micro LOS and NLOS environments combined scheme using spatial and polarization is advantageous and as the level of correlation is loose, that is, antennas distance is wide, the spatial multiplexing strategy exerts effectively.

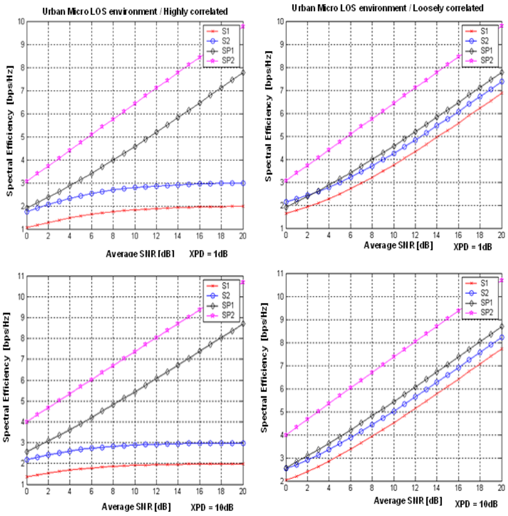

Fig. 5. Antenna types in urban micro LOS environment

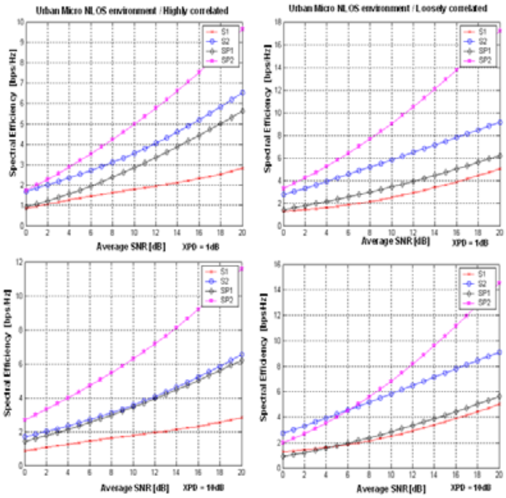

Fig. 6. Antenna types in urban micro NLOS environment

4.2 Performance of antenna selection algorithm

We consider an MMSE SM system. The average capacity is used as a performance measure and is obtained by averaging a large number of random capacity variables computed in every channel realization. The closed loop MIMO capacity is the maximum rate achievable by transmitting over the channel and by allocating power by water-filling solution. The open loop MIMO capacity is the maximum rate achieved by transmitting over the channel and by allocating equal power.

Where, Figures denotes 'Optimal' is used heuristic method. And Proposed is applied SVD algorithm, 'Close' marks capacity applying water-pouring algorithm of which transmitter knows channel and 'Open' presents capacity of which transmitter did not know channel condition.

Linear arrangement of the antenna array is assumed at the transmitter and receiver with the spacing of two cases $d_T = 0.5\lambda$ and $d_R = 0.5\lambda$ or $d_T = 10\lambda$ and $d_R = 10\lambda$ which correspond to highly correlated channels and loosely correlated channels, respectively, at the transmitter end [6].

Using singular values of channels, the spatial channel was first determined by environment parameters. Then we can select the number of antennas. Spatially, if the number of antenna is decided we can make the available combination about polarizations. It is fact that the available cases are made by fewer events which are considerable. It is known that the case of loosely correlated channels decrease effects of XPD. Figure 8 describes that the higher correlation and XPD, the better performance is obtained in Urban Micro NLOS environment. But the loosely correlated parts have problem which is lower than open loop capacity under high averaged SNR. For Urban Micro LOS propagation environment, refer to Figure 7, it can be seen that polarization multiplexing systems can hardly be separated, resulting in high XPD required. Also the curves of capacity linearly increase because the heuristic decision and proposed algorithm is only determined by polarization combinations. It is important that proposed algorithm curves approached the heuristic method. It reduces the calculation complexity.

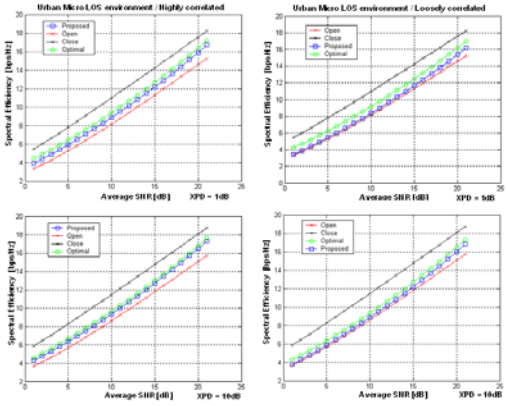

Fig. 7. Antenna selection in urban micro LOS environment

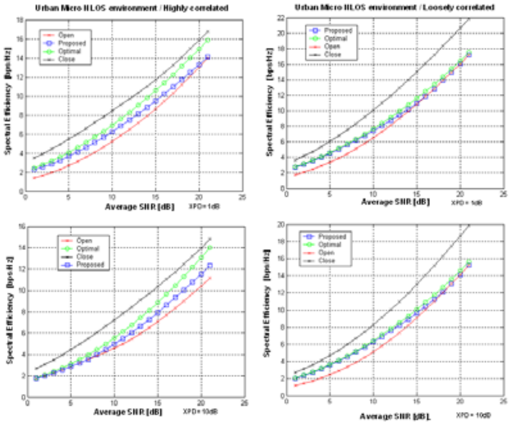

Fig. 8. Antenna selection in urban micro NLOS environment

Ⅴ. Conclusion

In this paper, it first focused on designing the combined channel model with spatial and dual polarization using SCM. That a high XPD results in a trade off between reduced ability to exploit polarization on the one hand, and an increased orthogonal property among MIMO sub-channels due to the polarization preservation on the other hand.

For channel environments, applying highly correlated fading channels, the disadvantage of losing channel energy is minor than an increased channel orthogonal characteristic when increasing XPD in the Urban Micro NLOS case. Also it is known that higher correlation and XPD, the better performance is obtained in Urban Micro NLOS environment. But the loosely correlated parts have problem which is lower than open loop capacity under high averaged SNR. For Urban Micro LOS propagation environment, it can be seen that polarization multi-plexing systems can hardly be separated, resulting in high XPD required.

Through the designed channel this study was presented by the Kronecker product of spatial and polarization channels. So this paper proposed choosing a low complexity algorithm for an active transmit antenna subset and its system capacity to be maximize. A singular value decision procedure that simply if the channel environment is determined it can first get singular values of spatial channel part which is made of environment parameters and distance between antennas that is, the level of correlation. Then this method will select antenna which have either spatially one or two.

After spatial channel structure is decided, it contacts polarization types which have considerable cases. Then the capacity are determined by transmit antenna polarization type.

Therefore, proposed procedures have to select maximum determinant value of Kronecker product for spatial and polarization channel. The results showed that the proposed decision procedure approached to the heuristic capacity in which the optimal active transmit antenna subset and its system capacity are determined such that the transmission data rate is maximized over all possible antenna subsets and that induces a negligible capacity loss compared with the heuristic decision strategy for researched environments. That is, It is important that proposed algorithm curves approached the heuristic method. It reduces the calculation complexity.

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