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STUDY OF HANDOFF IN A MULTI-SERVICE SYSTEM

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ABSTRACT

Call handling mechanisms can enhance the efficiency of cellular mobile networks. The use of these cellular systems has been a very popular means of enhancing the capacity of the wireless communication networks. It experiences the handoff phenomenon, wherein which a call already in progress in a cell is due to user mobility that hands over (switched) to another cell. The cellular network is a multi-state system that comprises of cells. In this study, the analysis of the Interarrival time, arrival rate, service time, and the theoretical cumulative distribution function (CDF) is compared to the empirical (CDF). New customer arrival and handoff customer were compared to determine which one offers a better quality of service. A similarity to the cellular network is drawn to the Blue café which has a similar arrangement. The café is a multi-service center located in square four at the University of Essex, where there are several counters to offer services to customers. The café gives us a practical model of a cellular system and for the purpose of gathering experimental data for analysis. This result has a good property for modeling of communication networks.

KEYWORDS: *Blue Café, Cellular Networks, Cumulative Distribution Function (CDF), Customers' Arrival, Handoff, New Arrival, Service Time*

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INTRODUCTION

In Wireless cellular system, call arrivals are classified as either new calls or handoff calls. New calls are generated by mobiles originating from the chosen cell while a call-in progress may experience handoff when a user moves from one cell to another. During the user mobility, the call will be admitted to a new cell, as dropping a handoff call is not pleasant sign to the user. Handoff calls are always given a higher priority compared to new calls as studied in [1]. A new call attempt can be easily blocked but the blocking of handoff call is more severe from the user's view as in [2]-[3]. Handoff call dropping is extremely important in cellular systems since it leads to the undesirable experience of forced call termination. A good assessment of the new call probability and the handoff blocking probability will help the system designer to make planned decisions to improve the Quality of Service as discussed in [4]. The motivation for studying the new call and handoff probabilities is that the Quality of Service (QoS) in cellular networks is mainly determined by these two qualities as studied in [5]-[6]. To improve the quality of service as perceived by the users, various methods have been devised to prioritize handoff requests over call initiation requests when allocating voice channel in [7]-[8].

Related Works

In a cellular system, the service area is divided into cells, a cell is defined as the supplying area of a transmitter, and its boundary is given by the attenuation of the radio signal due to the wave propagation laws. Each individual cell interacts with neighboring cells through the handoff process. Cells are grouped into clusters. Each cluster utilizes the entire available radio spectrum. The reason for clustering is that adjacent cells cannot use the same frequency spectrum because of interference. The frequency bands must be split into chunks and distributed among the cells of a cluster as examined in [9]. The spatial distribution of chunks of radio spectrum within a cluster must be done in a manner such that the desired performance can be obtained. In [10]-[11] both analyses the importance of network planning in cellular radio. The cellular concept allows every piece of subscriber equipment within a country or continent to be manufactured with the same set of channels so that any mobile may be used anywhere within the region.

Channel frequency for mobile radio systems are allocated to base stations to be used in each cell by channel assignment schemes. The channel assignment scheme is a group as either fixed or dynamic. In the fixed channel scheme, each cell is allocated a channel and a group channel is then assigned to the base station. The unused channel is only used to serve call attempts in that channel. Rappaport [12] discussed that the effect of channel blocking and why subscribers do not receive calls. If all the channels are occupied, the call is blocked, and the subscriber does not receive any service. In dynamic scheme, no fixed relationship exists between frequency and cell. Any channel can be used in any cell. Each time a call request is made, the serving base station request a channel from the mobile switching center. In TDMA or CDMA networks, each radio frequency channel carries several time slots or codes associated with voice channel was studied by [10].

In [13] handoff methods for cellular manufacturing were examined using a case study of gym center but a café was used in this analysis. In the café, this system comprises of serving counters, new customer arriving to the serving point, handoff customer moving from one counter the next, and servers attending to the customers. In the same way, drawing a correlation to cellular network, the counters may represent cells, the new customers stand for new call arrival, and handoff customer may be referring to as handoff calls as reported in Awasthi [14]. When a mobile moves into a different cell, while a conversation is in process, the mobile switching center automatically transfers the call to a new channel belonging to the new base station. In the handoff process, the voice and the control signal is also transferred. In deciding when to handoff, it is important that the measured signal level is not below the threshold level due to momentary fading. This function is carried out by the base station. In today's fourth generation systems, handoff decisions are mobile as discussed in [15].

