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Comparison of Statistical Prediction Models For Spectrum Utilization

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Abstract—Wireless networks depend on radio frequency networks spectrum. The word spectrum is a range of radio-waves that are used for communication purposes. This includes the FM or AM radio broadcasts and even other wireless forms of communication like Bluetooth and Wi-Fi. Spectrum provide a great economic opportunity for Nation hence spectrum management have great importance. The number of devices connected to mobile networks worldwide is around five billion today and could rise to 50 billion by 2020. Cognitive Radio (CR) is said to be a distinctive approach to improve the spectrum utilization and alleviate the spectrum scarcity. The prediction of spectrum utilization has already been studied by some research groups. In the paper, we reviewed the existing techniques for the statistical prediction model measurement and prediction of spectrum utilization. We have taken a case study of Unnat Bharat Abhiyan which includes different schemes and studied on their spectrum requirement in the future years.

Keywords- Spectrum measurement, CRN, Spectrum prediction, Wireless Infrastructure.

I. INTRODUCTION

The term radio spectrum commonly alludes to the full recurrence run from 3 kHz to 300 GHz that might be utilized for remote correspondence. Expanding interest for administrations, for example, cell phones and numerous others has required changes in the rationality of range administration. Interest for remote broadband has taken off because of mechanical development, for example, 3G and 4G mobile services, and the quick extension of remote web administrations.

The radio frequency spectrum differs from low recurrence radio waves at around 10 kHz (30 kilometers wavelength) up to 100GHz (3 millimeters wavelength). The radio range is isolated into recurrence groups saved for a solitary utilize or a scope of perfect employments. Inside each band, singular transmitters frequently utilize isolate frequencies, or channels, so they don't meddle with each other.

The quantity of gadgets associated with mobile networks worldwide is around five billion today and could ascend to 50 billion by 2020[10]. Connected gadgets are relied upon to be ruled not by cell phones as it is today but rather by machine to machine gadgets upwards of 50 billion by some gauge. Range administration has been essential component of correspondence policy [11]. The advance toward higher frequencies and littler cell sizes is a critical improvement, effectively under way, that will contribute a fundamental component of the new design. Little cells of radio scope utilizing GHz frequencies will progressively offer a more successful utilization of spectrum.

Higher frequencies are less entering, both in air and through building, and are in this manner suited to administrations that transmit just over little regions. The utilization of littler cells makes it simpler to "reuse" a given recurrence for geologically isolated administrations, which directly expands the total transmission capacity accessible to clients by expanding the quantity of get to focuses in a given zone. Little cells likewise fit better with present day gadgets that are both transmitters and receivers.

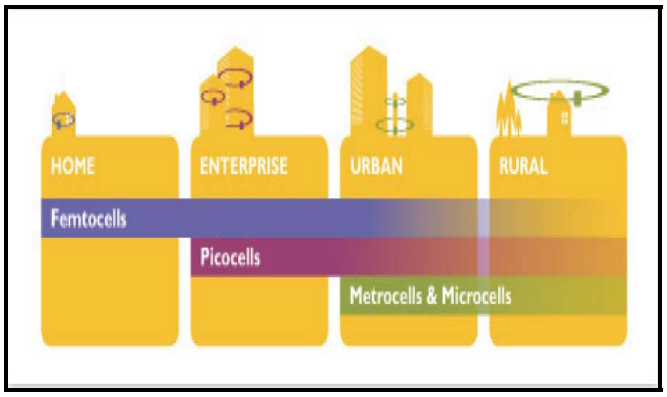

Fig.1 Small Cells Allow Greater Geographical Coverage [12]

Future Architectures will Increasingly Include Dense and Short Range Capabilities to Provide Aggregate Capacity. Diminishing cell sizes brings about more cells covering a given range, expanding the network's capacity, or capacity to deal with countless clients.

Small cell design offers an extra inspiration for moving to extensive range squares. Little cell benefits normally offer high information transmission rates to their clients using generally high data transmission; Wi-Fi transfer speed, for instance, has developed from 20 MHz to a present draft standard of 160 MHz. Arrangement of high pinnacle information rates is best proficient, both in fact and from a monetary point of view, if there are wide range obstructs in which the administrations can be deployed.

