Course research project : Exploring the Road to 6G: ABC - Foundation for Intelligent Mobile Networks

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***Abstract*—We have entered the era of 5G now. Many mobile operators have released their 5g services in many cities and others are in the phase of testing it. 5G equipped mobile phones and WiFi routers have become a standard now. So, now it's time to plan the road-map for the next generation i.e the Sixth generation "6G".**

In this generation of mobile networks,it is certain that 3 components will play the major role. They are Artificial Intelligence, Big data and Cloud Computing. Interestingly if we take the initials of these 3, We get the A, B and C of 6G! In this paper we will emphasize on the wireless form of Big data, Wireless Big Data (WBD) and the wireless form of Artificial Intelligence (WAI) . WBD gives us the learning resource to train our WAI models using the knowledge + data driven deep learning (KDDL) method. All the computing objects that will be involved in this process will be facilitated by a layered mobile network providing cloud, edge and terminal computing capabilities.

***Index Terms*—**

- **Wireless big data : WBD, Wireless BD**
- **Knowledge + data driven deep learning : KDDL**
- **Wireless Artificial intelligence : W-AI, WAI, Wireless AI**
- **Layered network : Layered N**
- **Wireless Cloud computing : Wireless CC**
- **Layered computing : LC**
- **6^{th} generation : 6G**

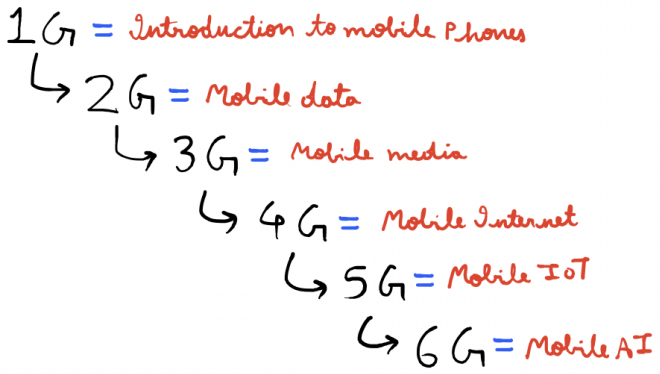

Fig. 1: evolution of mobile networking

I. Introduction

A. Motivation

For understanding the motive behind the development of 6G, we need to first look back at the previous generations to see what breakthrough they achieved. This will help us in focusing on what is left to achieve. On looking back we can see that the target goal of all the generations from 1 to 5 was to establish a better connectivity between peoples and other wireless things. From this analysis we can observe that 6G will need to full fill 4 requirements as it's core motive.

- More comfortable mode of communication between humans and internet enabled devices.
- Higher level of connectivity between the physical and cyber world
- Better penetration of the micro and macro world
- A significant overlap between information communication and cognitive perceptions

It's understandable that implementing all these demands as an add-on to the existing generation of networks would be very difficult and complicated. So, we will need a fresh development approach for 6G. As of now it is known that AI, Big Data and Cloud Computing would play a critical role in full filling these demands in 6G networks. Companies like Huawei and Baidu have also agreed upon this and has showcased their concept of using A,B and C as the backbone of 6G at various summits and conferences. Also it is seen that Big data would act as the bond between AI and Cloud Computing. Thus, it can be called as the kernel of ABC. Same kind of integration is present in the wireless forms of ABC too in which the wireless big data (WBD) is the central connector between wireless AI and wireless cloud computing.

Therefore, the prime motivation for developing the 6G networks is in laying the foundation of wireless ABC.

B. Related works

In today's digital world, every institution be it industries, government departments or health and educational institutions have recognised the importance of big data. It is a revolutionary technology which the whole world is trying to adopt as fast as it can. So, there is a lot of research going on in the field of big data focused on removing few of its bottlenecks that it have like storage of data, privacy concerns [1] and higher order of complexity and forming efficient solution about what data to keep and what to discard. Also new studies are taking place to identify and draw creative results from the big data set. [2]

AI on the other side, has again come into spot light of researchers for it's now discovered importance in the field

of wireless communication and integration with big data. New applications of deep learning, reinforcement learning and machine learning are being discovered everyday and Wireless AI has started to gain significance.

