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Prediction of Call Arrival Process and Call Holding Time using Stochastic Modeling Process

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Abstract

Modern telecommunications networks are designed in such a way that to accommodate a mix of heterogeneous wireless networks of traffic classes to perform different services. Traffic models are important to analyze the performances of telecommunication systems namely traffic, interference and channel estimation. This paper provides an approach for evaluating the channel availability and predicting of the call arrival rate and call holding time. The simulation results show the comparison of call holding time of T with stochastic modeling process.

Keywords: call arrival, call holding time, PDF, channel utilization.

Introduction

The current utilization of the spectrum is quite inefficient as consequently, if properly used, there is no shortage of the spectrum that is presently available. Therefore, it is anticipated that more flexible use of spectrum and spectrum sharing between radio systems will be key enablers to facilitate the successful implementation of future systems. CR is known as the most intelligent and promising technique in solving the problem of spectrum sharing.

Traffic models are at the heart of any performance evaluation of telecommunications networks. An accurate estimation of network performance is critical for the success of heterogeneous wireless networks. Such networks need to guarantee an acceptable quality of service (QoS) level to the users. Therefore, traffic models need to be accurate and able to capture the statistical characteristics of the actual traffic. Prediction of future idle times of different channels based on history information allows a cognitive radio (CR) to select the best channels for control and data transmission. In this paper, the proposed technique of spectrum sharing among users of service providers is to share the licensed spectrum of the licensed service providers. For that, the traffic pattern of the primary user has to be evaluated before the available free spectrum of the primary user is allotted to the secondary user.

In order to avoid the temporal connection loss or interference with the primary user, the secondary user has to evaluate the channel availability before using the channels of the primary user and predicting the traffic pattern of the primary user. This would increase the channel utilization and reduces the call blockage and interference.

The paper structure follows: In Section II & III, related work and Stochastic models are briefly discussed. Channel availability evaluation, Prediction of call holding time and simulation results are discussed in section IV, V and VI. Finally, we draw our conclusions in Section VII.

Related work

The author in [1], has discussed about the queuing system with a M/M/N/N queue for two types of users compete for the N resources for traffic prediction. The users may have different arrival and service rates and they were denoted as primary or secondary users. In this context, the primary users have certain rights to use the resources, whereas the secondary users must make opportunistic use of the resources without impacting too much on the performance of the primary users. For all priority settings, the mean number of primary and secondary users was derived as are the blocking probabilities for both users.

In [2], the author considered prioritized unlicensed user traffic in which the licensed users' transmissions can happen at any time instant. Therefore, the DSA scheme should perform spectrum handoff to protect the licensed user's transmission. Different DSA schemes (i.e., centralized and distributed) are considered to manage the prioritized unlicensed user traffic. These DSA schemes use different handoff mechanisms for the two classes of unlicensed users and also studied the impact of sub-channel reservation for the high priority secondary users in both DSA schemes and derived performance measures for both high and low priority unlicensed users.

In [3], the author proposed a simple traffic prediction mechanism using the Recursive Least Squares algorithm and highlights its applications in proactive network management and this work demonstrates that traffic load at a future time point can be predicted accurately based on recent observations (measurements collected during the past intervals) in a computationally efficient way.

In [4], the author proposed a method which works not only with a specific type of traffic but learns and classifies the traffic type of each channel over time and can select the prediction method based on that. Different prediction rules were applied to partially deterministic and stochastic ON-OFF patterns. The author also illustrated how a CR predicts how long the channels were going to be idle and the channel with the longest predicted idle time was selected for secondary use. Here, the predictive channel selection method outperforms opportunistic random channel selection both with stochastic and deterministic ON-OFF patterns. The classification-based method has even a higher gain when channels of interest include both stochastic and deterministic traffic.

Xiukui et al. [5] attempt to predict the call arrival rate of the primary users using a linear ARMA predictor following which the call holding time was estimated. The author forecasted the traffic pattern of primary users, so that the secondary users can estimate the utilization of frequency bands and select one for radio transmission to reduce the frequency hopping rate (the rate of switching from one frequency band to another) and the interference effects. They author also estimated the call arrival time and the call holding time within a time period of the traffic process.

The call holding time distribution in cellular systems was analyzed for several system performance measures. Several statistical distributions were used to model the call holding time distribution in 3rd and 4th generations cellular systems, such as exponential, Erlang, Gamma, and generalized Gamma in [6] and several factors affecting the call holding time such as the service plan, the class of the service area, and some of the system design parameters, the parameters of the distributions used to model the call holding time were assumed, and the effects of some factors on the call holding time are eliminated. The author also derived the probability density function (PDF) of the call holding time based on actual data and the PDF of the call holding time is approximated by gamma distribution and its parameters are derived using Maximum Likelihood Estimation.

