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ENHANCED BANDWIDTH-DELAY BASED ROUTING ALGORITHM FOR A PACKET-SWITCHED VIRTUAL CALL CENTRE ENVIRONMENT

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ABSTRACT

Traditionally call centres were based on circuit-switched systems. But with the advancement of communication technologies, call centres have shifted to packet-switched systems. This packet-switched system aids the creation of virtual Call Centre Environments. The current dynamic routing algorithms used for circuit-switched systems do not fully support packet-switched virtual call centre environments. We addressed this issue in this paper by developing a new call routing algorithm capable of supporting this type of virtual environments. This was done by performing a comparison study on our hybrid routing algorithm, Enhanced Bandwidth-Delay Based Routing Algorithm. Our hybrid routing algorithm was compared with a commonly used call routing algorithm known as Minimum Expected Delay. We used both analytical and simulation methods to achieve our goal of comparison study. Call centre data collected from a real-call centre was utilised to aid our model development, validation and scenario generation. The results from this study concluded that under high traffic arrival rates, systems running EBDRA outperforms MED by possessing a lower probability of delay.

1 INTRODUCTION

1.1 Background

In this day and age, most of our daily interactions with companies and organisations revolve around call centers. Call centers act as the first point of contact with customers/clients of companies and organizations. They have a history that dates back to the expansion of the initial Public Switch Telephony Network (PSTN) concept that saw physically wired telephones change from a point-to-point connection to central telephone switches around the late 1800's. The operators of these switches were the first telephony call centre agents who answered and patched calls to their destination. The success of an organization is highly dependent on the agents representing the organization. High agent efficiency and productivity directly affect the overall call centre performance.

The Enterprise Telephony (ET) represents the core on which traditional telephone call centers are built on. It is a scaled down version of the PSTN designed for businesses and organizations. Modern call centers on the other hand adapt new technology and media to further provide additional services and extend capabilities of ETs. These modern call centers are referred to as contact centers.

G. Koole and A. Mandelbaum (Koole and Mandelbaum 2001, Koole and Mandelbaum 2002) and R. Stolletz (2003), highlighted that call centers can be categorize based on the features they possess. Features such as functionality, size, geography, agent characteristics, initiation of contact and communication channel. A general characteristic of a call centre is whether it handles inbound or outbound call traffic (Gans, Koole and Mandelbaum 2003). Call centers can be divided into four distinct layers, the network, equipment, personnel and report layer. The personnel layer is responsible for 60% to 70% of call centre annual expenses (CM Insight, ContactBabel & Call and Contact Centre Association May, 2004). For this reason call centre managers are always looking for more efficient ways to extend their capacity and performance.

1.2 Motivation

Efficient call routing is a tool that can be adapted to improve call centre performance especially in the case of Virtual Call Centers (VCCs). Research into VCCs are very few and far between, this doesn't tie in with the developments in this area. Call centers are already adapting a virtual nature to try to reduce cost and at the same time expand their customer capacity. Figure 1 shows a diagram representing a Virtual Call Centre Environment (VCCE)

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based on circuit-switched technology supported by current call routing algorithms covered in section three. The future is likely to see the introduction of more call centers deployed in a packet-switched environment. VCCEs involve multiple geographical locations with multiple groups of agents with different skills used to serve multiple classes of customers with different needs (Whitt 2005). It has been noted by N. Van Dijk (2000) that delays and queuing problems are most common features in networking and telecommunication environments.

Currently the trend being observed is hardware manufacturers claiming support for VCCE implementation, but how this can be effectively and efficiently used and whether it can be deployed on a large scale is yet to be seen. Advances in technology and integration of synergistic technologies have resulted in the development of numerous features that have enhanced the growth of call centers (Sharp 2003).