In managing handoff requests, different systems use various policies. Some systems handle handoff requests in the way they handle originating calls. In such systems, the probability that a handoff request will not be served by a new base station, which is equal to the blocking probability of incoming calls. However, from the user's point of view, having a call abruptly terminated while in the middle of a conversion is more annoying than being blocked occasionally on a new call attempt as examined in [12].

In order to analyse the behavior of any system involving random events, we first require a model that determines the time instants at which the events occur. The most common way to do this is to use a Poisson arrival process. It often turns out that a good approximation of the time between arrivals of customer entering a system is to use the exponential distribution. The Poisson arrival process models this type of inter arrival time distribution and the same process as explored in [16] – [17]. However, the data gathered is used to analyse the arrival rate, service rate and Quality of Service. The new customer arrival is compared to the handoff customers to determine which has a better Quality of Service. The mean queue length is examined to determine whether the system behaves like an M/M/1 queue system.

MATERIALS AND METHODS

Model Description

The cellular network is a multi-state system that comprises of cells. A similarity to the cellular network is drawn to the Blue café which has a similar arrangement. Blue café is a multi-service center located at square four at the University of Essex, where there are several counters to offer services to customers. The Blue café is used for this study to enable us gather experimental data for analysis. For the purpose of this study, we are considering two serving counters in the Blue café: counter one and counter two, that is sandwich and drink counter. Customer may arrive at counter one or to counter two. Some customers may move from one counter to another counter. We have two serving points representing two cells that is a two-server system in which customers at a Poisson rate λ at server one. After being served by server 1, they may depart or join the queue in front of server 2, to access more services.

In observing the tandem queue at Blue café, we can see customers' arrival, according to Poisson process of λ (mean number of events per unit time). The probability of n numbers of customers having been generated at the serving point, still in progress somewhere in the shop is given by Poisson distribution as stated by [18].

P_r {n arrivals in a time} =

$$\frac{(\lambda T)^n}{n!}\exp(-\lambda T) \quad \text{.....} \quad (1)$$

Where λ=new call arrival rate to a cell. T=inter-arrival time. n=number of arrivals. The tandem queue with customer arrival is a Poisson process because customer arrives at a constant rate with λ representing all potential customers. The customers move from one service point 1 to the service point 2 similar to a cellular system where their handoff is from cell 1 to cell 2. When the customers are either served at point 1 or point 2, some may decide to depart like the departure rate μ of a cellular network.

Gathering Empirical Data

Two sets of data were gathered on separate days during the busy hour between 12.00 and 13.00. The arrivals are referred to as customers. "Arrive" is the time when the customer enters counter one or counter two. "Served start" refers to the time service that commences for a customer while "Served End" indicates the time the service is concluded. The server status indicates the number of servers attending to the need of various customers. If more customers are in queue, the server status changes from one to two depending on queue length. If the queue is so long some customers may decide to return without being served that is, they have been lost [16]. It often happens that arrivals become discouraged when the queue is long or when they cannot make a proper choice and do not want to wait. Such model is the M/M/c/K; that is, if people see K is the result of physical restriction such as no more sandwiches or drinks. When the call is completed in the cell, the channel is released and it becomes available to serve another call. When the mobile crosses a cell boundary into an adjacent cell while the call is in process, the call requires a Base Station and channel frequency to continue. This procedure of changing channel is called *handoff* in [16].

In modelling the arrival process, we assume that the interarrival is independent and continuous random variable. Interarrival time T_i is the time between a typical arrival time and the next arrival time. The independence assumption means that the value of T1 has no effect on T2, T3. One of the most interesting properties of the Poisson distribution when interpreted as an arrival process turns out to be the distribution of time between arrivals, called the Interarrival time distribution. The constant λ can thus be interpreted as the mean numbers of arrivals per unit time and is called the arrival rate. The time between arrivals is exponentially distributed studied in [19]. The exponential distribution is memory less, which means that the time until the next arrival is independent of the time since the last arrival and hence independent of the past [20]. Mean queue length is the average number of customers waiting in the queue described in [16] and is given as

$$Lq = \frac{\lambda^2}{\mu(\mu - \lambda)} \quad \text{(2)}$$

Software Use

The software used in this work is Java. The sun Java 2 Software Development Kit (J2SDK) version 1.4 and Java development kit-1.5.0 [21] are the versions used. Codes are used to generate the theoretical cumulative distribution functions for successive arrival and service time, which is shown in this report. The theoretical and empirical data were plotted using Microsoft Excel. The second set of code is used to generate the queue length from the empirical data by assigning +1 to an arrival value and -1 to a departure value. The first set of data shown in the plot shown in fig.4 was generated from the analytical results.

