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MERGING LINK-LEVEL AVAILABILITY BASED ON FADED AND NOISY CHANNEL CHARACTERTIZTION

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System level performance evolution of mobile wireless communication networks has been addressed by only resource insufficiency where as the effect an unreliable wireless channel has largely been ignored. Wireless communication systems are subject to short and long fading of channel. Signal is likely to suffer from the damaging effects of channel fading. In this paper the system level performance of mobile wireless networks is studied where the effect and characterization of "Average Network Availability Time" due to shadowing and fading channel model used to calculate the interruption probability when a desired signal and interference undergo short fading and shadowing simultaneously.

KEYWORDS: *Link availability, Channel modeling, Outage probability.*

I. INTRODUCTION

Considerable studies have discussed the problem when the call is blocked due to insufficient radio resources (time, frequency or code) [1]–[2]. The performance evaluation of a certain mobile communication network as well as the call behavior characteristics are usually analyzed or simulated based on the assumption that the link layer can reliably combat the signal degradation, so that the call level is not affected by the erroneous wireless channel.

In wireless communication systems, the received signal is subjected to the adverse effects of the channel in the form of short- and long-term fading, also known as shadowing [3]. Short-term fading arises from the existence of multiple paths between transmitter and receiver. Shadowing is the result of the topographical terrains structure elements such as tall buildings, trees and other structures in the transmission path. Dropped calls are increased as a result of bad channel conditions. For instance, the main cause and criteria for handoff is essentially the weak signal power resulting from the severe channel degradation. Hence, it is more reasonable to study the call-level performance and packet-level performance with the effect of wireless channel impairment characteristics in the mobile network [4].

In general, the physical link is said to be unreliable if the experienced signal-to-noise ratio (SNR) becomes lower than a certain level (SNR threshold) for more than a specified period of time (time threshold) [5]. In [6] it was stated that the reason for a large part of calls which are forced to terminate is the highly time varying and unreliable wireless channel. So, it is recommended as in [4] to study system-level and link-level performances by taking into account the effect of wireless channel impairments in mobile networks. Additionally, for convenience and mathematical tractability, the system performance is commonly investigated under the assumption that both the unencumbered service time and the cell dwell time are exponentially distributed; that is, only the mean values of these time variables have been relevant for the performance metrics [7].

Rest of the paper is organized as follows: in section II, system model description is provided. In section III, distributions of the average network availability time is presented. In section IV, assessment criteria are given. Section V contains, numerical results and analysis, and comparison to the previously published work in [13].In addition, the performance assessment parameters are illustrated and investigated for different distributions. Finally, conclusions are provided in section VI.

II. SYSTEM MODEL

A. Modeling for average network availability time

The mathematical notations and the used time variables are explained and defined, respectively. By defining the unencumbered service time per call X_s (also known in the literature as the call holding time) as the duration of a requested call connection and it is equivalent to the call duration in the fixed telephone network.

Now, the cell dwell time or the cell residence time X_d (j) is defined as the time that an mobile station (MS) spends in the j^{th} (for j =0, 1, .) handed off cell, irrespective of whether it is engaged in a call (or session).

The residual cell dwell time X_r is defined as the time between the instant that a new call is initiated and the instant that the user is handed off to another cell. Notice that the residual cell dwell time is only defined for new calls.

The channel holding time X_c (j)is the time that a call occupies a given set of radio resources in the j^{th} (for j =0, 1, ..) handed off cell before its call is either completed, handed off to another cell, or interrupted due to link unreliability. Notice that the channel holding time X_c (j) could easily be measured at the base station (BS) in real cellular networks. In fact, the total channel holding time (i.e., the aggregated channel holding time X_c(j) in the different cells a user roams until its call is either concluded or interrupted due to either resource insufficiency or link unreliability) is used for billing purposes.

The Average network availability time X_a (j), it is defined as the period of time from the epoch that the MS establishes a link with the j^{th} handed-off cell (for j =0, 1, . . .) until the instant that the call would be interrupted due to link unreliability assuming that the MS has neither successfully completed call nor been handed off to another cell. Physically, this time represents the period in which a call would be terminated under the assumption that both the cell dwell time and the unencumbered service time are of infinite duration. This variable assumed to be independent and identically generally distributed (IID) [8].

