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A Simulation Based Distributed MIMO Network Optimisation using Channel Map

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Abstract— Channel map is an essential tool in network planning and optimisation. In this work, we present an example of MIMO channel map for distributed MIMO network optimisation. Based on the simulation of MIMO channel map, we optimise the MIMO channel capacity and the bit error rate. The results demonstrate that the effectiveness of the MIMO channel map in network optimisation.

1. INTRODUCTION

With the increasing demand for higher data rate communications, wireless network operators are facing the challenge of providing high quality network services. Network planning plays a key role in meeting the ever increasing demand for high data rate networks. The purpose of network planning is to deploy the network nodes in optimal locations to provide guaranteed quality of network service. The network nodes location planning relies on the channel information map which gives channel information over the physical location on a map.

A lot of research work has been focused on finding the optimal base station locations to achieve the optimal network performance. To achieve the target of optimal base station deployment, a signal coverage map over the deployment space is essential. Various candidate locations in the map are compared and the optimal one is chosen. Such a coverage map is widely used in the network planning practice. To accurately predict the channel information requires significant amount of computation and resources, hence computer-based simulation tools such as the WiSE tools by Bell Labs [1] was specially designed for planning indoor networks. The method of building such channel maps is mainly based on two deterministic channel modelling methods: finite-difference time-domain (FDTD) related models and ray based models. The work in [2] first used the name of channel map and proposed a ray tracing method for building the channel map. The work [3] proposed a computationally efficient numerical method for building the channel map. A complete review of the channel modelling in HetNet can be found in [4]. The channel map has long been widely used as an essential tool in network design. However, it still lacks a rigorous mathematical formulation thereby limiting the further application of the channel map as an essential tool in network planning, especially for MIMO network planning.

With the application of advanced wireless transmission techniques, such as MIMO, the network performance is largely improved [4]. Meanwhile, to plan networks equipped with these advanced techniques is challenging, especially due to a lack of rigorous formulation for the channel map. This limits the application and functionality of the channel map as a tool in advanced network planning, such as MIMO network planning. The purpose of the paper is to demonstrate the MIMO channel map tools for advanced MIMO network planning and optimisation.

2. AN INDOOR MIMO CHANNEL MAP

In this section, we give an example of the MIMO channel map to demonstrate its application in distributed MIMO systems. We build a distributed 2×2 MIMO channel map for a typical indoor network deployment scenario. The simulation tool for single channel map construction is the computer simulation tool presented in [3].

The simulation scenario is a typical office environment. The floor map is shown in Figure 1. The environment comprises walls, doors, windows and ceilings. The frequency is set to be 2.4GHz. The bandwidth is set to be 15kHz as one single carrier bandwidth in the long term evolution (LTE) networks. We deploy a 2×2 distributed MIMO system in the environment.

For the purpose of demonstration, we only choose one set of locations to deploy the 2 distributed transmitter antennas. The transmitter locations are marked in Figure 1. The simulated channel amplitude maps and channel phase maps are shown in Figure 2 and Figure 3, respectively.

