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A NOVEL MULTIHOP BASED PROTOCOL FOR DEVICE-TO-DEVICE COMMUNICATION FOR COGNITIVE RADIO WITH ONLINE NETWORK DYNAMICS

Md. Tabrej Khan
Faculty of Computer science
Pacific Academy of Higher Education and Research University
Udaipur (Rajasthan), India

Ashish Adholiya
Faculty of Computer science
Pacific Academy of Higher Education and Research University
Udaipur (Rajasthan), India

Abstract

Because it is anticipated that the volume of traffic in networks based on 5G will expand exponentially, efficient techniques are required in order to make the most of the section of the wireless spectrum that is currently underused. The proliferation of different mobile applications over the past several years has led to a large increase in the amount of data traffic carried by cellular networks. Because of this, it is absolutely necessary to expand the capabilities of the network in order to support the introduction of new applications and services. On the other hand, multihop D2D communication necessitates the use of additional nodes for the purpose of data forwarding, and this is especially the case when cooperative relays are included. We need to address the issues of transmission scheduling, routing, and channel allocation in order to realise our goal of achieving effective multi-hop D2D cooperative communication. The system architecture that has been presented places an emphasis, among other things, on using online algorithms to manage network dynamics.

Keywords—Multihop protocol; Cognitive Radio; Network Dynamics; Machine Learning; Device-to-device communication

1. Introduction

In recent years, the ever-increasing popularity of smartphones and tablets has driven wireless cellular networks to become one of the major systems accessing the Internet with a huge number of customers due to their pervasive availability. As a result of this, wireless cellular networks have become one of the major systems accessing the Internet. Numerous mobile applications running on these portable devices have been responsible for the massive volume of data traffic that has been created. For instance, mobile data production in North America reached 222 petabytes per month in 2012 [3]. [Citation needed] According to projections made by Cisco, the volume of worldwide mobile data traffic would increase 13-fold between the years 2012 and 2017 [3]. This growth is expected to continue for the foreseeable future. Wireless cellular networks have been evolving to give increased network capacity in order to manage such enormous traffic needs. This has been accomplished by combining a wide variety of innovative technologies. The second generation, or 2G, standard was the first digital cellular system to offer voice services and low-speed data transfer when it was introduced in the early 1990s. This evolution began with this standard. The fourth generation, or 4G, of wireless networking has arrived, and there are now two options that are being actively developed: 3GPP LTE-Advanced and IEEE 802.16m. LTE-Advanced [6] is an upgraded version of LTE (Long Term Evolution) that will either meet or beyond the criteria of the 4G standard. It will have a bandwidth of 100 MHz and a peak data rate of 1 Gbps. In order to accomplish these goals, it integrates new technologies that can be divided into two categories: those that aim to provide higher channel capacity, such as the multi-antennas technique and carrier aggregation, and those that focus on developing new communication models, such as network traffic offloading [2]. Specifically, the multi-antennas technique and carrier aggregation are examples of technologies that fall into the former category. A lot of work is being done to increase the capacity of wireless channels by investigating different coding strategies and the benefits of using numerous antennas. For instance, turbo coding and processing [1, 9] is proposed to approach the Shannon limit on channel capacity, whereas space-time coding [8, 10] increases the possible channel capacity by exploiting the rich multipath nature of fading wireless environments. Both of these methods are examples of approaches to the Shannon limit. However, they are a long way from finding a solution to the issue of increasing the network capacity. This is due to the following factors: (1) the wireless channel capacity has a physical limit and cannot be increased infinitely; (2) the equipping of multiple antennas incurs additional hardware costs and is not adopted by the majority of mobile devices; and (3) the growth of traffic is outpacing the development of communication technologies. The offloading of traffic from cellular networks offers a fresh communication paradigm as a solution to the issue of increasing network capacity. It is possible to divide it into two distinct categories, namely device-to-device communication and micro, pico, and femto cells. Cellular network capacity can be significantly increased by offloading the network traffic from the traditional cellular base stations to local low-power access points with reduced interference ranges. This can be accomplished by deploying multiple cost-efficient access points at locations where large amounts of data are generated. These access points may make use of a variety of wireless technologies, such as WiFi and WiMAX, to create heterogeneous networks (HetNets), which are designed for mobile users. According to the old model, as illustrated in Figure 1, all network traffic is required to pass via the base station, which serves as the bottleneck for the entire network. It is possible for certain mobile users to communicate via the local cells when numerous local access points are built. As a result, the traffic strain that is placed on the macro base station can be minimised.