B. Channel Model

To characterize the average network availability time by means of link-level statistics (in terms of its probability density function pdf and mean), two discrete channel models are used, that is, Fritchman and Gilbert–Elliot. These models have widely been used to capture the periods of signal degradation [9]. In the Gilbert–Elliot model (two-state Markov chain model), as shown in figure (1), the state space of the wireless channel consists of $\Omega = \{good; bad\}$. The transition probabilities are defined as follows. Given that the current state is a good one, the probability that the next state is a good one is denoted by (P_G), and the probability that the next state is a bad one is denoted by ($1 - P_G$). On the other hand, given that the current state is a bad one, the probability that the next state is a bad one is denoted by (P_B), and the probability that the next state is a good one is denoted by ($1 - P_B$). Then, the channel is modeled by a sequence of alternating good and bad states. For this model, a channel cycle is defined as the continuous good state and its next consecutive bad state. The good time $X_g^{(K)}$ and bad time $X_b^{(K)}$ variables are defined as the time duration of the good and bad states of the K^{th} cycle, respectively. The RVs used to represent these times are $X_g^{(K)}$ and $X_b^{(K)}$ (for k = 1, 2, ..), respectively.

On the other hand, the Fritchman channel model is a generalized Gilbert–Elliot model in which the channel is modeled by a sequence of several good or bad states. The time residence in certain state is determined by the transition probabilities. Then, the time that the channel stays in each state can be assumed IID. The presented work tries to take into consideration more practical operational scenarios. This may be done via the many process of three different probability distributions. As in [9], for these two channel models, we assumed that the calls in the good channel state can communicate with error free and those in the bad channel state may fail, but not definitely, to complete the conversation or session owing to the broken link.

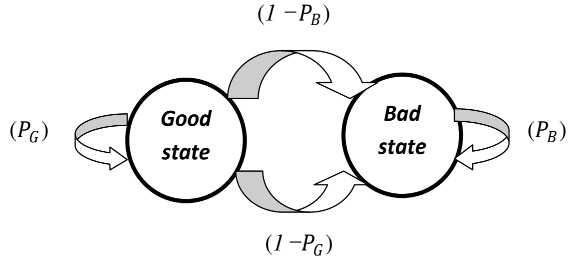

Figure 1. Example Gilbert–Elliot model (two-state Markov chain model)

When the channel turns from a good state to a bad state, the call may not immediately be dropped because of the link layer error protection scheme. In wireless channel bad state, the call connection is not necessarily terminated. Link Re-establishment (LRE) is the procedure for a call to attempt rebuilding the link between MS and BS upon encountering link breakage. Specifically, as the wireless channel associated with an ongoing session becomes degraded, the BS link layer will inform the relevant module to re-establish the impaired link. When term the timer in link layer to monitor the channel state as Monitoring Channel Timer (T_{mc}). As the channel becomes worse and no messages are exchanged between MS and BS in the period T_{mc} , LRE REQUEST message is sent out with the attempt to re-establish the physical link. Upon sending the message LRE-REQUEST, the timer TIMER-LER with length TLER is started to monitor the message transmission. If no acknowledgement LRE-ACK is received in the duration TLER, TIME-LER expires. Then, message LRE-REQUEST is sent out again [10]. If after NLER times attempts and no message LRE-ACK received, the voice channel is released and can be used by other users.

To analytically find the pdf of the average network availability time, it is necessary to define p_{cr} as the probability that the link could not be re-established during the bad state in presence of noise effect only. This probability is mathematically expressed as:

$$p_{cr} = P\{X_b > TLER*NLER+T_{mc}\} \quad (1)$$

In the case under study the duration of bad state in presence of call outage probability, the short-term fading that observed in wireless systems can be modeled using the Nakagami distribution. The probability density function of the envelope of the signal is expressed as:

$$f_X(x) = \frac{2m^m x^{2m-1}}{\Gamma(m) y^m} e^{-(\frac{m}{y})x^2}, \quad x > 0 \quad (2)$$

where m is the Nakagami parameter [3]. The effects of fading on wireless channels are measured in terms of m, with severe fading occurring when m is small and weak fading occurring when m is large. In the absence of any shadowing or long-term fading, the average power of the received signal, expressed in terms of y of (3), is deterministic. Shadowing is present, y is random and the expression for the density function of the envelope needs to be expressed in conditional form as [4].

