Effect of Service Time Distribution on Link Maintenance And Link Failure Probabilities In Cognitive Radio Network

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Abstract- *For today's intense applications, the fifth generation (5G) of wireless communication protocols and cognitive radio (CR) are seen to provide the solution. In CRN, spectrum handoff is critical for ensuring the cognitive user's (CU) seamless and reliable service while maintaining the CR network's quality of service (QoS). This study proposes an analytical integrated model of a non-stationary CU's spectrum handoff method across different cells in a heterogeneous environment (HetSE) using a pool-based and cell-based spectrum handoff procedure. Considering K number of cells, In both opportunistic and negotiated situations, we predict the CU's connection maintenance and link failure probabilities. In an opportunistic context, the proposed model has a greater link maintenance probability than in a negotiated situation. The impact of service time distributions of the user's on performance measurement measures is also presented in this paper, and the results reveal that for a CU under HetSE of LSPs, Lognormal call holding time distribution model for CU and PU offer better link maintenance probability compared to Exponential, Erlang-m, Erlang-m,n distributions.*

Keywords- Cognitive radio; dynamic spectrum access; negotiated situation; opportunistic situation and handoff.

I. INTRODUCTION

The use of smart devices is raising day by day, the rapid development and expansion of wireless applications has resulted in high traffic (cell phones, tablet computers and so on) [1-2].Two significant channel access tools, obligation cycle quieting (DCM) and tune in before-talk (LBT), have been developed to address the issues brought on by the flood in the interest of portable information traffic and progressive range[3].Wireless-telecommunications have become increasingly significant in the current context, both in terms of economics and technological advancements, over the last decade. In wireless transmission, spectrum plays a critical function as a physical medium. Extra spectrum is necessary to meet user demands due to the exponential growth of wireless applications [1-2]. In our obviously digitalized society, the demand for more effective range usage is becoming more stated [4]. The existing fixed spectrum allocation approach, on the other hand, is unable to meet user requests. The Federal Communications Commission (FCC) advocated in 2002 [5] that the current fixed network strategy be replaced with a dynamic allocation spectrum policy to assure communication channel availability. The unused spectrum band of licenced or primary users (PUs) can be supplied to secondary or cognitive users (CU) at any time and location without interfering with PUs under this policy. Thus, in 1999, J. Mitola introduced the Cognitive Radio (CR) technological proposal to move the globe away from fixed spectrum allocation and toward dynamic spectrum allocation to employ unused radio frequencies [6]. By allowing CU to access the unused RF spectrum before PU, a CR technology improves the flexibility and efficiency of dynamically exploiting the unused RF spectrum [6].To make use of the unused frequencies, CR's dynamic spectrum allocation policy necessitates the development of a spectrum management infrastructure. The four major functions of the CR spectrum management framework are Spectrum Sensing (detects the presence/absence of PUs in a spectrum band to improve its utilization); Spectrum Decision (selects the best accessible spectrum for better communication); Spectrum Sharing (fairly shares the available spectrum bands among users); and Spectrum Mobility (is responsible for seamless switchover of unbroken communication upon interruption).By maintaining unbroken contact between CUs, spectrum mobility assures the effective execution of service in order to increase network performance [2]. When a PU decides to resume use of an existing fixed frequency band that the SU is currently using, the SU must vacate the current channel and switch to another frequency band while maintaining service quality (QoS). Spectrum handoff (SH) is a frequency band switching method that can have an impact on overall system coverage and performance [10].

The authors of [11] proposed a cell-based spectrum handoff and evaluated non-stationary CU in a CR cellular network. [12] suggested a pool-based spectrum handoff that took into account the heterogeneous spectrum environment (HetSE) of both licenced and unlicensed spectrum pools and modelled the handoff performance parameters of a CU in both opportunistic and negotiated scenarios. The authors demonstrated a pool-based HetSE spectrum handoff between two licenced spectrum pools (LSPs) and analysed the performance in terms of CU blocking, dropping, and non-completion probability. However, no literature exists on the theoretical investigation of link maintenance probability and link failure probability for two different LSPs under HetSE. In this paper we analysed the we analyzed the impact of various service time distributions on link maintenance and link failure probabilities, when non-stationary CU experiencing K number of cells in both opportunistic situation and negotiated situation.