It is necessary to make extra investments in network infrastructure, such as micro/pico/femto access points, even though offloading traffic to micro/pico/femto cells demonstrates significant benefits in terms of boosting the volume of traffic on cellular networks. In addition, once these access points have been set up, it will be difficult to move them to a new location. A static deployment would result in poor offloading performance since the traffic on the network coming from mobile users is dynamic; that is, the traffic generation of different areas fluctuates over time. Device-to-device communication, often known as D2D communication [4,] is an alternative that offers flexible traffic unloading but does not require the support of any network infrastructure. It makes it possible for two devices that are relatively close to one another to establish a direct local link for the transmission of data. Multiple users will be able to send data at the same time within a single collision domain once some of the data traffic has been offloaded to D2D lines.

Figure 1 provides a demonstration of a D2D communication scenario. In cellular mode, users A and B communicate with one another over an uplink and a downlink, while all other nodes in the same cell (such as user C) are expected to maintain radio quiet. If the quality of the direct link between users A and B is sufficient, then user A will be able to transfer data directly to user B whenever D2D communication is enabled. In the meantime, user C will be able to connect to the network as long as they do not create any interference to the D2D pair. The direct-to-direct communications are able to take place not only between a pair of nodes that are placed within the same cell, which is referred to as an intra-cell D2D pair, but also between nodes that are situated in different cells. Base stations are often in charge of managing D2D communication. This means that base stations are the ones to decide whether or not a given pair of users will interact via cellular mode or D2D mode.

The strength of the connections between devices is a significant factor in determining whether or not there will be D2D communication. Unfortunately, without the support of a base station that is capable of powerful information collection and signal processing, transmissions on D2D links are likely to be jeopardised by many factors such as fading or environmental noise. The low transmission rate that would result from this would reduce the incentive for users and network operators to adopt D2D communication. The use of cooperative communication (CC) [7] has proven successful in the fight against fading, allowing for the achievement of high channel capacity and dependability in a cost-effective manner. This type of communication is ideally suited to the context of direct-to-direct communication. The fundamental concept behind it is to allow a relay node to transfer the signal that it has received from a transmitter to its receiver. This is done in order to achieve diversity gain for the same signal while it is travelling along multiple paths resulting from direct and relay transmissions. Figure 2 is an illustration of a well-known model of CC that consists of three nodes. In this model, user A sends data to user B with the assistance of a relay node. On a frame-by-frame basis, any and all transmissions are carried out. In the more common form of direct transmission known as DT, user A sends data to user B throughout the entirety of the frame. The application of CC results in each frame being split into two separate time periods. User A sends a signal to user B within the first time window that is available. Because wireless communication is broadcast, this signal is also picked up by the relay node. This is because of the nature of wireless communication. The relay sends the amplified or decoded version of the received signal to user B in the second time slot after first processing it. In the end, in order to reconstruct the initial signal, the user B mixes the signals that were received in two separate time windows under varying attenuation conditions. When D2D communication is strengthened by CC, which is referred to as cooperative D2D communication, new issues are presented for optimal resource allocation in cellular networks. These new challenges include relay selection, channel allocation, and transmission scheduling.

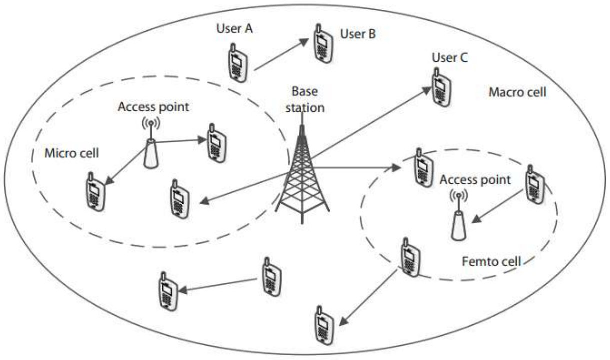

Fig. 1. Traffic offloading in cellular networks

To begin, it is hard to designate a dedicated channel for each of the active D2D links that would be present in a cellular network because of the huge number of D2D links that would be present. In a network that is limited in the number of channels it can use, especially one that makes use of cognitive radio, it is of the utmost importance to effectively allocate channels among all communication links. This includes D2D links, cellular uplinks and downlinks, and links between individual cells. Second, the scheduling of many communication links that share a single channel needs to be done with great care in order to ensure a particular degree of quality-of-service (QoS). Because using a relay node can increase the link transmission rate, but it would also enlarge the interference range of a link, which would result in reduced space multiplexing, this problem becomes more difficult when CC is taken into consideration. This is because using a relay node would increase the link's interference range.