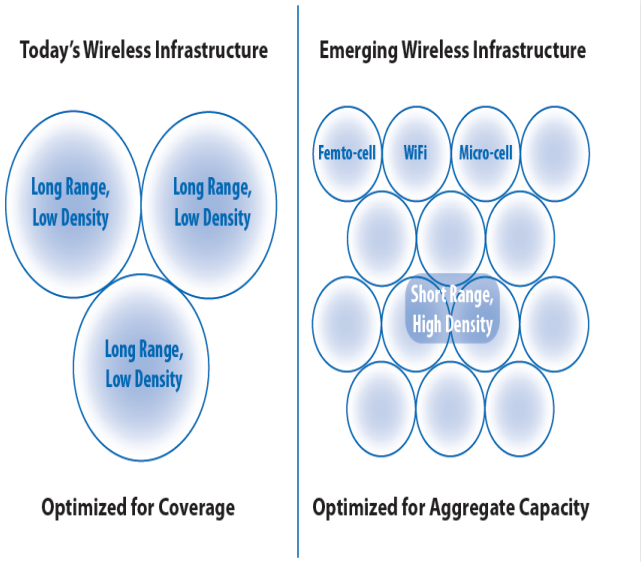

Fig.2 Wireless Infrastructure [17]

Use of finite spectrum resources is forcing policymakers and network operators to control the use of unused and currently using spectrum bands and new approaches to spectrum allocation. In many places we will use spectrum, consumers of spectrum largely limited to radio and TV companies, government bodies and mobile communication. Cellular network will probably not able to sustain the large applications. And also use of wireless services such as unlicensed Wi-Fi, educational broadcast services, automated meter reading and video surveillance uses spectrum. It is really difficult for single system to take advantages of all spectrums at any location because of governing spectrum use. But restricting spectrum band for single industry makes it unavailable for other users. So there is need of spectrum management. The advantage of wide spectrum bands are evident in the fact that there have always been efforts to keep compatible services in adjacent band, in order to reduce adjacent channel interference[14].

For efficient use of spectrum we should consider following things:

i. Using the Right network at Right Time.

We can use single large cell to handle many users having varying degrees of efficiency and throughput. We can alternatively use multiple smaller cells, lower power microcells, femtocells.

ii. Using the right spectrum Bands

We should consider power or density of cells to improve the capacity of neighboring network that uses the same spectrum band. The best power level or density depends both on propagation characteristics of the spectrum band and power used.

iii. Making use of all available spectrum.

A. Unnat Bharat Abhiyan – A Case Study

With a view to uplift rural India, the government has launched a new program — the Unnat Bharat Abhiyan. The program was being launched in collaboration with the Indian Institutes of Technology (IIT) and the National Institutes of Technology (NITs) across the country. The main concept for introducing the program was to provide definitive research that helps in national upliftment.

B. Spectrum prediction

Prediction of spectrum utilization is significant to design efficient spectrum sensing algorithm and also to optimize the spectrum access strategy. Normally, prediction of spectrum occupancy is done by measuring the received signal strength and estimating primary users' status. An ARMA (auto-regressive and moving average model) could be also used to predict the received signal strength of television services channel [15]. The methods mentioned above were used to handle stationary time series. For non-stationary time series, it is meaningful to apply the ARIMA (integrated ARMA model) [16], because this method could transform the non-stationary received signal strength into the stationary and periodic time series. In addition to the prediction of the received signal strength of the channel, many studies have focused on the prediction the state of the channel whether it is occupied at the next time.

II. PREDICTION TECHNIQUES

Many studies were done based on the spectrum prediction techniques. As per the study, we have obtained some results as shown in Table 1. In this, we have made classification of different parameters like response delay, energy consumption, interference and network throughput.

