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A small mobile communication system for communication in remote areas

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Abstract. In the age of the Internet, mobile communications have become an indispensable part of our everyday lives, let us connect with other people, get information, and participate in various activities but the communication in remote areas is still difficult due to terrain constraints and other factors. Although communication in remote areas is very important and challenging, there are also many measures and real cases exist. The article describes a small mobile communication system that can be used in remote areas and analyses its characteristics. First, the coverage area is hexagonal base stations, and I draw the distribution map of base stations and users, and then design a switching criterion to determine when a user changes the service base station during the movement. Second, the distribution is compared with the distribution of different types of base stations to study the difference in their system capacity and the effect of the number of antennas on them. to determine who is more efficient.

Keywords: Remote Area Communications, Base Station, Subscriber Rate, System Capacity, Small Mobile Communications System.

1. Introduction

In the age of the Internet, mobile communications have become an indispensable part of our everyday lives, let us connect with other people, get information, and participate in various activities. However, the benefits of mobile communication are not evenly distributed, and remote areas often suffer from limited connectivity. This essay aims to explore the challenges faced by remote areas in accessing mobile communications and the potential solutions to bridge this communication gap.

Mobile communications play a crucial role in remote areas, offering numerous benefits to both individuals and communities. Firstly, it facilitates improved access to education and healthcare. Through mobile devices, remote communities can use online learning resources and engage in virtual classrooms, and receive telemedicine services, enhancing their overall well-being. Mobile communications enable remote students to access educational content, connect with teachers, and collaborate with peers, leveling the playing field for education.

Secondly, mobile communications enable economic growth by connecting remote areas with markets, suppliers, and customers. It opens up opportunities for remote entrepreneurs, enabling them to expand their businesses and improve their livelihoods. With mobile connectivity, individuals in remote areas can access e-commerce platforms, market their products and services, and engage in online transactions, thereby increasing their economic prospects.

Lastly, mobile communications provide a vital lifeline during emergencies, allowing residents in remote areas to call for help or receive critical information during crisis situations. Mobile devices can be invaluable in disseminating emergency warnings, coordinating rescue efforts, and providing real-time updates to affected communities. Access to mobile communications can significantly improve emergency response times, thereby saving lives and minimizing the impact of disasters.

Despite the advantages, remote areas face numerous challenges in accessing mobile communications. The primary obstacle is the lack of infrastructure. Remote locations often lack cellular towers, internet connectivity, and reliable power supply, making it difficult for mobile signals to reach these areas. The cost of infrastructure deployment and maintenance is also a significant deterrent for telecommunication companies, as the low population density in remote areas may not justify the investment. Additionally, the lack of access to electricity poses a challenge, as mobile devices require a reliable power source for charging.

Moreover, the rugged terrain and geographical barriers pose significant challenges. Remote areas often have mountainous landscapes, dense forests, or vast deserts, which obstruct mobile signals and make it challenging to establish reliable connections. The installation of cellular towers becomes more complex in such areas, requiring specialized equipment and expertise. Additionally, extreme weather conditions, such as hurricanes or heavy snowfall, can damage infrastructure, further hampering connectivity and making maintenance more challenging. Besides, socioeconomic factors contribute to the communication gap in remote areas. Limited financial resources and low literacy rates in these areas often result in a lack of awareness about the benefits of mobile communications. Many individuals in remote areas may not fully understand the potential of mobile communication or have the means to afford access to these services. Additionally, the cost of mobile devices and data plans can be prohibitively expensive for individuals in remote areas, making it difficult for them to afford access to these services.

To bridge the communication gap in remote areas, various solutions can be implemented. Firstly, governments and telecommunication companies should collaborate to improve infrastructure in remote locations. This can be achieved through the construction of additional cellular towers, the installation of satellite receivers, and the expansion of internet connectivity. Governments should provide incentives to telecommunication companies to invest in remote areas by offering tax breaks or subsidies for infrastructure development. Public-private partnerships can also be formed to share the costs and benefits of infrastructure deployment.

