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Comparative Study on Performance Evaluation of Handoff Call Arrival Rate in Microcell of Wireless Networks by Traffic Models

Elsanosy M. Elamin
Department of Electrical Engineering, Faculty of Engineering, University of Kordofan, Sudan.
*Corresponding author: Elsanosy M. Elamin, E-mail: esanosy@hotmail.com.
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ABSTRACT
The unavailability of bandwidth in the wireless network systems is the main source of the most difficulties that the systems experienced. The handoff process is the most problem that the research addressed and contributes in it is solution. This paper is present a comparative study on performance evaluation of the hard handoff call arrival rate in microcell of wireless networks by traffic models. The Hong-Rappaport and Steele-Nofal models are used to assist in improving the system performance. The aim of the paper is to determine which traffic model is valid and in which area because sometimes the mathematical model is not valid over all the parameters ranges. Accordingly, the two different traffic models provided good mathematical results related to the different parameters. It is found that the effect of the blocking probability of originating calls (Bo) and the arrival rate of originating calls in a cell (λo) on the handoff call arrival rate (λ_H) are the same in both traffic models. But for the other parameters, it can be generally said that in relatively low probability of the system parameters, the Steele-Nofal model is more effect in evaluating the handoff call arrival rate in microcell. Whereas in relatively high probability of the system parameters, the Hong-Rappaport model is the best in system performance evaluating.

Keywords: *handoff call rate, blocking probability, traffic models, performance evaluation*

1. INTRODUCTION

The essential key factor in wireless network systems is the handoff process which characterizing the system performance. The handoff process is fundamentally representing a process of changing some of the channel parameters [1] such as frequency, time slot, spreading code, or combination of them to ensure the continuous existing connection. The handoff process is might take place by crossing a cell boundary [1], [2] or by a deteriorated the quality of signal received on a currently serving channel. The heavy signaling traffic that occupied the channel due to the handoff process and other related functions in the network which lately affect the QoS inversely [4]. In the first generation, there was no need for handoff in which only uses one channel at any time, it experienced high probability to loss of connection and dropped call or block. It was only strategy of handoff process that mainly carried out by the network because the signal strength or levels were measured by base stations and supervised by Mobile Switching Centre (MSC). Lately, the handoff decision was made by network which in turn is known as Network-Controlled Handoff. In addition to previous type, there are two different types of handoff decisions; Mobile-Assisted handoff and Mobile-Controlled Handoff [8], [9], [10], [12]. In the second generation and up, the handoff process was significantly starting to affect the system performance due to the growing of the low data rates and the gradual increasing of wireless network deployment [2]. At that time, there are a various types of handoff such as:

1. Intra-BTS handoff,
2. Inter-BTS Intra BSC handoff,
3. Inter-BSC handoff,
4. Inter-MSC handover.

These various different handoff types characterized with a lot of features which enhanced the mobility and QoS at the cellular system [13], [14]. Base stations (BS) is the only responsible object of measuring the signal levels with feedback from mobile station (MS) and then network made decision and controlled it. This results in less load on the network from handoff signaling. Handoff is a time-critical factor in wireless mobile network to provide seamless services under changing radio resource conditions [10]. Mobility and QoS all are the fundamental factors in wireless network to strongly support a continuous good service to improve the system performance [11]. On the other hand, its failure can result in ongoing call termination. The handoff failure probability is always associated with two crucial features; call dropping and call blocking probabilities. Both of them are so important in system performance improvement and capacity [10], [11]. A handoff failure is often due to lack radio resources such as bandwidth in the new cell because of low capacity and narrow cell coverage area, and consequently the call is dropped [15], [16]. The Call Dropping Probability (CDP) is a very important issue that associated with deterioration of QoS and is due to a handoff failure [11], [18].