The System Model and Analysis presented in Section II The results from the analytical model described in Section III. Section IV contains the conclusion to this work.

II. SYSTEM MODEL AND ANALYSIS

The figure shows pool based spectrum handoff process of a non-stationary user considering K number of cells. The cognitive user encounters two cells, Cell A and Cell B, in order to perform its overall service, and will be unable to transmit the service among themselves, whereas the service should be sent to the cell closest to the SU, which in this case is Cell B. The service transfer occurs between the channels in Cell B.CU begins its service in Cell A and ends it in Cell B. Intercell handoff is taking place right now. Intercell Handoff is required when the Cognitive user transfers from Cell A to Cell B in order to preserve ongoing contact. This problem can be described as follows: if the SU is moving or mobile, the channels in Cell A.

Two network situations are considered: the opportunistic situation (OS) and the negotiated situation (NS) . Because the OS lacks a network controller to manage the spectrum, each user is assigned to their own band. However, in NS, there will be a central controller with all accessible channel information as well as the PU's service time. As a result, whenever a PU enters the system, the controller will assign the PU any available channel from that spectrum pool, resulting in fewer CU interruptions than in the OS scenario. We assume that PUs follow Poisson’s arrival process to arrives in different LSP’s.

When a PU arrives on the same channel in LSP1 that a CU is already utilising, its vacating chance can be calculated as follows:

$$P_v = \frac{\sum_{i=0}^{c_1-1} \frac{1}{(c_1-1)} P_i}{1-P_{b_1}} \quad \text{....(1)}$$

When all of LSP_1's channels are occupied, the blocking probability in LSP_1 is given by,

$$P_{b_1} = \frac{\rho_1^{C_1}}{C_1!}\left[\sum_{i=0}^{C_1} \frac{\rho_1^i}{i!}\right]^{-1} \quad \text{.........(2)}$$

Where,

When all of LSP_2's channels are occupied, the blocking probability in LSP_2 is given by,

$$\rho_1 = \frac{\lambda_{PU_1}}{\mu_{PU_1}} \quad \text{.......(3)}$$

Where,

$$\rho_2 = \frac{\lambda_{PU_2}}{\mu_{PU_2}}$$

If a PU comes while a CU is using a channel, three scenarios may occur.

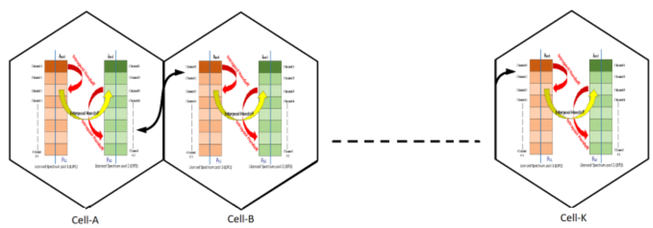

Fig 1 Pool based spectrum handoff process of a Non-Stationary User considering K-Cells

CASE 1: *Atleast one channel free in* LSP_1

If the switching delay to the available link is less than Dth, the CU link will be retained.

$$T_{sw} = \min(t_{sw,1}, t_{sw,2}, \ldots t_{sw,i}) \;;\; 1 \le i \le C_1 - 1 \quad \text{...(4)}$$

CASE 2: *All channels in* LSP_1 *are busy, atleast one channel free in* LSP_2

If all the channels are occupied by PUs in LSP_1, the CU will transfer its ongoing communication to available channel of LSP_2. The link of the CU will be maintained if the switching delay to that channel is less than D_{th}.