Secondly, innovative technologies can be utilized to overcome geographical barriers. For instance, the use of drones equipped with mobile signal boosters can help establish temporary connections in remote areas. These drones can be deployed to areas where traditional infrastructure is not feasible or during emergencies to restore communication quickly. Similarly, low Earth orbit satellites can be deployed to provide reliable coverage in areas with challenging terrain. These satellites can be smaller, cheaper, and more flexible than traditional satellites, making them ideal for remote areas.

Moreover, community-based initiatives can play a vital role in bridging the communication gap. Non-governmental organizations (NGOs) and local communities can collaborate to establish community-owned mobile networks. These networks can be powered by renewable energy sources such as solar panels, reducing reliance on the main power grid. Community members can share the cost of infrastructure setup and maintenance, making mobile communications more affordable and accessible. This approach not only empowers the local community but also ensures that their specific needs and challenges are addressed. Governments should focus on raising awareness about the benefits of mobile communications in remote areas. Educational campaigns can be conducted to inform residents about the advantages of mobile communications, encouraging them to invest in mobile devices and data plans. Governments can also collaborate with telecommunication companies to offer subsidized rates for mobile devices and data plans, making them more affordable for individuals in remote areas. Additionally, digital literacy programs can be implemented to equip individuals with the necessary skills to navigate and utilize mobile technologies effectively.

Another solution is the deployment of innovative technologies specifically designed for remote areas. For instance, solar-powered mobile charging stations can be set up in strategic locations, allowing individuals in remote areas to charge their devices without relying on a stable power supply. Additionally, the development of low-cost, durable, and energy-efficient mobile devices can make them more accessible to individuals in remote areas. These devices should be designed to withstand harsh environmental conditions and have extended battery life to cater to the unique needs of remote areas.

Furthermore, partnerships between telecommunication companies and content providers can enhance the relevance and attractiveness of mobile communications in remote areas. By offering localized content, such as educational resources, agricultural information, or local news, mobile communications become more valuable to individuals in remote areas, increasing their motivation to access and utilize these services.

Mobile communications have the potential to transform the lives of individuals and communities in remote areas. However, the challenges faced by these areas in accessing mobile communications must be addressed. By improving infrastructure, utilizing innovative technologies, promoting community-based initiatives, and raising awareness, the communication gap in remote areas can be bridged. It is crucial for governments, telecommunication companies, NGOs, and local communities to work together to ensure equitable access to mobile communications for all, regardless of their geographical location. Only then can remote areas fully benefit from the advantages offered by mobile communications and participate in the digital revolution. By embracing mobile communications, remote areas can overcome isolation, unlock economic opportunities, and improve the overall quality of life for their residents.

2. The example of remote area communications

There are many ways and cases of using mobile technology to help remote areas where mobile communication is not convenient due to factors such as geography. For example, according to a report in The Times of India on 2 June 2015, India’s Minister for Women and Child Development, Maneka Gandhi, announced in New Delhi the launch of a digital education project that aims to provide women in remote areas with educational information related to health and nutrition via mobile phones. The project, initiated by the Ministry of Women and Child Development, is supported by the Indian Academy of Paediatrics, the United Nations Children’s Fund (UNICEF), Healthy Mobile Educational Videos and Vodafone mobile operators [1]. Besides,in the Melghat region, the government has allowed the use of transmission towers for transmission of high voltage cables in the integrated development projects in the region, in order to isolate the RF cables from the distance and to ground them also by taking proper safety precautions, which has resulted in a reduction in the required capex by more than 50 percent [2]. Ongoing 5G network development does not adequately address connectivity in remote and rural areas. For complementing the mobile network operator driven connectivity market to serve the underserved,it’s important to build alternative operator models that promote the establishment of locally deployed networks to serve the under-served [3]. 5G network deployments reported by Mobile Network Operators currently place little emphasis on how to connect unconnected areas, instead targeting high-demand areas. Complementing MNOs, other operator models are emerging to enable connectivity in challenging areas [4]. Maritime communications are currently limited to the use of HF/VHF radios and satellites. HF communications have been widely used for data transmission from ocean buoys to land, but they are proprietary narrowband communications [5]. VHF analog radios are commonly used for ship-to-ship and ship-to-shore communications; however, they are also narrowband and limited to voice applications [6]. Gliders commonly use satellite to transmit data collected underwater. Satellite can be used to visit the Internet on the sea, but they are proprietary, expensive and bandwidth is still limited [7]. Land-based cellular networks and Wi-Fi communications in the unlicensed 2.4 GHz and 5 GHz bands provide broadband standard wireless communications that are commonly used by unpiloted surface and underwater vehicles (when they surface), but only enable near shore operations [8]. Population density outstrip hundreds of users on square kilometer determines the profitability boundary [9], at that time, the range of recent generations (4G) and the next generation (5G) of radio access technologies (RANs) was no more than a few kilometers, in other words, a short distance from the