Mathematical Traffic Models

The salient best feature of the wireless network systems is the user mobility that enable free movement in all direction within the geographical coverage area of wireless network. In the same time, this feature drive all the users to exploit the wireless technology in wide broad application in their life and made the number of users increasing continually and dramatically [5]. The mobility feature imports various complicated challenges to the wireless system designers to comply with the current or future system requirements. To cope with the dynamic continuous changes that occurs in wireless network systems, there is a real and ongoing studies and analysis performing to overcome the difficulties or predict expected continuous expansion in the wireless systems [6], [7]. Simulation and mathematical models are the most two well-known tools that can be performed to assist in system analysis and improvement. Mathematical modeling aims to evaluate the different aspects of the real systems, their performance, and their changes through mathematics. It also ensures both theoretical analysis and experimentation to become more evident [6]. The traffic performance is the fundamental and vital key of the wireless network systems which required to be deeply analyzed to make a conceptual context for better performance, efficiency, and QoS. In this paper, the traffic performance is investigated and analyzed by two different mathematical traffic models which are; Hong-Rappaport and Steel-Nofal models. These models evaluate the handoff call arrival rate (λ_H) in wireless network system, which can be generally describe as:

$$\lambda_H = \frac{Number\ of\ successful\ handoff\ calls}{Number\ of\ total\ handoff\ call\ requests} \quad (1)$$

Mathematical Hong-Rappaport Traffic Model

It is one of the many various one dimensional mathematical models that are used as tool in analyzing the system performance under multi different conditions to support in evaluating the handoff calls arrival rate. The model is function of different fundamental and vital parameters to help in calculating the probability of handoff calls arrive rate (λ_H). Hong-Rappaport traffic model is proposed for hexagonal microcells and assume that the user is in the vehicle which is in high moving within the service area of the cell. So the location of the vehicle when call initiated or called destination is uniformly distributed in the microcell. It also assumed that the vehicle initiating a call can move from the current location to another in any direction of the microcell. Accordingly, the model is recast in the following format to evaluate and assess the handoff arrival calls rate (λ_H) as:

$$\lambda_H = \frac{P_h(1 - Bo)}{1 - P_{hh}(1 - Pf)} \lambda_o \quad (2)$$

Where: P_h: the probability that a new call that is not blocked would require at least one handoff, P_{hh}: the probability that a call that has already been handed off successfully would require another handoff, Bo: the blocking probability of originating calls, Pf: the probability of handoff failure, λo: the arrival rate of originating calls in a cell [6]

Mathematical Steele-Nofal Traffic Model

The handoff strategies management in the wireless communication networks are becoming more popular in public life, there is rapidly dynamic continuous increasing in both data, voice, and video traffic. So, the mathematical and/or simulation traffic models are required to help and support in understanding system changed to predict the good performance under various conditions. Steele-Nofal mathematical traffic model is used to assist in evaluating the handoff arrival call rate to continually support in minimizing the probabilities of call dropping and call blocking. This model is a function of different parameters that are all compose the entire notion about the key parameters with very high important positive effect on the overall wireless system performance. The model is clearly shown below in equation as:

$$\lambda_H = \sum_{m=1}^{n} \lambda o(1 - Bo)\beta[P_h + 3P1(1 - Pf)P_{hh}\beta] \quad (3)$$

Where: β: the fraction of handoff calls to the current cell from the adjacent cells, P_1: the probability that a new call that is not blocked will require at least one handoff.

Numerical Results

Hong-Rappaport traffic model as well as Steele-Nofal model are all have different numbers of the inconstant parameters. The Hong-Rappaport model have only five parameters, whereas the Steele-Nofal model have seven parameters. The two models are only differing in;

1. The fraction of handoff calls to the current cell from the adjacent cells, β
2. The probability that a new call that is not blocked will require at least one handoff, P_1