Cumulative Distribution Functions (CDF)

The following methods were used to compute the cumulative distribution functions for the empirical and theoretical distribution. They were calculated for the successive arrivals and service time. The theoretical (CDF) result was computed using the assumption that the Poisson process is a general independent process with negative exponential interarrival time distribution was computed using the expression from [18]. The theoretical cumulative distribution function of the interarrival time was plotted using

$$\Pr\{T \le t\} = 1 - \exp(-\lambda t) \quad \text{(3)}$$

Where λ = 1/mean interarrival time. The empirical (CDF) was computed by taking the interarrivals of the counter under consideration and find their cumulative distribution. This is carried out by dividing each sample by the total number. The cumulative distribution was normalised to one. The (CDF) ranges from zero to one. Plotting of the theoretical and the empirical (CDF) for each of the counters was carried out using Excel interface and Java scripts from [21].

RESULTS AND DISCUSSION

The service time distribution tells how long the customer has spent in the server. The service time for different customers was assumed to be independent random variables. An exponential distribution with parameter μ has a density function.

$$\Pr\{T \le t\} = 1 - \exp(-\mu t) \quad \text{(4)}$$

Where μ= service rate the equation (4) is used for the theoretical (cdf of the service time distribution. The empirical result was plotted by taking all the service time and finding their cumulative distribution. The cumulative distribution was normalized to one. Service time is very small. Then Plotting of the theoretical and the empirical (CDF) each of the counters is carried out using Excel interface and the code is display.

Data Analysis

This analysis is used to calculate the interarrival, arrival rate, service rate, cumulative distribution functions and the QoS of each of the counters. This Counter consists of the following parameters: Arrive 1, Served 1, and Served End1. The mean interarrival time in seconds are calculated, this value is used to compute the arrival rate. The arrival rate λ=1/mean interarrival time =9.8209E-3. The number of arrivals is 34 because more than one arrival occurs at a given instant, that is *Bulk arrivals* are allowed. The theoretical (CDF) is computed using equation 3 by substituting the value of arrival rate which is 9.8208E-3 and the time range of 0 and 330 seconds. The empirical (CDF) was computed by taking the interarrivals of the counter under consideration and finding their cumulative distribution. This is carried out by dividing each sample by the total number. The results are shown in figure1; the empirical value follows the theoretical value from the origin but deviated at point 60 seconds. The empirical results follow the exponential distribution. The service rate μ =

$$\frac{n}{S_1 + S_2 + ... + S_n}$$

Where the service time S = number of arrival/mean service =

$$\sum_{i=0}^{n} \left(ServedEnd_i - ServedStart_i \right) \quad \text{……………………………………………………...…………… (5)}$$

Hence the service rate μ = 0.0175 Using Eq. (4) the theoretical (CDF) was computed with the value of the service rate as 0.0175 and the empirical result was computed by taking all the service time and finding their cumulative distribution. This is carried out by dividing each sample by the total number. The time range is 0 and 140 seconds. The result is display in figure 2, the empirical value is scattered round the theoretical results, and from 30 seconds to 80 seconds, it looks linear. Most customers spent less than two minutes being served. While from point 119 seconds, it follows the exponential curve. The mean queue length is calculated using the computed values of λ and μ, the mean queue length L_q=0.71777.

This queue length was plotted using the sets of data generated at counter 1-1. During the plotting, it was assumed that when a customer arrive the queue length is +1 and when a customer departs the queue length takes a value of -1. Based on that assumption, a java code was used to generate the plot as display in figure 4. With this plot, we can find the average queue length by calculating the total area under the curve divided by total time. This empirical value of the queue length is equal to 2.35. From the two theoretical value of 0.7177 and the experimental value of 2.35. From the plot, the arrival times and departure vary at every time because there are randomly distributed. There is a great different in value; the system does not behave like M/M/1 queue.

