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Adopting Makov's Chain Queuing Model in Channel Allocation

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Abstract:— This paper proposes a novel approach to dynamic channel and packet assignment (DCPA) scheme to serve efficient circuit-switching in voice traffic and packet-switching for Internet traffic communications in wireless cellular networks. The DCPA, as a distributed-controlled scheme, assigns channels or packet-slots to handoff and new calls based on their traffic type and channel status of cells. When the blocking probabilities of handoff and new calls in a cell become unacceptable, then the cell requests its neighboring cells to move appropriate free channels if possible. The rest of this work presents the DCPA algorithm, uplink service access, and the frame structure used in packet-based communication. Markov chain model is used for calculating blocking and dropping probabilities of the proposed DCPA scheme. An algorithm was developed to realize a model which is able to capture the properties of both voice and data traffic. Simulation results, based on a circuit-switching and packet-switching traffic model, show that the DPCA scheme provides better QoS than a dynamic channel allocation scheme designed for circuit-switching communications only.

I. INTRODUCTION

The future wireless cellular networks need to transmit not only voice and text but also images, videos and multimedia data. A significant part of the traffic in the future cellular networks is expected to involve with mobile data services such as web browsing, wireless e-mail, file transfer, database access, and credit card verification. This requires wireless cellular networks to efficiently support packet data traffic [1, 2]. Therefore, the key challenge in the design of wireless networks is to support both voice and packet data services for multiple classes of traffic with different QoS parameters. One aspect of this challenge is to develop an efficient and fair scheme for assigning frequency resources to handoff/new call of different traffic types. To meet this aspect of the challenge, this project proposes a dynamic channel and packet assignment (DCPA) scheme to utilize frequency spectrum efficiently and fairly for circuit-switching (e.g., telephony) and packet-switching (e.g., Internet traffic) communication. The DCPA scheme lays the fact that the developed DCPA algorithm assigns dynamically not only packet but also channels, assuming that any new/handoff call requests either a channel or a packet slot. In the DCPA algorithm, it is assumed that not only data traffic but also voice traffic may be transmitted as packets. If no free channel is available in a cell, a voice call may be assigned some free packet slots of a channel. [1]

II .CHANNEL ALLOCATION

Dynamic Channel Allocation has been well studied in multi-cellular system networks [5]. But according to [7] applying existing Dynamic Channel Allocation algorithm to channel is non-trivial for several reasons [4]. First of all, traditional Dynamic Channel Allocation schemes assume a predetermined Signal to Interference Noise Ratio (SINR) threshold (for homogenous applications such as voice) [6],[8], modern data networks utilizes adaptive modulation which makes channel assignment decision non-binary from Signal to Interference Noise Ratio standpoint [[9],[10]. Secondly, channels are frequency selective and their data rate requirements are also different [11], [12]. Third is the measurement and signaling overhead since Orthogonal Frequency Division Multiple Access channels are broadband [13], [14].

III .METHODOLOGY AND SYSTEM ANALYSIS

Markov chain with Poisson process is the primary methodological frame work for analyzing DCPA network. Its use often requires simplifying assumptions since, unfortunately, more realistic assumptions make meaningful analysis extremely difficult. Nevertheless, these models often provide a basis for valuable qualitative results and worthwhile insights. When a new call is assigned a channel, the call is also assigned a channel holding time which is generated by an exponential distribution function. Call arrival is modeled as a Poisson process with different mean arrival rates, and the call duration is exponentially distributed with a mean value of 15 time slots. The traffic is characterized by the arrival rate of new calls and by the transition probabilities of handoff calls. The arrival process of voice calls is Poisson with rate λv. The voice call duration follows an exponential distribution with rate μv. The arrival process of data calls is also Poisson with rate λd. Each packet call requires an exponential transmission time with rate μd. We assume that base station has a buffer with a substantially large buffer capacity to avoid significant packet loss.