The most interesting field of research among these two is the one in which we discover ways to bridge the gap between these 2 fields and combine their unique abilities to discover their new applications. The major problem that arises on integrating them is training of models. This process takes a lot of time in a very big data set. So, cloud computing methods are being developed that will enable hierarchical knowledge + data driven deep learning models to facilitate this. This research paper is just one example of the many new possibilities that combination of big data and artificial intelligence offers.

C. Contributions

Now as we have seen the various challenges associated with bridging the gap between big data and artificial intelligence, my contribution would be to tell about the fundamental properties of these technologies and how can we use the wireless versions of big data and AI along with the power of wireless cloud computing to establish the next generation of networking. Majorly my contribution can be seen in 3 parts:

1) Discover and analyze the capability of Wireless BD to perform spatial resolution and prediction. Using the knowledge characteristics of WBD to build new learning models for our AI.
2) Proposing a KDDL model. This model will contain the following features at its core:
   - A learning architecture that is trustworthy
   - The training model parameter as initialization
   - Back propagation
3) introduce the computational capabilities in every layer of mobile networks. This will help in revamping the existing computing architecture cloud and edge computing to form a new layered architecture facilitated by WBD.

This concludes the section I of the paper, the rest paper is organised in the following way:

- In the Section 2, we will understand various fundamental properties and the features that are present in Wireless BD.
- In Section 3 I will be proposing architectures related to WAI that are trustworthy
- In Section 4 will give an overview of the layered computing mechanism in mobile networks
- In Section 5 there will be a conclusion

II. WBD AND ITS FUNDAMENTAL PROPERTIES

A. Introduction to WBD

To sum up the definition of WBD, it is a collection of current and historical data which is collected via various wireless sources e.g. mobile users data. This data set is then used for optimization and reformation of existing wireless communication technologies. Now we will discuss the problem associated with dealing with this kind of data set.

If we take a wireless event $, in which a very large data set **S** is generated. Generally the this **S** is a function of 3 things:

- *X*- A parameter
- *Q*- Resource
- *Y*- Environment

So, we can express **S** as:

$$\mathbf{S} = f(Q, X, Y) - - - (1)$$

where $Q = (q_1, q_2, q_3, ...), X = (x_1, x_2, x_3, ...) and Y = (y_1, y_2, y_3, ...)$ may have very large amount of data. So, as we can see that equation (1) is a function with multiple variables and also is a high dimensional complex function, we can conclude that finding its solution and optimization of this function is not feasible.

If we further observe the raw data which we have derived from $ and taking time which is T = 0 as the point of start, we an store the historical data set $S^{T=0}$ as

$$S_n^{(0)} : (S_{n,1}^{(0)}, ..., S_{n,m}^{(0)}, ..., S_{n,M}^{(0)}), n = 1, 2, ..., N$$

in which the max ordinal number is N of data set $S^{T=0}$.

Hence, We can write the data set in real time S^T as:

$$S^{(T)} : (S_1^{(T)}, S_2^{(T)} ..., S_m^{(T)}, ..., S_M^{(T)}) - - - (2)$$

By using the method of predictive analysis, we can also fix the environmental variable Y and the parameter variable X of the even $ and the deterministic equivalent technique [3]. We denote the fixed values as X_N and Y_N respectively where the data set's max ordinal number is *N*.

Now, our target of optimization is to determine the Q whose resource overhead is the least. So, for finding Q_min we can use a modified form of Eq. (1)

$$f(Q; X_N, Y_N) - - - (3)$$

So, this equation (3) can be solved by us for obtaining an optimized solution in which the resource consumption is minimum when data is transmitted on demand of the event $.