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optical lines and "asphalt". The density of rarely populated rural and remote areas (RRDs) varies by tens of times. Therefore, the truly indispensable non-alternative way to ensure that the economic barriers to 5G RANs in rural and remote areas are overcome is to rely on the development of a green wireless network paradigm to increase the number of effective users [10], in this case, the coverage area or air interface range of the broadband cell will increase by tens of times, approaching the fundamental limits of Shannon's spectral/power efficiency [11].

3. A program in remote area communications

The situation considered in this paper is in a partially mountainous area with a dispersed distribution of inhabitants and a limited number of base stations, where it is necessary to reasonably determine the users to be served by each base station as well as the users on the move.

3.1. Part I: Base stations with hexagonal coverage

Assume that there is a small mobile communication system A as follows: there are seven base stations in the system, each covering a hexagonal area with a radius of 2km, with 10 users uniformly distributed within each hexagon. In a time slot, each base station serves one user within its coverage area, and each user occupies 200 kHz of bandwidth. The simulation achieves the functions of user scattering, scheduling and switching of the system. The specific requirements are as follows:

(1) Draw the distribution map of base stations and users (as shown in Figure 1);

(2) Design two or more scheduling methods to determine which user is served by a base station.

(3) Design a switching criterion to determine when a user changes the serving base station during movement.

(4) Simulation to verify and analyse the effect of cell radius on system capacity.

(5) Do the users scheduled in different time slots change without the user's location changing?

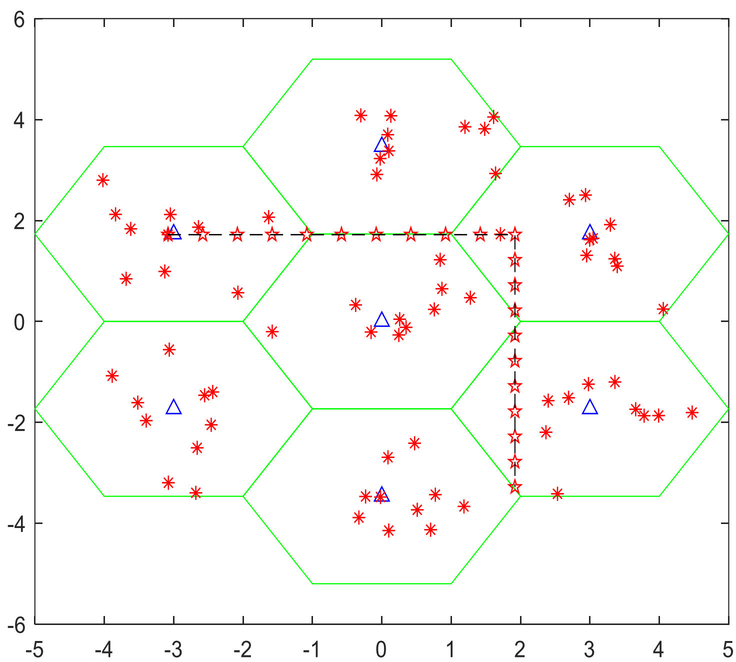

Figure 1. Distribution of users and base stations.