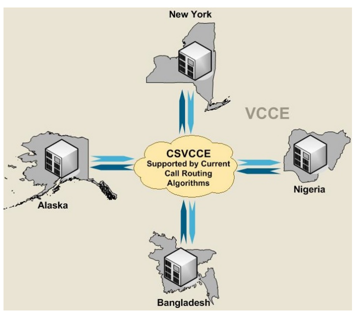


Figure 1: CSVCCE with current call routing algorithms

1.3 Research Questions

The diagram in Figure 2 highlights the fact that no call routing algorithm has been tested to verify full functionality under the packet-switched environment. This lead us to define a new algorithm in section four, and conduct a performance analysis on it in section five. We were therefore motivated to provide answers to the following research questions,

1. What are the factors that cause delays and queuing problems within a Packet-Switched VCCE (PSVCCE)?
2. What metrics are used in call centers to determine performance levels?
3. What functional parameters are used to determine success of routing calls to call centers in the PSVCCE?
4. Which call routing algorithm can be best used to manage calls on a PSVCCE?

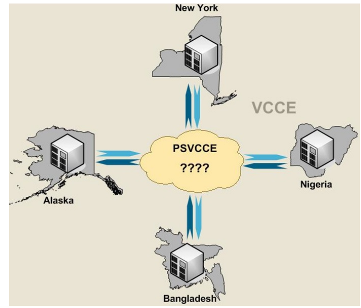


Figure 2: PSVCCE lack call routing support

1.4 Research Paper Objectives

Most researchers are focused on knowledge driven research while other are problem-driven oriented (Mandelbaum, Sakov and Zeltyn 2001). This paper focuses on finding a practical solution to the problem of implementing a modern VCCE based on packet-switch technology. Our objectives are divided into three, the first objective is to look at commonly used circuit-switched call algorithms and develop a new model capable of creating a valid VCCE. This model will act as a test-bed for the well-known call routing algorithm. The second objective is to use the best performing call routing algorithm identified from our previous objective to create a new call routing algorithm for packet-switched environments. Thirdly, to use the developed VCCE models to perform a comparison study of between our new packet-switched algorithm with the best circuit-switched algorithm identified from our first objective.

1.5 Contribution

There are three techniques we considered in achieving the above-mentioned objectives, analytical modeling, simulation modeling and measurement. We draw the benefits of using both analytical and simulation modeling forms of research work to achieve the our objectives. This was done by contrasting these two modeling techniques together. We also used the measurement of a real life call centre to act as input and validation data to both modeling techniques. According to N. Gans et al, “having analytical models in one’s arsenal, even limited in scope, improves dramatically one’s use of simulation” (Gans, Koole and Mandelbaum 2003).

The rest of the paper is organized as follows; Section 2 describes the various types of VCC and the relevance of remote agents (teleworkers). In Section 3, we discuss MED and EBDRA in more details highlighting their similarities and differences. In Section 4, we present our analytical and simulation models along with the performance metrics and implemented assumptions. Our results are presented and analyzed in Section 5 drawing up a performance evaluation conclusion on the results.

2 VIRTUAL CALL CENTRES AND TELEWORKERS

Presently, there are three ways of implementing a VCC, a fully Circuit-Switched VCC (CSVCC), a fully PSVCC and thirdly, a hybrid of the two technologies. A typical CSVCC composes of the following devices and connections; a circuit switch hardware based PBX used for call distribution, Trunk lines used for interconnecting the networked call centers as well as terminating customer calls. Telephone handsets for individual agents, Computer Telephony Integrator (CTI), Automatic Call Distributor (ACD) and Interactive Voice Response unit (IVR) servers.

The ACD of a PSVCC network on the other hand is a soft-switch-based system that resides on either an upgrade PBX or a computer server. This soft-switch-based system has the characteristic of separating the signaling components from the device controllers. These soft-switch-based systems communicate between the separated components through the packet switch network. The current VCCE structure is based on two or more dispersed call centers interconnected together. It is also possible to introduce Virtual Agents (Teleworkers) to further virtualise the VCCE.

Teleworking has evolved since the 1970s into three main types, home-based Teleworking, satellite offices and mobile working. A phenomenal take off of Teleworking was predicted to occur (Baines 2002, Baruch 2000, Bryant 2000), however this expansion of teleworking has failed to meet the expectations of the EU Commission (Bangemann May 1994). The benefits of adopting teleworking according to Pérez, Sánchez and de Luis Carnicer (2002), Markby (1995), Kurkland and Bailey (1999), and Shin, Sheng and Higa (2000) are,

- Increased human resource productivity and savings on the need to purchase real estate by companies to house their employees. The most significant barriers are access to technology and the teleworking integration into the company's organizational structure.
- Teleworking also introduce flexibility for both the teleworkers and company, with evidence that a teleworker's productivity is higher than that of non-teleworker.

