

Advanced Base Station Concept for Wireless Connectivity in Rural Areas

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Abstract—In this paper, we discuss an advanced base station system with smart algorithms operating on its multiple directional antenna arrays to provide seamless full-directional wireless connectivity and present its simulation result for 5G using Matlab. The system has six-sectors for communication and a scanning array for user discovery. Based on angle-of-arrival (AoA) estimation, optimized beamforming algorithm is employed to establish communication link between respective sector with optimized beams and the identified users. This system modifies the physical layer without affecting other layers and can be installed on the existing infrastructure. All the standards for WiFi, LTE and 5G radios are kept intact. The initial results of simulation show that continued connectivity and tracking with high data rate in multiuser LTE and 5G environment can be achieved.

Keywords—beamforming, rural area connectivity, wireless communication, advanced base station, optimization, Wifi, LTE, 5G

I. INTRODUCTION

The construction and continued management of current commercial base stations in the rural areas is challenged by the geographical environment with hills, mountains and rough terrains, and by the small population scattered throughout the region. The small population density often means minimal usage of the available infrastructure and its continued operation incurs more monetary loss and energy waste. The six-sectored advanced base station developed by our team in [5] mitigates the energy waste problem with its directional networking solution employing advanced algorithms; where a sector activates only when user is discovered in its vicinity.

This paper describes the key features and procedures behind coordinated operation of the multiple directional antenna arrays in the advanced base station system [1] to deliver wireless connectivity. The split functionality between three antenna arrays in the system namely: ‘User Discovery’ to find user, ‘Communication Link’ responsible for establishing and maintaining the connection with mobile user, and ‘Node-to-Node link’ array for backhaul connection, limits all the changes to physical layer making the system compatible with any radio standards that adheres to OSI model.

In section II advanced approach with antenna arrays and smart algorithm is discussed. Newly developed

standard, 5G NR, is simulated in multiuser environment using advanced base station system and the simulation results are presented and discussed in section III. The superiority of system is reasoned in section IV and Section V concludes the paper.

II. TECHNICAL APPROACH

In this section, we describe the basic functions of the dedicated antenna arrays in the base station and related algorithms that provide estimation of angle of arrival (AoA) and beamforming capabilities.

A. Antenna Arrays

The base station has six sectors dedicated for communications. The communication link array is directional to provide longer range and save energy with dedicated narrow beam but fails to hear the connection request made by user outside its beamwidth i.e. it experiences deafness problem [2]. To overcome this, a dedicated ‘User Discovery’ antenna array is added to the system that runs appropriately timed scan of the vicinity to discover new users. The six-sectored structure of the system enables it to keep the communication link array in each sector dormant until a user is discovered in its coverage area. This not only creates range and energy benefit but also allows better frequency reusability. Computationally enhanced algorithms with low execution time are run to achieve this performance. The physical layer modification with its control algorithms doesn’t require upper OSI layer changes, thus making the system standard-independent. While this can be developed as separate functional base station on its own right, it can also be integrated to existing infrastructures as an upgrade.

B. Smart Algorithms

Angle of arrival (AoA) estimating algorithm called MUSIC [4] is run in user discovery array to discover the locations of new users, identify and notify the sectors responsible for establishing communication links with them. The communication link antenna array radiates towards the discovered users utilizing beamforming

algorithms. Initially, deterministic beamforming was used with the predefined beamwidth and weights on antenna arrays. Its execution time together with MUSIC when tested using Xilinx Virtex 7 FPGA was at $0.615\mu s$ [5] which conforms to timing requirement of the available standards. The simulation results presented in this paper use a recently developed “optimized minimum energy beamforming algorithm”.

III. SIMULATION RESULTS AND DISCUSSION

In [3], a single mobile user communicating with the advanced node using WiFi and LTE radio was simulated in Matlab using respective toolboxes. As a continued effort, tracking of multiple mobile users within a sector and from one sector to another is simulated for LTE. Fig. 1 shows simulation result for tracking of three mobile users within a sector in (1.a) and (1.b) along with the Bit Error Rate (BER) and Signal to Noise Ratio (SNR) for each user.

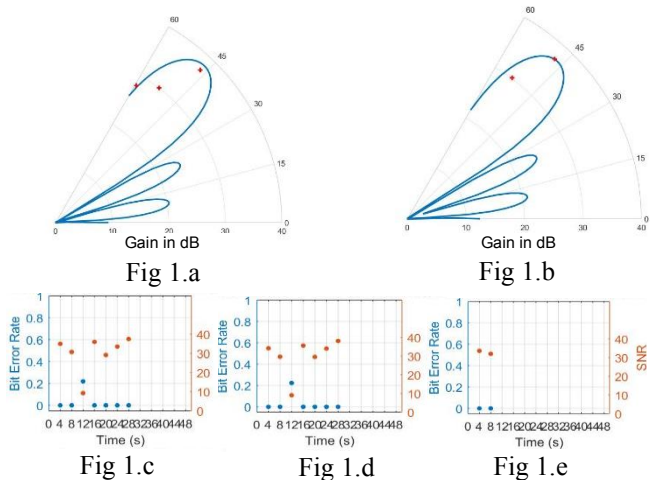
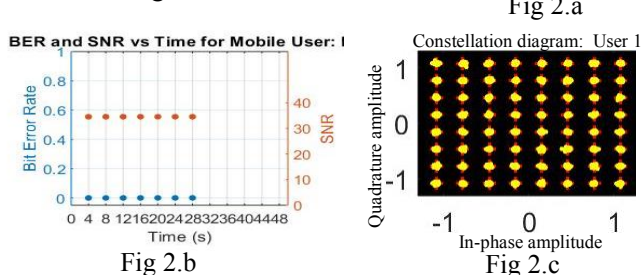


Fig 1: Multiple user tracking in LTE. 1.a shows sector 1 with three users, one of which moves into sector 2 after two movements. 1.b. shows remaining users during third move. 1.c and 1.d shows BER & SNR of first two users. 1.e shows BER & SNR recorded at base station for the third user.

The 5G toolbox in Matlab is used to perform the simulation of multiple users communicating with the smart node using 5G standalone radio. Two users being tracked through the sector is shown in Fig. 2.a. BER and SNR at



each step for one user is shown in Fig. 2.b, and the constellation diagram in Fig 2.c represents respective signal strength of that user.

IV. SYSTEM ADVANTAGES

The advanced base station system accommodates newly enrolled 5G standard as well. As 5G works with mmwave, it requires massive MIMOs but increases the computational complexity and requires high beam steering capabilities. It has much shorter range than LTE, increasing the number of base stations to be constructed for same coverage area and the cost of deployment. Through simulation results, we can see that proposed system tackles the complexity and offers long range coverage with high data rate, reduction in signal interference, and cost.

It is also cost-effective to build, maintain and update an advanced ground base station, or to upgrade the available existing regular node to advanced base station in rural areas than construction, deployment and continued maintenance of a fleet of air-borne base stations [6].

V. CONCLUSION

Through the simulation of advanced base station integrating WiFi, LTE, 5G radio, we can see that our proposed approach supports multiuser tracking and connectivity in available standards. This physical layer based, six sectored base station overcomes deafness through dedicated antenna array for user discovery. It's longer reach with controlled energy expenditure makes it cost and energy-effective and a viable solution to provide wireless connectivity in rural areas. In the future work, system validation will be carried out using Software Defined Radios boards.

VI. REFERENCES

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