The blue triangle is the base station, the green hexagon is the serviceable range of the base station's customers, the red dot is the subscriber, and the red pentagram is the trajectory of one mobile subscriber.

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The system capacity is calculated as the sum of user rates:

$$C = \sum_{k=1}^{K} R_k \quad (1)$$

The user rate can be calculated with the Shannon's formula.

$$R = B * log_2(1 + SNR) = B * log_2(1 + snr * h^2) \quad (2)$$

where B is the bandwidth; SNR is the signal-to-noise ratio at transmitter side, usually given in dB (e.g. 0-20dB), need to be converted to real values; h=d^{-2}*h_0 is the channel between base stations and user; d is the distance between base station and user (unit km) and h_0 is the normal distribution with mean 0 and variance 1.

It can be obtained that the closer the user is to the base station, the larger the value of h is, so its user rate and system capacity become larger, which is consistent with the Figure 2.

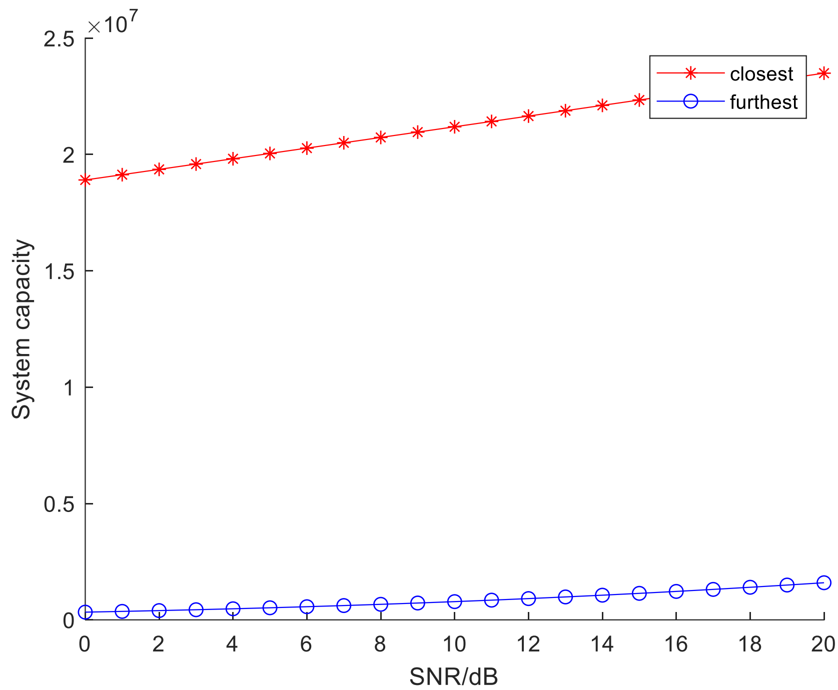

Figure 2. Effect of distance on system capacity.

Based on the movement trajectory of the red pentagram (user) in Figure 1, it can be seen that he first runs in the direction away from the base station, so his user rate is decreasing. Also according to the switching criterion, so he will choose the base station that is connected to the one that is closest to him, so in the later movement he keeps changing the base station and his user rate is fluctuating. It's consistent with Figure 3.