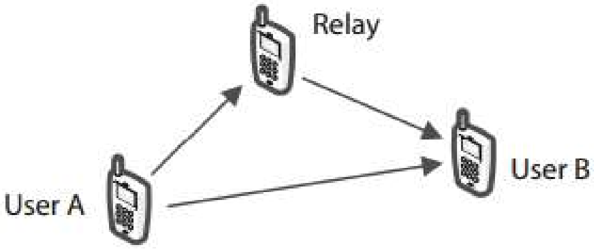

Fig. 2. A three-node model of cooperative device-to-device communication

Opportunistic spectrum access mechanisms are intended to make use of the licenced spectrum bands that are currently available. These spectrum bands can be made available to unlicensed users (referred to as secondary users or SUs) without causing harmful interference to licenced users' devices (referred to as primary users or PUs). The dynamic spectrum access device-to-device (D2D) communication that takes place over cognitive radio networks is made possible by the sharing of spectrum bands by both PUs and SUs devices (CRNs). In these kinds of situations, the devices at the source and the destination can be connected by either a direct connection or a multi-hop path. Our primary focus is on an opportunistic multi-channel D2D communication protocol that, in order to improve the efficiency of the network, chooses the way that is going to be the least congested along with the channel assignment for devices that are speaking with one another. Our protocol takes into consideration the number of available channels, the link-quality circumstances, and the channel availability durations of each accessible channel when determining pathways and assigning channels between communicating devices. This ensures that the appropriate channels are assigned.

Offloading cellular traffic to WiFi or other networks is the subject of a significant amount of research [26, 39] that has been conducted over the past few years. The goal of this study is to reduce the amount of bandwidth used or the amount of energy consumed. In [7], a quantitative study of the spike in mobile data traffic as well as a strategic solution to the problem of traffic unloading are offered. In their paper [24], Korhonen et al. discussed existing traffic offloading solutions. They also presented and evaluated three different IP traffic offloading solutions. These solutions aim to work on the internet layer and rely only on the standard IETF2 defined TCP/IP protocol suite. Additionally, they do not require any accesstechnology-specific knowledge. A quantitative investigation on the performance of 3G mobile data offloading across WiFi networks has been presented by Lee et al. [26]. Their tracedriven simulation made use of the gathered whole-day traces, and it revealed that WiFi already offloads approximately 65 percent of the overall mobile data traffic, hence saving 55 percent of the battery power and not requiring any delayed transmission. Two different techniques for the delay-tolerant offloading of cumbersome, socially suggested material from 3G networks have been developed by Rstanovic et al. [39]. They come to the conclusion that both proposed strategies are effective in unloading a sizeable portion of the traffic, which has a beneficial effect on the user's battery life. Recent years have seen a surge in interest in the study of device-to-device, or D2D, communication due to the benefits it offers in terms of unloading data traffic at base stations in cellular networks. Janis et al. [19] propose in their early work to facilitate local peer-to-peer communication by using a D2D radio that operates as an underlay network to an IMT-Advanced cellular network. This would be accomplished through the use of a D2D radio. Later on, they studied D2D communication in three different modes, namely, reuse mode (in which D2D links share common channels with cellular links), dedicated mode (in which D2D links use dedicated channels), and cellular mode (in which all communication is relayed by base station), and designed a mode selection algorithm for a three-user (one D2D pair and a cellular user) cellular network [9]. In the reuse mode, D2D links share common channels with cellular links. Yu et al. [51] have examined the throughput optimization problem over shared resources while simultaneously fulfilling prioritised cellular service requirements. Their research is based on a network model that is quite comparable. For more generic models, D2D communications have been subjected to in-depth research on a variety of fronts, including interference management and control, power management, and spectrum sharing, amongst others. For instance, Janis et al. [18] have proposed a method that is both practical and effective for generating local awareness of interference between cellular and D2D users at the base station. This method then exploits the multiuser diversity that is inherent in cellular networks in order to reduce the amount of interference that occurs. A distributed dynamic spectrum protocol has been devised by Kaufman and others [22], which allows ad-hoc D2D users to access the spectrum actively being used by cellular users in an opportunistic manner. In the paper [36], there is a proposal for a brand new interference control technique that aims to improve the dependability of D2D communication. They determine the outage probability in close form and then devise a mode selection method to reduce the outage probability as much as possible. Lee et al. [27] have presented a framework for the D2D communication that utilises a two-stage semi-distributed resource management system. The base station (BS) is responsible for the centralised distribution of resource blocks (RBs) during the first stage of the framework.