It is noted that the two parameters β and P_1 are affecting the handoff arrival calls rate (λ_H) in Steele-Nofal model. It is also obviously found that the probability that a new call that is not blocked will require at least one handoff (P_1) is directly proportional to the λ_H depending on the P_{hh}[1]. So, for better comparative results, it is supposed that the probability of P_1=1 that is mean that it is experiencing crossing three microcell in high way traffic road with high speed vehicle. In addition, the handoff calls to the current cell from the adjacent cells (β=1) means that all the handoff call requests are all successfully handed off. The other parameters have different probability values in between minimum and maximum as stated in table 1. The case 1 up to case 5 in table 1 are classified according to the mean probability values of the five parameters versus the handoff arrival calls rate (λ_H). Case 1 showed that all the parameters at their mean probability value, whereas the blocking probability of originating calls (Bo) varied in very low probability from 1% – to – 4%. Case 2 is highlighted on the arrival rate of originating calls in a cell (λo) as main variable which is also lain in low range from 10% - to – 30%. Case 3 considered the probability of handoff failure (Pf) in the range of 1% - to -20%. As well, case 4 took the value of the probability that a new call that is not blocked would require at least one handoff P_h in between 70% - to – 98%. Case 5 dealt with the probability that a call that has already been handed off successfully would require another handoff (P_{hh}) in the range from 60% - to – 98%. These cases showed strong effect on the wireless network performance which in turn will definitely support in reducing the probabilities of call drop and call block as well as handoff strategies management.

Table1 the parameters values in all cases for the two models

The values of parameters			P_1= 1.0 and β =1.0				
Parameter	Min	Max	**Case1**	**Case2**	**Case3**	**Case4**	**Case5**
B_O	0.01	0.04	**0.01 – 0.04**	0.025	0.025	0.025	0.025
λo	0. 1	0.3	0.2	**0.1 – 0.3**	0.2	0.2	0.2
P_f	0.01	0.2	0.105	0.105	**0.01 – 0.2**	0.105	0.105
P_h	0.70	0.98	0.84	0.84	0.84	**0.70 – 0.98**	0.84
P_{hh}	0.60	0.98	0.79	0.79	0.79	0.79	**0.60 – 0.98**

Table2 λ_H versus *Bo, λo, Pf, Ph, and Phh of the* Hong and Rappaport traffic model

Case1		**Case2**		**Case3**		**Case4**		**Case5**	
Bo	λ_H	λo	λ_H	Pf	λ_H	P_h	λ_H	P_{hh}	λ_H
0.010	0.5677	0.10	0.3055	0.010	0.7517	0.700	0.4659	0.600	0.3538
0.013	0.5660	0.12	0.3666	0.029	0.7033	0.728	0.4846	0.638	0.3818
0.016	0.5643	0.14	0.4277	0.048	0.6607	0.756	0.5032	0.676	0.4147
0.019	0.5626	0.16	0.4888	0.067	0.6230	0.784	0.5219	0.714	0.4538
0.022	0.5609	0.18	0.5499	0.086	0.5893	0.812	0.5405	0.752	0.5010
0.025	0.5591	0.20	0.6110	0.105	0.5591	0.840	0.5591	0.790	0.5591
0.028	0.5574	0.22	0.6721	0.124	0.5319	0.868	0.5778	0.828	0.6326
0.031	0.5557	0.24	0.7332	0.143	0.5072	0.896	0.5964	0.866	0.7282
0.034	0.5540	0.26	0.7943	0.162	0.4846	0.924	0.6151	0.904	0.8580
0.037	0.5523	0.28	0.8554	0.181	0.4640	0.952	0.6337	0.942	1.0439
0.040	0.5505	0.30	0.9165	0.200	0.4451	0.98	0.6523	0.980	1.3328

Table3 λ_H versus *Bo, λo, Pf, Ph, and Phh of the* Steele and Nofal traffic model