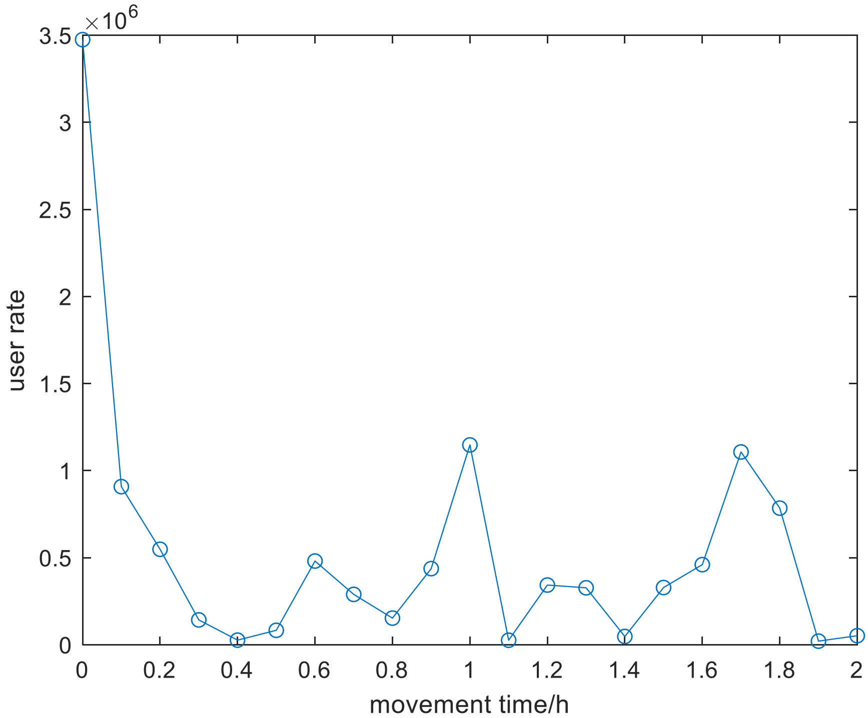

Figure 3. Variation of user rate with travel time.

As shown in Figure 4, with the cell radius increases, the randomly distributed users become more dispersed, and the more dispersed the users become the further away from the average distance of the base station, so both the user rate and the system capacity are decreasing, consistent with the image. Because the channel state is different each time, the graph is oscillating, shown in Figure 5.

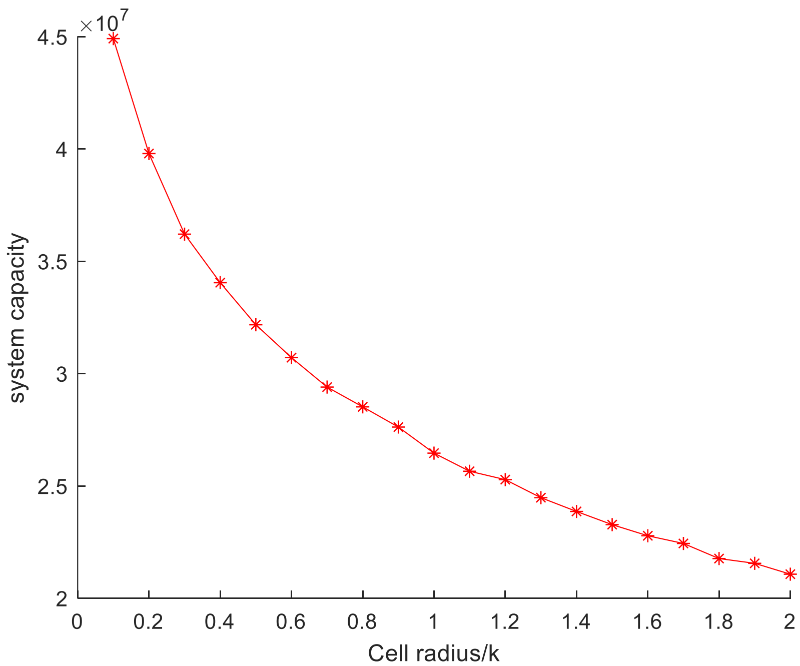

Figure 4. Impact of cell radius on system capacity.