In [7], the author presented a study of channel occupancy times and handoff rate for mobile computing in MC (Mobile Computing) and PCS (Personal Communications Services) networks, using general operational assumptions. The author shown that, for exponentially distributed call holding times, a distribution more appropriate for conventional voice telephony, the channel occupancy times were exponentially distributed if and only if the cell residence times were exponentially distributed. They also showed that the merged traffic from new calls and handoff calls was Poisson if and only if the cell residence times were exponentially distributed, too.

In wireless mobile networks, quantities such as call blocking probability, call dropping probability, handoff probability, handoff rate, and the actual call holding times for both complete and incomplete calls are very important performance parameters in the network performance evaluation and design. In the past, their analytical computations are given only when the classical exponential assumptions for all involved time variables are imposed.

In [8], the authors illustrated the exponential assumptions for the involved time variables and, under independence assumption on the cell residence times, derive analytical formulae for these parameters using a novel unifying analytical approach. It turns out that the computation of many performance parameters was boiled down to computing a certain type of probability, and the obtained analytical results can be easily applied when the Laplace transform of probability density function of call holding time is a rational function. Thus, easily computable results can be obtained when the call holding time was distributed with the mixed-Erlang distribution, a distribution model having universal approximation capability. As per the author’s contribution, they developed a new analytical approach to performance evaluation for wireless networks and mobile computing systems.

In [9], the authors were studied the probability distributions and statistical moments for the number of handovers per call for a variety of combinations of the call holding time (CHT) and cell residence time (CRT) distributions. Here, they have derived explicit forms for the Probability mass function (pmf) and the statistical moments of the number of handovers during a random call holding time (CHT) when the CHT distribution was well-fitted by a mixture of exponential distributions while the cell residence time (CRT) was arbitrarily distributed.

In [11], the authors discussed the effect of long calls on the call holding distribution and concluded that call holding time was best modeled by a 4-component phase type distribution. The author in [10] described call holding time for PCS networks and provided analytical study for each of Gamma, (staged) Erlang, hyper exponential and hyper-Erlang distributions. Previous research shows that it was possible to achieve good fit using a mixture of log-normals when the long hold times were truncated. Although this truncation permits a good fit, it might lead to loss of significant fraction of calls. On the other hand, leaving all the calls including the few extremely long duration ones might lead to infinite variance/mean distribution [11]. According to the author, the exponential and Erlang distributions have simple properties for modeling service time. This simplicity makes analyzing the queuing system easier.

In paper [12], classification method and predictive channel selection method outperforms opportunistic random channel selection both with stochastic and deterministic patterns.

Thus, the literature survey gives an idea about the traffic prediction scenarios and stochastic modeling process used for prediction of call arrival and call holding time.

Stochastic Modeling Process

A counting process $\{(N(t)\}_{t=0}^{\infty}$ is a continuous time, non-negative integer valued stochastic process, where N(t)=max$\{$n: $T_n \leq$ t $\}$is the number of traffic arrivals in the interval (0,t). An interarrival time process is a real valued random sequence $\{A_n\}_{n=1}^{\infty}$, where A = $T_n - T_{n-1}$ is the length of the time interval separating the n-th arrival from the previous one. The equivalence of these descriptions follows from the fact that $T_n = \sum_{k=1}^{n} A_k$.

The interarrival times $\{A_n\}$ are assumed to form a stationary sequence, unless otherwise stated. An alternative characterization of point processes, called stochastic intensity theory. Consequently, models which capture the auto correlated nature of traffic are essential for predicting the performance of call arrival rate and call holding time.

From a practical point of view, stochastic models of traffic streams are considered relevant to network traffic engineering and performance analysis, to the extent that they are able to predict system performance measures to a reasonable degree of accuracy; additionally, a practitioner’s confidence in a traffic model is greatly enhanced, if the model can capture visual features of the empirical traffic in addition to approximating its statistics.

Traffic modeling is the problem of representing our understanding of dynamic demands by stochastic processes. Accurate traffic models are necessary for service providers to properly maintain quality of service. Many traffic models have been developed based on traffic measurement data. Teletraffic theory is the application of mathematics to the measurement, modeling, and control of traffic in telecommunications networks. The aim of traffic modeling is to find stochastic processes to represent the behavior of traffic. A. K. Erlang famously characterized telephone traffic at the call level by certain probability distributions for arrivals of new calls and their holding times. Erlang applied the traffic models to estimate the telephone switch capacity needed to achieve a given call blocking probability. In this section, we will discuss some stochastic models used for the traffic data that can be described in statistical terms.