B. Wireless BD's ability of Spatial resolution

As the original raw data is very confusing and big, we need to include the usage of AI to filter or mine the data that is of importance to us. We will need to do this at all level of wireless communication for exploring the various behavioral characteristics and make the application of WBD effectively. For filtering data out we need to reduce the dimensions of our high dimensional space of WBD. This is very necessary and is achieved with a technique known as spatial resolution.

1) Technical Behaviour characteristics: The data set on which we are going to work on is a function of many parameters like time, varying moving speeds, distinct users, different application media, different geographical locations.... and many more.

In this case behavioral analysis of WBD is very important to extract the important information required to us. We can group or classify the various behavioral depended variables

(also known as feature parameters) of the wireless problem [4].

For this purpose we already have a proposed big data analysis model [5] which takes important features like privacy and security into consideration while achieving the target of demand driven aggregation of information sources and mining data from them.

2) Wireless BD's Spatial Extension: In the previous section we have used different behavioral characteristic features of Wireless BD to mine the orthogonality of various groups and create more orthogonal bases. These bases can be extended and mapped to many spaces who have lower amount of complexity. This enables us to simplify problems with high complexity into solvable. problems with low complexity.

As a general observation we can see that lesser the amount of demands an user has, the more the density of the matrix lowers down. The spatial resolution capability of WBD is also considered as one of the basic foundations of machine learning's classification. It doesn't matter if it is unsupervised or it is supervised learning.

C. Prediction ability in WBD

WBD can be considered as a type of an observational data in the domain of wireless networks. But every observation cannot be considered as 100% accurate as there are always some fluctuations and deviations.

1) Prediction error theorem in WBD: For a usable data **S** , the *prediction error* can be stated as the difference between original value S of **S** and the average of observational data's standard deviation $\hat{S}_\sigma$

$$\delta_S = |\hat{S}_\sigma - S|$$

Based on the data and error analysis method in [6], if *G* data sets are derived from the usable data set **S** 's experiment observations , We get M_g data discovered in the g^{th} data set.

Theorem 1: *Using the prediction error definition, On partitioning the observed usable data* **S** *into G different data sets, where M_g observation data are present in the g^{th} data set . The observed s_m's probability will be $p_m(s)$. It follows the Laplace-Gauss distribution also known as the standardized normal distribution. Hence, on taking the average of G times, the prediction error Δ_G is:*

$$\delta_S = \sqrt{\frac{\sum_{g=1}^{G} p_g(\sigma) \sum_{m=1}^{M_g} p_m\left(s_m\right)\left(s_m - \hat{s}_g\right)^2}{GM_G}}$$

2) Direct Evaluation Theorem in WBD: A target function can be expressed with continuous distribution also known as direct evaluation. We can do this by using the observation data set.

We denote the continuous target function as *S(x)*, that is

$$\mathbf{S}(x) = \begin{cases} S(x) & |x| \le D \\ 0 & |x| > D \end{cases}, S(x) = \int_D S'(x)dx$$

where D is non-zero interval of *S(x)*

Theorem 2: *Let there be an event S(x). It is known that the event is located in D and is a non zero continuous function. We will next, partition the D interval into N sub-intervals. Then we will use the values collected randomly from these to predict the wireless event S(x). The standard variance or the prediction error σ_D which we obtain is a probability function of N sub-intervals. This can be expressed as:*

$$\sigma_D = \sqrt{\frac{\sigma_{\delta_n}^2 + \sigma_{\delta_{sn}}^2}{2}}$$
$$= \sqrt{\frac{\sum_n^N \left(\Delta S_n\right)^2 + \sum_n^N \left(\delta_{S_n}\right)^2}{2N}}$$

D. WBD's Knowledge characteristics

We know that the final goal of mining data from WBD is to gather "new wireless knowledge". But as we know that WBD is just a gigantic space full of data, So, how can this vast data space translate to knowledge?

For this conversion of Data into knowledge, we involve mainly 4 steps.

1) Ordered data: This is the first step. In this the data on the basis of various user specific parameters is ordered in a such a way that a clear relationship can be drawn from it. It should be more understandable and regular than the original raw data.

