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Developing Adaptive Antennas for High-Capacity Communication Systems and Tracking Multiple Cellular Phones

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***Abstract*— In the lower microwave region, researchers are looking into solutions to overcome the problem of a crowded spectrum and limited accessible bandwidth. Researchers have recently devised systems that use directional antennas to overcome the problem of restricted channel bandwidth by combining sector beams from multiple directional antenna elements. By boosting channel capacity, enhancing spectral efficiency, extending range coverage, customizing beam shapes, and allowing multiple beams to steer to detect and track numerous mobile users, this strategy increases system performance. This study assumes and discusses a strategy for creating numerous beams. The goal is to build a physical representation of the cellular phone network. It is suggested that a beam guiding algorithm be used.**
***Keywords*— steering algorithm, directed antenna, bandwidth, sector beam, spectral efficiency**

I. INTRODUCTION

A. *General Overview*

Today, the field of wireless mobile communications is the fastest growing and includes a wide range of technology areas. This has been proposed in recent years Antennas for mobile communication systems are used and developed to overcome the problem of limited channel bandwidth, thereby meeting the ever-increasing demands on communication channels for a large number of mobile phones.[1]. Numerous studies have shown that deploying arrays in cellular communication systems can improve system performance by increasing channel capacity and spectral efficiency, extending range coverage, adjusting beam shape, steering multiple beams to track multiple cellular phones, and electronically compensating for aperture distortion. multipath fading, channel interference, system complexity and cost, BER, and failure probability are also reduced. Adaptive antennas and the algorithms to control them are considered crucial for the development of high-capacity communication systems. [2].

B. *Wireless Generation*

Wireless generation is defined as changes in transmission technology and frequency bands over time, which are further divided into 1G, 2G, 3 G, 4G, and 5G. Each generation has its own characteristics, strategies, and

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strengths that make it unique. [3]. Cellular technologies range from the first generation (1G) to the fifth generation (5G) (5thG).

First-generation services include low-bit rate mobile voice and data; second-generation services include low-bit-rate mobile voice and data; third-generation services include high volume data movement; fourtnnnnnnnnnnnn services include high-speed technology and high mobility fifth-genennnnnn services Businesses include high bandwidth, large coverage mobile communication systems.

C. *Types of antenna and classifying*

Several types of antenna designs have been proposed in recent years, each with different mobile communication performance gains. [4]. The I/O port type is the most basic way to classify antennas. Single-input single-output (SISO) antennas are easy to design and implement. The size of a single crystal antenna must be large to produce high gain. [5]. In the frequency band above 6 GHz, the signal suffers severe propagation loss and service degradation. The other is multiple-input multiple-output (MIMO), which allows the use of multiple antennas to intelligently transmit multiple signals, significantly increasing channel capacity. For MIMO, the strategy to reduce the number of antennas is to use multi-band antennas that cover a variety of wireless applications. [6]. MIMO is a more advanced technique that addresses the shortcomings of SISO. Compared to SISO, MIMO achieves better bit error rate (BER), provides higher data rates by transmitting multiple data streams/symbols simultaneously, and improves coverage. MIMO is the vision of non-line-of-sight (NLOS) communications and the solution for multipath propagation. MIMO is also more efficient in terms of spectral efficiency and capacity. According to the literature, another important classifition technique can be based on the type of antenna suitable for 5G applications: • Monopole: A monopole consists of a straight microstrip line of length /4, where the wavelength is the resonant operating frequency of the antenna. antenna. Several variants have been proposed in the literature, which modify the basic structure into different shapes, such as cones, spirals, etc., depending on the use and requirements. [7, 8]. Dipole antenna: cocansists of two straight microstrip lines, each with a length of λ/4, fed between the two microstrip lines. So, the total length of the dipole antenna is λ/2 [9, 10]. MIMO antennas can also be classified as broadband antennas or multi-band antennas according to their frequency bands. Metal trimmed multi-element antennas and non-metallic trimmed multi-element antennas are two types of broadband and multi-band antennas. Cell phones benefit from the mechanical strength and aesthetic appearance of metal edge antennas. Also, for compact devices, a MIMO antenna with higher isolation is recommended for higher transmission rates [11] 3GPP Release 15 in 2019 introduced a non-standalone (NSA) 5G alternative that enables dual connectivity of LTE and 5G New Radio (NR) communication channels. For control plane and redundancy. Use LTE service and mm Wave 5G connectivity for high-speed data transfer.