Poisson Process. Poisson models are the oldest traffic models, dating back to the advent of telephony. A Poisson process can be characterized as a renewal process whose interarrival times $\{A_n\}$ are exponentially distributed with rate parameterλ. Equivalently, it is a counting process, and the number of arrivals in disjoint intervals is statistically independent(a property known as independent increments).

Poisson processes enjoy some elegant analytical properties. First, the superposition of independent Poisson processes results in a new Poisson process whose rate is the sum of the component rates. Second, the independent increment property renders Poisson a memoryless process. This, in turn, greatly simplifies queueing problems involving Poisson arrivals. Third, Poisson processes are fairly common in traffic applications which physically comprise a large number of independent traffic streams, each of which may be quite general. It roughly states that under suitable but mild regularity conditions, such multiplexed streams approach a Poisson process, as the number of streams grows but the individual rates decrease so as to keep the aggregate rate constant. Thus, traffic on main communications arteries are commonly believed to follow a Poisson process as opposed to traffic on upstream tributaries which are less likely to be Poisson. However, traffic aggregation (multiplexing) need not always result in a Poisson stream.

Exponential Distribution. It is non-negative values to model time intervals. Applications of the Exponential distributions are to model renewal arrival process (interarrival times), and to model holding time of the call.

Gamma Distribution. The gamma distribution, like the lognormal distribution, is an alternative to consider for ecological variables that seem to be highly skewed. The gamma distribution is one of the waiting time distributions that may offer a good fit to time to failure data. Even though this distribution is not widely used as a lifetime distribution model, it is used in many other important practical problems. Two-parameter gamma tolerance limits and prediction limits are used in monitoring and control problems.

Channel Availability Evaluation

Spectrum usage deals with the availability of the free channel which is not used by the primary users. The Primary users are said to be a licensed owner of a frequency band and the one who uses the spectrum opportunistically for communication of the licensed user are called Secondary users. Secondary users sense the presence of primary user with the help of Cognitive radio. It tunes the spectrum band or channel which is not currently in use for communication. If the primary user returns to the channel in which the secondary user is active, then the secondary user has to vacate the channel. This type is called as a forced termination. Then the secondary user has to shift to another available channel and continues its process. Sometimes this type of shifting may leads to interruption in communication. Inorder to overcome this difficulty, the secondary user has to predict the channel availability of the primary user and then they have to go utilizing the channel in an efficient manner.

Since the availability of the channel for the secondary user depends upon the traffic of the primary user, number of the secondary user has been service also varies with the primary user traffic. The amount of service that can be squeezed in from the free bands in a spectrum accessed by unrestricted primary users is called the capacity of secondary users.

In order to assess the communication environment, all communication channels may be monitored at least once and preferable several times per second. Through repetitive monitoring of the communication spectrum, an accurate history of channel usage can be developed. Once an accurate usage history is established, predictive methods can be used to select a channel likely to be available. In one aspect of the present disclosure, the channel selection process is based on evaluation of available frequencies based on three criteria:

- The most recent spectrum activity scan--If a channel shows activity in the current scan, it is presumed to be busy for the next operational period and is excluded from selection for use.
- Database of excluded frequencies--If a channel falls within a range of excluded frequencies; it is excluded from selection for use.
- Availability prediction based on historic use--The channel prediction algorithm attempts to reduce the chances of interference by steering the channel selection to those frequencies which are least likely to show activity by other stations in the next operational period.

In a traditional way of evaluating the call arrival process of a wired or wireless networks was done with the help of Poisson process. In a Cognitive radio system, the number of subscribers licensed to a service provider is low or the call request/ call attempt is found to be low. In such cases, the secondary user can easily share the available spectrum among them.

We consider the number of call arrivals of primary user within a period of time t is limited. Hence, considering the total number of call arrivals of primary user is NA within t, then the call arrival would follow the Binomial distribution i.e., $X \approx Y(N_A, P)$ where P is the probability of the service request of an user.

The mean $E\lambda$ of binomial distribution is NA.P. Hence, P will be given as

$$P = \frac{E\lambda}{N_A} \quad \text{(Eq. 1)}$$

$$= \frac{\lambda t}{N_A} = \lambda \Delta t \quad \text{(Eq. 2)}$$

where λt is the number of user arriving i.e., call arrival rate and Δt is the mean value of the call arrival. From Eq. 2, $\Delta t = \frac{t}{N_A}$. $E\lambda$ is the mean number of call arrivals for a given time period t and λ refers the mean number of call arrivals per unit time. This gives the call arrival rate of the primary user.