$$f_{X|Y}(x|y) = \frac{2m^m x^{2m-1}}{\Gamma(m) y^m} e^{-(\frac{m}{y})x^2}, \quad x > 0 \quad (3)$$

We can use the gamma pdf to describe the long-term fading [11]. This means that $f_Y(y)$ is a gamma pdf given by:

$$f_X^G(y) = \frac{y^{M-1}}{\Gamma(M) y_0^M} e^{-(\frac{y}{y_0})} \quad (4)$$

The pdf of the envelope in a shadowed short-term fading channel becomes

$$f_X^C(x) = \frac{2b}{\Gamma(m)\Gamma(M)} \left(\frac{bx}{2}\right)^{M+m-1} K_{M-m}(bx), \quad (5)$$

$$x > 0, m > 0.5, M > 0$$

where K_(M-m) ( ) is the modified Bessel function [24] of order (M-m) and b = 2 m/y_0. The level of shadowing is measured in terms of M. The superscript C of f_X^C (x) indicates that it is a compound pdf incorporating both short term fading and shadowing [11]. Use of the gamma distribution can be justified on the premise that it is a very versatile distribution.

Equation (5) can model pure short-term fading when (M→∞) and for various values of M and m, the amount of fading allowing it to vary from zero (no fading/no shadowing) to infinity (severe fading, severe shadowing or both).Thus,(5) provides a closed-form expression to model fading and shadowing simultaneously. The parameter is the signal-to-noise ratio, expressed as the average value of a gamma random variable having a pdf in (4) as:

$$Z_{av} = y_0 M = \frac{4Mm}{b^2} \tag{6}$$

Signal-to-noise ratio fails to reach a threshold that is determined by the specific modulation format, multiple access scheme used, etc. [3]. If Z^T is the threshold, the compound outage probability can be expressed as:

$$p_{out}^c = \int_0^{\sqrt{Z^T}} f_X^C(x)\,dx \tag{7}$$

where f_X^C (x) is the pdf of the envelope given in (5).The probability of outage probability in terms of the compound pdf model can be expressed by:

$$p_{out}^c = \frac{\Gamma(M-m)(Z^T b^2/4)^m}{\Gamma(M)\Gamma(m+1)} \times 1F_2(m,[1-M+m,1+m],\frac{Z^T b^2}{4}) + \frac{\Gamma(m-M)(Z^T b^2/4)^M}{\Gamma(m)\Gamma(M+1)} \times 1F_2(M,[1-m+M,1+M],\frac{Z^T b^2}{4}) \tag{8}$$

In (8), $1F_2$ is the hypergeometric function [12].

III. DISTRIBUTIONS OF THE NETWORK AVALIABILITY TIME

The pdf of the average network availability time X_a (j) is found by considering the Fritchman channel model. The average network availability time is the aggregated time that a call spends in the good and bad channel states. Notice that a call should always start in a good state because a call could not be established if the channel is in a bad state. On the other hand, if a call is not interrupted in the bad state of a certain cycle, it should go through the good state of the next cycle before it could be interrupted. By using the good time $X_g^{(K)}$ and bad time $X_b^{(K)}$ variables, the average network availability time X_a for calls interrupted in the first cycle is given by $X_g^{(1)} + X_b^{(1)}$, which occurs with probability P_0 (if the re-establishing procedure is unsuccessful).