IV .STRUCTURAL ANALYSIS AND DESIGN METHOD

The existing cellular system was proposed by Schulte in 1960 called dynamic channel and packet allocation (DCPA); it partitions the available spectrum into channel sets. The reuse distance constraint is satisfied by assigning these channel sets to the cells in each cluster in a manner determined by a graph coloring problem. A base station is allowed to transmit to and from mobiles in its cell not only on channels in its assigned channel set but dynamically [6]. Each cell is serviced by a base station (BS). A number of BS's communicate with a mobile switching center (MSC) through wire-line links, while a base station communicates with the mobile users (or stations) through wireless links. We assume that the total number of channels available in the cellular network is 128. Initially, each cell is assigned an equal number of channels. Since we assume that the reuse pattern of the cellular network equals 3, the number of channels assigned initially to each cell is approximately equal to 128 divided by 3.

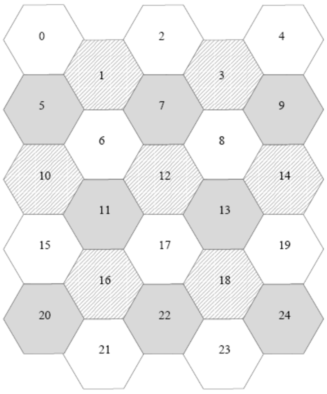

Fig.1.Shows The Adjacent Cellular Network

After the initial assignment of channels, they move dynamically among cells based on traffic conditions and blocking probabilities of calls. Each channel can support 9 packet slots. A new call is assigned at most 3 packet slots.

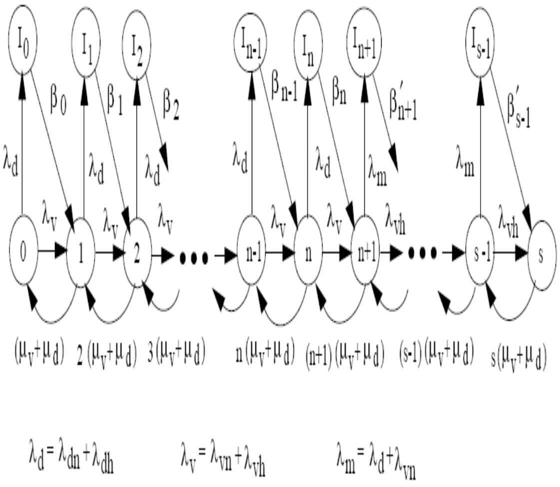

Fig.2. Shows The State Transition Diagram For The Model Of A Cell Operating Under The Proposed Algorithm.

For a cell having S channels, the model has 2s+1 states, namely 0, 1, 2, 3, S, $I_{O,}$ I,………I_{S-1}.A cell is defined as cold cell if it is in state K, for $0 \le K \le n$, whereas a cell is called hot cell if it is not a state greater than n. If a data call with rate λd (respectively, a voice call with rate λv) arrives in a cold cell with state K, then the cell enters state I_K (respectively, state K+1). On the other hand, if a data call with rate λm or a new voice call with rate λvn arrives in a hot cell in state j for j>n, then the cell enters state Ij. A handoff voice call is always assigned a whole channel. However, a new voice is assigned a whole channel if the cell is a cold cell.

Let Pj denote the steady state probability that the process is in state j, for j =0; 1; 2; _ _ _;S. Assuming that all channel holding times are exponentially distributed.

For j = 0 (i.e., states 0 and I_0):

$(\lambda d + \lambda v)P_0 = P_1 (\mu d + \mu v)$ ……......................... (1)

$\Lambda d\ P_0 = P\ I_0$ ………………………………... (2)

It follows from (1) that

$$P_1 = \frac{\lambda d+\lambda v}{\mu v+\mu d} P0 = \rho P_0 \text{..............................} (3)$$

For j = 1; 2; …….. n

$(\lambda d + \lambda v)Pj + j(\mu v + \mu d)Pj = \lambda v\ P_{j-1} + (j + 1)(\mu v + \mu d)P_{j+1} + PI_{j-1}\ \beta_{j-1}$.............(4.4)

$\lambda dPj = PIj\ \beta j$ ………………………………………(4)

Eq. (1.5) implies that $\lambda d\ P_{j-1}$ can be substituted for $PI_{j-1}\ \beta_{j-1}$ in (4.4). Hence, Eq. (4.4) can be rewritten as

$(\lambda d + \lambda v)P_j + j(\mu v + \mu d)Pj = \lambda vP_{j-1} + (j + 1)(\mu v + \mu d)P_{j+1} + \lambda dP_{j-1} = (\lambda d + \lambda v)P_{j-1} + (j + 1)(\mu d + \mu v)P_{j+1}$ ……….(5)

By solving (1.6) recursively by letting j = 1; 2; 3 and n-1 in order to obtain

$P_2 = 1/2!\ \rho^2 P_0$

$P_3 = 1/3!\ \rho^3 P_0$

$P_4 = 1/4!\ \rho^4 P_0$

$P_5 = 1/5!\ \rho^5 P_0$ and

$P_n = 1/n!\ \rho^n P_0$ respectively.