We have to calculate the probability of the number of primary user arrival in certain time duration. For this, we can decide that the arrival of users within a time t and not focusing on the waiting times, but concentrating on the number of the users. We can assume that the probability of users in a given time t as [16-18]

$$P_{pu} = \binom{N_A}{0} P^0 (1-P)^{N_A - 0}$$

$$= (1-P)^{N_A}$$

$$= (1 - \lambda \frac{t}{N_A})^{N_A} \qquad \text{(Eq. 3)}$$

Where N_A is large. Eq. 3 is an approximated one got from the Poisson distribution.

Apply non-homogeneous Poisson process to consider the call arrivals of the primary user. Let A(t) (for $t \geq 0$) be the number of call arrivals arriving in the time interval[0,t] with A(t) = 0. The rate parameter of the call arrival process is A(t) is a(t) where a(t) may change over time. The expected call arrival rate between time t1 and t2 is given as

$$A_t = \int_{t_1}^{t_2} a(t)dt \qquad \because [P(A \leq t_2)] \qquad \text{(Eq. 4)}$$

The number of call arrivals A_t to occur during any time interval of length t, then it will be given using Poisson process as [14]

$$P[A(t) = n] = P_n(t) = \frac{e^{-\lambda t}(\lambda t)^n}{n!} \qquad \text{(n=0,1,2…)} \qquad \text{(Eq. 5)}$$

Since A_t is Poisson with parameter λt; an average of λt arrivals occur during a time interval of length t, so λ be the average number of call arrivals per unit time or the call arrival rate.

If the number of call arrivals A_t to occur within the time interval $(t + \Delta t)$ which follows a Poisson distribution with parameter $\lambda_t, t + \Delta t$, i.e.,

$$P[A(t + \Delta t) - A(t) = n] = P[A(\Delta t) = n]$$
$$= \frac{e^{-\lambda_{t,t+\Delta t}} (\lambda_{t,t+\Delta t})^n}{n!} \qquad \text{(n=0,1,2..)} \qquad \text{(Eq. 6)}$$

Thus, Eq. 6 gives the chance of call arrival rate in the time interval $[t, t + \Delta t]$ is Poisson distributed with mean equal to the length of the interval. Also, the probability of no arrival during the interval $[t, t + \Delta t]$ is given as $1 - \lambda\Delta t + o(\Delta t)$ and the probability of more than one arrival occurring between $[t, t + \Delta t]$ is $o(\Delta t)$.

Here, Network user's behavior may be measured as the time of calls, the average length of the call or the number of calls made in a certain period of time. For Telecommunication companies, they often use call inter- arrival time and call holding time to calculate the call blocking rat, Interference and to determine the spectrum utilization efficiency. In the analysis of network traffic, the call inter-arrival time are exponentially distributed, while the call holding time fits a lognormal distribution.

Generally, a traffic period will be divided into 24 time intervals. The number of user calls is considered as the important calling behavior pattern in the voice network [15]. A general metric followed in the telecommunication industry is the hourly number of calls. Hence, the 24 time intervals will be considered as

$$(t_n, t_{n+1}) \qquad \text{(n = 0,1,2,…23)}$$

Then the time duration will be t_d i.e.,

$$t_d = t_{n+1} - t_n \tag{Eq. 7}$$

for one time interval i.e. one hour. Thus, the call rate parameter $\lambda(t)$ will take the constant value $\frac{\lambda_n}{t_d}$ in each interval of time (t_n, t_{n+1}) i.e.,

$$\lambda(t) = \frac{\lambda_n}{t_d} \quad [t \in t_n, t_{n+1}] \tag{Eq. 8}$$

where λ_n is the total number of call arrivals in the time interval (t_n, t_{n+1}). Consider the number of call arrivals within the time interval $t_n \langle t \langle t + \Delta t \leq t_{n+1}$ i.e., t and Δt are within the same time interval (t_n, t_{n+1}). Hence, the expected call rate Δt is given as

$$\lambda_{t,t+\Delta t} = \frac{\lambda_n}{t_d} \Delta t \tag{Eq. 9}$$

If we consider, Eq. 4 and Eq. 8, we get call arrivals with different time intervals and period of time. This provides the number of call arrivals of the primary user within the time interval (t_n, t_{n+1}). From this we can predict or evaluate the channel for the secondary user. From Eq. 7, we get the call arrival rates of the primary user. If the secondary user finds the channel to access, it plans to start its transmission over this channel. Before that, it predicts the call arrival of the primary user in the current time interval. If no primary user occupies the channel during the time interval, it has to evaluate the probability of no primary user for call holding time. From Eq. 6, we can generate the probability as

$$P = \frac{e^{\frac{-\lambda_n}{t_d}\Delta t}\left(\frac{\lambda_n}{t_d}\Delta t\right)^0}{0!} = e^{\frac{-\lambda_n}{t_d}\Delta t} \tag{Eq. 10}$$

It is difficult to predict the ongoing call holding time of a secondary user. This can be taken in a random manner. Hence in Eq. 10, the call holding time is replaced with the average call holding time of the secondary user and calculate $\bar{t}$ based on the total number of calls within a time duration and cumulative total call holding time. In the following discussion, we can consider the total number of arrivals of primary user NA for the secondary user. For this, we have to consider three approaches inorder to predict the average call holding time $\bar{t}$ of a secondary user. This $\bar{t}$ is calculated using the historical calls and it does not depend upon the last call.