$$T_1 = \min(t_{sw',1}, t_{sw',2}, \ldots t_{sw',j}) \;;\; 1 \le j \le C_2 \quad \text{.....(5)}$$

CASE 3: *All channels are busy in both* LSP_1 *and* LSP_2

If all of the channels in both LSP1 and LSP2 are being used by PUs, CU will wait for a threshold period and if any of the PUs completes its service within that time, the CU service will be switched to that channel, and the link will be maintained.

$$T_2 = \min(t^r_{PU,1}+t_{sw,1}, t^r_{PU,2}+t_{sw,2}, t^r_{PU,3}+t_{sw,3}, \dots t^r_{PU,C_1-1}+t_{sw,C_1-1}, t_{PU,C_1}, t^r_{PU',1}+t_{sw,1}, t^r_{PU',2}+t_{sw,2}, \dots\dots t^r_{PU',C_2}+t_{sw,C_2}) \quad \dots(6)$$

The link maintenance probability in case of opportunistic situation with respect to arrival rate of PUs is,

$$q_{s\_opp} = p_v\Big[\big(1-p_{b1}\big)p_r\big(T_{sw} \le D_{th}\big) + p_{b1}\Big[\big(1-p_{b1}\big)p_r\big(T_1 \le D_{th}\big)\Big] + p_{b1}p_{b2}p_r\big(T_2 \le D_{th}\big)\Big]$$
$$= p_v\Big[\big(1-p_{b1}\big)\big(1-\alpha^{c1}\big) + p_{b1}\big(1-p_{b2}\big)\big(1-\beta^{c2}\big) + p_{b1}p_{b2}\Big[\Big(1-\beta_1^{c_1-1}\gamma\xi^{c_2}\Big)\Big]\Big] \quad \dots(7)$$

Where,

$$\alpha = p_r\big(T_{sw} > D_{th}\big) = 1 - F_{t_{sw}}\big(D_{th}\big)$$
$$\beta = p_r(T_{sw'} > D_{th}) = 1 - F_{t_{sw'}}(D_{th})$$
$$\beta_1 = P_r\big(T^r_{PU} > D_{th}\big) = 1 - F_{t^r_{PU}}\big(D_{th}\big)$$
$$\xi = P_r\big((t^r_{pu'} + t_{sw'}) > D_{th}\big) = 1 - F_{pu'+t_{sw'}}\big(D_{th}\big)$$
$$\gamma = P_r\big(t_{pu} > D_{th}\big) = 1 - F_{tpu}\big(D_{th}\big) \quad \dots(8)$$

If all of the channels in the system are occupied by PUs, the CU's link will fail if no channel becomes available within Dth. The probability of a link failure can be calculated as,

$$q_{f\_opp\_intra} = P_vP_{b_1}P_{b_2}P_r(T_2 > D_{th}) = P_VP_{b_1}P_{b_2}\beta_1^{C_1-1}\gamma\xi^{C_2} \quad \dots(9)$$

In case of negotiated situation, the link maintenance and link failure probability can be modelled as

$$q_{s\_neg\_intra} = p_v\Big[\Big[\big(1-p_{b2}\big)\big(1-\beta^{c_2}\big)\Big] + p_{b2}\Big[\big(1-\beta_1^{c_1-1}\gamma\xi^{c_2}\big)\Big]\Big] \quad \dots\dots(10)$$
$$q_{f\_neg\_intra} = p_vp_{b2}\beta_1^{c_1-1}\gamma\xi^{c_2} \quad \dots\dots(11)$$

Non-Stationary user is still in Cell A:

The cognitive user may suffer spectrum handoff prior to crossing Cell A due to the arrival of Primary users. If any channel in the same spectrum pool is accessible, a CU's service is interrupted by higher priority PUs, and intrapool spectrum handoff is performed. Otherwise, it will use Cell A's interpool spectrum handoff. When all of the channels in Cell A are busy, it will wait up to D_{th} time for an available channel. The link will be maintained if any channel is available within D_{th} time, otherwise it will fail. In this situation, the Cognitive User T_{CU} should have a shorter service time than the cell residence time T_s . Link Maintenance probability of a Non-Stationary CU in case of opportunistic situation can be calculated by

$$\begin{aligned} q_{s\_opp} &= P_r(T_{CU} < T_s) * P_v[(1-P_{b_1})P_r(T_{sw} \le D_{th}) + P_{b_1}[(1-P_{b_1})P_r(T_1 \le D_{th})] + p_{b_1}p_{b_2}p_r(T_2 \le D_{th})] \\ &= f^*_{CU}(\mu_s) * P_v[(1-P_{b_1})P_r(T_{sw} \le D_{th}) + P_{b_1}[(1-P_{b_1})P_r(T_1 \le D_{th})] + p_{b_1}p_{b_2}p_r(T_2 \le D_{th})] \\ &= f^*_{CU}(\mu_s) * P_v\Big[\big(1-P_{b_1}\big)(1-\alpha^{C_1}) + P_{b_1}\big(1-P_{b_2}\big)(1-\beta^{C_2}) + P_{b_1}P_{b_2}\Big[\big(1-\beta_1^{C_1-1}\gamma\xi^{C_2}\big)\Big]\Big] \quad \dots(10)\end{aligned}$$

Where,

$$P_r(T_{CU} < T_s) = f^*_{CU}(\mu_s) \quad \dots\dots(12)$$

When the cell residence time T_S follows exponential distribution with parameter , the term

$$f^*_{CU}(\mu_s) = \mu_s \big/ (\mu_s + \mu_{CU}) \quad \dots\dots(13)$$

If the PUs in cell A occupy all the channels, the CU's link will fail if no channel becomes available within Dth. As a result, the Link Failure Probability can be calculated as follows:

$$\begin{aligned} q_{f\_opp} &= P_r(T_{CU} < T_s) * P_vP_{b_1}P_{b_2}P_r(T_2 > D_{th}) \\ &= f^*_{CU}(\mu_s)P_vP_{b_1}P_{b_2}P_r(T_2 > D_{th}) \\ q_{f\_opp} &= P_r(T_{CU} < T_s) * P_vP_{b_1}P_{b_2}P_r(T_2 > D_{th}) \\ &= f^*_{CU}(\mu_s)P_vP_{b_1}P_{b_2}P_r(T_2 > D_{th}) \\ &= f^*_{CU}(\mu_s)P_VP_{b_1}P_{b_2}\beta_1^{C_1-1}\gamma\xi^{C_2} \quad \dots\dots(14)\end{aligned}$$

In a Negotiated Situation the link maintenance and failure probability can be described as follows :

$$\begin{aligned} q_{s_{neg}} &= P_r(T_{Cu} < T_s) * P_v[[(1-P_{b_2})(1-\beta^{c_2})] + P_{b_2}[(1-\beta_1^{c_1-1}\gamma\xi^{c_2})]] \\ &= f^*_{CU}(\mu_s) * P_v[[(1-P_{b_2})(1-\beta^{c_2})] + P_{b_2}[(1-\beta_1^{c_1-1}\gamma\xi^{c_2})]] \quad \dots\dots(15) \\ q_{f\_neg} &= P_r(T_{CU} < T_s) * P_vP_{b_2}\beta_1^{c_1-1}\gamma\xi^{c_2} \\ &= f^*_{CU}(\mu_s) * P_vP_{b_2}\beta_1^{c_1-1}\gamma\xi^{c_2} \quad \dots..(16)\end{aligned}$$

Non-Stationary user is in Cell B:

After crossing from cell A to cell B, since the user is moving Intercell handoff will occur. Post intercell handoff, Cognitive user may experience pool based spectrum handoff due to the arrival of primary user in cell B. In an opportunistic situation, the link maintenance probability is given by,

$$q_{s_{opp}} = \big(1-P_r\big(T_{CU}<T_s\big)\big)*P_v\Big[\big(1-P_{b_1}\big)P_r\big(T_{sw} \le D_{th}\big) + P_{b_1}\Big[\big(1-P_{b_1}\big)P_r\big(T_1 \le D_{th}\big)\Big] + p_{b_1}p_{b_2}p_r\big(T_2 \le D_{th}\big)\Big]$$
$$= \big(1-f^*_{CU}(\mu_s)\big)*P_v\Big[\big(1-P_{b_1}\big)P_r\big(T_{sw} \le D_{th}\big) + P_{b_1}\Big[\big(1-P_{b_1}\big)P_r\big(T_1 \le D_{th}\big)\Big] + p_{b_1}p_{b_2}p_r\big(T_2 \le D_{th}\big)\Big]$$
$$= (1-f^*_{CU}(\mu_s))*P_v[(1-P_{b_1})(1-\alpha^{C_1}) + P_{b_1}(1-P_{b_2})(1-\beta^{C_2}) + P_{b_1}P_{b_2}[(1-\beta_1^{C_1-1}\gamma\xi^{C_2})]] \quad \dots..(17)$$

Link failure probability in case of opportunistic is given by,

$$q_{f\_opp} = (1 - P_r(T_{CU} < T_s)) * P_v P_{b_1} P_{b_2} P_r((T_2 > D_{th}) \\ = (1 - f^*_{CU}(\mu_s)) * P_v P_{b_1} P_{b_2} P_r(T_2 > D_{th}) \\ = (1 - f^*_{CU}(\mu_s)) * P_V P_{b_1} P_{b_2} \beta_1^{C_1 - 1} \gamma \xi^{C_2} \quad ....(18)$$

If any of the channels is vacant in cell B, then the link of the CU will be maintained. Therefore, the Link Maintenance probability in negotiated situation can be modeled as,

$$q_{s_{neg}} = \left(1 - P_r\left(T_{CU} < T_s\right)\right) * P_v \left[\left[\left(1 - P_{b_2}\right)\left(1 - \beta^{c_2}\right)\right] + P_{b_2}\left[\left(1 - \beta_1^{c_1 - 1} \gamma \xi^{c_2}\right)\right]\right] \\ = \left(1 - f^*_{CU}(\mu_s)\right) * P_v \left[\left[\left(1 - P_{b_2}\right)\left(1 - \beta^{c_2}\right)\right] + P_{b_2}\left[\left(1 - \beta_1^{c_1 - 1} \gamma \xi^{c_2}\right)\right]\right] \quad ..(19)$$

In case of negotiated situation, the link failure probability can be described as

$$q_{f\_neg} = (1 - P_r(T_{CU} < T_s)) * P_v P_{b_2} \beta_1^{c_1 - 1} \gamma \xi^{c_2} \\ = (1 - f^*_{CU}(\mu_s)) * P_v P_{b_2} \beta_1^{c_1 - 1} \gamma \xi^{c_2} \quad ....(20)$$

III. RESULTS AND ILLUSTRATIONS

This section shows the results of non stationary CU connection maintenance and link failure probabilities in different cells (here, three cells) for various distributions in both Opportunistic and Negotiated situations. Here, we consider the following specifications for the measuring of analysis.