As a result, there is now a range of networking options, each with its own antenna requirements and technology. Considering the increased air loss and proportionally narrow antenna design, beamforming and MIMO are considered necessary for 5G services to work in the mm Wave range. MIMO is gaining traction as a way to support large numbers of concurrent users and machine-to-machine communications within a cell, placing a new set of requirements on antenna systems and base station infrastructure.[12].

II. DIRECTIONAL ANTENNAS

Cell phone frequency reuse mode. Cell towers often use directional signals to improve reception in high-traffic areas. In the United States, the Federal Communications Commission (FCC) limits omnidirectional cell tower signals to 100 watts of power. The FCC allows cell phone carriers to transmit up to 500 watts of effective radiated power (ERP) if the tower has a directional antenna. The original cell tower produces a stable omnidirectional signal, is in the center of the cell, and is omnidirectional, and the cell map can be redrawn with the cell tower at the corners of the hexagon where the three cells meet. Each tower has three sets of directional antennas, pointing in three different directions, 120 degrees per cell (360 degrees in total), and receiving/transmitting to three different cells on different frequencies. This provides at least three channels and three towers per cell and greatly increases the chance of receiving a usable signal from at least one direction. The numbers in the figure are the channel numbers repeated every 3 cells. For high volume areas, large cells can be subdivided into smaller cells. Cellular companies also use this directional signal to improve reception along highways and in buildings such as stadiums and arena [13].

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III. MOBILE PHONE NETWORK

The most common example of a cellular network is a cellular (cellular) network. A cellular phone is a portable telephone that receives or makes calls through a base station (base station) or cell tower. Radio waves are used to transmit signals between cell phones. Modern cellular networks use cells because radio frequencies are a limited shared resource. Base stations and cell phones change frequencies and use low-power, computer-controlled transmitters, allowing many callers to use a usually limited number of radio frequencies simultaneously with less interference. Cellular operators use cellular networks to provide coverage and capacity to their users. Larger geographic area is divided into smaller cells to avoid line-of-sight signal loss and support a high number of active calls within the area. All cell sites are connected to telephone exchanges (or switches), which in turn are connected to the public switched telephone network.in cities, each cell site may have a range of up to approximately 1⁄2 mile (0.80 km), while in rural areas, the range could be as much as 5 miles (8.0 km). It is possible that in clear open areas, a user may receive signals from a cell site 25 miles (40 km) away. Since almost all mobile phones use cellular technology, including GSM, CDMA, and AMPS (analog), the term "cell phone" is in some regions, notably the US, used interchangeably with "mobile phone". However, satellite phones are mobile phones that do not communicate directly with a ground-based cellular tower but may do so indirectly by way of a satellite.

A. *Structure of the mobile phone cellular network*

A simple view of the cellular mobile radio network consists of the following:

A network of radio base stations that form the base station subsystem. The core circuit-switched network to handle voice and text calls. A packet-switched network to manage mobile data. The public switched telephone network to connect subscribers to the larger telephone network. This network is the basis of the GSM system network. There are many functions that this network performs to ensure customers get the desired service, including mobility management, registration, call setup, and handover. Any phone connects to the network through an RBS (radio base station) in a corner of the corresponding cell which, in turn, connects to the mobile switching centre (MSC). The MSC provides a connection to the public switched telephone network (PSTN). The link from a phone to the RBS is called an uplink while the other way is termed downlink. Radio channels effectively use the transmission medium through the use of the following multiplexing and access schemes: frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and space division multiple access (SDMA).

B. *Cells types*

Base stations are broadly divided into the following categories

1- Macro cells –towers, masts and poles providing wide are coverage less than 2 Kilometres

2- Micro cells – small antenna at street level providing local area coverage

3- Pico cells – very small antennas providing dedicated coverage spots. Picocell less than 200 meters

4- In Building Systems – Small antenna inside a building providing dedicated coverage around 10 meters

C. *Cell size*

Table (1) shows the dependency of the coverage area of one cell on the frequency of a CDMA2000 network.

TABLE I.