Therefore, for $0 \le j \le n$, we obtain

$Pj = 1/j!\ \rho^j P_0$…………………………………………. (6)

For j = n+1, n+2,…………… S-1, we have the following balance equation in the equilibrium case

$(\lambda m + \lambda vh)P_j + j(\mu v + \mu d)Pj = \lambda vhP_{j-1} + (j + 1)(\mu v + \mu d)P_{j+1} + \lambda mPI_{j-1}(\lambda d + \lambda v)\ P_j + j(\mu d + \mu v)Pj = (\lambda d + \lambda v)\ P_{j-1} + (j+1)(\mu d+ \mu v)\ P_{(j+1)}$...(7)

Where $\lambda d + \lambda v = \lambda m + \lambda vh$

Note that Equation (10) is the same as Equation (7) therefore Equ. (10) also holds for j= n+1, n+2,…………………………S-1…….(8)

For j = S

$S(\mu v + \mu d)P_s = \lambda vh\ P_{s-1} + PI_{s-1}\ \beta'_{j-1} = \lambda vh\ PI_{s-1} = (\lambda vh + \lambda m)P_{s-1} = (\lambda d + \lambda v)P_{s-1}$……(8)

$P_s = 1/S!\rho^s P_0$……….…………………………….(9)

Thus for $0 \le J \le S$, the steady state probability, P_j is

$P_j = 1/J!\ \rho^j P_0$……..…………………………………. (10)

The P_0 for handoff dropping probability, P_{0d}, and new call blocking probability, P_{0b} are equal to the same steady-state probability P_{0s}, that is,

P_0 for $P_d = P_b = P_s$

If a handoff calls requests a free packet slots of a channel and is available. Then based on the algorithm proposed

$P_d = 1/3j!\ \rho^j P_0$.. (11)

When a new call is assigned a channel, the call is also assigned a channel holding time, which is generated by an exponential distribution function with a mean value of 15 time slots. Call arrival is modeled with Markov Chain as a Poisson process with different mean arrival rates, and the call duration is exponentially distributed with a mean value of 15 time slots. The traffic is characterized by the arrival rate of new calls and by the transition probabilities of handoff calls. It is assumed that base station has a buffer with a substantially large buffer capacity to avoid significant packet loss. Table 1 & 2 is shown in Appendix.

V. SYSTEM IMPLEMENTATION

SIMULATION RESULT AND ANALYSIS

Some basic traffic parameters used to evaluate the performance of Dynamic Channel and Packet Allocation are: offered traffic load (G), mobility of calls (α), blocking Probability (P_b), and dropping probability (P_d).

Offered load, G, is defined as the ratio of call arrival rate of cellular network to call completion rate of cellular network. It is a measure of the demand made on all cells of cellular network.

Mobility of calls, α, is the ratio of handoff call arrival rate of cellular network to new call arrival rate of cellular network. A is a measure of terminal mobility.

Blocking probability, P_b, is defined as the probability that a new call request is not accepted while the DCPA scheme is being implemented in cellular network.