S. Baines 2002 (Baines 2002), highlights the fact that teleworking is slow in uptake, while one of the barriers identified in M.P. Pérez et al. (2002) was the inaccessibility of the technological know how. Moreover to the best of our knowledge current circuit-switched call routing algorithms and packet-switched data routing algorithms are insufficient to deal with VCCEs calls based on packet-switched data. But our call routing algorithm Enhanced Bandwidth-Delay based Routing Algorithm (EBDRA) is aimed at facilitating the growth of teleworkers and VCC capacity within the VCCE.

We developed this algorithm by first identifying the routing algorithm that function best under different conditions on circuit-switched networks. The next phase in the concept was to identify the major functional parameters that affect the routing of calls within the PSVCCE. These two elements would then be combined to form our call routing algorithm.

3 CALL ROUTING ALGORITHMS

3.1 Call Routing Strategy

The equipment known as ACD perform the call routing function in a call centre, this unit uses a routing process or processes to handle and route incoming calls to their respective destination. Good routing algorithms can help call centers reduce the number of calls in the system, which therefore affects service levels in a positive way. There are two ways call routing algorithms can be implemented when delivering the calls from the ACD to either the agents or call centers within the VCCE, these two systems are know as push (pre-delivery) and pull (post-delivery). S.A. Pot (2006) describes the push system as when arriving calls are assigned to an available agent that is chosen by the ACD, while the pull system notifies agents about a call in the queue, the call is serviced by the agent who reacts the fastest.

There are various types of call routing types mostly provided by the service provider that utilize the pre-delivery routing strategy, they range from Area-Code routing, Exchange Routing, Time-of-Day routing, Day-of-week routing, Holiday Routing, Emergency Routing, All-Trunks-Busy-Routing and Call Allocation Routing (Gable 1993).

Call routing supported by post-delivery make their routing decisions based on the current state of the VCCE, these call routing types are further divided into static and dynamic routing algorithms. Static routing algorithms are predetermined rules that are used to specify where to route the calls, the Bernoulli Splitting algorithm (Arian and Levy 1992) and Most Regular Sequence (MRS) (Arian and Levy 1992, Hajek 1985) are good examples of a static routing algorithm.

Dynamic routing algorithms on the other hand, dynamically alter their decision making process to suit the current network state. Examples of dynamic call routing algorithms are Bandwidth-Delay based Routing Algorithm (BDRA) (Wang and Crowcroft 1995), Generalised Round Robin (GRR) (Arian and Levy 1992); Join the Smallest Actual Waiting time queue (JSAW) (McDonald and Turner 2000), Join the Shorter Expected Waiting time queue (JSEW), Join the Shortest Queue (JSQ) (Lin and Raghavendra 1996, McDonald and Turner 2000, Turner 2000, Whitt 1986), Minimum Expected Delay (MED)

(Kogan, Levy and Milito 1997), and Shortest Delay Rule (SDR) (Houck 1987, Winston 1977, Ephremides, Varaiya and Walrand 1980, Weber 1978).

Queue centric call routing algorithms work well for CSVCCE, algorithms such as GRR, JSQ, JSAW, JSEW and MED. While some concentrate on just the queue size (JSQ), other algorithms take other factors into consideration when deciding how to handle the call, factors such as number of agents and average service rate. These added factors help improve the performance of routing algorithms; therefore algorithms such as GRR, MED and JSAW have an added advantage over the likes of the JSQ algorithm.

The principle of multiple instances of a call on all call centers queues within the VCCE as supported by JSAW is good, however highly dependent on Intelligent networks (IN). This principle forgoes the service rate information of each call centre within the VCCE by duplicating a single call arrival across all the call centers. This works well for small to medium sized VCCEs, however when the network size increases further, more demand would be put onto the IN infrastructure to try and maintain this multiple call instance. Therefore resources required for routing the calls are diverted in trying to maintain the queue of calls waiting to be answered.