These RBs are allocated to BS-to-user device (B2D) links and D2D links. At the second stage, the base station (BS) schedules the transmission using the RBs that are allocated to B2D links, while the primary user device of each D2D link carries out link adaptation on the RBs that are allocated to D2D links in a distributed manner. This occurs while the BS is scheduling the transmission using the RBs that are allocated to B2D links.

2. RELEATED WORK

A two-tier 5G cellular network that involves a macrocell tier (i.e., BS-to-device communications) and a device tier (i.e., device-to-device communications) has been suggested in [46]. This network would consist of a device tier that would involve device-to-device communications. Li et al. [34] have investigated the fundamental problems of how D2D communication improves the system performance of cellular networks and what is the potential effect of D2D communication, with the assistance of optimal solutions for the system resource allocation and mode selection obtained under the realistic user and mobility conditions. Their findings have shown that D2D communication has the potential to have a positive effect on the system performance of cellular networks. In particular, they obtain the theoretical upper bound to the system's content-downloading performance by formulating a max-flow optimization problem. This problem maximises the content downloading flows from all of the cellular base stations to the content downloaders through any possible ways of transmission.

The foundational concept of CC was initially presented in the seminal publication [47]. After that, Laneman et al. [25] examined the mutual information and outage probability between a pair of nodes employing CC while operating in both the AF (amplify-and-forward) and DF (decode-andforward) mode. As a result of the ground-breaking work that they did, CC has been thoroughly researched from the points of view of both the physical layer and the network layer. In this section, we provide a synopsis of the most pertinent research in the following areas: energy efficiency; relay assignment; and time-spectrum allocation in cooperative communications. Both virtual-MISO (multiple-input-single-output) and decode-and-forward are significant types of cooperative diversity schemes that are used in wireless sensor networks. Simic et al. compare the energy-efficiency of these two major types of diversity schemes in [45]. They demonstrate that decode-and-forward performs better than virtual-MISO due to the fact that it does not require explicit local communication between the cooperating nodes. [17] does research on the topic and looks on how energy efficient CC is in wireless body area networks.

3. Materials and Methods

3.1 Device to Device Communication Model

Due to the limited capacity of communication offered by mobile devices, they are only able to communicate within a constrained area. Through system may construct a data path with other nodes located at a distance, which provides in greater options for D2D communication by utilising multihop communication strategies. When multihop D2D communication is used, a greater number of nodes are utilised for data transfer, particularly when cooperative relays are implemented. In order to establish successful multi-hop cooperative D2D communication, we need to solve the issues that arise during the transmission cycle, in the routing, and with the channel allocations. In addition to this, the complexity of the networks is managed by online algorithms that we build. In real cellular networks, mobile users can join or leave the network at any time, and because of this, the effectiveness of the wireless channels can vary greatly from one client to the next. As a result, online algorithms need to be developed in order to manage these complicated network events. These answers, which may be found in this system, serve as the theoretical boundaries for online instances and the guideline for the creation of online algorithm.

As online network topology is increasingly being used, my primary focus for the design implementation is on the Internet of Things. IOT, The proliferation of devices that may be placed in the category of "Internet of Things" is a recent development that has given rise to a new business in the field of computer engineering (IoT). These are typically embedded devices that are able to execute a limited set of functions, in addition to being able to connect to the Internet and other devices in the immediate area. These devices are equipped with a variety of radios, including Bluetooth and Wi-Fi, that make it possible for them to control one another or be controlled by a centralised interface. Embedded devices like these frequently make use of cutting-edge operating systems like Brillo, which is founded on Android. Because of this, it is able to run Android applications, which are typically written in Java and share the same codebase with mobile phones and computers [2]. The predecessor of Android Things is known as Brillo. This makes use of current developments in the business, most notably the rise in popularity of smartphones, declining costs associated with technology, and the accessibility of Wi-Fi networks. One command can control the lights, blinds, and other gadgets in the home, and all it takes is one app or a voice-activated assistant. It is believed that there are currently 23 billion devices linked to the Internet. These devices include mobile phones, tablets, and personal computers. Within the next few years, it is anticipated that this number will increase by a factor of two. Because there are so many devices linked to the internet, those devices will compete for bandwidth on weak routers, which will have an impact on the functionality of the routers and cause performance issues for all users