Dropping probability, P_d, is defined as the probability that a handoff call request is not accepted while the DCPA scheme is being implemented in cellular network. To evaluate the proposed cellular network, extensive computer simulations using MATLAB are run varying uniform load. Offered traffic has a uniform spatial distribution with arrival rates and exponentially distributed holding times. In the beginning of simulation, data on blocking and dropping probabilities are generated by varying traffic load according to the modeled equations in chapter four. (P_0 is a data gotten from MTN communication company while P_{b1}, P_{b2}, P_{b3}, P_{b4} are gotten using the mathematical model in chapter four).As seen from the graph in Appendix A, as the traffic load increases the probability of blocking also increases but that of P_0 increases sharply to an extent before decreasing even as the number of traffic increases because of the more packet slots being allocated to the channels. Thus, this enhances the quality of service of the network by ensuring that new calls are not blocked but in P_1, P_2, P_3 and P_4 the probability of blocking is still high which needs to be optimized by applying DCPA (assigning new calls to different cells without queuing up and blocking new calls). Hence that of P_1 is more preferable. (P_0 for handoff is also the same for new call but that of P_1, P_2, P_3, P_4 are gotten from the mathematical model)

From the graph in Appendix B, as the number of traffic load increases dropping probability increases but that of P_1 is also recommended due to the availability of free packet slots whenever an ongoing communication requests a free channel. However, DCPA is implemented in P_0 to ensure that handoff calls are not dropped but improves the quality of service. From the analysis in the simulation result the following is hereby recommended

1. The distance between one cells to another must be above 4km for CDMA and 8km for TDMA. This will ensure a more effective network.
2. They must acquire a bandwidth that will be in excess to whatever target customers they are expecting to have. At least, this will always ensure a free channel for data transmission.

VI .CONCLUSION

The rapid growth of wireless mobile subscribers and their increasing demand for mobile multimedia services indicate that wireless data traffic through Internet will have an explosive growth. The fourth generation wireless networks (4G) are, therefore, expected to support efficiently not only mobile telephony but also packet-switched and Internet services with QoS guarantee. Internet services will significantly influence the network architecture of 4G.In conclusion, to have backward compatibility and a smooth transition from third-generation wireless cellular networks to 4G, we designed a dynamic channel and packet assignment scheme (DCPA) for third-generation wireless networks with the features:

1) Efficient channel utilization,
2) Supporting both voice and data services,
3) Distributing channels dynamically and fairly among cells,
4) Contention-free uplink transmission after mobile terminal is assigned resources, and
5) A distributed-controlled scheme from the perspective of the assignment of channels to cells.

The DCPA scheme can be adapted to TDMA-based systems such as GSM. Simulation results have shown that the DPCA scheme provides better QoS than a Fixed Channel Allocation (FCA) scheme designed for circuit-switching communications only. The DCPA scheme can be adapted to TDMA-based systems such as GSM. Simulation results have shown that the DPCA scheme provides better QoS than a Fixed Channel Allocation (FCA) scheme designed for circuit-switching communications only.