For this reason, we focused on GRR and MED, which utilizes the service rate and number of calls queued at each call centre of the VCCE to generate an expected delay value to make route decisions. We carried out performance evaluations for these two algorithms along with another routing algorithm with the results and discussions presented in (Adetunji et al. 2007).

3.2 MED Routing Algorithm

The MED routing algorithm operates by assigning the next incoming call to the queue whose current allocation does not exceed the target allocation and also exhibits the least delay within the VCCE. This routing algorithm is represented by the equation shown in (1), the target allocation refers to the maximum time a call is expected to wait in the queue before being served.

$$r_{n+1} = \min\{i; k_n^i(t) \le np_i(t)\} \tag{1}$$

r_{n+1} represents the current routing process, i is the queue number, $k_n^i(t)$ represents the expected delay of all calls in queue i up to and including the *nth* call arrival, and p_i is the target allocation of queue i at instance n. k_n^i is the derivative of the expected delay equation shown in (2), and represents the minimum k from $k_n^i < k_n^{i+1} < ..... < k_n^z$.

$$k_n^i(t) = \frac{n_i(t) - S_i + 1}{S_i \mu_i} \tag{2}$$

$n_i(t)$ is the number of calls in queue i at time t, S_i equals the number of agents assigned to queue i, while μ_i is the exponential service mean at queue i.

When a call arrives at a call centre under the influence of the MED routing algorithm, the expected delay of the calls within the local call centre queue is checked. If it is greater than the target allocation, this expected delay is then used to determine the call centre with the least expected delay within the VCCE. Once this has been ascertained, the call is routed to the resulting call centre.

The MED algorithm has been shown to function well in a circuit-switched VCCE (Kogan, Levy and Milito 1997; Adetunji et al. 2007), however there has not been any paper that addresses call routing within packet-switched VCCEs. We therefore propose in this paper the EBDRA routing algorithm designed to take bandwidth into consideration when routing calls. The next section covers the functionalities of EBDRA.

3.3 EBDRA Routing Algorithm

In the CSVCCE, the trunk line availability acts as one of the functional parameters that determine if a call will be successfully routed to other call centers within the VCCE. However this doesn't apply to PSVCCEs, a more applicable functional parameter that determines the success of routing calls to call centers in the PSVCCE is bandwidth.

Bandwidth plays an important role as the number of concurrent voice channels depends on the amount of available bandwidth. This parameter is however not the only functional parameter used in determining success of call completion, other parameters that are closely related to bandwidth are, packet loss, Quality of Service, codec size and delay.

In order to create a call routing algorithm that functions well within a PSVCCE, the beneficial properties of MED routing algorithm (calls are routed to queues' of call centers with the least delay) is taken and combined with the consideration of bandwidth contention and loss probability, similarly to Z. Wang and J. Crowcroft's BDRA (1995). A path (call centre) with a large resulting value from the EBDRA equation is likely to be a better choice in terms of bandwidth, delay and loss probability. This routing algorithm is represented by the equation shown in (3). During the routing process, an update of the current available bandwidth is checked to ascertain if it can support a session between the agent and the caller.

$$r_{n+1} = \max\{i; b_n^i(t) \ge np_i(t)\} \tag{3}$$

b_n^i in (3), represents the maximum value from $b_n^i > b_n^{i+1} > ..... > b_n^z$, which is calculated with the bandwidth expected delay formula (a combination between bandwidth delay and MED) shown in (4).

$$b_n^i(t) = \frac{C_n^i}{k_n^i(t)P_B} \tag{4}$$

The loss probability P_B in (4) is derived from (5), which includes the blocking probability and arrival rate λ, while k_n^i represents the expected delay calculation (2).

$$P_B = \frac{\lambda - \lambda^{'}}{\lambda} \tag{5}$$

C_n^i in (4) represents the current available bandwidth at queue *i* during the *nth* routing process. Calls are therefore routed to the call centre displaying the highest EBDRA value upon completion of the routing process.