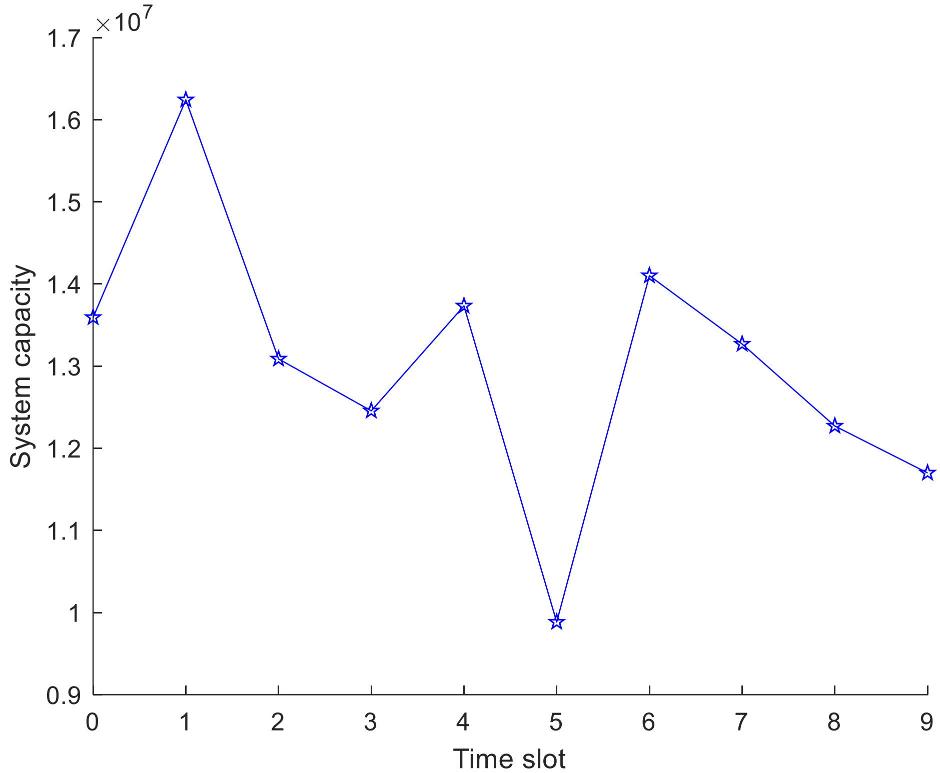

Figure 5. Impact of time slots on system capacity.

3.2. Part Ⅱ: Comparison of different types of base stations

Assume that there are the following three small multi-antenna mobile communication systems, System B: Compared with System A, each base station has four antennas, and each base station uses all of its antennas to serve a single user within its coverage area during a time slot. System C: A large-scale antenna base station with 128 antennas is deployed at the centre of a circular area with a coverage radius of 2 km, and 64 single-antenna users are uniformly distributed in the area. In one time slot, the station serves 64 users at the same time, and each user occupies a bandwidth of 200 kHz. System D: 128 single-antenna BTSs and 64 single-antenna users are uniformly distributed in a circular area with a coverage radius of 2 km (as shown in Figure 6). In one time slot, all the base stations work together to serve all the users, and each user occupies a bandwidth of 200 kHz. Project 1-2 Simulation to compare the performance of different mobile communication systems. The specific requirements are as follows:

(1) Compare the system capacity of System A and System B.

(2) The effect of the number of base station antennas in System B on the system capacity.

(3) Compare the system capacity of System C and System D.