CELL PARAMETERS

Frequency (MHz)	Cell radius (km)	Cell area (km2)	Relative Cell Count
450	48.9	7521	1
950	26.9	2269	3.3
1800	14.0	618	12.2
2100	12.0	449	16.2

D. *Physical model*

Actually, a planning cells are irregular, but for simplicity a circular shape used to represent the cells. Fig. 1 shows the physical model of three adjacent cells. Each Cell has a sector antenna with a maximum beam width of 120 degrees as in Fig. 2. Each antenna is an array antenna with a beam steering capability

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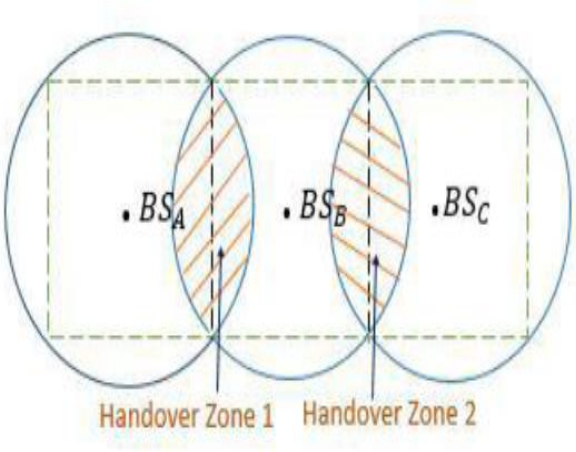

Fig. 1. The physical model

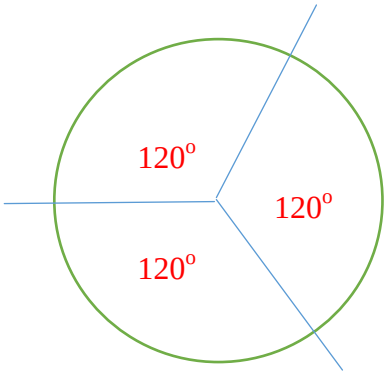

Fig. 2. Sector antenna coverage in each cell

The model can be considered as a rectangle with a length of 2Km for each cell. Thus, the three cells together have a window of 6Km, and width 2Km, which, represent in Fig. 3.6 in the x-axis and y-axis, and assuming that the number of users in each cell vary according to three scenarios; low traffic, medium traffic and high traffic.

IV. Mathematical Model

Two diminution coordination system considered at the beginning of the simulation windows as in Fig. 3 The top view of the simulation area applied to visualize the mobile terminal distribution. The mobile location is generated randomly according to uniform random distribution within the interval [0-6000] for the horizontal position (x-axis) and [0-2000] for vertical position (y-axis).

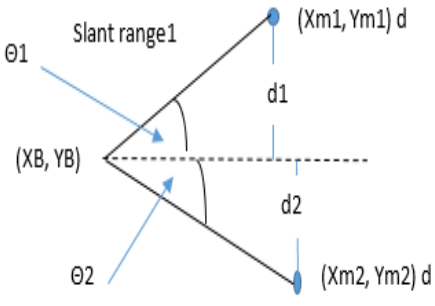

Fig. 3. Geometrical view

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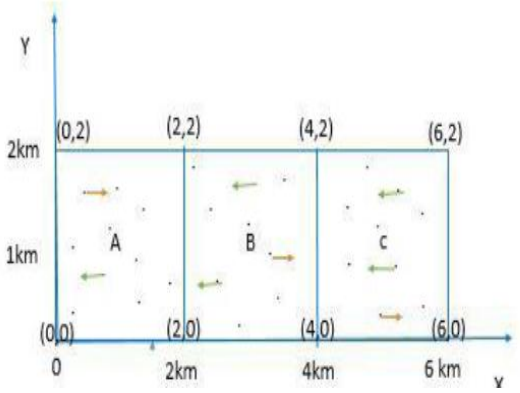

Fig. 4. Simulation window layout

The traffic generated randomly, connection holding time and connection starting time are generated according to Poisson distribution, with two different mean value (λ_1, λ_2). sites for mobile users in a specific area and generate access times for calls to the mobile phone. Poisson distribution use to predict the random-access times for calls to random variables in discrete time periods. Poisson distribution gives the number of arrivals in the fixed period (t) and the average value (λt).