Approach 1: Primary user ends its transmission at one time t1 and secondary user starts its transmission at the same time t2 i.e., t1= t2.

Here, the secondary user has to estimate the probability of the arrival of the primary user within the time $\bar{t}$. Thus, the probability P_0 of no primary user's arrival within the time $\bar{t}$ is given by

$$P_0(t) = e^{-\lambda t} \tag{Eq. 11}$$

Approach 2: The arrival of users between time t1=0 and t2 =1, not by focusing on the waiting time but concentrating on the number of arrivals of the user. This approach does not tell immediately when the users arrive, but it only provides the information that in a given time interval the number of customers should have a Poisson distribution, with a parameter which is proportional to the length of the interval i.e., it must be non-decreasing. The number of arrivals that have occurred in the interval (t1, t2) and it is given by t1<t2.

Here, the primary user ends its transmission at t1 and secondary user starts its transmission at t2. The probability that there is no occurrence before time t is, according to the current approach, equal to $e^{-\lambda t}$. Hence, the probability $P_0^{'}$ of the no arrival of the primary user will be given by

$$P_0^{'} = t_1 + t_2$$
$$P_0^{'}(t) = -\lambda P_0(t)$$
$$P_0^{'}(t) = -\lambda e^{-\lambda t} \qquad \text{(Eq. 12)}$$

Where (t 1+t2) = P (no occurrence before t1 +t2)
= P (no occurrence before t1) P (no occurrence between t1 and t2);

Approach 3: In this approach, the primary user starts its transmission at t0 and ends at t2. The secondary user intends to start its transmission at t1. This will be given as t0<t1<t2.

We have to assume that the secondary user holds the call for some time otherwise it would drop the call Th. In this case, the event that representing the current primary user vacate the channel within Th is X and no primary user arrives within the time $\bar{t}$ is Y. when the probability P_1 will be available within the time duration Th + $\bar{t}$ and given as

$$P_1 = \text{Probability}\{\text{X and Y}\}$$
$$= \text{Probability}\{\text{X}\}.\text{Probability}\{\text{Y}\}$$
$$f(t) = \lambda(\lambda t)^{k-1} e^{-\lambda t}$$

Thus,

$$P_1 = \int_0^{T_h + t_1 + t_2} f(t)dt \cdot \lambda^{-\lambda t} \qquad \text{(Eq. 13)}$$

Where f(t) represents the probability density function (pdf) call holding time of the primary user.

It is hard to obtain practically the probability density function (pdf) for the secondary users. Hence, the secondary user has to estimate the call holding time of the current primary user and probability of no primary user arrival within time $\bar{t}$. Then only the secondary user has to proceed, otherwise it has move to the other available spectrum or to drop the call.

It is difficult to predict the mean number of call arrivals per unit time and to estimate the call holding time of the primary user. This will be explained in the following section of predication of call arrival rate.

Call Holding Time using Stochastic Modeling

The duration of call holding time is a fraction of the total call duration. The duration of the requested call connection is referred to as the call holding time. Factors such as mobility, cell shape and size because the dwell time to have a different Probability Distribution Function (PDF) to that of call duration. This difference being greater for higher mobility and smaller cell sizes.

The selection of the call holding times was typically assumed to be Gamma distribution and exponentially distributed. Such an assumption may be reasonable when the calls are charged based on the lengths of the call holding times. To determine the call completion, we should evaluate the call arrival distribution, call holding time and cell residence time i.e., a mobile stays in a cell.

However, the time needed for a call to complete should be estimated. It is desirable to know how much time is needed for a complete call to finish and how much time an incomplete call spends using the resource bandwidth.

The data used in this paper is from a mobile switch centre in GSM system of Salem, India. The call start time and call holding time are selected from the signaling command. In one hour, all calls to and from the mobile switching centre are recorded. These data has been used for constructing a data sample and also used to find out the traffics of the communication.

Three data samples are constructed using the information obtained from three different days i.e., 21st, 24th and 25th August 2012. The values over 180 seconds are all recorded as 180 seconds. The following tables, Table 1, Table 2, and Table 3 show the statistical values of three data samples respectively. The call duration of the data samples used in this thesis are from 3 to 180 seconds because the values under 3 seconds are considered to be caused by noise or interference or may not be normal calls.

