11 (2) 2025 123-130
Register: *Jurnal Ilmiah Teknologi Sistem Informasi*
ISSN 2502-3357 (online) | ISSN 2503-0477 (print)

Contents lists available at www.journal.unipdu.ac.id

Register

Journal Page is available to www.journal.unipdu.ac.id/index.php/register

Research article

Analytical Estimation of Jitter for the MMPP-N Traffic Model

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ARTICLE INFO

Article history:
Received June 7th, 2025
Revised October 25th, 2025
Accepted December 31st, 2025
Available online January 29th, 2026

Keywords:
QoS;
Jitter;
MMPP-N;
Traffic Modeling;
Network Performance;

Please cite this article in IEEE style as:
H. Magri, M. Rachdi, and M. Azzouazi, "Analytical Estimation of Jitter for the MMPP-N Traffic Model," *Register: Jurnal Ilmiah Teknologi Sistem Informasi*, vol. 11, no. 2, pp. 123-130, 2025.

ABSTRACT

Nowadays, consumers demand powerful and adequate communication techniques to meet their desires for communication and exchange. These techniques, such online chats, VoIP, video conferencing, and AR/VR services, require well-defined Quality of Service (QoS) properties, such as minimal transmission delay, high throughput, low inter-arrival time, and low packet delay variation. Among these, jitter is an important QoS parameter in IP networks that can affect the performance of real-time applications and services. In this paper, we provide an overview of jitter and relevant studies. We propose an analytical calculation of jitter for the MMPP-2 and MMPP-N traffic models and analyze the jitter behavior for voice traffic.

1. Introduction

Quality of service (QoS) has become a current and future development focus. The new types of services and applications supported by the 5G system and beyond, such as live video streaming, autonomous driving, , VoIP calls, online gaming, and the massive number of IoT connections, define a set of QoS properties and requirements. These expectations and requirements will continue to grow and evolve with the variation of 6G services and demand. These QoS guarantees can be described using different parameters and values, such as end-to-end delay, jitter, bandwidth, and packet loss rate.

In this way, multimedia and real-time services are extremely sensitive to jitter, and high jitter can affect their performance and quality. For example, for voice and video, voice packets should not be significantly delayed or affected by jitter, and the recommended jitter value must be under 30 ms. Thus, optimizing multimedia and real-time services requires complete visibility of the jitter behavior. To meet these strict quality of service requirements for these services, the traffic models used for performance evaluation must be accurate and simulate the statistical characteristics of real traffic.

For many years, several efforts have been made to model traffic sources for different networks [2-4]. Initially, to analyze traffic in traditional telephony networks, the widely used traffic model was the Poisson model. In this model, arrivals form a Poisson process, and inter-arrival times are exponentially distributed with a rate parameter λ. However, for voice, video, and real-time applications, inter-arrivals consist of a succession of active and inactive periods known as the ON/OFF model, which is the most appropriate model for simulating voice, video, and VoIP [3]. Moreover, to study traffic engineering issues in wireless communications [4], another model called the Interrupted Poisson Process (IPP), derived from the ON/OFF model, was designed.

ISSN 2502-3357 (online) | ISSN 2503-0477 (print)
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For the IPP model, packet inter-arrival times follow an exponential distribution during the ON period, while no packets arrive during the OFF state. The advantage of using the IPP model for voice traffic is that the aggregation of multiple independent voice sources can be modelled as an MMPP-N process (i.e., a Markov Modulated Poisson Process with N homogeneous IPP-type sources), since the IPP is a special case of MMPP-N and the superposition of multiple IPP sources naturally forms an MMPP process. This paper is organized as follows: First, we provide an overview of jitter and relevant studies on the topic. Next, we examine the characteristics of the IPP and MMPP-N models. We then present the analytical formula for jitter in the IPP model and propose an analytical calculation for jitter in MMPP-N models. Furthermore, we analyze the behavior of jitter as a function of the arrival rate and the average durations of the active (ON) and inactive (OFF) periods. Finally, we conclude our findings in the final section.

2. Materials and Methods

2.1. A Review of Related Works on Jitter and its Impact on Network Performance

For voice, video, and multimedia traffic, packets are transmitted in a continuous stream, with each packet evenly spaced apart from the others. In this way, jitter is defined as a variation in delay at the reception of packets [29-30]. This parameter, which is very sensitive for real-time flows such as video, audio, and VoIP streams, mainly depends on several factors, such as the volume of traffic on the network and the number of devices. Consequently, network congestion, incorrect queue management, or configuration errors can influence it.