$$P(\mathrm{x},\mathrm{t}) = \frac{(\lambda t)^x}{x!} e^{\lambda t} \quad (1)$$

The trigonometry applied for the beam width calculation. Consider a certain sector in one of the eNodeB station and let us calculate the require beam width for their coverage. Assume that the coordination of the eNodeB is (X_B, Y_B) the first mobile coordination is $(X_{m1}, \mathrm{Y}_{m1})$ and the second mobile coordination is $(X_{m2}, \mathrm{Y}_{m2})$. Fig. 3 shows this arrangement. So, the distance between the eNodeB and first mobile, which called the slant range 1 can be determine by the following equation:

$$\text{Slant rang1} = \sqrt{(\mathrm{X}_B - X_{m1})^2 + (\mathrm{Y}_B - Y_{m1})^2} \quad (2)$$

$$d_1 = |Y_{m1} - Y_B| \quad (3)$$

$$\theta_1 = \sin^{-1} \frac{d_1}{slantrange1} \quad (4)$$

In a similar way the slant ranges 2, d_2 and the angle θ_2 can be calculated. The optimum beam width to cover those two active mobiles can be determined by adding $\theta_1$and θ_2. This summation can be called the angle between mobiles θ_m.

V. PERFORMANCE OF SECTOR ANTENNA DURING LOW TRAFFIC LOAD

In the base station with 120-degree coverage, thus three antennas are required for circular coverage 360 degree. Fig.5 shows the random distribution of the mobile terminals within the cell coverage at the intimal time, that is when the simulation time is zero. The average inter arrival was 20 second, assuming that it is a city area. Fig.6 shows the arrival time, which is the cumulative sum of the inter arrival. Fig.7 shows the random distribution of the holding time with an average value of 180 second.

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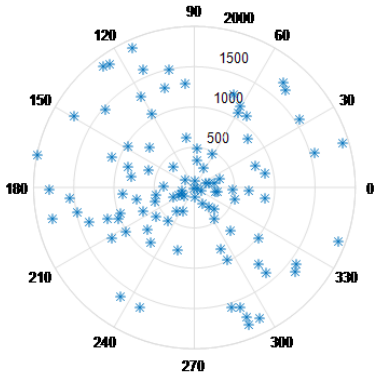

Fig. 5. Initial Position of the mobile terminals

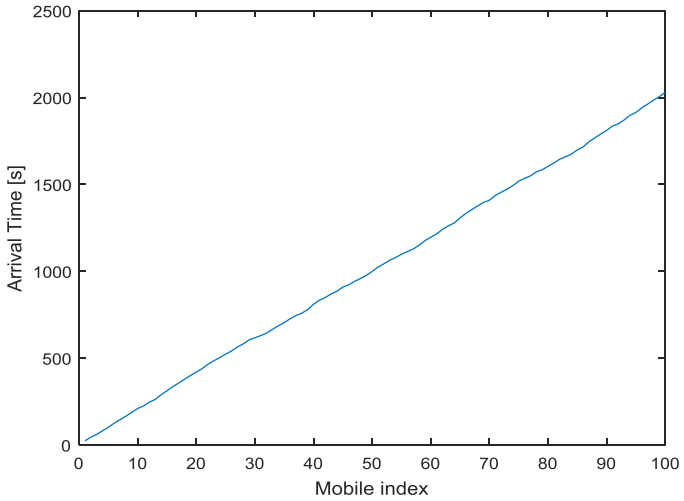

Fig. 6. Arrival time of the calls in seconds

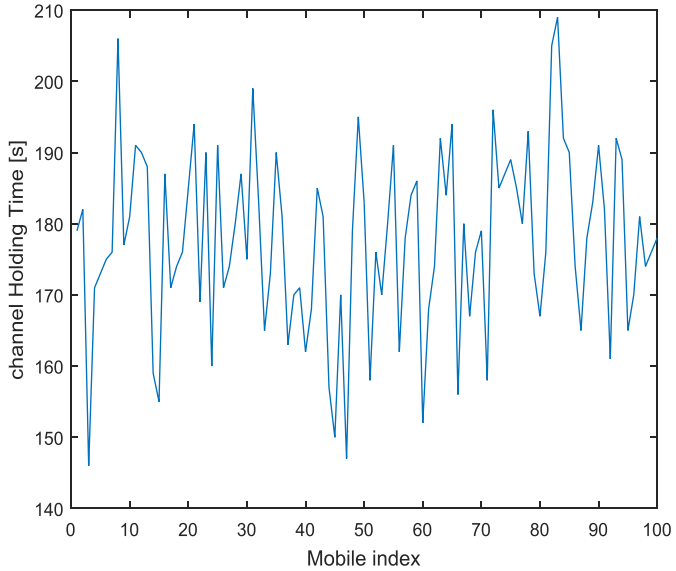

Fig. 7. The calls holding time in seconds

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The channel in each sector is 24 and each sector identified by a certain channel type. Sector one has a channel of type one, sector two has a channel of type two and sector three has a channel of type three. If the mobile idle, then the channel type by default is zero. Fig.8 shows the histogram of the channel types, and it can be noted that there is a large number of the type zero channels and this due to the short period of the simulation 300 seconds.