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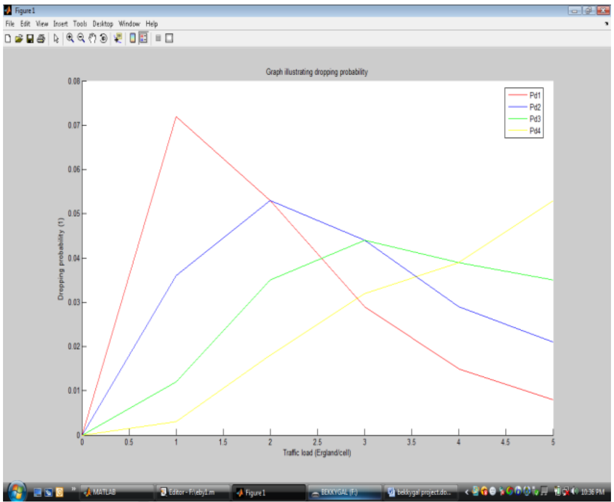
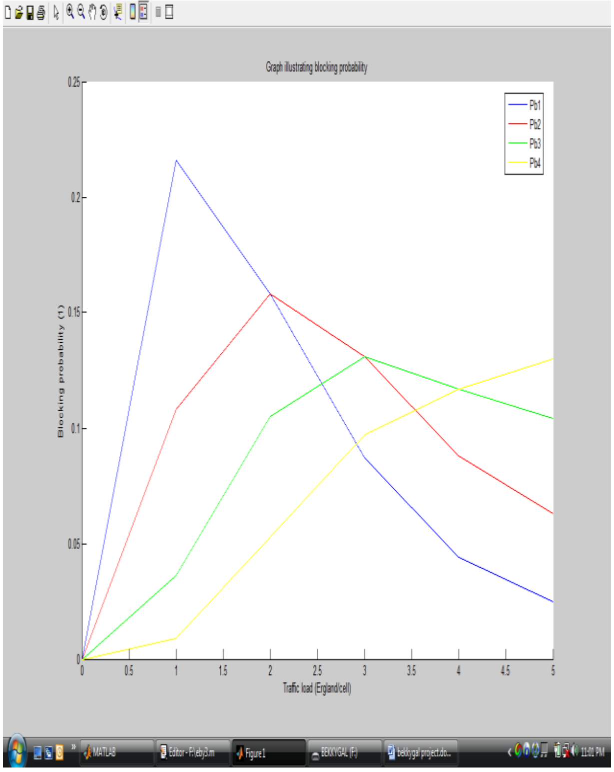
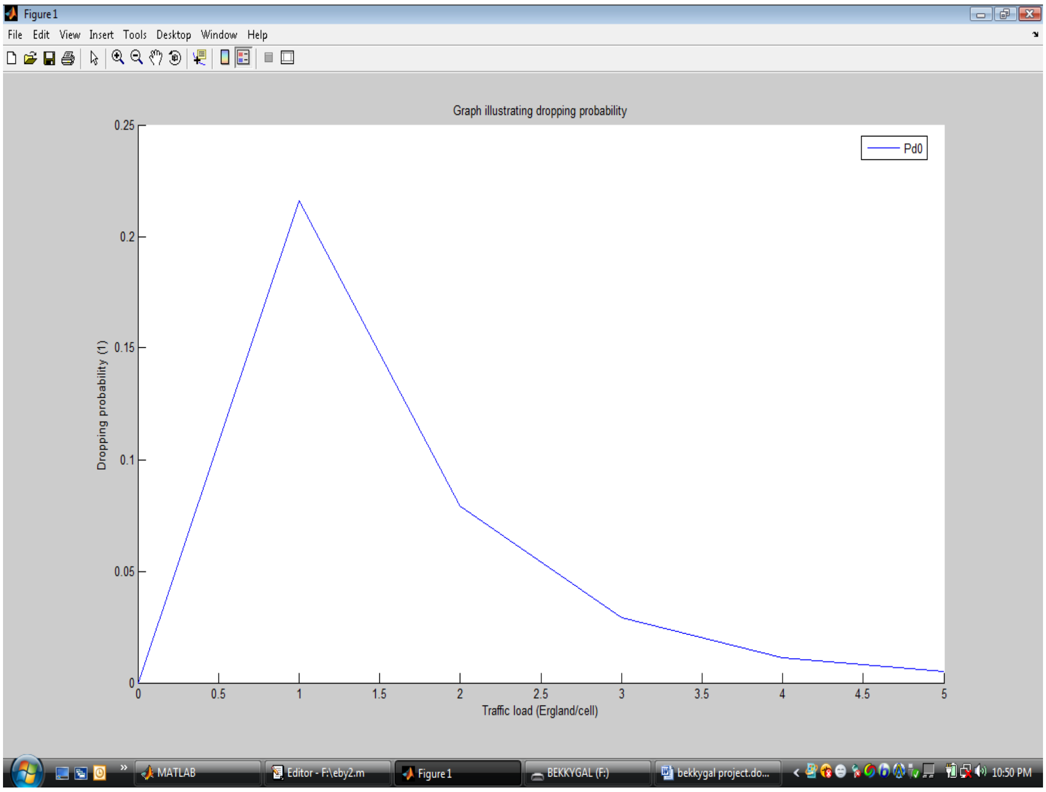
APPENDIX