If the re-establishing procedure is successful in the first cycle and unsuccessful in the second cycle, the average network availability time is given by $X_g^{(1)} + X_b^{(1)} + X_g^{(2)} + X_b^{(2)}$ with probability $(1 - P_0) P_0$, and so on. Thus, the pdf of the average network availability time can be expressed in terms of the pdf of the good and bad states as:

$$f_{X_a}(t) \approx f_{X_g}^{(1)} + X_b^{(1)}(t)P_0 + f_{X_g}^{(1)} + X_b^{(1)} + X_g^{(2)} + X_b^{(2)}(t)(1-P_0)P_0 + \cdots \tag{9}$$

$$E[X_g^{(K)}] \gg E[X_b^{(K)}] \tag{10}$$

$$f_{X_a}^*(s) \approx \sum_{n=1}^{\omega} \left(f_{X_g}^*(s)\right)^n (1-P_0)^{n-1}P_0 \tag{11}$$

where f_{Xg}^* represents the Laplace – Stieljies transform, this summation converges to:

$$f_{X_a}^*(s) \approx \frac{f_{X_g}^*(s)P_0}{1 - f_{X_g}^*(s)(1-P_0)} \tag{12}$$

where X_g is considered negative exponentially distributed (i.e., when the channel is modeled by a Gilbert–Elliot channel model) with parameter , it is easy to show that the distribution for is given by

$$f^*_{X_a}(s) \approx \frac{\mu_g P_0}{s + \mu_g P_0} \tag{13}$$

Then, in this case, X_a approximately follows a negative exponential distribution with mean $1/(\mu_g P_0)$.

The characterization of the average network availability time X_a by using the Fritchman model. From (12), it is easy to obtain a closed form for the Laplace transform of the pdf of the average network availability time by considering that the good state duration has an n-order Erlang or hyperexponential distribution.

Laplace transforms of the pdf of the average network availability time considering that the good state duration has an n-order Erlang or hyperexponential distribution are

$$f^*_{X_a}(s) \approx \frac{\mu^n P_0}{(s+\mu)^n - \mu^n(1-P_0)} \tag{14}$$

Where μ represents the parameter of each stage of the Erlang distribution

$$f^*_{X_a}(s) \approx \frac{\sum_{l=1}^{m} \frac{\alpha^l \mu^l}{(s+\mu^l)}}{1 - \sum_{l=1}^{m} \frac{\alpha^l \mu^l}{(s+\mu^l)}} \; \frac{P_0}{(1-P_0)} \tag{15}$$

where μ^l represents the parameter of the l^{th} phase, α^l represents the probability of choosing the l^{th} phase, and m represents the number of phases of the hyperexponential distribution. Also we can define the following:

$$P_{eff} = P_{cr} + P^c_{out} - P_{cr}\, P^c_{out} \tag{16}$$

where,

$$P_0 = \begin{cases} P_{cr} & \text{noise effect only} \\ P^c_{out} & \text{fading effect only} \\ P_{eff} & \text{effective noise and fading} \end{cases} \tag{17}$$

IV. ASSESSMENT CRITERIA NETWORK

A. Interruption Probability Due to Link Unreliability

Link unreliability is the other cause of forced termination. Then, to adequately evaluate the system performance, it is necessary to obtain the call interruption probability. By considering the proposed model, a call will be forced to terminate due to the link unreliability. This is occurred when the average network availability time in the handed-off cell, is smaller than both unencumbered service time and cell dwell time in j^{th} cell. It can be expressed as follows:

$$\beta^{(j)} = P\left\{X_a^{(j)} < min(X_s^{(j)}, X_r^{(j)})\right\} = \frac{\gamma}{\mu + \eta + \gamma} \tag{18}$$

B. Successfully Call Completion Probability

Considering the proposed model, a call will be successfully terminated in a given region, a cell j when services time is smaller than both network availability time and cell dwell time then, mathematically, it can be expressed as:

$$\xi^{(j)} = P\left\{X_s^{(j)} < min(X_a^{(j)}, X_r^{(j)})\right\} = \frac{\mu}{\mu + \eta + \gamma} \tag{19}$$

where 1/γ represents the mean value of the average network availability time, 1/η represents the mean value of the cell dwell time (cell residence time) and 1/μ represents the mean value of service time as in [2].