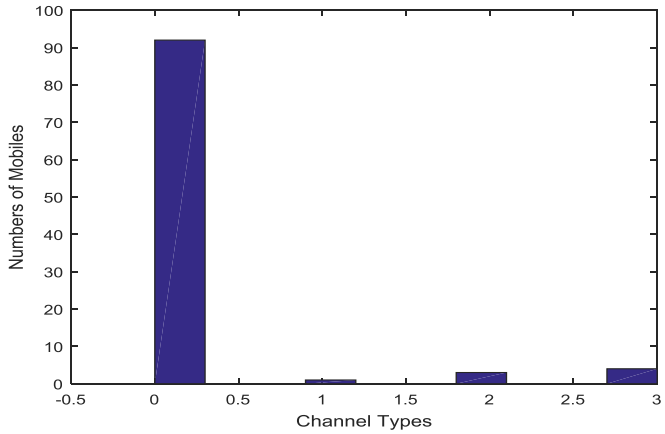

Fig. 8. Histogram of the channels types

Fig.9. shows the number of available channels at the end of the simulation in each sector. Fig.10 shows the number of the handover request in each sector, which is executed on the available channels of the sector. There is no handover failure and also there was no new call blocking.

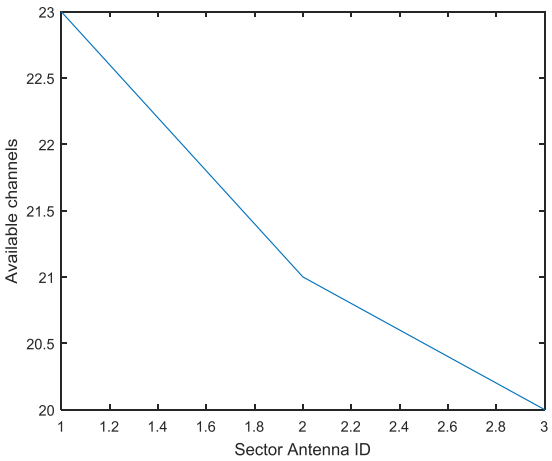

Fig. 9. Numbers of the Available channels

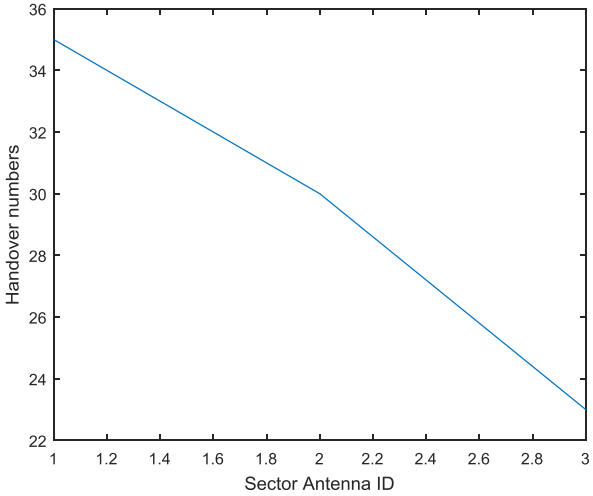

Fig. 10. Numbers of the executed handover

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TABLE II.

THE FINAL POSITION OF THE MOBILES

ID	MA	MD
1	293.3854	602.3
2	197.0153	1483.3
3	204.1986	378.3
4	337.6669	1379
5	104.6199	371.8
6	266.2376	732.8
7	274.7247	1252.4
8	137.069	1560.3

Table 4.1 shows the active mobile parameters such as (ma) which stand for the mobile angle or direction of the arrival of the mobile signal and (md) mobile distant in meters from the base station antenna. Fig.11 shows the mobile status zero indicates the number of the idle mobiles, one indicates the active mobiles, 2 indicated the new call failure, three indicate the numbers of the mobiles which finished their calls during the simulation time returned the channels, four indicates the number of the mobile moved outside the cell coverage area and 5 indicates the number of the handover failure.