2) Relation data: This is the second step. In this step we mine a new data set. This data set is known as the relationship set. This is mined by first identifying multiple variables which are of our concern while solving a problem. These identified variables are then used to form a relationship set derived from the ordered data in step 1.

3) Association data set: It is a set formed my when on analyzing some existing data sets related to the problem, we discover a new data set.

4) cognitive set: This is the final step to reach to knowledge from data. In this step we take all feature sets obtained in the previous steps and derive some useful knowledge that might help in solving our problem.

These are the various fundamentals of WBD that we discussed above. Mining techniques for WBD is a very interesting field of study [7]

III. Data + Knowledge based Wireless Artificial Intelligence

If we see the trends in the research domain in recent times, wireless artificial intelligence has emerged as one of the most interesting research fields. There are numerous researches going on around the world focusing on wireless problems solvable through the Use of reinforcement learning and deep learning. But existing architecture of this technology is still not proposed in detail and often acts as a bottleneck in this research domain. But when we use theoretical approach for countering various problems in the wireless networking domain, we take the help of a combination of data driven approach along with the model driven approach [8]

In the previous section we have already seen the performance analysis of our wireless BD, in this section we will take help of the spatial capability in Wireless BD to train our WAI model. Using this capability we will be able to accomplish the task of both unsupervised and supervised learning. We will then also use the power of predictive ability present in WBD

to make our AI more powerful and set our requirements by configuring it's parameters.

We will further address the problem of implementing this model in highly dense networks by using UDN, also known as Ultra dense networking [9]. Further we will explore various aspects of our WAI and propose certain techniques. These techniques will enable us to use our WAI and WBD combined solution at its full potential.

A. Wireless AI's Computable reverse decision

This reverse decision methodology is very similar to what we know as back propagation in machine learning by neural networks (deep learning). This method is one of the most commonly used algorithm for training of neural networks. I am not going to explain the working of this algorithm and why are we specifically using this algorithm only. For this readers can refer [10]

IV. MULTI LAYER COMPUTATION IN MOBILE NETWORKING

Nowadays in the mobile wireless communications the most popular kind of computational method is cloud computing. We also have fog computing which is a kind of decentralised computing solution in which partial load and store is in the cloud and partial in the data source [11]. It has gained significance mostly due to the evolution of IoT devices. Also a newer computing technology known "edge computing" is gaining significance recently. It focuses on bring the computational task more close to the data sources. This is gaining the attraction of researchers mainly due to the development in common user hardware. The mobile handsets which we use in 2020 are much more powerful than the most powerful server grade computing chip of 2010. Just for a comparison The flagship server chip from intel in 2010, the Xeon X5680 has a single core and multi core score of 615 and 3369 in a standardized benchmarking software, whereas the chip present in the latest iphone has a single core and multi core score of 1500 and 4000 respectively. This leap in performance over the decade has has enabled the users to compute tasks of very high complexity on their portable mobile handset which were previously only possible on the servers. Hence, it is also expected that in this improvised generation of 6G the terminal devices will play a major role along with the existing cloud computing interface.

So, in the newer generation of mobile networks, we are taking advantage of all the types of computing methods by combining their powers into creating a layered computing structure. This layer structure is very crucial in the building of intelligent mobile networking architecture.

A. Combining the layers of computing (terminal, edge and the cloud)

In today's era, almost all the newer computational infrastructure is present in the cloud. This is very useful for the users as they don't need to worry about having lesser computing resources as they could get their task done in the cloud without spending on expensive hard ware. These cloud infrastructures are present in various servers and storage data centers present all over the world which are remotely accessible.

These cloud based services are further improvised with the help of fog computing in which it delivers location-based specialised services which significantly improves the performance of remote computing. A very common example of its application is in online games. In these games usually there are multiple servers distributed around the world say 1 server in each continent and when a user logs in, his location is mapped to the closed server geographically. This significantly reduces the ping or network lag in the games and provide a seamless gaming experience. [12].