Table 1. Parameter-wise Results

PARAMETER - WISE RESULTS					
Techniques	**Applications**	**Response delay**	**Energy consumption**	**Inference**	**Network Throughput**
Artificial Neural Network	to increase the robustness of cognitive radio applications	less	less	minimum	average
Hidden Markov Model	for spectrum decision and spectrum mobility	minimum	low	minimum	average
Multilayer Perceptron Neural Network Based Prediction	for spectrum sensing	high	very low	minimum	average
Bayesian Inference based Prediction	for spectrum sensing and spectrum decision	low	low	minimum	very high
Moving Average Based Prediction	for spectrum sensing	low	low	minimum	good
Static Neighbor Graph Based Prediction	for mobility prediction	high due to network	high	high	average
Channel State Prediction	for wireless spectrum occupancy prediction	high	high	high	low

A. PREDICTION BASED ON ARITIFICIAL NEURAL NETWORK:

ANNs are powerful tools for modeling and are widely used in prediction problems due to their simplicity in terms of training. Whereas other prediction schemes require continuous training, neural network are trained once in an offline fashion when the observed process is stationary. Neural networks are nonlinear parametric models which create a mapping function between the input and output data. Using the binary series, the neural network predictor is trained to predict the channel status in the next slot based on the slot status history. In a multiple channel system, a predictor is assigned to each channel.

B. PREDICTION BASED ON MULTI-LAYER PERCEPTRON:

An MLP network is a multi layered structure consisting of an input, output and a few hidden layers. Each layer (excluding the input layer) consists of a number of computing units called neurons which calculate a weighted sum of the inputs and perform a nonlinear transformation on the sum. The MLP predictor tries to create a mapping function between the input vector and the desired value.

C. PREDICTION BASED ON BAYESIAN INFERENCE:

Bayesian Inference is a method of statistical inference which uses Bayes' theorem. The probability for a hypothesis is updated by using Bayes' theorem as more data becomes available. Spectrum sensing process is modeled as the Non-stationary Hidden Markov Model (NSHMM) and model parameters are estimated through Bayesian Inference using Gibbs sampling.

D. PREDICTION BASED ON HIDDEN MARKOV MODEL:

This technique prediction enables agile and proactive spectrum access and efficient utilization of spectral resources. Hidden Markov Models (HMM) provide powerful and flexible tools for statistical spectrum prediction. A HMM-based spectrum prediction is an algorithm for applications that accurately predicts multiple slots in the future. Traditional HMM prediction approaches use two hidden states enabling the prediction of only one step ahead in the future. By extending the number of hidden states and formulating the prediction problem as a maximum likelihood (ML) classification approach enables a prediction span of multiple slots in the future even with fine spectrum sensing resolution.

E. PREDICTION BASED ON MOVING AVERAGE BASED PERCEPTRON:

Moving average (MA) based prediction is commonly used to predict a trend in a sequence of values. MA based prediction is used to enhance the spectrum sensing performance. Each CR user collects the history energy level of the channels as observations and predicts the future energy level via an MA based predictor. Then, the CR user skips the sensing duty on those channels whose predicted energy level is higher than a preset threshold (considered as occupied by the PUs). Through this approach, the whole spectrum sensing time and energy consumption can be reduced.

F. PREDICTION BASED ON CHANNEL STATE PREDICTION:

Channel state prediction in cognitive wireless networks involves the analysis of the radio environment and evaluation of certain parameters which can be used to make the best decision for optimal communication. In this context, we can talk of CSI, i.e. Channel State Information which refers to the channel properties that affect the propagation of signal from the transmitter to the receiver. In cognitive radios, CSI is estimated at the receiver and usually quantized and fed back to the transmitter via feedback channel. The cognitive module at the transmitter end receives the information and based on the history of signal transmitted and received, it trains itself using the machine-learning algorithms. The more comprehensive its test database, the better is it trained to predict the channel behavior and this allows the cognitive radio to exploit the resources at its disposal.

G. PARAMETER-WISE ALGORITHM CLASSIFICATION:

As per the study made in Table 1, it can be concluded that the spectrum prediction techniques which requires minimum

response delay are ANN and HMM. The energy consumption is minimum in multi-layer perceptron neural network and interference is found comparatively low in Bayesian Interference and Moving Average Based Prediction. Also network throughput result is better in these two algorithms.