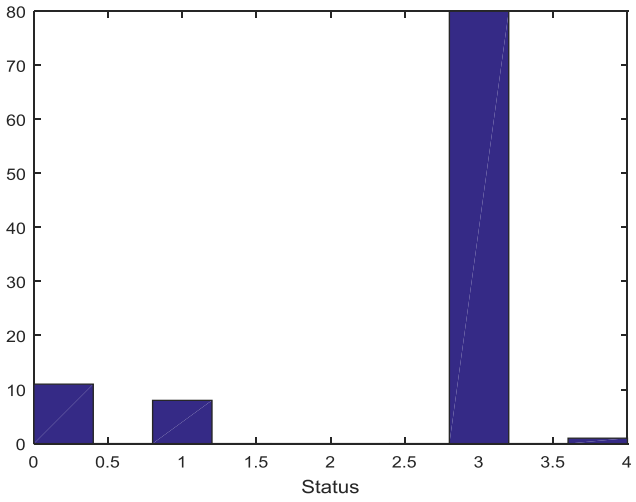

Fig. 11. Mobile status in scenario one

A. *Scenario two high traffic load*

In the second scenario the traffic increased by reducing the average inter arrival time to ten second and the call duration is increased to 1800 second. The simulation time is set to 1800 second. Fig.12 shows the mobile distribution at the begin of the simulation time. Fig.13 shows the cumulative sum of the inter arrival. Fig.14 shows the call duration for all mobiles with an average value of 1800 second.

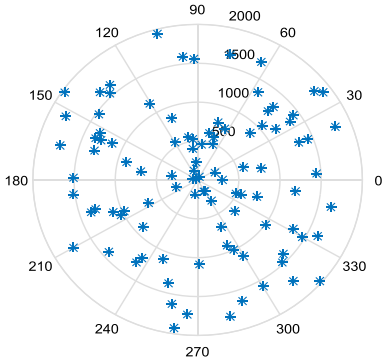

Fig. 12. The mobile distribution in the second scenario

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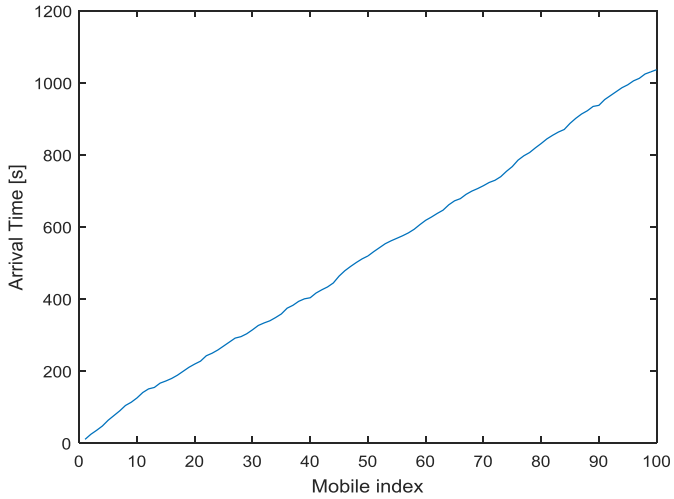