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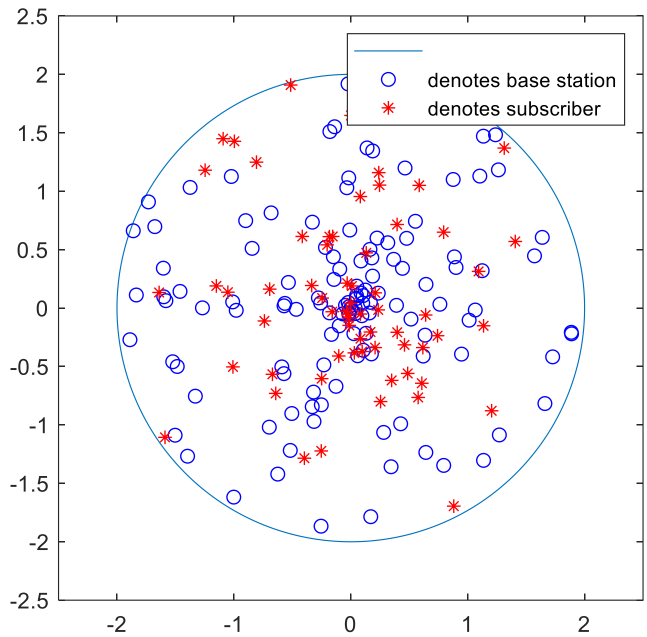

Figure 6. Distribution of 128 base stations and 64 users.

This is because System B has four antennas per base station compared to System A. In a time slot, each base station uses all of its antennas to serve one user within its coverage area. So the system capacity of System B is greater and is consistent with the Figure 7.

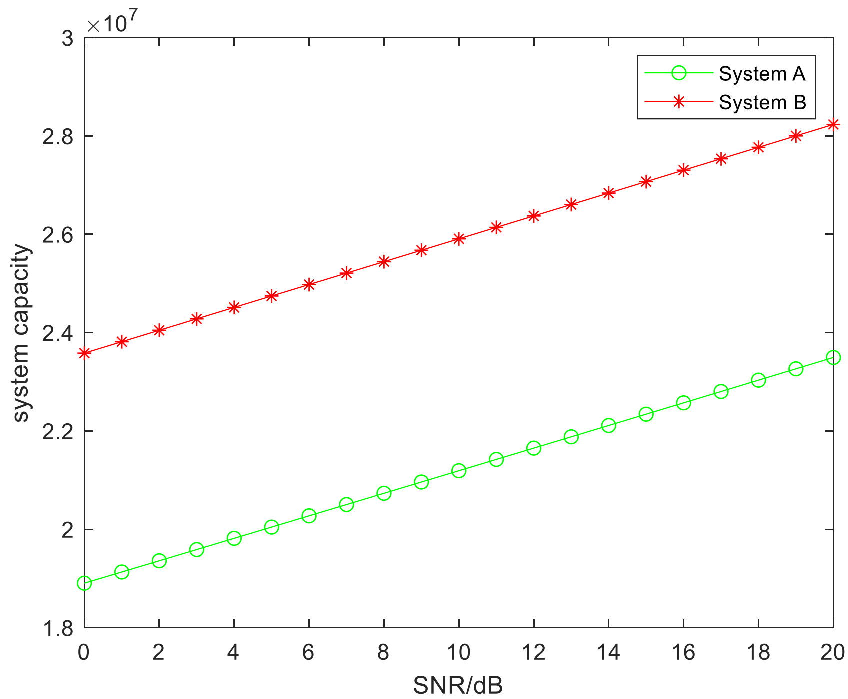

Figure 7. Comparison of System A's System Capacity and System B's System Capacity.

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As shown in Figure 8, the higher the number of base station antennas, the higher its system capacity.

From Figure 9, it can be concluded that the performance of system D is better than that of system C because the system capacity of D is larger for the same signal to noise ratio.