Simulation of blocking probability





Simulation of dropping probability



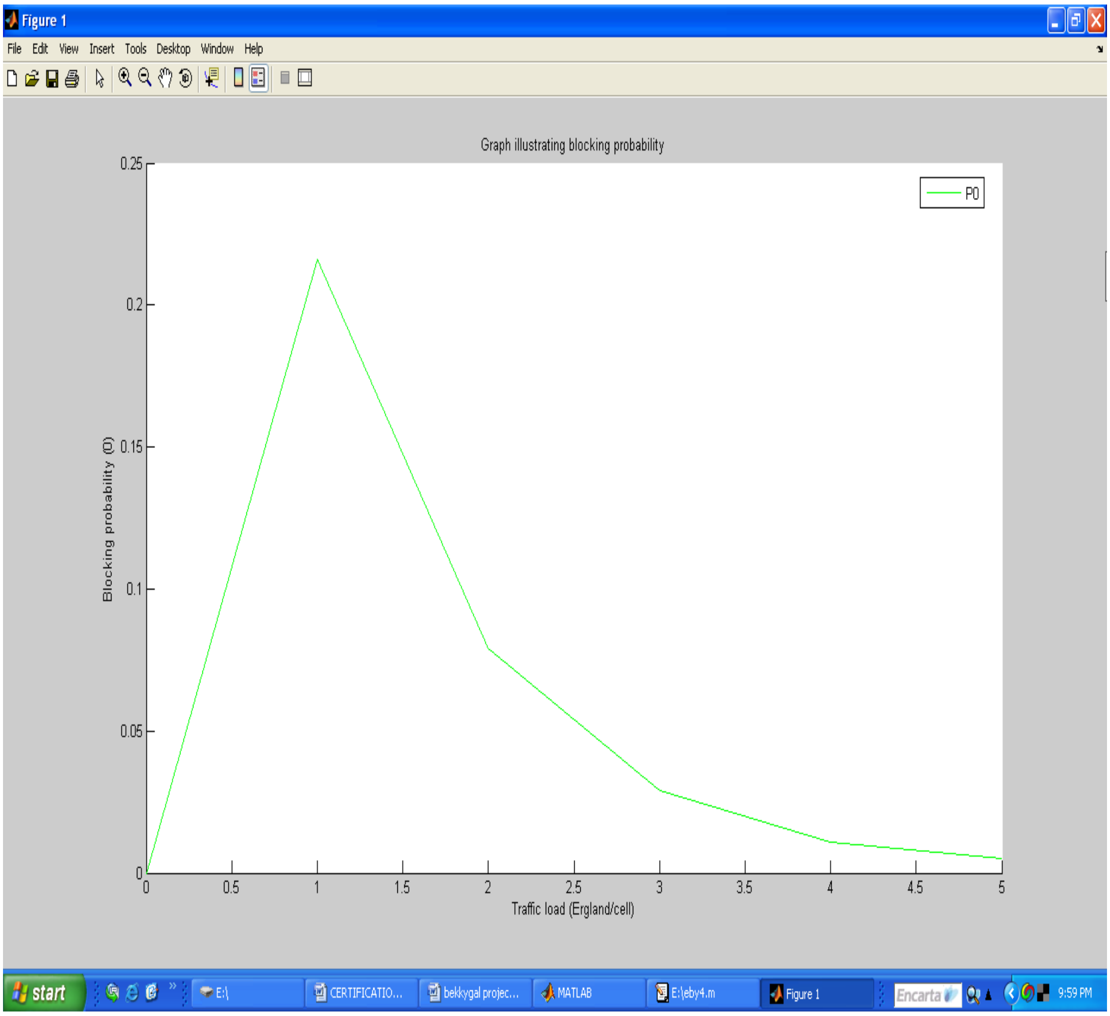


Table 1 illustrates the table for determining blocking probabilities

P Traffic load(Ergland/cell)	$P_{0(\%)}$	$P_{b1(\%)}$	$P_{b2(\%)}$	$P_{b3(\%)}$	$P_{b4(\%)}$
0	0	0	0	0	0
1	0.216	0.216	0.108	0.036	0.009
2	0.079	0.158	0.158	0.105	0.053
3	0.029	0.087	0.131	0.131	0.097
4	0.011	0.044	0.088	0.117	0.117
5	0.005	0.025	0.063	0.104	0.130

Table 2 shows the table for the determination of dropping probabilities based on the DCPA algorithm

ρ Traffic load(Ergland/cell)	P_0	P_{d1}(%)	P_{d2}(%)	P_{d3}(%)	P_{d4}(%)
0	0	0	0	0	0
1	0.216	0.072	0.036	0.012	0.003
2	0.079	0.053	0.053	0.035	0.018
3	0.029	0.029	0.044	0.044	0.032
4	0.011	0.015	0.029	0.050	0.039
5	0.005	0.008	0.021	0.068	0.053