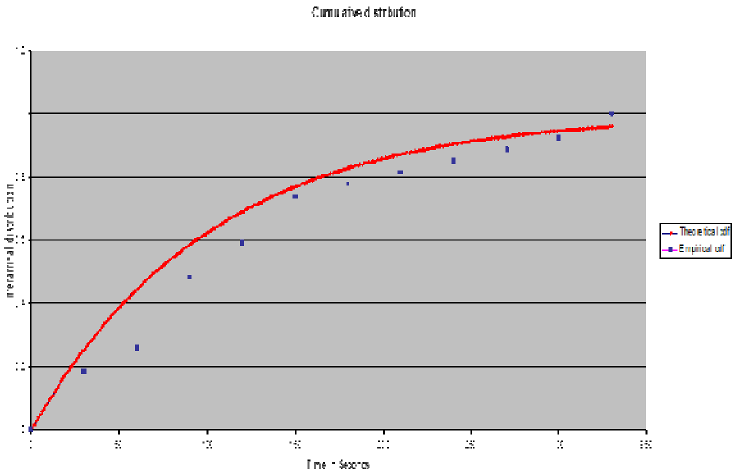

Figure 1: Cumulative Distribution Functions for Interarrival Time Counter 1-1.

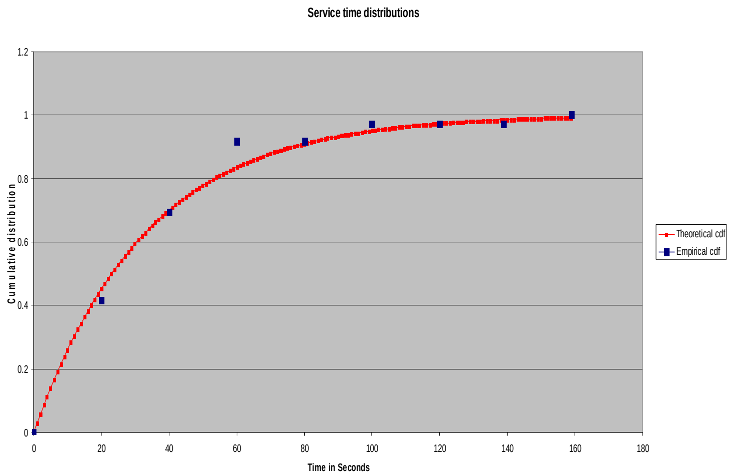

Figure 2: Cumulative Distribution Functions for Service Time of Counter 1-2.

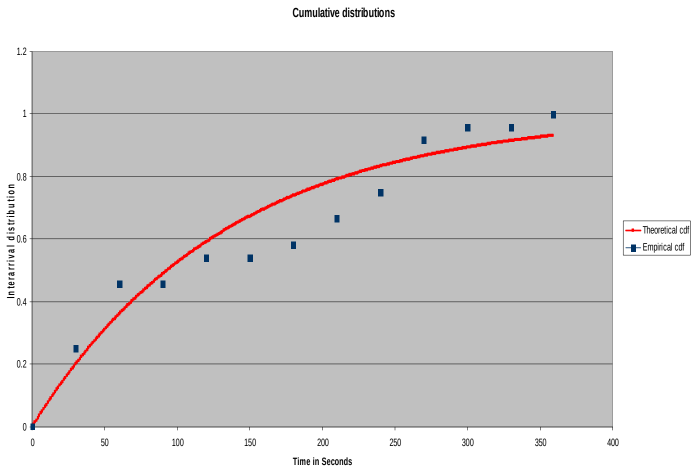

Figure 3: Cumulative Distribution Functions for Interarrival Time of Counter 2-1.

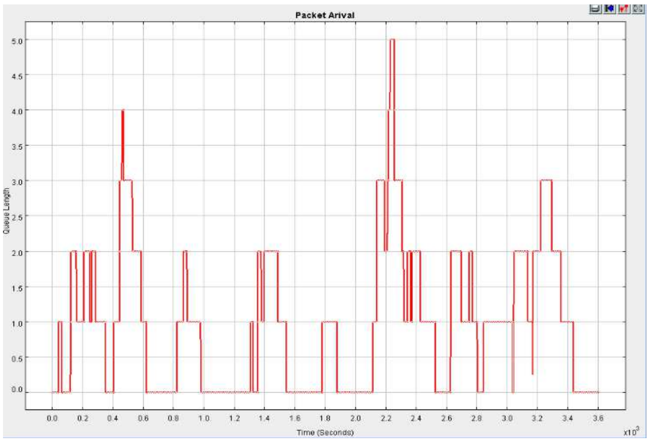

Figure 4: The Behaviour of the Queue Length of Counter 1-1 for One Hour.

This Counter consists of the following properties: Arrive 2, Served Start 2, and Served End 2. The Interarrival time (seconds) is calculated. The arrival rate λ=1/mean interarrival time = 0.01056. The theoretical CDF was computed with value of arrival rate as 0.0105 and the empirical values were computed by taking the interarrivals of the counter under consideration and finding their cumulative distribution. This is carried out by dividing each sample by the total number. The interarrival time range is 0 and 330 seconds. The result is shown in figure3, the empirical value deviates away from the theoretical values 30 seconds to 150 seconds but at 180 seconds, it follows the exponential distribution. The service rate μ =0.03011.