3.2 Cognitive Radio

The Cognitive radio, often known as CR, is a relatively new technology that allows for the dynamic allocation of spectrum to various devices in order to make the most of the available bandwidth in locations with limited availability. They do this by utilising software-defined radios, which are radios that can vary their frequency based on a programme that is loaded onto the device. A study article at the University of Stockholm authored by Dr. Joe Mitola is where the concept of cognitive radio was first presented. The concept was to make handsets, mobile phones, and cellular networks adapt their modes of communication dependent on the surroundings in which they were operating. Figure 3 depicts the behaviour in a graphical format and may be found up top. The purpose of defining Radio Knowledge Representation Language was to create "a standard language within which such unforeseen data exchanges can be defined dynamically." This was accomplished by defining RKRL as a way to give "a standard language." In turn, this might be implemented in cognitive radios to improve performance and increase battery life. One further characteristic of the system is that it has the capability to "choose the most appropriate network for the service requirements of the user." This feature, which enables users to communicate with one another over Wi-Fi, was only recently added to mobile phones.

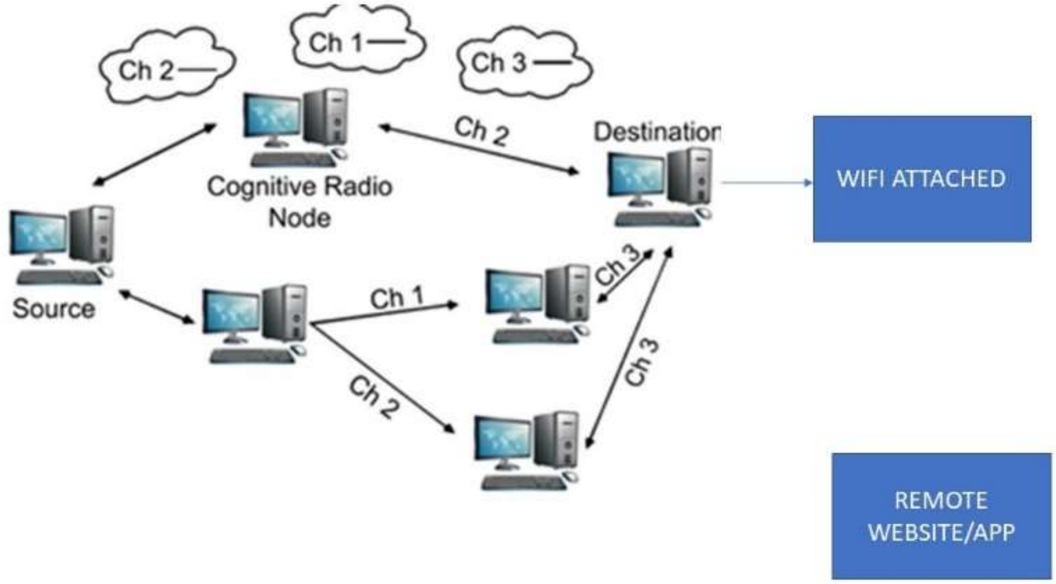

Fig. 3. Design of Proposed system

Figure 3 depicts the design of the system that has been suggested; it makes use of a multichannel and multihop protocol, both of which will contribute to an increase in the effectiveness of the communication. The system establishes a connection to the wifi network, allowing us to watch the dynamics of the internet network from a remote location using either a website or an android app.

4. Results and Discussion

Figure 4 shows the used nodes for the experiment Figures 5,6,7 shows the impulse response plot, Input signal and output signal from the wifi simultaneously.

Figure 4 graph displays the "Total Error Rate" as a function of the "Threshold" value, with different curves representing different values of n (from n=1 to n=10). There is also a specific curve marked with n=5 by modelling. The curves appear to have minima, indicating optimal threshold values for each corresponding n, beyond which the error rate increases.

Figure 5 plot shows decaying oscillations, typical of an impulse response where the system initially reacts strongly and then settles down to a steady state.