Indeed, the continuous stream can become irregular, or the delay between each packet can vary instead of remaining constant. The instability of this metric for multimedia and real-time services implies a discontinuity in data restitution at the destination. For example, delay variation in a video transmission could cause deterioration of video or image quality with repeated playback. To mitigate these effects and meet jitter requirements, several studies [5], [7]-[11] have focused on estimating and evaluating jitter. The key research studies on the analytical calculation and behavior of jitter are summarized in Table 1. This table provides an overview of significant research works on the analytical calculation and behavior of jitter across various network scenarios. Table 1 highlights contributions related to jitter modeling, delay variation analysis, and Quality of Service (QoS) across various network types, including IP, LTE, IMS, and others. The studies cover diverse traffic conditions and types, such as voice, video, and real-time application traffic, and they offer analytical models, simulation results, and practical insights for optimizing jitter performance for these types of traffic.

Table 1. An Overview of Related Works on Jitter and Its Behavior (1)

Survey	Authors	Contribution
[1] A Simple Formula for End-to-End Jitter Estimation in Packet-Switching Networks	Olivier Brun, Charles Bockstal, Jean-Marie Garcia	This paper presents an analytical approximation for the evaluation of end-to-end jitter incurred by a periodic packet stream with a constant packet size. The proposed method has been validated through comparisons with event-driven simulations, which demonstrate its precision.
[5] Analytic approximation of the jitter incurred by CBR traffics in IP networks	Olivier Brun, Charles Bockstal, Jean-Marie Garcia	The paper presents an analytical approximation of end-to-end jitter for periodic traffic with a constant packet size. It first examines the single-node case. A simple analytical approximation is obtained and validated through event-driven simulations.Then, the approximation is extended to the multi-node case. The results show that the approximation remains accurate under IP network conditions.
[7] An analytical model for jitter in IP networks	H. Dahmouni, A. Girard, B. Sanso	The paper presents an analytical approximation of end-to-end jitter for Poisson traffic. The authors give a simple formulas for the jitter through a single queue. It shows that jitter decreases as packets move along a path. The study's results include : Jitter can decrease when the network load increases and The location of congestion significantly affects path jitter.
[8] An interarrival jitter model using multi-structure network delay characteristics for packet networks	Edward J. Daniel, Christopher M. White, Keith A. Teague	This paper explores the modeling and simulation of network jitter in real-time multimedia communication applications. A simulation model for jitter is developed and validated using collected packet delay variation statistics
[9]Characteristics of Network Delay and Delay Jitter and its Effect on Voice over IP (VoIP)	L.Zheng, L.Zhang, D. Xu	The paper studies the performance behavior of delay and delay jitter at the IP packet level by using a transient queuing solution. The authors examine how various traffic parameters impact the jitter behavior of packet voice streams. Numerical results are presented to illustrate the effects of delay and jitter on periodic voice stream

http://doi.org/10.26594/register.v11i2.5679

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Table 1. An Overview of Related Works on Jitter and Its Behavior (2)