The service rate value of 0.03011 is used in computing the theoretical CDF using Eq. (4) and the empirical result was computed by taking all the service time and finding their cumulative distribution. This is carried out by dividing each sample by the total number. Most of the results and distributions shows similar properties indicating that empirical values follow exactly the theoretical value excepts at point (60second, 917). The mean queue length L_q = 0.1890.

The empirical value of the mean queue length which is given by the total area under the curve is 0.60. This is in comparing the theoretical results of 0.1820 with the empirical result of 0.60. There is a great different in value from the plot, arrival time and the departure time varies during the plot but at 1600 seconds, the time interval was smaller. Then the queue seems to be constant.

Quality of Service of New Customers and Handoff Customers using the First Set of Data

For handoff customers, the average time spent = total time of handoff customer/ total number of handoffs=76.9seconds. For new customers, the average time spent = total time new customer/ total number of new customers =103.75 seconds. From the result, the handoff customer has a better Quality of service than the new customer. The handoff customer spends less time than the new customer. This counter consists of the following properties: Arrive 1, Served 1, and Served End 1. The mean interarrival time seconds is calculated. This value is used in computing the arrival rate. The arrival rate λ=1/mean interarrival time =7.4557E-3.

The theoretical (CDF) was calculated using the value of arrival rate 7.455E-3. The values of the empirical (CDF) was computed by finding cumulative distribution of the interarrival and the normalised to one. The distribution of this counter from the empirical value at point 30 seconds to 60 seconds is linear and is distributed around the theoretical (CDF) but behaves as an exponentially distributed function. Hence, μ = 0.01103.

The cumulative distribution functions of the service time. Considering service time distribution, Eq. (4) was used to calculate the theoretical values with a service rate of 0.01103 and the empirical values were computed. It is observed that from the empirical result that service was not completed within 30 seconds. From 30 seconds to 90 seconds, the empirical values move away from the theoretical values, but curve still follows the exponential distribution. The mean queue length is calculated using the computed values of λ and μ. The mean queue length L_q =1.410

This counter consists of the following properties: Arrive 2, Served Start 2, and Served End 2. The Interarrival time (seconds) is calculated from the table. The arrival rate λ =1/mean interarrival time = 6.872E-3. The Cumulative distribution functions of successive arrival. The theoretical (CDF) was calculated using the value of arrival rate 6.872E-3. The values of the empirical (CDF) was computed by finding cumulative distribution of the interarrival and the normalised to one.

Quality of Service of New Customers and Handoff Customers using the Second Set of Data

For handoff customer, the average time spent = total time of handoff customer/ total number of handoffs = 67.56seconds. For new customer, the average time spent = total time new customer/ total number of new customers =117.95 seconds. From the result, the handoff customer has a better Quality of service than the new customer because the handoff customer spends less time than the new customer.

CONCLUSIONS

The consequence of forced call termination can be reduced by a good evaluation of handoff scheme. This evaluation helps the system designer to make strategic decision to improve the Quality of Service. Since blocking a handoff call is less desirable than blocking a new call, specific schemes have been developed to prioritize handoff which include handoff calls queuing and guard channel. The queuing of handoff reduces the probability of forced termination of a call due the lack of available channel. Using the guard, channel improves the probability of successful handoffs by reserving a fixed or adjustable number of channels for handoffs. It is observed from the analysis of new customer and handoff customer that the handoff customers use less time than new customer arrival in the counter. This gives the handoff customer a better Quality of service. Similarly, drawing some inferences to cellular system, the handoff calls have a better Quality of Service in a cell than new call arrival.

The gathering of empirical data from the café gave us a useful model for the study. Two set of data were analysed to authenticate results. The study examines the interarrival time distributions and the service time distributions using the exponential distribution to determine their performance. The empirical cumulative distribution was normalised before carrying out the plotting. The theoretical (CDF) and empirical (CDF) were plotted together on the same plot. From the results of the four interarrival time distribution functions of the counters, the empirical cumulative distribution functions followed an exponential distribution and similarly, the results of the four-service time distribution of the empirical cumulative distribution function of the counters also followed the exponential distribution. Based on these results, it is deduced that in the café, both the customer arrival and handoff customer are independent identical random variables. This also illustrate that the arrival rate and the service rate are both Poisson. This result has a good property for the modelling of communication networks.

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