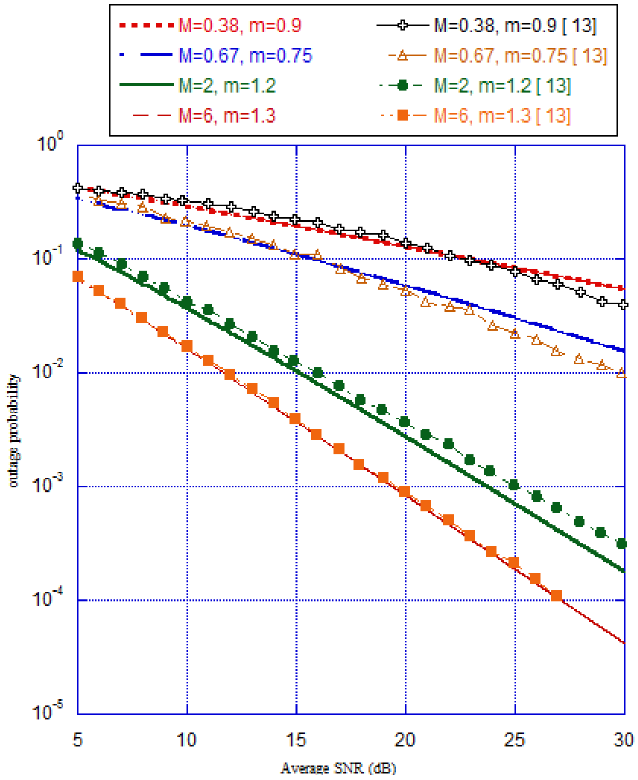

Figure 2. Outage probabilities in shadowed fading channels with different fading parameters

V. NUMERICAL RESULTS AND ANALYSIS

A. The Validation Models

In order to verify the validation of obtained results the system parameters have been chosen to match those of the previously published work in [13].

Figure 2, shows that the outage probabilities in shadowing environments with short and long schemes. The current validation curve with value of Z^T= 5 dB was used as the threshold.

B. Pdf of the Average Network Availability Time Due to Fading Channel.

In order to investigate the fading channel effect on average network availability time. Fig. 3 clearly shows the obtained pdf of the average network availability time in three different distributions schemes: Negative exponential, Erlang and Hyperexponential probabilities distributions of fading channel, which is summarized as follows: NLER = 3, TLER = 1000 msec, mean value of T_{mc} = 6 sec, E[X_g] = 24 sec, and E[X_b] = 3 sec. Note that the values are chosen to be consist

In Fig. 3 it is important to observe that the pdf of the average network availability time strongly depends on distribution of good and bad state duratipn.pdf of the average network availability time follows many different forms. Consequently, it is concluded that to obtain more realistic results it is more reasonable to study the system-level performance.

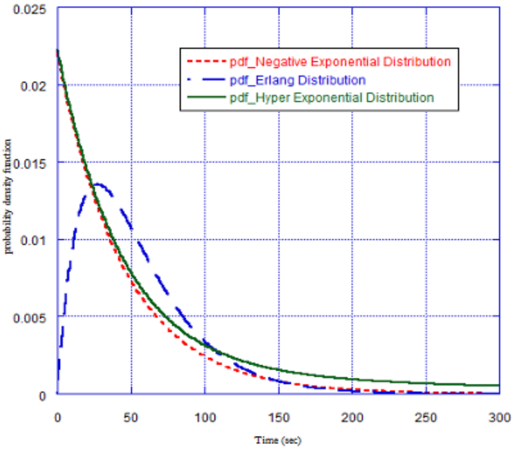

Figure 3. pdf of average network availability time for fading channel

C. Performance Assessment Parameters

The goal of numerical evaluations presented in this section is to understand and analyze the influence of link unreliability. The used for the numerical results shown in this section are: the mean service time is E{X_s} = 180 sec; and the mean of the cell dwell time is E{X_d} = 900sec. The cell dwell time and the average network availability time are modeled with n-order Erlang and negative exponential.

i-Performance Assessment for Noisy Channel Only

Figure 4 shows negative exponential distribution for interruption and successfully call completion probabilities as a function of the average network availability time for noisy wireless channel effect only. Fig. 4 also reveals that successfully call completion probability increases (as a function of the average network availability time) and the interruption probability decreases (as function of mean of network availability time). This may be explained as a result of having system orientation to be as good as possible, the resulting success rate will be increased more & more.