Although cloud computing looks like a one stop solution for all our computing needs but in many use cases the application are user-driven in which the real time response is very important. Thus, depending completely on the cloud is not an ideal solution, we need to some times shift the computational load more towards the users, also known as the edge. So, parallel with the development of 6^{th} gen networks, we need to also explore the various domains that edge computing opens up for us to utilize the layered computing architecture at its full extent. Also we need to identify various challenges and bottlenecks associated with utilizing the power or edge computing. [13]

Basis on the above analysis, it is highly anticipated by the researchers working the field of exploring 6G and also by the researchers working in existing field of 5G technologies that in the near futures more calculations related to communication will be performed by the end user hand held devices like mobile phones and smart IoT devices.

There are various parameters taken into consideration while determining the layered structure. Most important of them is the Allowable Delay. This variable is completely application based. It is determined by calculating the maximum delay that is tolerable for the smooth functioning of the application over a network. If the max delay which can be allowed is relatively more, then we can forward the computing request to cloud computing servers and derive the results but if the max allowable delay is very less then we will need to resort to edge computing or terminal computing at user's end to get our computational tasks accomplished with the least amount of delay possible. If the allowable delay lies somewhere between these two extremes, then we will need to take an approach in which we take best of the both worlds also referred to as fog computing sometimes.

Another parameter which need to take into consideration is the Complexity of the computational problem. In most of the cases the consumer grade hardware is significantly less capable than the server grade hardware (hardware used in cloud computing) while performing certain complex tasks. These highly complex tasks require lots of hardware resources like storage, memory and multi threaded processing power which the hardware at user end fails to provide. In these scenario we need to depend on the cloud hardware. Similarly if the problems are of a very simple nature, then we can shift closer to the edge!