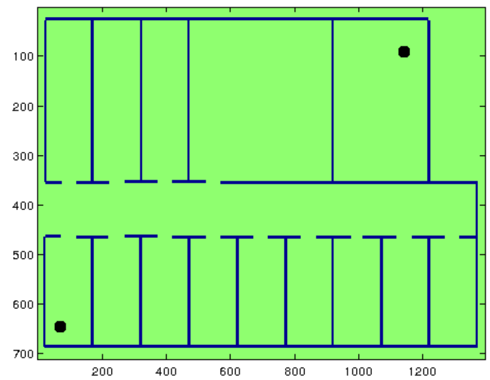

Figure 1: The Transmitter Antenna Locations

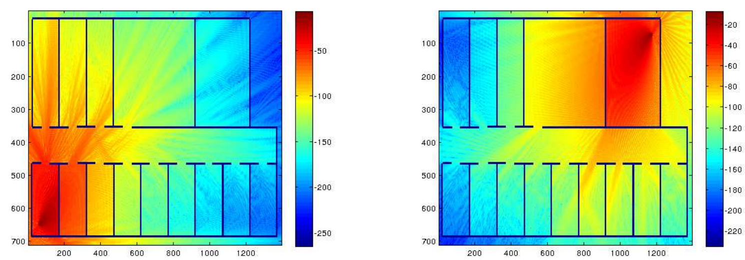

Figure 2: Channel Amplitude Map Vector

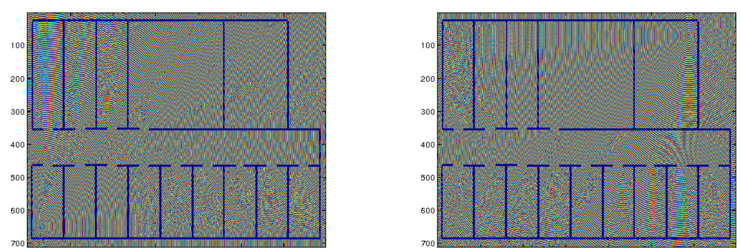

Figure 3: Channel Phase Map Vector

Although distributed receiver antennas are still rare in mobile terminals, it is a potential technique for high data rate backhaul connection. It also has the potential to be implemented in a form of cooperative networks. We first construct the channel map vector. The channel amplitude map vector generated by the simulation tool with transmitters at 2 locations is shown in Figure 2. The channel phase map vector is shown in Figure 3. We arrange the 4 channel maps to a form of channel vector.

The total number of location points in the map is 988320. The number of the total potential location vectors is $C^2_{988320} \sim 4.8839 \times 10^{11}$. It costs high computational resource to search the whole possible combinations of the receiver locations. We sample the 988320 receiver locations to choose 2000 locations as the candidate locations. Thus, the search space reduces to $C^2_{2000} = 1999000$. We generate the complete set of the receiver location vector according to the combination of the location set. Each element in the set is then applied to the channel map vector to identify the channel value as:

$$\mathbf{H}(\mathbf{L}) = \begin{bmatrix} f_1(l_1) & f_1(l_2) \\ f_2(l_1) & f_2(l_2) \end{bmatrix} \tag{1}$$

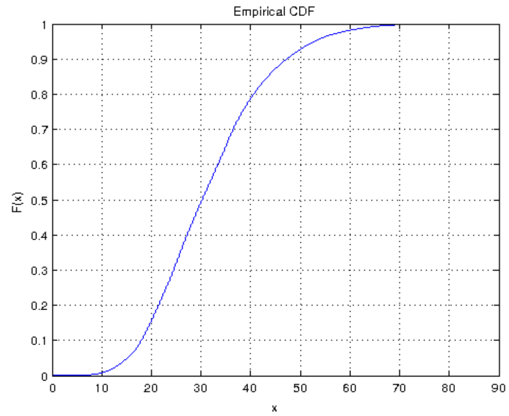

Figure 4: The CDF of Capacity in Distributed MIMO

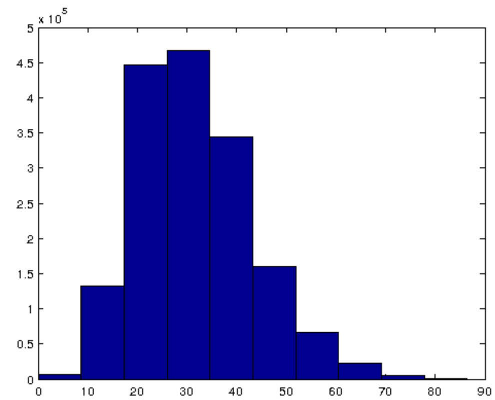

Figure 5: The PDF of Capacity in Distributed MIMO

3. CHANNEL CAPACITY OPTIMISATION

In this part, we optimise the network performance by choosing the receiver locations which achieves the maximum channel capacity.

We look up the channel matrix values in the channel map corresponding to all the receiver location vectors. The result is a table mapping from the receiver location vector to the corresponding channel matrix. In this case, the SNR at the transmitter is fixed and we then adopt the the capacity formula to calculate the capacity:

$$C = \log_2 \det(I + snrHH^*) \tag{2}$$

where H^* is the complex conjugate of the matrix H and snr is the signal-to-noise-ratio at the transmitter.

The cumulative distribution function (CDF) of the resulting channel capacity is shown in Figure 4. The probability density function (pdf) of the capacity is shown in Figure 5. The statistics of the resulting capacity values are summarised in Table 1. The mean value of the capacity is 31.5006 bits/s/Hz and the maximum value is 86.4459 bits/s/Hz. The optimal receiver antenna locations that achieve the maximum capacity are indicated in Figure 6.