4 MODEL DEVELOPMENT

The two general models traditionally used to setup and manage call centers are Erlang B and Erlang C. A Danish mathematician called A.K. Erlang in 1917 while he was with the Copenhagen Telephone Company developed the Erlang C formula (Cleveland and Mayben 1997, Koole 2002), this formula is represented by the queuing model in equation (6).

$$M/M/n \tag{6}$$

Our model can be specified based on the taxonomy for input models used by L.M. Leemis (2004). We therefore base our models around Markov chains, which is a discrete-state Markov process. The system represented with a Markov process moves from one state to another, this is known as transition and represents occurrences of arrival and service completion.

4.1 Analytical Model

When representing different call centers, there are different types of analytical queuing models that can be used to represent their behavior. However, most call centre model representations use Markov processes. Queuing theory is an analytical technique that is used to analyze systems performance; a Markov process on the other hand represents events, which are independent of past occurrences but dependent on only the present.

4.1.1 MED

Looking at the complementary CDF delay of MED we developed an analytical model, this was done as an expansion to what was already covered by Y. Kogan et al (Kogan, Levy and Milito 1997). The complementary CDF delay of MED is given as,

$$\overline{F}_{MED}(x) = 1 - F_{MED}(x) \tag{7}$$

Where,

$$\overline{F}_{MED}(x) = e^{-S\mu x} g(x) \tag{8}$$

Therefore,

$$\overline{F}_{MED}(x) = e^{-\frac{S\mu x}{i}} \sum_{j=0}^{n-iS} \frac{\left(\frac{S\mu x}{i}\right)^j}{j!} \sum_{n=iS}^{\infty} \pi_{MED}(n) \tag{9}$$

4.1.2 EBDRA

The EBDRA queuing system is represented as a *M/M/S/C* Markovian multi-server system, with *S* representing the number of servers and *C* representing the space available on the trunk/bandwidth concurrency. The bandwidth concurrency represents the total number of calls that can concurrently exist on the link without congestion occurring.

The blocking probability is calculated based on the *M/M/S/S* Erlang's Loss queuing system, where there are no waiting queues, here arriving callers that find all servers busy are dropped without entering into the system. Therefore the probability of finding all trunks busy or bandwidth fully utilized is based on the assumption that *S*=*C* and is calculated as,

$$P_b = \frac{\frac{(Ca)^C}{C!}}{\sum_{j=0}^{C} \frac{(Ca)^j}{j!}} \tag{10}$$

This formula represents the EBDRA functionality, thereby by combining both equations (9) and (10), the delay distribution of EBDRA can be deduced by the resulting equation in (11).

$$\overline{F}_{MED}(x) = \frac{\frac{(Ca)^C}{C!}}{\sum_{j=0}^{C} \frac{(Ca)^j}{j!}} e^{-\frac{S\mu x}{i}} \sum_{j=0}^{n-iS} \frac{\left(\frac{S\mu x}{i}\right)^j}{j!} \sum_{n=iS}^{\infty} \pi_{MED}(n) \tag{11}$$

The analytical models of both the complementary cumulative distribution frequency of delay for EBDRA and MED were carried out using MATLAB. The two mathematical equations, equation (9) for MED and equation (11) for EBDRA were used under MATLAB to compare the differences in the generated results which are discussed in the next section.

4.2 Simulation Model

The modeling process adopted is centered on the real world and simulation world relationship with verification and validation modeling defined and explained by R. Sargent (2004). The real world contains problem entities that lead to the development of system theories and definitions about the characteristics of the proposed system that are highly applicable to the simulation realm. The real world call centre used was that of an anonymous bank in Israel (Guedj, Mandelbaum 2007). Other sources of call centre data were also considered, however they lacked vital information such as data collated based on every entry rather than a sample time.

The simulation model development process starts with a system definition by specifying the characteristics of the real world system to be represented in the simulation world. The real world system data is feed into the simulation world to act as a base for validation and verification while the real world system results are used to compare with the results generated from the simulation world. This technique is used in validating and verifying our simulation models.

We studied the arrival/service process and information on the collated data to describe how calls are processed. Our call centre model is composed of node and process models. The underlying process models define the behavior of the node models; each node model contains several process models. Node models specify the manner of how different functions of the call centre operate and interact with each other. The process model on the other hand deals with the logical operations performed on the call, this section of our model is represented by C/C++.