Case1		**Case2**		**Case3**		**Case4**		**Case5**	
Bo	λ_H	λo	λ_H	Pf	λ_H	P_h	λ_H	P_{hh}	λ_H
0.010	0.5716	0.10	0.2887	0.010	0.6213	0.700	0.5501	0.600	0.4779
0.013	0.5699	0.12	0.3465	0.029	0.6125	0.728	0.5556	0.638	0.4978
0.016	0.5682	0.14	0.4042	0.048	0.6038	0.756	0.5610	0.676	0.5177
0.019	0.5665	0.16	0.4619	0.067	0.5950	0.784	0.5665	0.714	0.5376
0.022	0.5647	0.18	0.5197	0.086	0.5862	0.812	0.5720	0.752	0.5575
0.025	0.5630	0.20	0.5774	0.105	0.5774	0.840	0.5774	0.790	0.5774
0.028	0.5613	0.22	0.6352	0.124	0.5686	0.868	0.5829	0.828	0.5973
0.031	0.5595	0.24	0.6929	0.143	0.5599	0.896	0.5883	0.866	0.6172
0.034	0.5578	0.26	0.7507	0.162	0.5511	0.924	0.5938	0.904	0.6371
0.037	0.5561	0.28	0.8084	0.181	0.5423	0.952	0.5993	0.942	0.6570
0.040	0.5543	0.30	0.8661	0.200	0.5335	0.98	0.6047	0.980	0.6769

The numerical results in tables 2 and 3 are obtained from the Hong-Rappaport and Steele-Nofal traffic models respectively according to the different cases. These cases are all expressed the possible performance of the wireless network during the system performance conditions. The effect of handoff call arrival rate on the system performance is the most critical in system evaluation.