Table 1: Call Duration statistical values of data set 1

21st Aug 2012	Number of calls	Percentage of Total Calls	Traffic Carried	Percentage of Traffics Carried
Total	2366		54.33	
3-60 sec	1001	42.31	18.04	33.20
61-120 sec	717	30.30	17.09	31.46
≥ 180 sec	648	27.39	19.20	35.34

Table 2: Call Duration statistical values of data set 2

24th Aug 2012	Number of calls	Percentage of Total Calls	Traffic Carried	Percentage of Traffics Carried
Total	2032		44.29	
3-60 sec	950	46.75	17.81	40.21
61-120 sec	612	30.12	14.44	32.60
≥ 180 sec	470	23.13	12.04	27.18

Table 3: Call Duration statistical values of data set 3				
25th Aug 2012	**Number of calls**	**Percentage of Total Calls**	**Traffic Carried**	**Percentage of Traffics Carried**
Total	2172		47.56	
3-60 sec	1000	46.04	17.78	37.38
61-120 sec	691	31.81	18.36	38.60
≥ 180 sec	481	22.14	11.42	24.01

Distribution Models such as Erlang distribution, Exponential distribution, lognormal distribution, Normal distribution and the Gamma distribution are used to approximate the channel or call holding times in the past. Exponential distribution can be used for one parameter approximation of the measured data where as the Gamma distribution can be used for two parameter approximation.

Although the exponential and Erlang distribution models have simple good properties for queueing analysis, however, they are not general enough to fit the field data. The generalized Gamma and log normal distributions are more general. Gamma distribution has been used to approximate the call holding time of Personal Communication Service systems.

In this thesis, the call holding time is calculated in different time intervals follows Gamma distribution with different parameters. The Probability Density Function (PDF) of call holding time is given by

$$f(t) = \frac{\beta^{\alpha}}{\sqrt{\alpha}} t^{\alpha-1} e^{-\beta t} \qquad \text{(Eq. 14)}$$

With the changing value of Parameter β gives the formula as

$$f(t) = \frac{1}{\beta^{\alpha}\sqrt{\alpha}} t^{\alpha-1} e^{-\frac{t}{\beta}} \qquad \text{(Eq. 15)}$$

where

$$\sqrt{\alpha} = \int_{0}^{\alpha} \beta t^{\alpha-1} e^{-\beta t} dt$$

Here, t is a gamma distributed random variable with parametersα, β. The probability p_i that of x is gamma distributed with parametersα, β is given by

$$E(T) = \sum_{i=1}^{n} p_i [t \frac{1}{\sqrt{\alpha \beta_i \alpha_i}} t^{\alpha_i - 1} e^{-\frac{t}{\beta_i}} dt] \qquad \because t > 0, n = 1,2,\ldots$$

$$= \sum_{i=1}^{n} p_i \alpha_i \beta_i \qquad \text{(Eq. 16)}$$

During the time interval i, the call holding time T follows gamma distribution and p_i is the ratio of the total time in the time interval i over the total time in one period.

Simulation Results

In this section, Using NS2 simulation the performance of the overall system efficiency has been evaluated. The call arrivals are modeled using the Poisson distribution, while the call holding times are exponentially distributed.