4.2.1 Characteristics and Assumptions

Our PSVCCE model is formed from the combination of several process and node models. Our model is an extension from the single call centre model developed and validated in (Adetunji 2007), with the following characteristics and assumptions taken into consideration;

- All models and their corresponding scenarios were subject to the same traffic traces.
- All models were also subject to Poisson, Exponential and Pareto statistical distribution, these distribution were used to generate different call arrival rates. The Pareto distribution specifically simulates bursty periods. This allowed us to identify how each call routing algorithm manages periods of intensive traffic arrivals and how these periods affect the system as a whole.
- Three call centres were interconnected with an Internet cloud, the available bandwidth for each call centre varied from one scenario to the next. If there was no available bandwidth during call arrival at the Internet cloud, the calls were queued at the local originating call centre.
- Three bandwidth sets were used, 8kbps, 200kbps and 400kbps, each representing 1, 25 and 50 concurrent calls because a voice codec of 8kps was used.
- Skilled-based routing was not considered in the PSVCCE model and simulation.

4.2.2 Call Centre Performance Metrics

Simulation contributes to the development and operations of call centres, this was shown in A. Avramidis and P. L'Ecuyer (Avramidis, L'Ecuyer 2005) where decisions based on simulation modeling had a direct impact on call centre performance. When conducting experiments, it is important to know what factors are being monitored and measured. Systems of parameters can be used to perform the required monitoring and measurements needed to provide interpretations of the model assessment being carried out.

The input metrics are the parameters our models were set to prior to simulation, after each simulation run, one or more of these parameters were altered to generate a new scenario for simulation. The parameters used were,

- Call arrival rate – Call arrival traces from the real call centre data were used to represent instances of call arrival in the simulation model. Also statistical distributions were also considered to further test the simulation models. The distributions considered were Poisson, Exponential and Pareto.
- Call service rate – Service rate traces also generated from the real call centre data was used to represent the average service rate of the simulation system.
- Routing Algorithm – Two call routing algorithms were used EBDRA and MED.

Performance metrics represent the output metrics for the system under study; they provide a good way of analyzing the experiments under different conditions and scenarios. The type of metrics used depends highly on the type and methodology of the experiment being carried out. The following performance metrics were used to evaluate the various models developed and simulated,

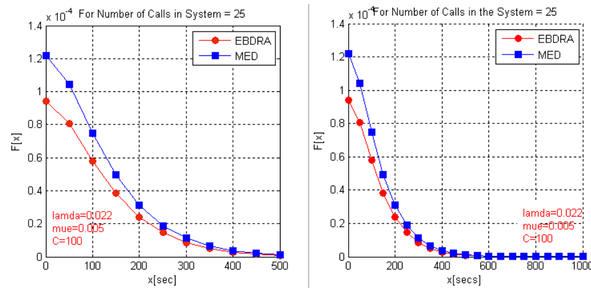
- Call delay - This represents the total call delay experienced by callers within the call centre or VCCE for the duration of the call. The call delay starting time normally starts from the moment the call enters the system on the trunk lines to when the call has been serviced by an agent or IVR and released; this also includes the time spent in queues.
- Agent Utilisation - This represents the number of earned hours of each agent over the number of scheduled hours, in others words it is a measure of the degree to which each agent is used. The higher the utilisation means the higher the frequency and duration the agent is engaged with callers.
- Call Centre Throughput - Throughput in terms of call centers and VCCE is the number of calls processed by the call centre per time unit. The throughput of a call centre gives an idea of the effectiveness of that call centre. Higher throughput means higher amount of calls are being answered within a specific time unit.
- Queue lengths - Queue lengths represent the number of calls that are queued at any given time of the simulation's life span. A queue is used to hold arriving calls in the event a CSR or IVR port is unavailable to service the caller. Calls waiting in queues contribute to the overall delay experienced by the call centre; therefore the performance of the call centre can be monitored to some extent with the use of real time queue analysis.

