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Explainable AI Controlled Architecture of D2D System for Massive MIMO based 5G Networks

A.Vijay[1] , Dr. K.Umadevi[2]

[1]*Department of ECE, Ambal Professional Group of Instititutions, (India)*

[2]*Professor/Dean.,Sengunthar Engineering College (India)*

ABSTRACT

The massive elevation in quantity of mobile users leads to a greater demand for higher data rate services leading to the demand for 5G networks. D2D communication technique is an optimized method to support various demands on massive data transfer rates among the users in 5G networks. Massive MIMO (Multiple-input and Multiple-output) based antenna systems are deployed to achieve these huge data demands in 5G technology. However, the drawbacks owing to expanding computational overhead in methods of allocating resource, reducing interference, energy optimization and several other problems in D2D networks are compromised with the help of emerging technology of Explainable Artificial Intelligence (XAI). Furthermore, a novel approach based on AI is implemented with an Architectural design for D2D network in decision making over the implementation of techniques based on the persisting situation in the D2D network.

Keywords: Explainable Artificial Intelligence, Massive MIMO, Big Data Lake, Software-Defined Radio, Cloud Server.

I. INTRODUCTION

Exchange of information between devices becomes essential these days due to demand which arises because of increasing quantity of mobile users [2]. It becomes difficult for centralized cellular network to meet out growing demands in data transfer, hence it paved way for D2D (Device-to-Device) Communication technology. Subsequently, full duplex relay data transfer based on D2D communication proves to be an eminent mode for huge data transfer [19]. Notably, D2D communication has the capability to operate with both the in-band and out-of-band frequencies [20] [21]. Furthermore, D2D communication provides proximity services like D2D discovery, D2D communication for effective data transfer [2]. Within a short time, there is no doubt that D2D communication technology will become backbone of entire wireless network communication across the globe.

It is impossible to accomplish IMT-2020 requirements without Massive MIMO technology. In order to increase the performance, Massive MIMO techniques are sorted separately for Indoor as well as for outdoor environments [25]. Notable merits of Massive MIMO over the conventional MIMO include spectral efficiency, diversity gain, multiplexing capacity and energy efficiency [26], [27]. Hence Massive MIMO becomes mandatory for the upcoming 5G networks.

In the recent days, Explainable Artificial Intelligence (XAI) plays a major role in the field of Artificial Intelligence, where its performance provides transparency and interpretability [23]. Furthermore, Evolutionary fuzzy systems (EFS) along with XAI provides solution to complex analysis and defining solutions, whose capabilities include simultaneous learning, rule selection, rule learning, data base learning and Tuning of parameters [1]. However, several models like supervised learning, unsupervised learning and reinforcement learning based on AI are deployed in the field of research relating to 5G networks [24]. Hence in this article, novel approaches for integrating XAI along with AI standard algorithms for improving the performance of D2D communication networks is been proposed.

II. SYSTEM MODEL

Network discovery and Interference management are the two main factors which determine performance for D2D communication [2]. But it is difficult to optimize the performance of the existing D2D networks because of various demands on techniques and protocols for the dynamic mobile devices whose efficiency mainly depends on distance between the nodes and the number of users present in the nearby environment. Furthermore, the techniques and its relevant algorithms cannot be defined earlier without examining the present scenario and the requirements at the moment.

To overcome the varying demands with respect to the situational requirements: Firstly, we need to analyze the present requirement of the network at the moment. Secondly, the estimate for cost plays a major role in the implementation of the network and hence a suitable cost analysis approach based on spline biorthogonal wavelets approach for signal analysis of filters is implemented based on AI [4]. Thirdly, the suitable cost efficient technique along with their relevant protocol to be implemented in D2D network is selected [2]. Finally, the suitable technique and its relevant protocols are implemented in the mobile device present in the 5G based D2D network to obtain the maximum efficiency in their performance.

Since the processor speed and the storage capacity of the Mobile device are not sufficient, it is difficult for SDR (Software-Driven Radio) present in the Mobile device to undergo such difficult process. Hence our proposed system is to use external cloud server which is automated by Explainable Artificial intelligent (XAI) mechanism that takes care of the entire process likely analyzing the requirement of the network, selecting the algorithm and technique and to transfer the software instructions from the cloud server to the mobile device for their effective operation as and when required based on the versatile requirements of the D2D network.

On the other hand, the entire operation is controlled and monitored periodically by XAI aggregator unit located in the remote high speed cloud server. This XAI aggregator unit connects and governs four aggregators namely Self Learning and Processing (SLP), Network database (NDB), Technique and Protocols transmission (TPT), Performance Analysis (PA) by its own programmed Main aggregator Server (MAS). The TPT contains all the relevant protocols and technique that are currently used to increase the system performance [2]. On top of that, Deep Q-learning along with supervised learning is deployed in the MAS for ultimate decision making [5]. Moreover, Path finding algorithms based on AI are used to evaluate the existing network traffic [22].