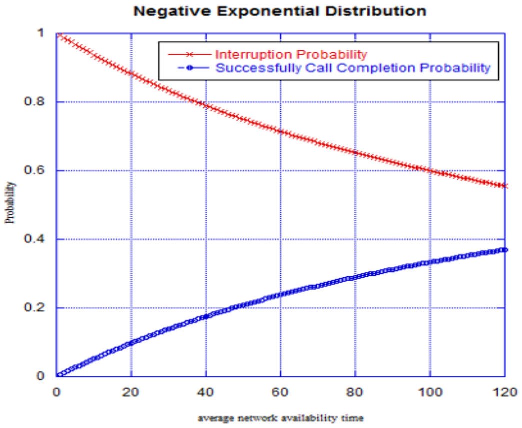

Figure 4. $\beta^{(j)}$ and $\xi^{(j)}$ versus average network availability time for noisy channel only

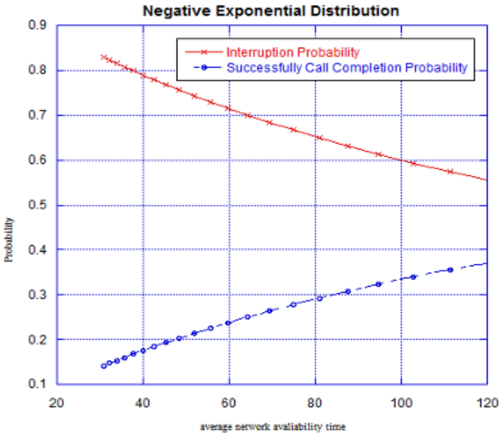

Figure 5. $\beta^{(j)}$ and $\xi^{(j)}$ Versus average network availability time for fading channel only

ii-Performance Assessment for Fading Channel Only

Figure 5 shows negative exponential distribution for interruption and successfully call completion probabilities as a function as the average network availability time for faded wireless channel effect only. Fig 5. Also reveals that successfully call completion probability is increases as a function of the mean of network availability time and the interruption probability decreases as a function of the average network availability time. Figure 5. Shows that the average network availability time in fading wireless channel is smaller than the average network availability time in noisy wireless channel according to the effect of the bad state. System tendency to stay in the bad state as a result of its suffering due to fading phenomenon.

iii-Performance Metric for Effective Noisy and Fading Channel

Figure 6 shows negative exponential distribution for interruption and successfully call completion probabilities as a function as the average network availability time for effective noise and fading wireless channel. Fig. 6 reveals that successfully call completion probability is increases as a function of the average network availability time.

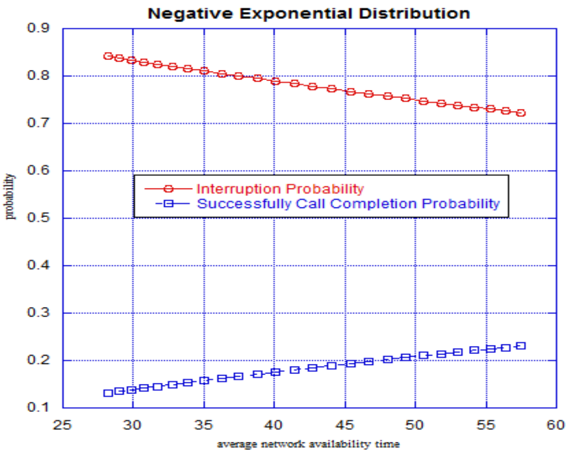

Figure 6. . $\beta^{(j)}$ and $\xi^{(j)}$ versus average network availability time for effective noise and fading channel

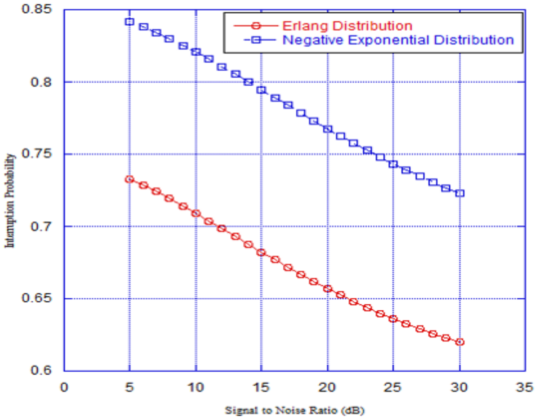

Figure 7. Negative exponential and Erlang Probabilities distributions for $\beta^{(j)}$ as a function of SNR considering the Effective Noisy and Fading Channel