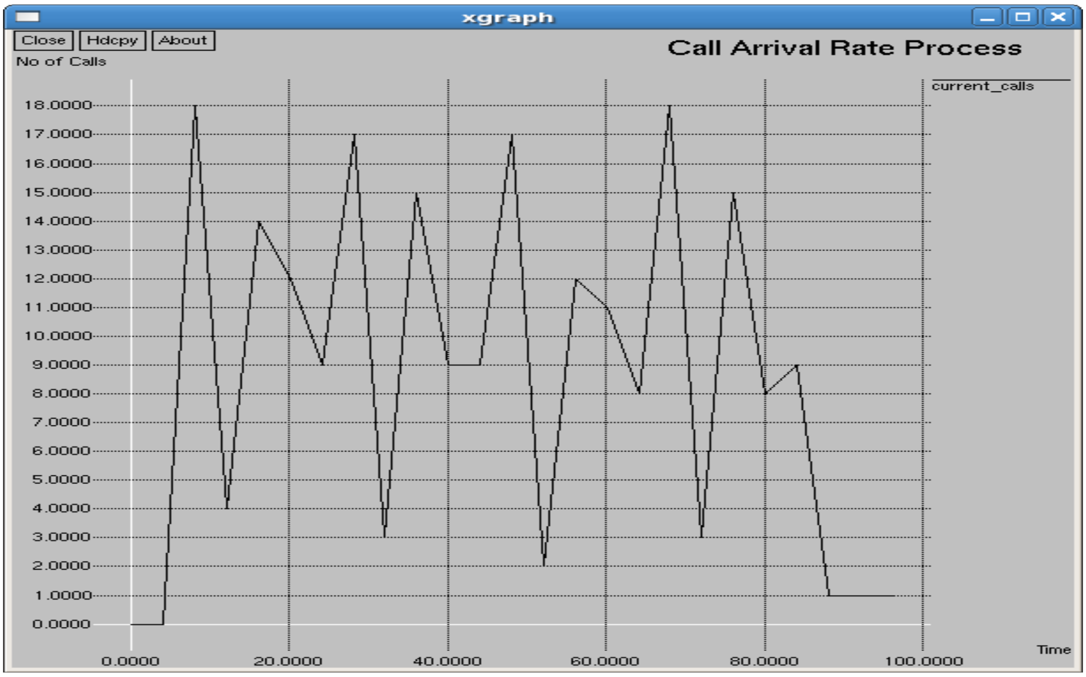

Fig. 1 Call Arrival Rate Process

To estimate the call arrival rate of the primary user within a given time, secondary users has to predict the number of call arrivals within a given time. The call arrival rate λ is 18 calls/second and it is illustrated in the Fig. 1. The licensed frequency bands can be used to carry voice or data in a cognitive system. The traffic pattern of primary users may vary with application. Taking the time interval into account, within a given period and the corresponding number of calls in that interval and set of number of call arrivals at various time intervals are also observed using discrete time series method.

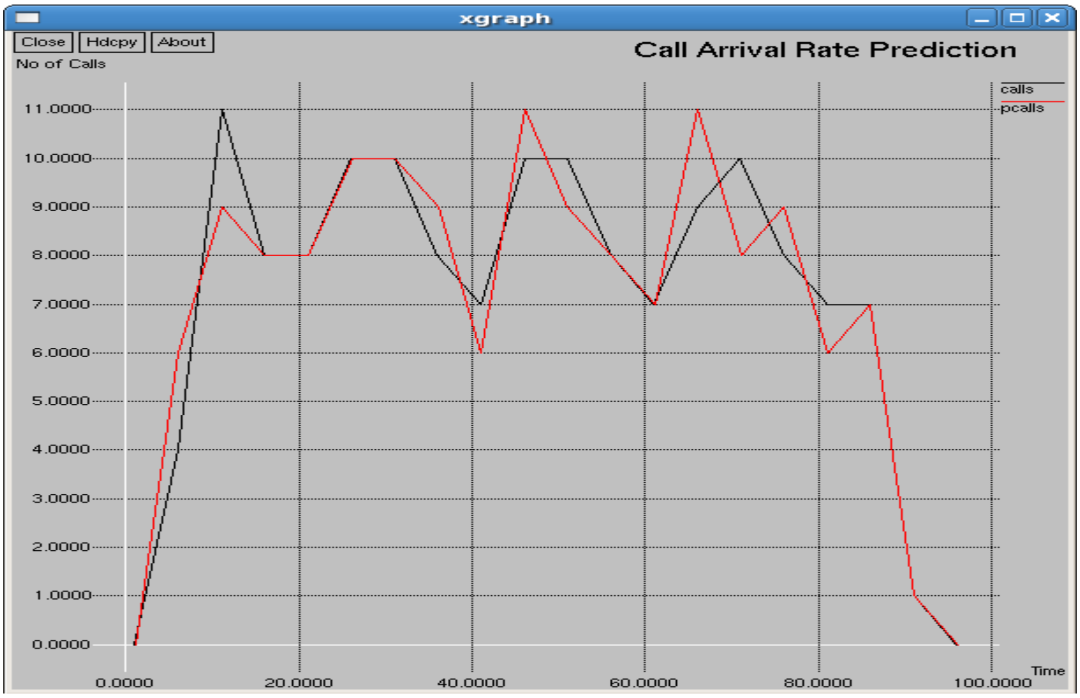

Fig. 2 Call Arrival Rate Prediction

Fig. 2 gives the call arrival rate prediction of the original calls and the forecasting (primary) calls. The call arrival rate predication is based on the mean square error. It is an absolute error measure with respect to the predicted traced variance. This figure visually demonstrates that the proposed predictor is capable of tracking the input trace in spite of variations.