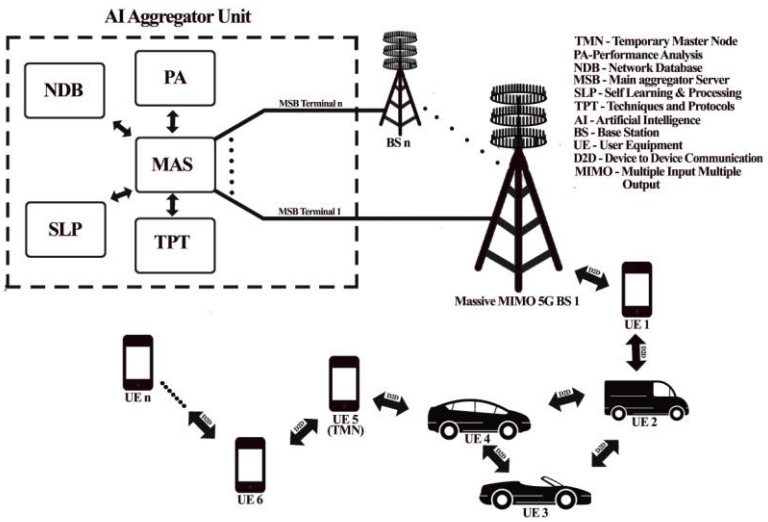

Fig. 1. Controlled SDR Architecture for D2D Systems for Massive MIMO based 5G Networks

Seeing the difficulty of interconnection of each node among the D2D network with the XAI aggregation unit, one device among several D2D network is selected as Temporary Master Node (TMN) by MAS through System identification approach [3]. TMN takes the advantage of connecting the additional nodes nearby through IEEE 802.11 standards and links with the XAI aggregator unit through Massive MIMO based 5G data network. Objective of this interconnection through TMN is to reduce the risk of interference and to increase the efficiency in performance of the D2D network.

III. SYSTEM OPERATION

The AI Controller Unit operates based on the performance of the D2D network by means of the information available in PA Aggregator. All the information and parameters collected from various SDR are transferred to the PA Aggregator through TMN. Moreover, ND Aggregator comprises of all the relevant data owing to the present and the past records which are needed for the analysis and performance of the system. Furthermore, the TPT Aggregator is the heart of the AI control unit which contains the List of Techniques with its diverse protocols and its installation files for governing the corresponding operations of the technique. The steps involved in the operation of the AI Controlled network are shown in fig. 2.

IV. XAI AGGREGATOR UNIT

The final decisions are carried out by MAS which acts as the heart of entire XAI aggregator unit. The operations and the proposed methodologies involved in each Aggregator mentioned in the system model are as illustrated below.

4.1 Network Database (NDB)

The most common parameters that are need to be monitored and stored for further reference are D2D Subscriber Profile, Subscriber Perspective, RAN Perspective, Subscriber Mobility Pattern, Radio Environment Map, Traffic

Profile, Subscriber-Centric Wireless Offload, transmitter power, Base Station transmitter power, Cell radius, Bandwidth, Thermal noise power, Noise figure in user equipment, Carrier frequency, D2D pair distance, Path loss exponent between devices, Path loss exponent between BS-device, Path loss Coefficient between devices, Path loss between BS-devices, Amplifier efficiency, Load independent power in BS, Power per BS antenna, Power per user equipment handset, Monte Caro runs [6][13]. All such parameters are stored in NDB. Since the requirement of an ultimate AI based network operation needs detailed history of all the parameters, data related to network performance, information owing to several networks, nearby routers, SDRs, Nodes and much more, the concept of Embedding AI in the Big date lake is used for storing the information effectively which can be further used as Master data Management system for further reference [7]. By the same token COBRA technology is utilized for gathering information from several servers, routers and end nodes which support cloud based platform for SDR operations with 5G as backbone network [8].

4.2 Techniques and Protocols Transmission (TPT)

Frequently used techniques for network discovery are SINR –based D2D discovery, Cell orthogonal and location based Reactive (Pull) discovery and proactive (Push) discovery, IPPO, BS-assisted network discovery. Additionally, techniques used in Interference management technique are FD-assisted interference cancellation, BS-assisted SIR-based optimization, Power control scheme with D2D and CU transmit power adjustment, Radio resource allocation based on the greedy algorithm, ILA-based on SIR,GA-based joint resource allocation and user-matching scheme (GAAM),Channel selection and power control, CoMP technology, ILA-based on SIR, Centralized and distributed power control scheme [2] [3]. SDR System installation Programs required for running all such techniques are stored in TPT. Additionally, the generated methods from SLP are also stored in TPT after the approval of MAS for further execution. Furthermore, Big Data Lake is utilized here for the storage of the installation files [7].