5 RESULTS AND ANALYSIS

5.1 Matlab Results

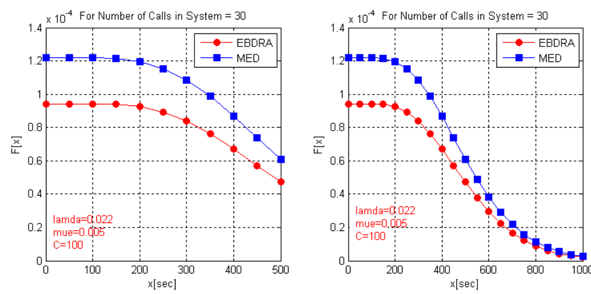
Figure 3a and b represents outcomes of the analysis when the traffic intensity is at 4.4 but at different time scales, 500 and 1000 seconds with 25 calls in the system. From the comparison of both graphs, we deduced that as the time increases from 0 to 1000, the probability of the occurrence of delay reduces. It is also noted that both EBDRA and MED merged when $F_{[MED/EBDRA]}(x)$ = 550secs at a cross-over point x_0, where $\overline{F}(x_0) < 0.1$ in Figure 3b. $\overline{F}(x)$ represents the outcome on the probability the waiting time is greater than *x*.

EBDRA in the graphs shows a better performance in minimizing the probability of delay for waiting times less than x. As the number of calls in the system is increased to 30 (Figure 4a and b), the probability of delay was prolonged in both EBDRA and MED. There is also an increase in the cross over point x_0 for MED to merge with EBDRA, this occurs when x_0 = 1000secs where $\overline{F}(x_0) <$ 0.1 in Figure 4b.



(a) (b)

Figure 3: Results of analytical modelling with 25 calls in the system (a) for 500secs (b) for 1000secs



(a) (b)

Figure 4: Results of analytical modelling with 30 calls in the system (a) for 500secs (b) for 1000secs

5.2 OPNET Results

The averages of all call centers data within the PSVCCE were taken for each bandwidth scenario and compared with each other. We outline our main results below:

5.2.1 Queue Length

The EBDRA algorithm always showed a reduced queue length when compared to the corresponding MED results under low bandwidth conditions. This can be seen in Figure 5(a). However as the bandwidth availability increases, both algorithms merge at 400kbps. Figure 5(a) also shows EBDRA systems possessing lower queue lengths when compared to the systems running MED when Poisson distributions is used.

5.2.2 Call Delay

The call delays experienced by the PSVCC using the EBDRA algorithm were lower than the call delay times experienced by the PSVCC under the influence of the MED algorithm. Also as the bandwidth availability increases, both algorithms merge at 400kbps (see Figure 5(b)). Figure 6b on the other hand represents results from using a Poisson distribution to generate traffic flow. Call delay is also shown to be lower in systems running EBDRA over MED.

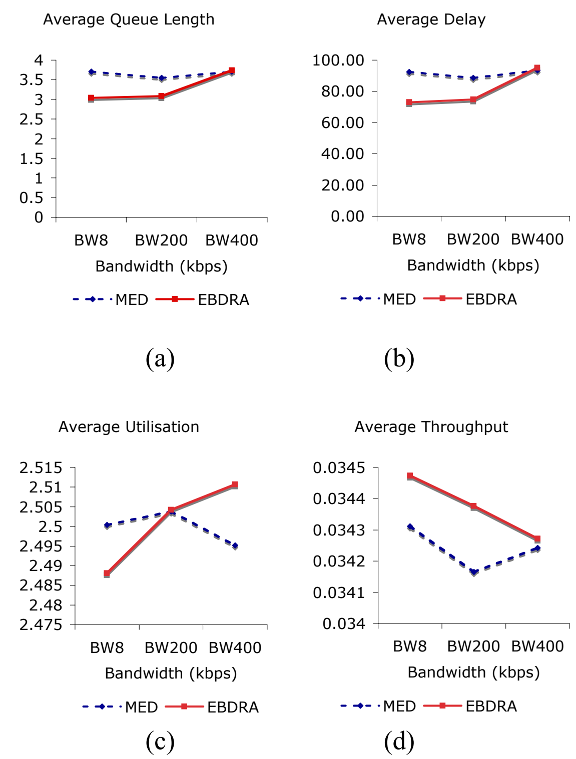


Figure 5: Shows graphs of real input data EBDRA and MED simulation results (a) Average Queue Length (b) Average Delay (c) Average Utilisation (d) Average Throughput

5.2.3 Agent Utilization

Agent utilization in the PSVCC using EBDRA call routing algorithms were lower when compared to that of MED, however these trend was reversed when the bandwidth availability increased to 200kbps (see Figure 5(c)). Although the MED results ended up lower than EBDRA, it still possessed a higher utilization at bandwidth levels of 400kbps in comparison to EBDRA at the 8kbps level.