Table 1: Statistics of the Capacity Values

Maximum	Minimum	Mean	Median	standard deviation
86.4459	0.0144	31.5006	30.2073	11.5412

The gain of optimally designed receiver location over a random choice of receiver locations is significant in this case. We can see that the majority of the receiver locations supports a capacity near the mean value of from 20 to 40 bits/s/Hz range. The optimal capacity value offers a nearly

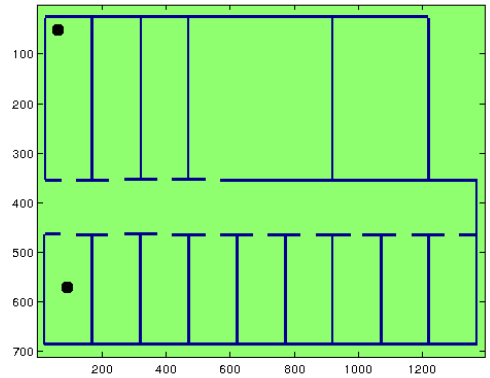

Figure 6: The Optimal Locations for Receiver Antennas

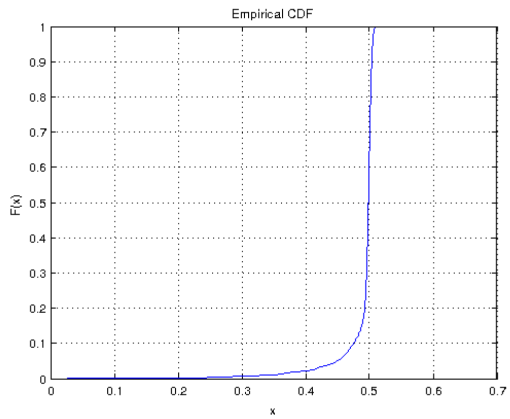

Figure 7: The CDF of Error Rate in the Distributed MIMO

3 times gain from these mostly likely receiver locations by random choice. This shows that the a significant capacity gain can be achieved by carefully choosing the locations of the distributed antennas.

4. ERROR RATE OPTIMISATION

By using the channel map generated for the distributed MIMO system, we also study the impact of receiver locations on error rate performance. We adopt the Alamouti block space time code to be used in the distributed MIMO system in our simulation. The SNR at the transmitter is set to be 10dB. We simulate the MIMO system using all the candidate channels from the candidate receiver locations. The CDF and the PDF of the error rates at all the candidate locations are given in Figure 7 and Figure 8, respectively.

The statistics of the error rate are given in Table 2. We see that by choosing the optimal locations of the receiver locations we can achieve the optimal error rate 0.0261 while the mean error rate is about 0.5, which is due to poor channel condition. The receiver antenna locations achieving this optimal error rate are indicated in Figure 9. This result shows that we can achieve good error rate performance even the the majority of the signal coverage is poor, by choosing the optimal receiver locations.

Table 2: Statistics of the Error Rate

Maximum	Minimum	Mean	Median	Standard Deviation
0.5161	0.0261	0.4906	0.4984	0.0321

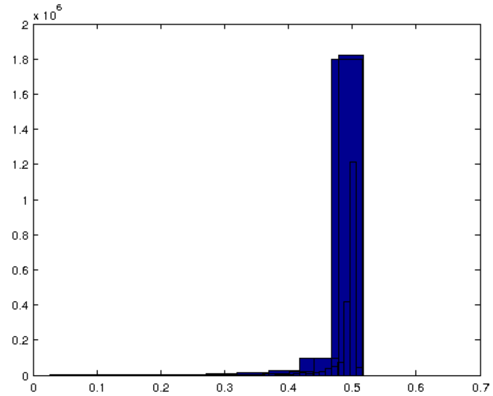

Figure 8: The PDF of Error Rate in the Distributed MIMO

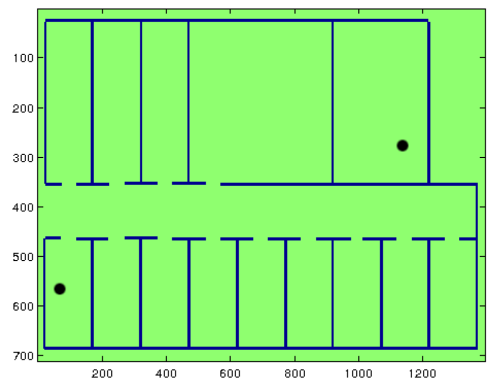

Figure 9: The Optimal Receiver Antenna Locations

5. CONCLUSION

In this paper, we give a MIMO channel map tool in network planning. Following the formulation we propose a method for constructing MIMO channel maps using existing single antenna channel map tools. The MIMO channel map extends the conventional single antenna channel map tools to advanced MIMO network planning scenarios. A numerical example is given to demonstrate the construction and application of the channel maps in MIMO network planning. The results show that the MIMO channel maps are an effective tool in MIMO network planning. Significant gains in both spectral efficiency and error rate performance are achievable by using the channel map tool to carefully plan the locations of the MIMO antennas.

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