Figure 6 plot displays an "Input Signal" over time. The signal fluctuates, showing significant variations over time, which could represent noise or some other form of variation in the input signal.

The figure 7 shows the trajectory of an output signal plotted in a two-dimensional plane. The x-axis ranges approximately from -500 to 400, while the y-axis ranges from -400 to 200. The signal path is depicted as a continuous blue line that traces the changes in the output signal over time.

The signal exhibits a complex, non-linear behavior with multiple sharp turns and intersections, indicating a highly dynamic system. There are several distinct regions where the signal trajectory crosses itself, suggesting potential points of instability or periodic behavior within the system. Additionally, the path includes a few dense clusters where the signal changes direction frequently within a small spatial region.

Overall, the signal's trajectory reflects a combination of rapid changes and more gradual variations, highlighting the intricate nature of the system being analyzed**.**

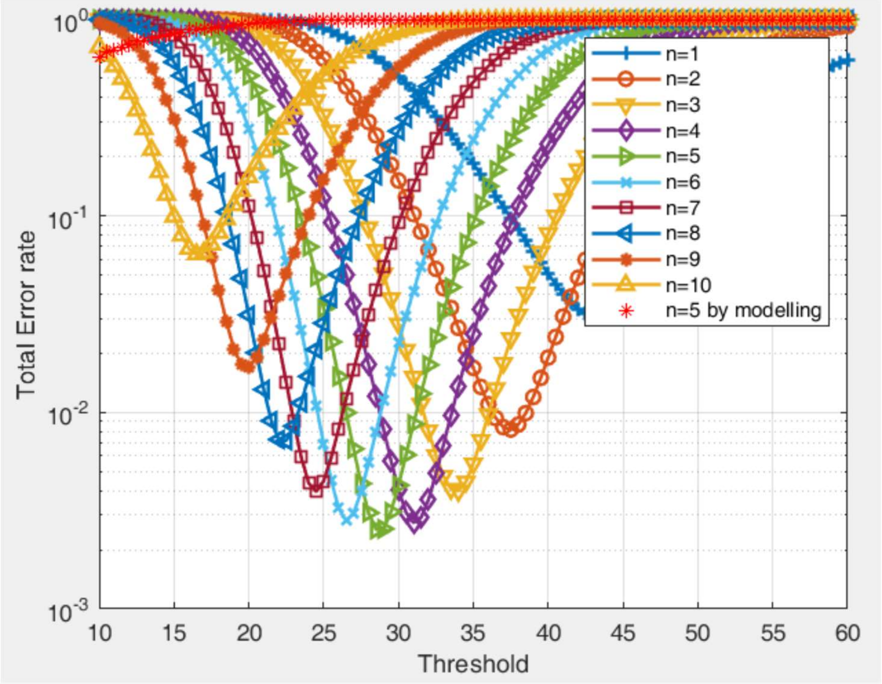

Fig. 4. Used Nodes

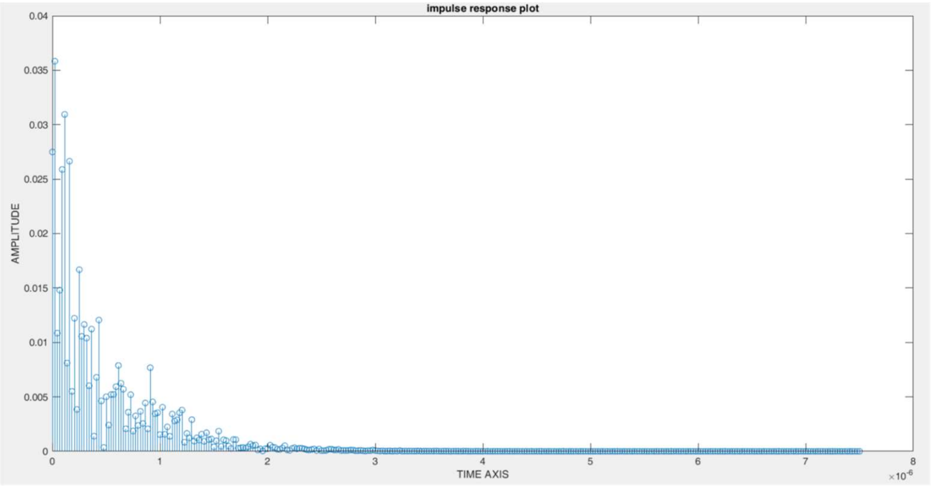

Fig. 5. Impulse Response Plot

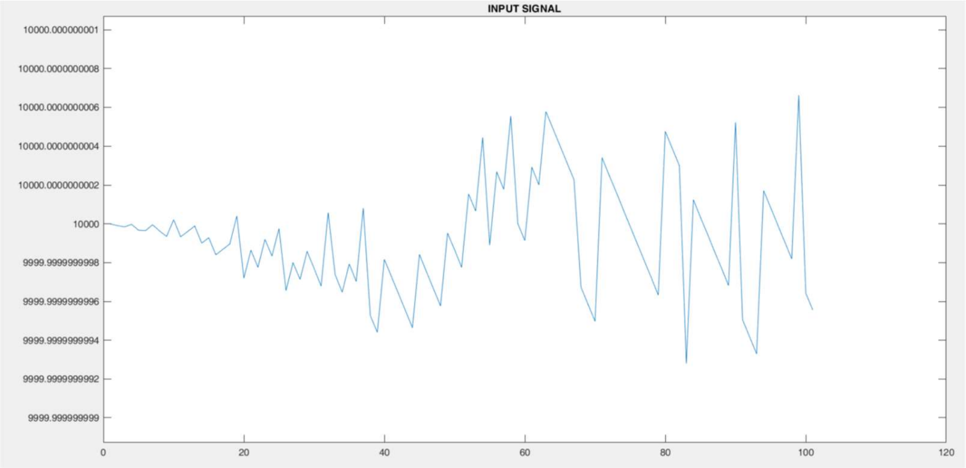

Fig. 6. Input Signal

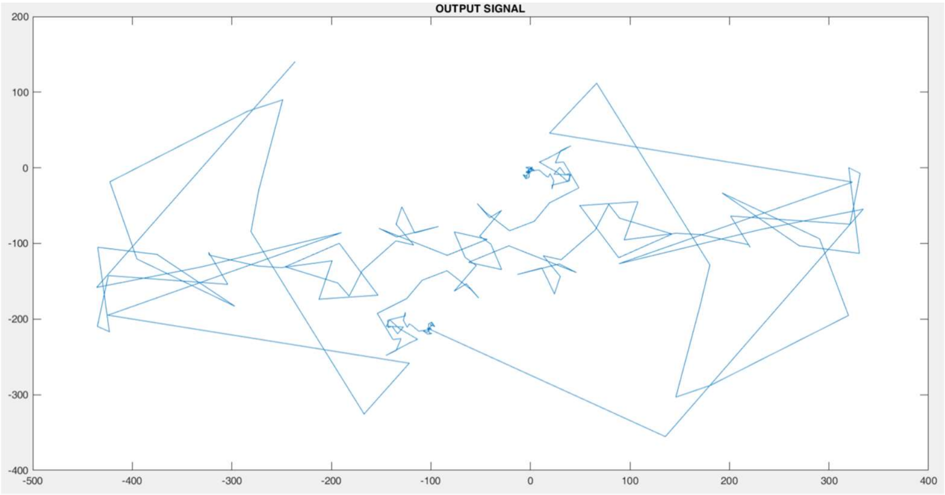

Fig. 7. Output Signal

5. CONCLUSION

The purpose of this article is to present a new cognitive dynamic network architecture (CDNA) for future 5G wireless networks. This architecture takes advantage of the density and heterogeneity of wireless devices in order to give Internet connection in any location. The benefits of this architecture include increased energy and spectrum efficiency, support for heterogeneous connectivity requirements, dynamic reconfigurability, and new commercial prospects. A distributed matching method has been devised for resource allocation in order to fully leverage its potential. This algorithm enables users to self-organize into a stable matching for data and spectrum trade, which can then be done more efficiently. This allows for a scalable and flexible reconfiguration of CDNA in response to changes in user activity and spectrum, which is made possible by the algorithm's ability to track network dynamics with a low communication overhead.

This article aims to articulate the potential of users' active role in future wireless networks in improving network performance and inspire research on such a paradigm shift towards collaborative architectures. Specifically, the article will focus on the potential of users to actively participate in future wireless networks. In addition to that**, several promising new**

lines of inquiry for the researchers of the future are identified.

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Conflicts of Interest

The authors declare no conflict of interest.

Ethics Approval

Not Applicable.

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