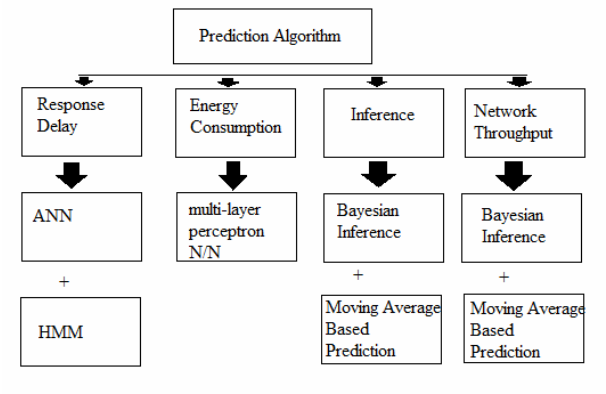

Fig. 4 Parameter-wise algorithm classification

Following figure shows the Unnat Bharat Schemes for different areas. As per the spectrum requirement for both rural and urban areas or for both, the different schemes from the Unnat Bharat Abhiyan are categorized under these categories. Under rural areas the schemes that come are Kisan Suvidha, mkisan and Gram Jyoti Yojana. Similarly, the schemes that come under rural and urban areas are khoya-paya, National Career Service Portal, Umang, Online Labs (OLABS), e-pathshala and Learning Management System (e-learning).

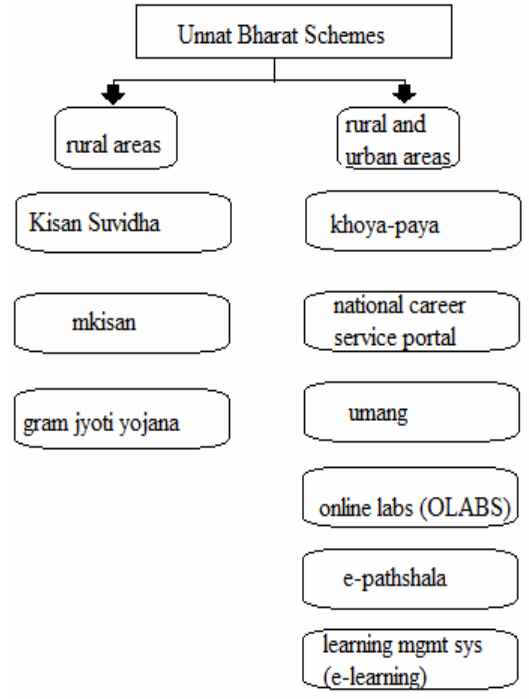

Fig. 5 Unnat Bharat Schemes for Rural and Urban areas

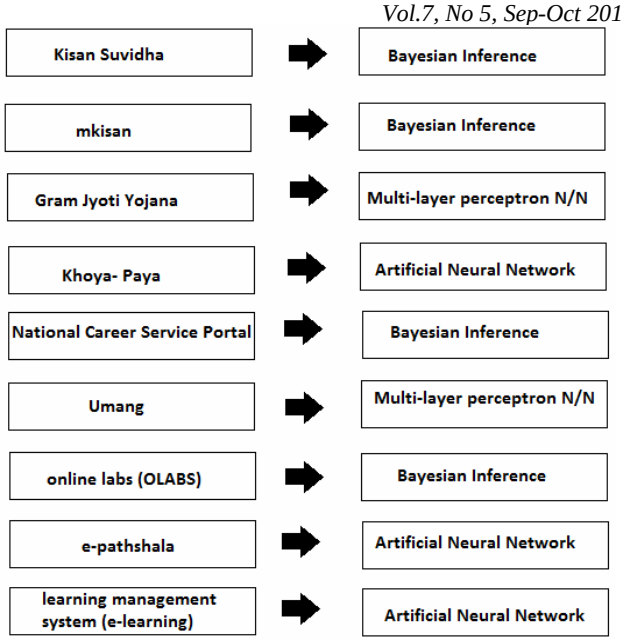

Fig. 6 Unnat Bharat Schemes classified under different prediction techniques

Fig. 6 shows the different Unnat Bharat Schemes that are classified based on different prediction techniques. The classification is based on the different parameters like response delay, inference, network throughput and energy consumption.