Survey	Authors	Contribution
[9]Characteristics of Network Delay and Delay Jitter and its Effect on Voice over IP (VoIP)	L.Zheng, L.Zhang, D. Xu	The paper studies the performance behavior of delay and delay jitter at the IP packet level by using a transient queuing solution. The authors examine how various traffic parameters impact the jitter behavior of packet voice streams. Numerical results are presented to illustrate the effects of delay and jitter on periodic voice stream
[10]Network Calculus Approach for Packet Delay Variation Analysis of Multi-Hop Wired Networks	Gore, Rahul Nandkumar, Elena Lisova, Johan Åkerberg, and Mats Björkman	This paper highlights the importance of ensuring network QoS for real-time services, particularly in industrial domains. It highlights the importance of maintaining acceptable end-to-end delay and low jitter (Packet Delay Variation, PDV) to ensure real-time performance in critical applications
[11]Jitter in IP Networks: A Cauchy Approach	L. RizoDominguez, D. Torres-Roman, D. Munoz Rodriguez, C. Vargas-Rosales	The paper introduces an IP network alpha-stable jitter model that presents a better fit compared to the exponential formulation. The model presented in this paper provides an approximation of jitter as a function of the number of nodes in the path, the stability index, and jitter dispersion.
[12] IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)	C. Demichelis, P. Chimento	This document describes a metric for measuring packet delay variation (jitter) across Internet paths. It is based on the difference in the One-Way Delay (OWD) of selected packets, referred to as IP Packet Delay Variation (IPDV)
[17] Analytical Models for jitter and QoS requirements with IPP and MMPP-2 Traffics	H. Magri, N. Abghour, M. Ouzzif	This paper proposes analytical formulas for the jitter of Interrupted Poisson Process (IPP) and MMPP-2 traffic. The paper presents an approximation for the jitter of Interrupted Poisson Process (IPP) and MMPP-2 traffic using a novel equivalent model (EPP)
[18] Impact of jitter and jitter buffer on the final quality of the transferred voice	O. Slavata, J. Holub, P. Hübner	This paper investigates the effects of jitter and jitter buffer on voice transmission quality in IP networks. It compares results obtained using the testing standard POLQA (Perceptual Objective Listening Quality Analysis) with those from older algorithms. The paper identifies the relation between the ratio of jitter/jitter buffer and MOS values delivered by different objective algorithms.
[19] Network Jitter Analysis with varying TCP for Internet Communications	S.Thombre	The paper explores the impact of TCP and UDP traffic on network jitter. The work provides an analytical model for network jitter under varying TCP/UDP traffic.
[20] Quality of service in networks with self-similar traffic	G. A. Hirchoren, N. Porrez, B. L. Sala, I. Buraczewski	The paper provides a comparative analysis of various QoS policies Priority Queuing (PQ), Custom Queuing (CQ), Weighted Fair Queuing (WFQ), Class-Based Weighted Fair Queuing (CBWFQ), and Low-Latency Queuing (LLQ). In this paper, QoS for video traffic is measured with average jitter and RTP packet loss percentage, while QoS for FTP traffic is measured with average throughput.
[21] An analytical jitter model in IMS network	B. A. Alassane and K. Karim	The paper presents an analytical model for approximating end-to-end jitter in IMS network. The results provided by the model can be utilized to determine various parameters for traffic dimensioning.
[22] Novel approach to analytical jitter modeling	A. Huremovic, M. Hadzialic	This paper presents an analytical jitter model using the Interrupted Poisson Process (IPP) to model incoming traffic. The study derives a single-node jitter model considering factors such as phase probabilities, traffic load, and the share of tagged traffic in the overall traffic flow. The authors extend the analysis to multi-node (N-node) scenarios, proposing a model for end-to-end jitter and offering efficient approximations that are useful for future network design and admission control. The proposed model is validated through comparison with different case scenarios and event-driven simulations, and the results are presented as practical guidelines for jitter evaluation in real IP networks.
[23] QOS parameter comparison of DiffServ-aware MPLS network using IPv4 and IPv6	A. Mushtaq, M. S. Patterh	This paper explores the use of Traffic Engineering (TE) over Multiprotocol Label Switching (MPLS) combined with DiffServ to improve Quality of Service (QoS) in IP networks. This paper investigates the impact of IPv6 on jitter in IP networks using Traffic Engineering (TE) over Multiprotocol Label Switching (MPLS) and DiffServ mechanisms. Simulations conducted using OPNET evaluate the QoS parameters: delay, jitter, packet loss, and throughput, across various real-time applications. Through simulations using OPNET, it was observed that IPv6 significantly reduces jitter across multiple real-time applications compared to IPv4.
[24] Simulation and Analysis of Quality of Service (QoS) of Voice over IP (VoIP) through Local Area Networks	F. Yihunie, E. Abdelfattah	This paper presents the design and simulation of a Local Area Network (LAN) to evaluate the impact of Quality of Service (QoS) on network performance. Performance parameters include voice jitter, voice Mean Opinion Score (MOS) value, voice packet end-to-end delay, voice packet delay variation, and voice traffic sent and received. The results demonstrate that QoS implementation guarantees rapid responses and significantly optimizes network resource usage.
[25] Evaluation of the voice quality and QoS in real calls using different voice over IP codecs	M. O. Ortega, G. C. Altamirano, M. F. Abad	This research evaluates voice quality and QoS in VoIP networks based on user perception (via MOS) and QoS parameters (latency, jitter, and packet loss). The results indicate that the iLBC-13.33 codec provides the best overall voice quality and QoS for the tested conditions.
[26] Delay and jitter analysis in LTE networks	N. Mesbahi, H. Dahmouni	This paper explores the impact of increasing network load on end-to-end (e2e) delay and jitter in LTE networks. The study emphasizes that QoS performance is highly influenced by network configuration and geographical size. The findings conclude that ensuring effective QoS at each network element is essential for achieving reliable e2e QoS in LTE-EPC networks.