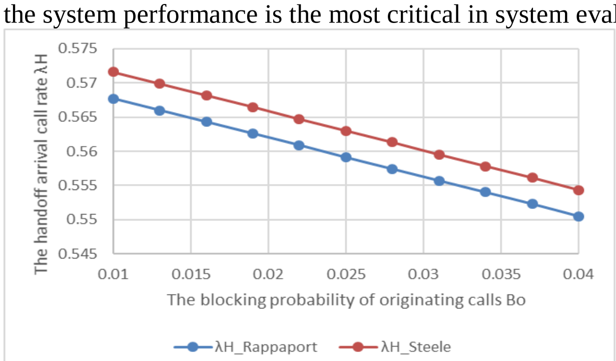

Fig. 1 the λ_H versus Bo of case 1

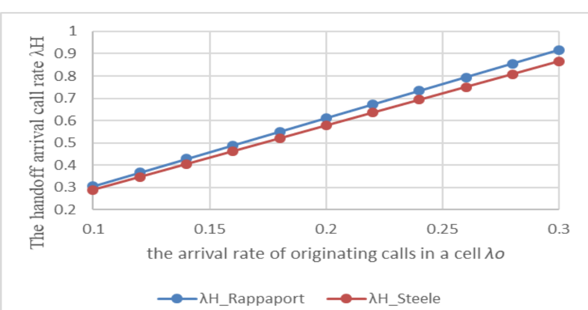

Fig. 2 the λ_H versus λ_O of case 2

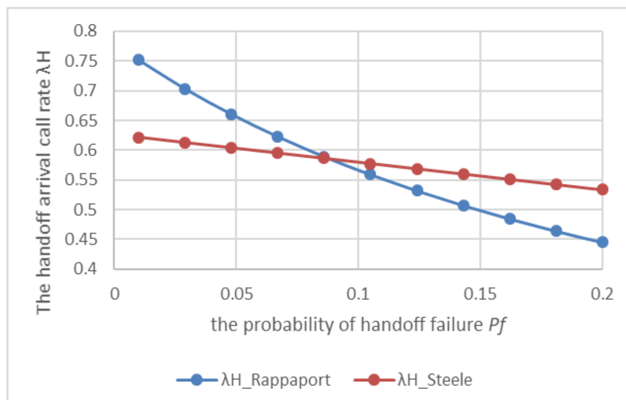

Fig. 3 the λ_H versus *Pf* of case 3

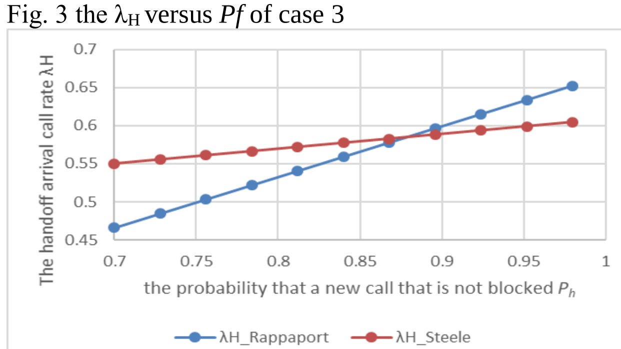

Fig. 4 the λ_H versus P_h of case 4

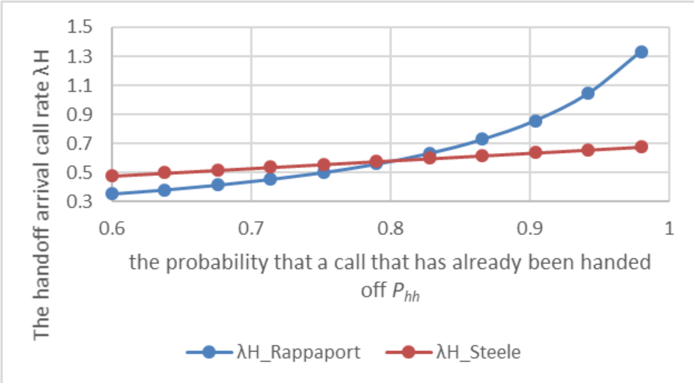

Fig. 5 the λ_H versus P_{hh} of case 5

DISCUSSION

During the mathematical traffic models carryout, the multi different cases showed dissimilar degrees of the different parameters on the handoff call arrival rate (λ_H). In fig.1 case 1, it is clearly that the effect of the blocking probability of originating calls (*Bo*) is inversely proportional to the λ_H over all the *Bo* range. The numerical results of *Bo* in the two traffic models are behave in the same mode, but are significantly different in their values. So, the difference can be controlled or adjusted by P_1 which represent the probability that a new call that is not blocked will require at least one handoff or by β which represent the fraction of handoff calls to the current cell from the adjacent cells. In fig. 2 case 2, it is also found that the λ_O which represent the arrival rate of originating calls in a cell was also clearly behave in the same mode in two traffic models with slight difference in their values. In other words, they are approximately identical over all the λ_O range with very low difference. In fig. 3 case 3, there was great difference in both traffic models. Both are act in different modes, where the probability of $Pf = 0.086$ is the value that the both traffic models are behaving equally. At probability of $Pf < 0.086$, the Hong-Rappaport model is more effective with inversely considerable proportional to the λ_H. Whereas at probability of $Pf > 0.086$, the Steele-Nofal model was more effective with slightly inversely proportional to the λ_H. In fig. 4 case 4, the two traffic models were also act as the same and in both the P_h is directly proportional to the λ_H. At probability of $P_h = 0.868$, both of traffic models are identical. At probability of $P_h < 0.868$, the Steele-Nofal model has strong effect than Hong-Rappaport model. Whereas at $P_h > 0.868$, the Hong-Rappaport model is the dominant. In fig. 5 case 5, both of them are behave in quite different modes. In the Hong-Rappaport model, the P_{hh} is linearly proportional to the λ_H. But in Steele-Nofal model, the P_{hh} is exponentially proportional to the λ_H. For the probability of $P_{hh} < 0.8$, Steele-Nofal model is dominant. Whereas for the probability of $P_{hh} > 0.8$, the Hong-Rappaport model is the dominant. So, generally it can be said that in relatively low probability of the system parameters, the Steele-Nofal model is more effect in evaluating the handoff call arrival rate in microcell. Whereas in relatively high probability of the system parameters, the Hong-Rappaport model is the best in system performance evaluating.

CONCLUSION

The wireless network system performance is evaluated by the two different traffic models under various conditions which categories into five cases. The mathematical results indicated that for the effect of both the blocking probability of originating calls (*Bo*) and the arrival rate of originating calls in a cell (λ_O) on hard handoff call arrival rate (λ_H), the two models are equal in evaluating the system. But for other parameters; in relatively low probability of the system parameters, the Steele-Nofal model is more effect and valid. Whereas in relatively high probability of the system parameters, the Hong-Rappaport model is the best in system performance evaluating. These two models can be applied especially in the microcells where there are uncrowded, low densely areas, and all the users are moving in high speed with no longer reside in the microcells.

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