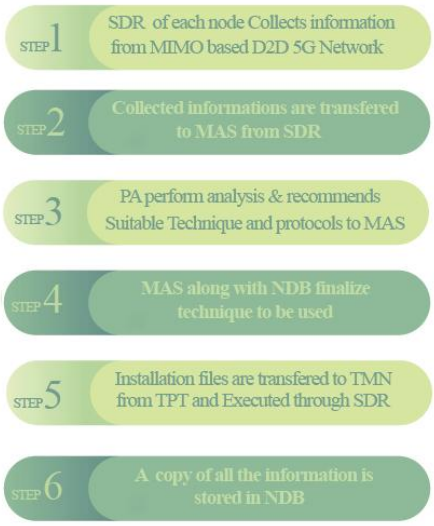

Fig. 2. Steps involved in the system operation.

4.3 Performance Analysis (PA)

The performance analyses of D2D networks are carried out in three different ways and are updated periodically with the MAS and NDB.

4.3.1 Self Evaluation: In the self evaluation process, Q-learning algorithm along with adaptive ε-greedy is implemented for evaluating network algorithms that are similar to TCP based D2D Communication which contains several complex algorithms like TCP Tahoe, TCP Reno, TCP NewReno, TCP Westwood, TCP Vegas and much more [9][10]. In such case it is difficult to choose specific technique among the others in the required network demands at the moment, hence Q-learning based adaptive ε-greedy technique is used for speedy analysis and evaluation [10].

4.3.2 Behavioral Analysis: Since the D2D network behaves in a vast different ways for the same situation and circumstances it is difficult to analysis and hence it is compared with the artificial emotion behavior model [11]. The artificial behavior decision is made after the internal emotional analysis as shown in the fig 3. Additionally, spiking neural network architecture is implemented for emotions based behavioral analysis and the same algorithm can be further utilized for self learning as well [15].

4.3.3 Feedback evaluation: With the increase in usage of mobile devices among D2D network data congestion will become unavoidable. To overcome such issues of network traffic proper feedback mechanism is mandatory. The essential feedback parameters like CSI (Channel State Information), QOS (Quality of Service) are analyzed based on Multicast based rate adaptation method for improvising the performance of D2D networks [12].

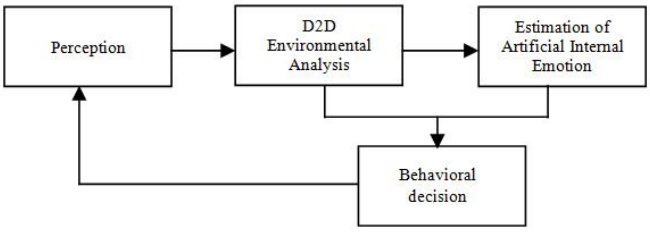

Fig. 3. D2D system model for Behavioral Analysis.

4.4 Self Learning and Processing (SLP)

To deploy the self learning with XAI, interpretable deep learning model is implemented for understanding the UE behavior and to learn the logical rules of protocols being used in D2D networks [14]. Additionally, adaptive big data analytics along with applied AI are established in the model of self learning to control and optimize the D2D network which helps in governing complex operations like capacity optimization, data driven coverage and much more [13]. Finally, probabilistic guided convergence strategy is implemented for finalizing the generated methods for further processing [16].

4.5 Main Aggregator Server (MAS)

For eminent operation of the system, apart from decisions recommended by Aggregators in particular PA and SLP, MAS undergoes final decision of choosing an optimized technique based on deep reinforcement learning(DRL) using multiple Deep Q-Networks [17]. Additionally, MAS maintains priority for taking decisions

from several aggregators which are altered based on performance of D2D network using bidding strategy model [18].

V. FUTURE WORK

Our proposed work is a platform which can be upgraded with the upcoming techniques with the D2D and AI algorithms. Further, the proposed protocols and techniques are not limited to the above mentioned methods in individual Aggregators and can be altered or added with some other eminent methods on deep learning studies based on simulation and real time research.

VI. CONCLUSION

In this paper, we presented an explainable AI controlled architecture of D2D system for massive MIMO based 5G networks to solve the issues relating D2D network and to meet out the requirements of IMT-2020. Several suitable aggregators based on XAI that best suits the existing D2D network were proposed with relevant techniques and algorithms. The proposed architecture stands to be an ideal platform for XAI based D2D network where the proposed techniques and algorithms related to D2D and XAI can be extended or altered depending on the requirement of the upcoming D2D network based on 5G and even beyond.

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