In addition the interruption probability is decreased function of the average network availability time. This may be have occurred as a result of having the system stay for long time provides in the good state so, the network more available and more operable. Fig. 6 shows that the average network availability time in effective noise and fading wireless channel is smaller than the average network availability time in noisy wireless channel only or in fading channel only according to the large bad effect of the bad state.

Figure 7 also reveals that the interruption probability is a decreasing function of signal to noise ratio. When the SNR increases the interruption probability decreases. Fig. 8 shows negative exponential and erlang probabilities distributions for successfully call completion probability as a function of signal to noise ratio (SNR) considering the effective noisy and fading channel model. Fig. 8 also illustrates that the interruption probability is a decreasing function of signal to noise ratio, when the SNR is increased the interruption probability increases. Finally, the required (SNR) should be increases in order to get the same successfully call completion probability. This is due to the combination of both of noisy as well as faded channel models. This may help in the more practical oriented estimation of the required link budget calculation for such common channels.

Figure 8 shows negative exponential distribution for interruption probability as a function of signal to noise ratio (SNR) considering the Effective noisy and fading channel model.

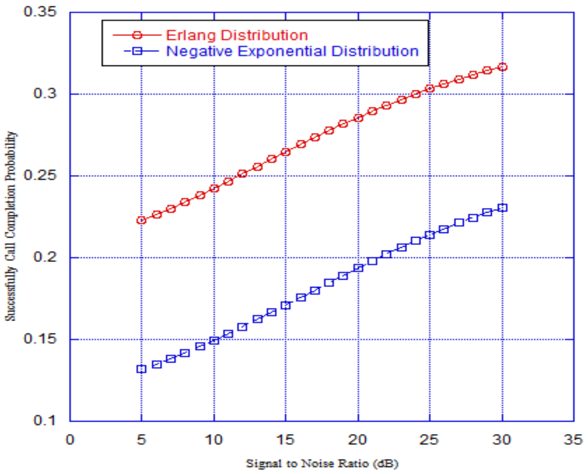

Figure 8. Negative exponential and Erlang probabilities distributions for $\xi^{(j)}$ as a function of SNR considering the effective noisy and fading channel only

VI. CONCLUSION

The current paper studies the system level performance of mobile wireless networks, the effect and characterization of “Average Network Availability Time” due to shadowing and fading channel model is used to calculate the interruption probability. This is done in conjunction with the desired signal strength and the interference that that undergoes short-term fading and shadow simultaneously. In addition, general and tractable mathematical expressions for different useful performances metrics are investigated under more realistic consideration. The paper analyzes the overall interruption probabilities in different operational scenarios; noisy as well as faded channels are investigated.

The obtained model shows that the system performance degrades as the SNR decreases. Also, different availability time distributions are investigated and the system performance is obtained.

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إمكانية دمج مستوى الوصلة بالاعتماد على خصائص و مواصفات القناة المشوشة المضمحلة

تم تقييم مستوي الأداء للنظام شبكات الاتصالات اللاسلكية المتنقلة من قبل وجهة نظر عدم كفاية الموارد رغم وجود وجهات نظر آخري مثل تأثير القناة اللاسلكية . وتخضع نظم الاتصالات اللاسلكية للخبو القصير والطويل في قناة الاتصال حيث تعاني الإشارة من تأثير قد يكون مدمرا نتيجة هذا الخبو .

وفي هذه الورقة البحثية تم تناول دراسة مستوي الأداء للنظام شبكات الاتصالات اللاسلكية المتنقلة خلال دراسة متوسط الوقت المتاح للشبكة مع وجود تأثير للتظليل والخبو للقناة وهذا الوقت هو المستخدم في حساب احتمالية انقطاع الخدمة عند تعرضها للخبو نتيجة للاضمحلال والتظليل .