Bayesian Inference basically reduces the interference or congestion in the network. Unnat Bharat schemes like mkisan, Kisan Suvidha, OLABS and national career service portal basically needs such a spectrum when the interference is low. For Gram Jyoti Yojana and Umang, it deals with the improvement of facilities in rural areas like electricity, water and other facilities that can be helpful. As it deals with different sectors, the requirement of bandwidth also varies and hence multi-layer perceptron neural network. Artificial Neural Network deals with many hidden layers and its response delay is comparatively lower that other prediction techniques and hence this would be a preferred technique for educational sectors like e-pathshala and learning management system.

SURVEY ON INTERNET TRAFFIC IN INDIA

The study, titled 'Estimating the Value of New Generation Internet based Application Services in India" and released by telecom minister Manoj Sinha in New Delhi, estimated the internet's contribution to develop around 16% of India's GDP by 2020, that converts to Rs 36 trillion ($534 billion), where the half comes from internet-based apps [19].

"According to a survey, 17% increase in the total internet traffic in India in 2015-16 contributed to an increase of Rs7 lakh crore (7 trillion) in GDP of which at least Rs 1.4 lakh crores (Rs. 1.4 trillion) was due to internet-based app services. This puts the internet's contribution to India's GDP at about 5.6% in 2015-16," the report said. The impact of the apps economy in India is double the global impact, the survey

showed. "A 10% increase in total internet traffic and mobile internet traffic led to an increase in India's GDP by 3.3% and 1.3% respectively as against the global average of 1.3% and 0.7%."

A 17 per cent rise in the total internet traffic in India was seen in 2015-16 that led to an increase of Rs 7 lakh crore in Gross Domestic Product (GDP), of which at least Rs 1.4 lakh crore were from net-based app services. Thus, the internet's contribution to the country's GDP was 5.6% in 2015-16. This may grow to nearly 16% (Rs 36 lakh crore) by 2020 [19].

The study emphasized the need to address a lack of digital infrastructure, invest in India's e-governance app-ecosystem, encourage development of vernacular content, use the Startup India program to accelerate growth in the sector, promote skill development for app developers, promote government and private sector collaboration, strengthen cyber security infrastructure, change perceptions and build awareness among consumers, disentangle regulatory needs, and develop a systematic approach to regulations.

In a recent research it was found that if there is a 10% increase in total Internet traffic and mobile Internet traffic, it increases India's GDP by 3.3% and 1.3% respectively [18]. In the study, if there is a 10% increase in total Internet traffic and mobile Internet traffic, it increases India's GDP by 3.3% and 1.3%, respectively. The key recommendations include a pragmatic approach to regulation, increased connectivity and network infrastructure, focus on developing vernacular content and cyber security infrastructure, among others.

We are focusing on the internet traffic that will arise after usage of apps like Khoya-Paya, Kisan Suvidha, OLABS, e-pathshala etc. Owing to its e-connectivity, will also become a site for learning. With increased bandwidth, lectures and workshops can be streamed into this center on agriculture, livelihood generation and development of local facilities and infrastructure [17]. Local students can learn from other centers as well as from local technical institutions, and other centers of expertise from around the country. In addition, local experts (artisans, artists, agriculturists) can also share their expertise with other parts of the country. This model will also help local universities (faculty and students) engage with local problems, further helping contextualized skill development that is needed in India.

III. CONCLUSION

In this paper, we reviewed the existing wireless infrastructure and prediction carried out by different research groups. For spectrum measurement, the utilization of spectrum rates is quite low, and they showed temporal, spatial and spectral correlation among different channels. For spectrum prediction, the prevalent methods are based on integrated moving averaging auto-regression, hidden although those methods have improved the prediction accuracy of spectrum utilization; there are still many difficulties and challenges for the prediction method, which will be the direction of our future research.

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