Fig. 13. Cumulative sum of the inter arrival

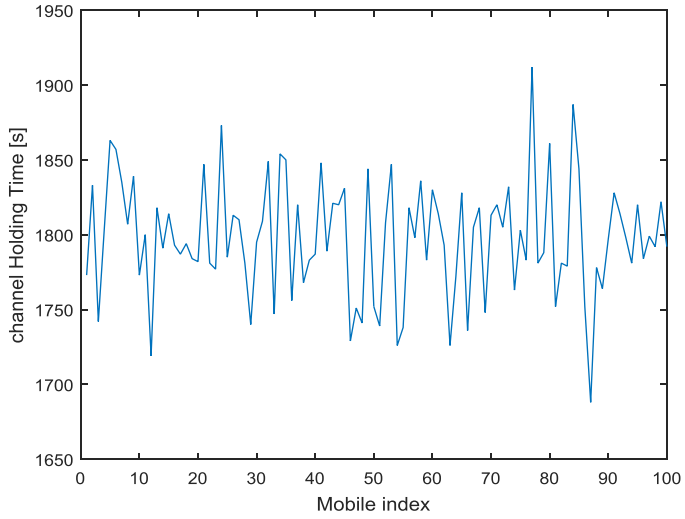

Fig. 14. Call duration for all mobiles in second scenario

Fig.15 shows the channel types distribution the channels. There is a large number of type zero channels and this because many mobile finished their call and return the channel. Fig.16 shows remaining channels in each sector and they are between one to two channels due to the high traffic load.Fig.17 shows the large number of the handover request. Fig.18 shows the handover failure. Fig.19 shows the number of the new call failure, which is more than the handover failure and this due to the large channel holding time.

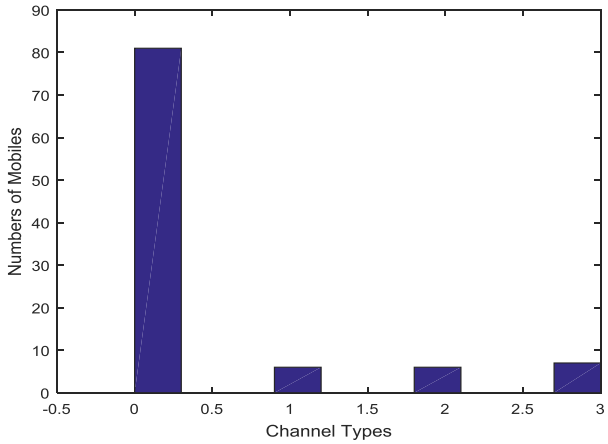

Fig. 15. The channel types distribution the channels

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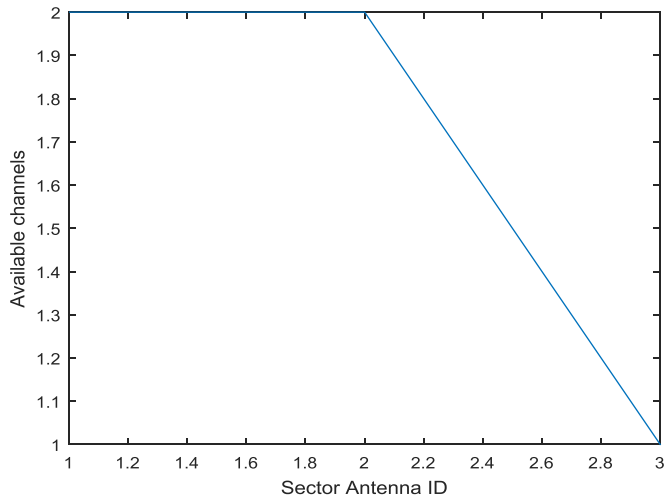

Fig. 16. Remaining channels in each sector in second scenario.

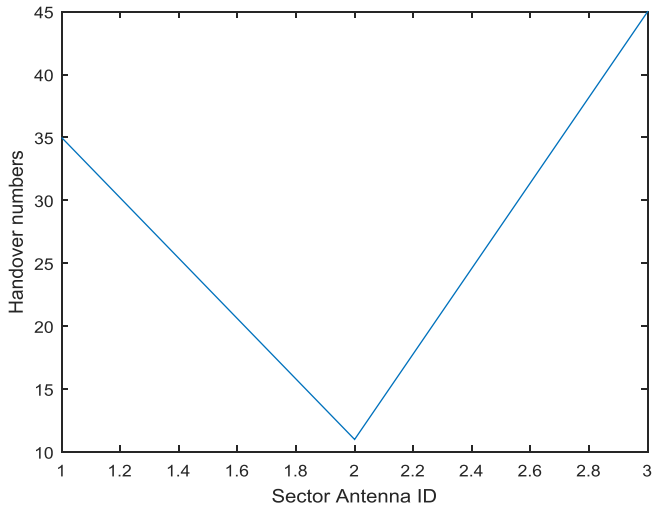

Fig. 17. The handover request in the second scenario.