5.2.4 Throughput

The main trend noticed in this graphical representation of throughput results presented in Figure 5(d) was, the throughput of the PSVCC running EBDRA was higher than the PSVCC running MED.

We further tested our models by scaling them up to support 80 agents at each call centre within the PSVCCE, making a total of 240 agents per PSVCCE. This was done to see if the EBDRA algorithm can support a larger call centre with increased amounts of call arrivals and processes. The results that are presented below in Figure 6 follow the same trend for systems running the EBDRA. Showing that the systems running the EBDRA call routing algorithm perform better than those running on MED.

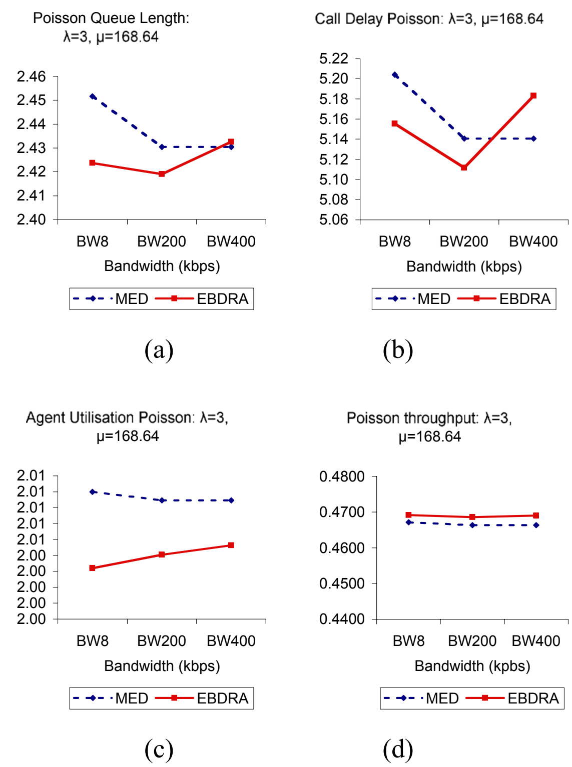


Figure 6: Shows graphs of real input data EBDRA and MED simulation results (a) Average Queue Length (b) Average Delay (c) Average Utilisation (d) Average Throughput

6 CONCLUSION

Modern call centers operate under many uncertainties and complexities (Avramidis, L'Ecuyer 2005), we therefore tried to tackle this problem by developing a call routing algorithm that is capable of improving the VCC performance. We went about achieving this goal by developing VCC models using the OPNET MODELER and analytical models using Matlab. Performance comparison was then carried out on our algorithm, EBDRA and one of the most commonly used call routing algorithms, MED.

The overall results from the Matlab analysis on the EBDRA and MED models showed that the probability of delay greater than x for models running EBDRA were lower than that for models running MED. We also showed that the merging points x_0 of the probability of occurrence of delay of the two algorithms increased as the number of calls in the system increased. This also causes the merging points between the two algorithms to increase, with the MED system taking longer to merge with the EBDRA system, as a result EBDRA possesses a performance advantage over MED.

From our Opnet results, it can be seen that EBDRA Algorithm performs well during times of low bandwidth availability and high bandwidth contention even when statistical distributions were used to generate call traffic. However in some cases, with a combination of different factors, it was noted that such a performance advantage of EBDRA became insignificant when enough bandwidth became available.

Current VCC networks are showing trends of virtualization based on agents rather than just call centers, this type of network creates a more distributed environment that is solely based on packet switching. The EBDRA call routing algorithm can be used to increase the efficiency and productivity of such a virtual environment because the bandwidth availability is taken into consideration during the route decision process, thereby accommodating the varying effects of bandwidth size on packet switched networks.

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