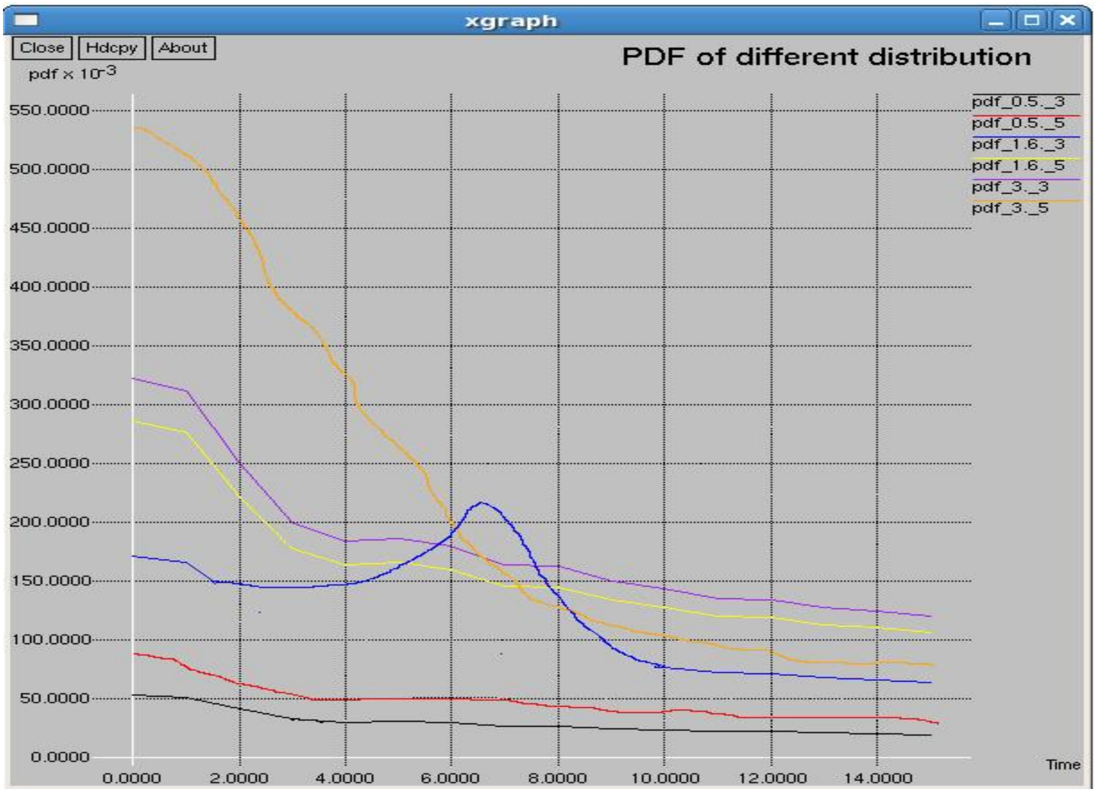

Fig. 3 PDF Comparison of T with Gamma and Exponential Distribution

Fig. 3 shows the comparison of the PDF of call holding time T at a particular period with the gamma and exponential distribution of equal mean. The mean values of different time intervals are used to estimate the call holding time during a particular time interval. Here, Gamma distribution parameters and the number of intervals are selected based on the field data which is given in the Table 1, 2, 3.

The estimated call holding time is the mean of $\alpha_i\beta_i$ of the gamma distribution at a particular time interval. For the approach 3, the call holding time is estimated for the PUs because the SUs can predict the probability P of the channel availability within a particular time interval T. Then, this probability can be compared with its waiting time.

From this prediction of call arrival rate and estimation of call holding time, the active users of the spectrum will be increased. This leads to decrease in call blocking and interference. Hence, the channel utilization will be increased by sharing the spectrum among the service providers with the prediction of channel availability.

The proposed work follows the coordination in a distributed manner. The goal of coordination in spectrum sharing is to distribute concurrent, conflicting links across channels to avoid interference and improve throughput. The control messages carry information of traffic load, available channels, and usage on each channel. The key challenge in this paper is how to address heterogeneity in channel availability and traffic load during channel selection.

Conclusion

The proposed method gives an approach to predict the call arrival rate and call holding time of the primary users. Predicting the probability of call arrival rate provides the secondary user regarding the channel availability to determine whether to use the channel or not. This proposed method leads to the optimal transmission and observation time to maximize sensing efficiency satisfying the strict interference constraint of primary networks.

If a secondary user accessing the licensed spectrum of the primary user, the secondary user has to vacate the channel of the primary user if the primary user arrives for accessing the spectrum. In such a case, the secondary user has to move on to another available channel. So that, there will temporal connection loss or communication will be dropped. The connection loss or communication dropping can be eliminated using the traffic prediction process.

In order to avoid the temporal connection loss or interference with the primary user, the secondary user has to evaluate the channel availability before using the channels of the primary user and predicting the traffic pattern of the primary user. This prediction enhances the channel utilization of the primary users and enhances the communication of the primary users.

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