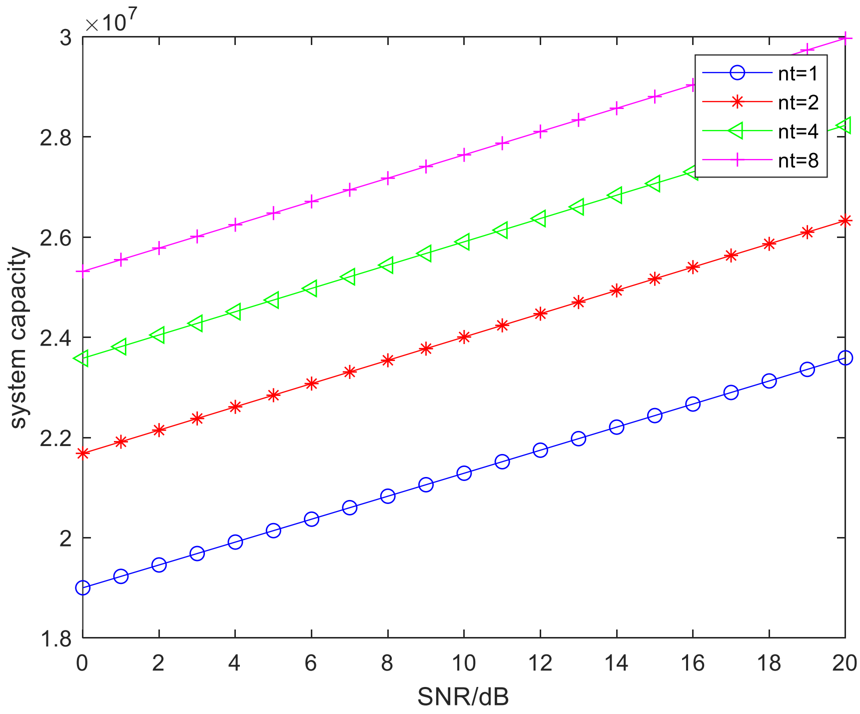

Figure 8. Link between number of antennas and system capacity.

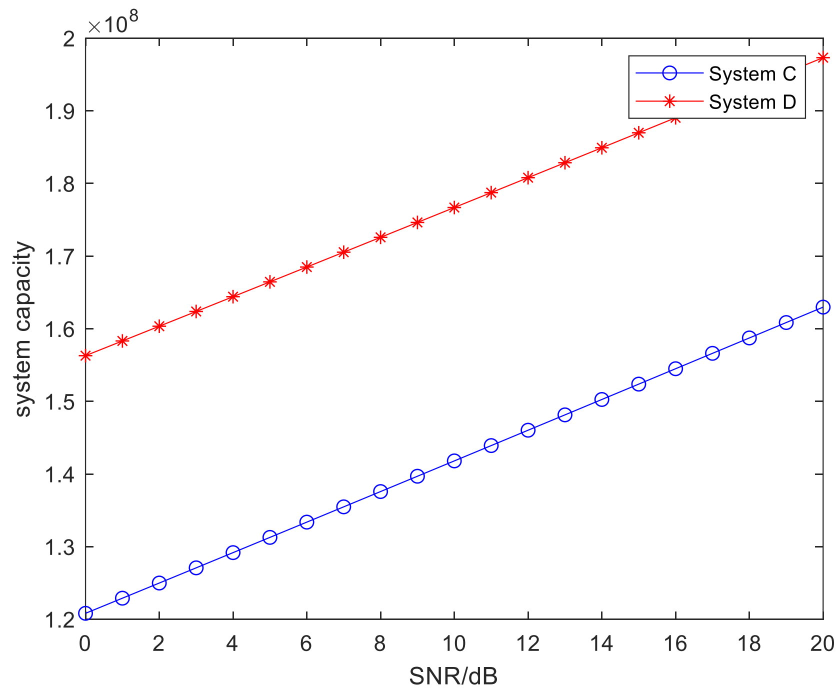

Figure 9. Comparison of System C's System Capacity and System D's System Capacity.

4. Conclusions

In order to solve the communication difficulties in remote areas due to terrain limitations and other factors, I designed a small mobile communication system. And its characteristics were analyzed. Firstly, the coverage is a hexagonal base station, I drew the distribution map of base stations and users, and then designed a switching criterion to determine when the user changes the service base station in the process of moving. Secondly, it is compared with the distribution of different types of base stations, and the differences in their system capacity and the effect of the number of antennas on them are investigated. In order to determine who is more effective.

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