The below results represents the

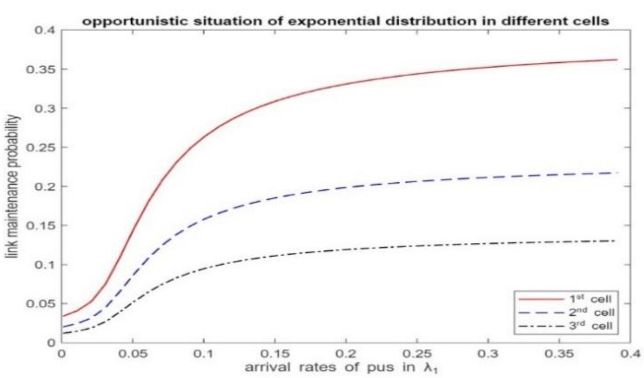

Fig 2 Link Maintenance Probability in OS for exponential service time distribution in different cells

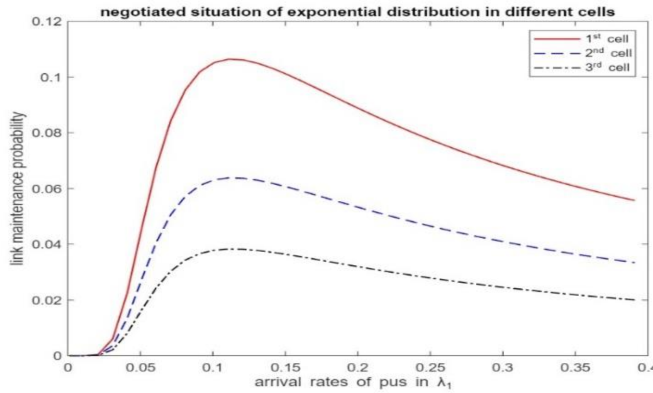

Fig 3 Link Maintenance Probability in NS for exponential service time distribution in different cells

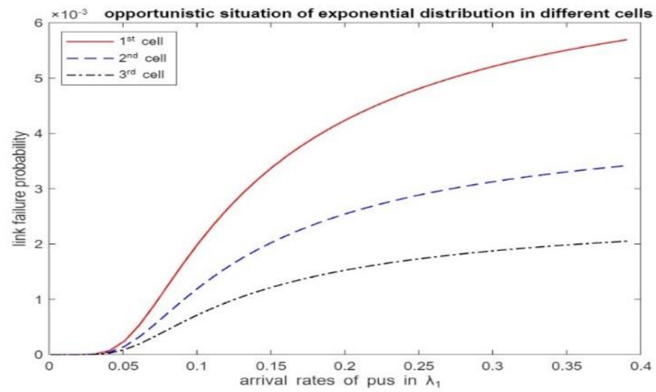

Fig 4 Link failure Probability in OS for exponential Service time distribution in different cells

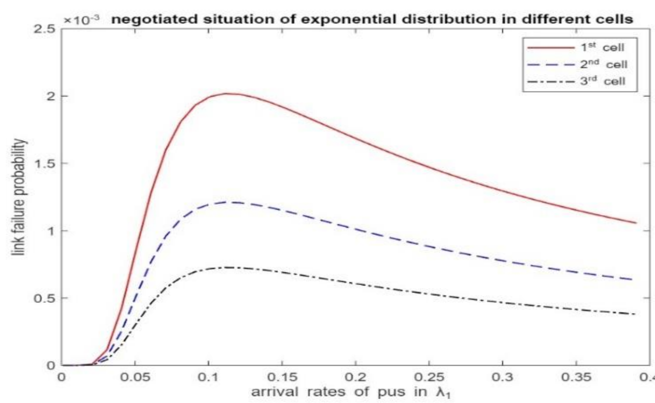

Fig 5 Link failure Probability in NS for exponential Service time distribution in different cells

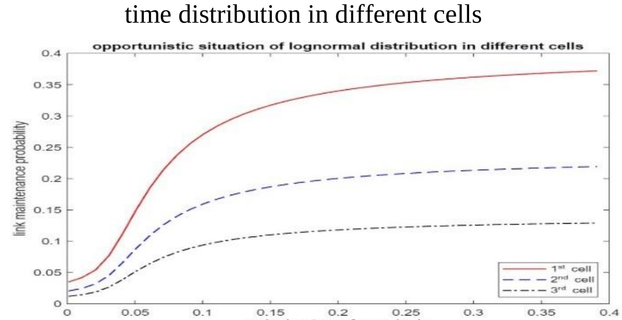

Fig 6 Link Maintenance Probability in OS for Lognormal distribution in different cells