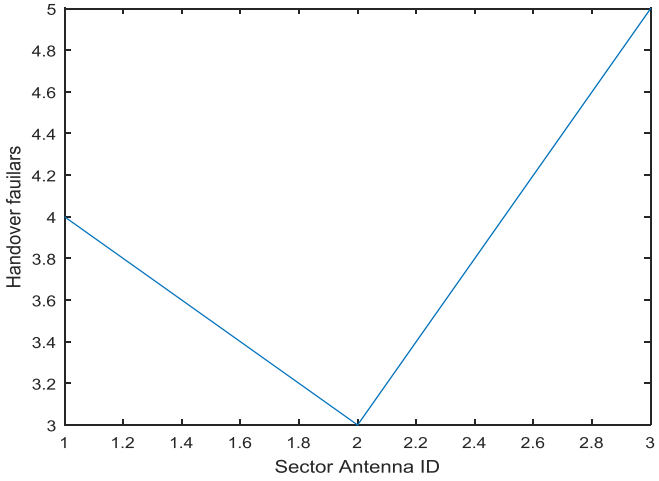

Fig. 18. The handover failure in second scenario.

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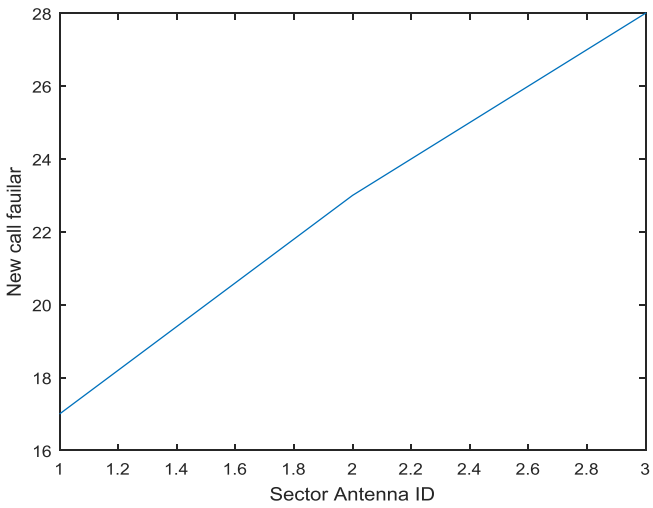

Fig. 19. The number of the new call failure

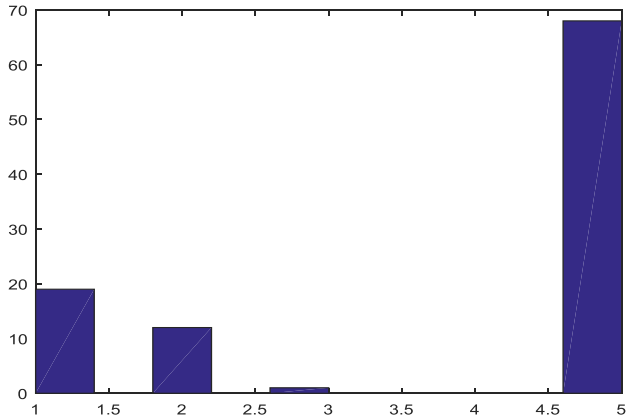

Fig. 20. The mobile status at the end of simulation scenario two

Table III shows the active mobile angle in degree and distance in km during the second simulation scenario. Fig.20 shows the mobile status at the end of simulation scenario two. There is a very high percentage of the handover failure.

TABLE III.

THE ACTIVE MOBILE ANGLE AND DISTANCE IN SCENARIO TWO

TM Mobile Angle	Mobile distance [km]	Mobile Angle	Mobile distance [km]
34.9109	1.4183	157.5238	1.0599
312.7063	1.6331	324.4393	1.9046
39.5285	1.4498	23.3513	1.1925
334.0781	1.4946	197.8029	1.0457
316.2152	0.2957	164.9657	0.0504
44.6261	1.5487	188.9918	1.7091
190.8971	1.6485	227.9438	0.4812
259.3214	0.3136	16.6671	0.2314
292.0041	0.6038	19.0535	1.6794

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VI. CONCLUSION

According to this paper, the number of mobile power generation technologies has been rapidly increasing over time. This paper describes the cellular network mechanism and the performance of the base station 120-degree sector antenna, which employs three 120-degree sector antennas to triple the number of channels and bandwidth per user. MATLAB simulations of the proposed network are used to evaluate the algorithm, which demonstrates that the beamforming of each user signal is multiplied by a complex weight that adjusts the amplitude and phase of the signal going in and out of each antenna. As a result, the output of the antenna array is sent or received in one direction while the output in the other direction is minimized.

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