I have proposed the layered computing structure in figure 2

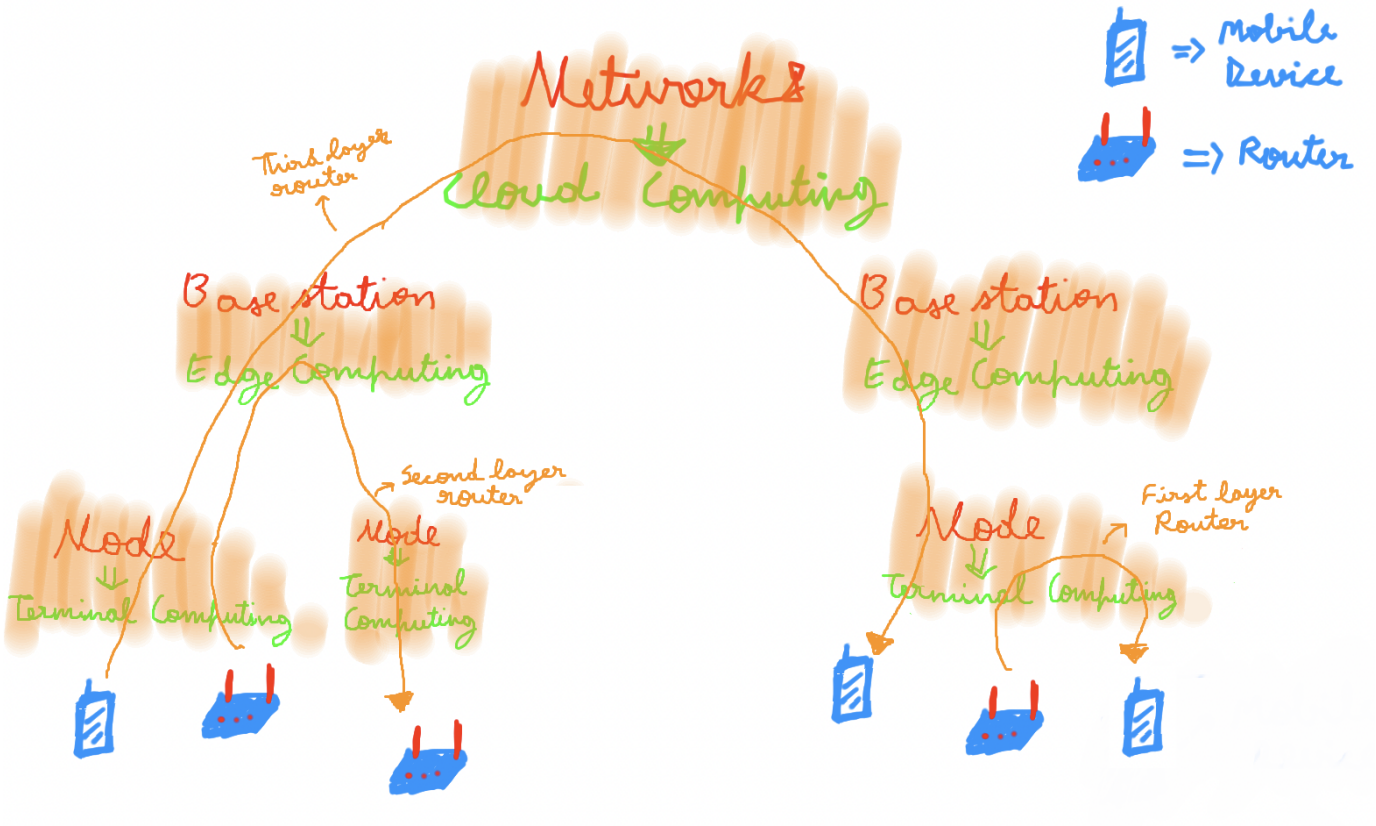

Fig. 2: working of layered networking

V. CONCLUSION

It is now very clear that when we step into the new territory of 6 G, Artificial Intelligence would be an indispensable part of the 6g era. For implementing AI in this networking architecture, we will require to study the fundamentals of Artificial Intelligence. We have already seen Many amazing breakthroughs in this field but it is a very vast area in which the major chunk is still left unexplored. Along with this we will also need to understand how to manage and take feedback from the data of billions of users that have come online during the past decade and billions of IoT devices that have emerged as part of the 5G era. For this we need to take the help of Big Data and use various techniques discussed to make it usable. Now the computational needs of all of these new technologies will also new computing architecture based on cloud, edge and terminal computing. These 3 aspects form the fundamental basis of 6G technologies, metaphorically the ABCs of 6G, where A is Artificial Intelligence, B is Big Data and C is for the new hybrid Cloud computing architecture.

In section II , I have discussed various features and basics of Wireless BD in general. These includes:

- It's prediction ability. This feature is based on the historically data. Thus, on analyzing the historically similar conditions, we can get a decent amount of prediction.
- It's ability to reduce the dimensions of data. This is achieved with the spatial resolution techniques. Spatial resolution is synonymous to the optical zooming mechanism in a Camera. It zooms in into the data which we need by filtering the data on the basis of appropriate conditions.
- It's potential to showcase knowledge characteristics. This is a very important feature as it directly helps our parallel AI model learn more efficiently.

In section III , I have laid down a deep learning model which will be based on KDDL. Also as all the learning process is taking place wirelessly with the data taken directly from the users, we have also taken privacy and trust into consideration.

In section IV, I have proposed a layered model based on a hybrid architecture consisting of edge computing, terminal computing and cloud computing elements. Then I have discussed the working of this model and various parameters contributing towards making this model efficient.

A. Future scope related to this research

I have made this paper on the basis of my analysis of the projection of where the technological revolution is heading to. So, considering all the constraints and the current in hand abilities of the computing world, this paper is return as a suggestive reference for all of them who wish to work in building the technology of the future. Although this area is in very fast development an is one of the foremost things in the radar of researchers all around the world , this research paper presents a clear road map. Based on this road map, the existing

structures of networking will be evolved and improvised to meet the needs of the future generation of networks. Now this research further diversify in the future while parallelly the prototyping of the 6G networks will also start. Finally in the near future i.e. a couple of years ahead, we will be hopefully witnessing a fully functional next generation of networking, The Sixth Generation of networking!

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