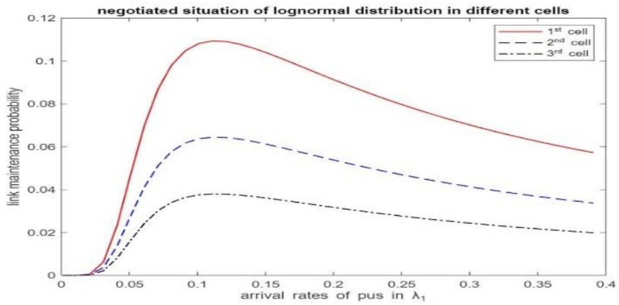

Fig 7 Link maintenance Probability in NS for Lognormaldistribution in different cells

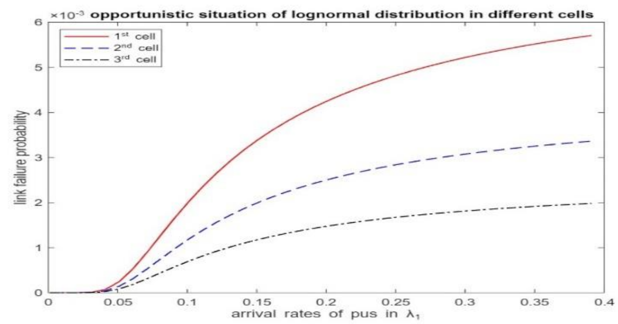

Fig 8 Link Failure Probability in OS for Lognormal distribution in different cells

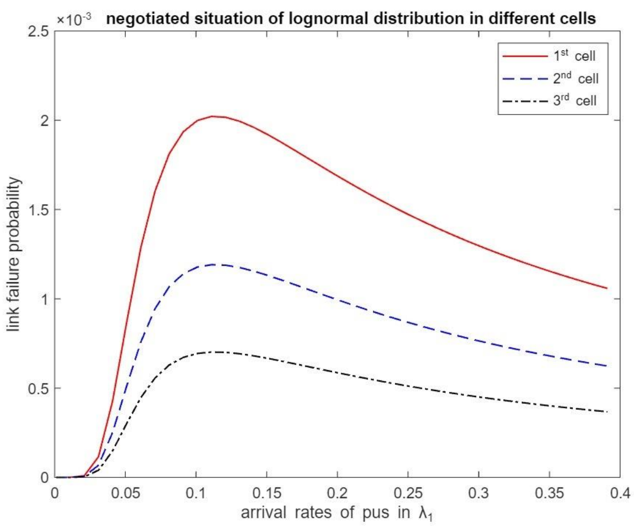

Fig 9 Link Failure Probability in NS for Lognormal distribution in different cells

From the above results, It is observed that the link maintenance probability is higher in first cell as compared to second and third cell i.e. as the mobility increases, the channel vacating probability will be higher which leads to higher link maintenance and link failure probabilities.

IV. CONCLUSION

In this paper, we created an integrated model of a non-stationary CU's cell-based and pool-based spectrum handoff, as well as the link maintenance and link failure probability using an allowable handoff threshold (Dth). When non-stationary CU encounters K no. of cells in both opportunistic and negotiated situations, we analyzed the impact of various service time distributions on link maintenance and link failure probabilities. The results show that the lognormal call holding time distribution model for CU and PU offers better link maintenance probability than the exponential model. The results of this analysis show a considerable difference between the Opportunistic and Negotiated Situations. Further results shows that as mobility of the non-stationary CU increases, link maintenance probability decreases. The work progress will be helpful in the designing and optimizing the CRN under different network architecture and can be used in 5G technology to design a network which can access different frequency bands.

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