http://doi.org/10.26594/register.v11i2.5679

ISSN 2502-3357 (online) | ISSN 2503-0477 (print)
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2.2. Jitter Model and Formula

Jitter refers to the variation in the delay of received packets. In an ideal scenario, all packets should experience the same delay. For example, for packets 1 and 2 in Fig. 1, jitter is calculated as the difference in delay between packet 2 and packet 1: (T6–T5) − (T2–T1)

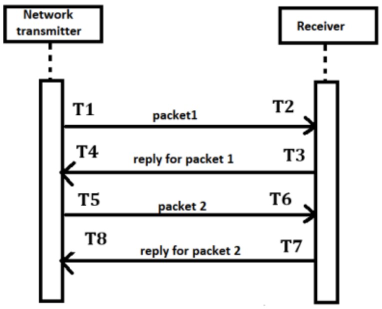


Fig. 1. An illustration of jitter

To find an accurate formula for jitter, it is important to consider various factors affecting transmission delays, such as network congestion, types of traffic, and route changes. In this context, the authors of Articles [1], [5], [7], and [12] have proposed analytical formulas for jitter. Article [1] presents a formula to evaluate the end-to-end jitter experienced by periodic traffic with a constant packet size. Similarly, Article [5] introduces a simple and accurate analytical approximation of jitter for CBR (Constant Bit Rate) traffic. In [7], the authors present the analytical formula for end-to-end jitter for Poisson traffic. The result of these works is the definition of jitter as the variation in delay, represented by the following formula [12]:

$$J = E\left(\left| T_{i+1} - T_i \right|\right) \quad (1)$$

Where Ti and Ti+1 represents the delay experienced by the j^{th} and $(j+1)^{th}$ packet going through a queue.

2.3. IPP Traffic Model

In this paper, we adopt voice modeling using the IPP process, which differs from the ON/OFF model in that, during the active period, the inter-arrival time of packets follows an exponential distribution. The IPP model is therefore characterized by the following parameters. The arrival rate in the ON state is λipp, and in the OFF state, there is no traffic; in other words, the arrival rate is zero. The transition rate from the ON state to the OFF state is r_{on}, and from the OFF state to the ON state is r_{off}.

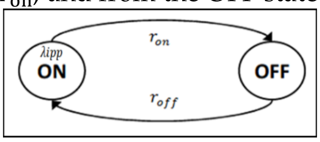
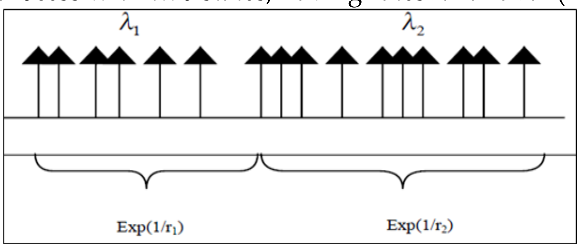


Fig. 2. IPP MODEL

2.4. MMPP-N Traffic Model

An MMPP-N (Markov Modulated Poisson) process, i.e., a Poisson process modulated by an *N*-state Markov process, is a doubly stochastic Poisson process in which arrivals occur according to a Poisson process whose rate varies according to an *N*-state Markov chain that is independent of the arrival process [2]. This model is commonly used for analyzing voice and video traffic and is generally applied to represent aggregate voice and video source traffic [27][28][31]. In this paper, the MMPP-N process is employed to model the superposition of *N* constant, homogeneous, and identical IPP sources. Although the two-state MMPP is most commonly used due to its simplicity (Fig.2), it has also been employed to model multiplexed multimedia traffic in ATM switching networks with multiple MMPP sources. In this way, the superposition of two-state MMPP sources results in an MMPP with a higher number of states. We consider the MMPP-2 process with two states, having rates $\lambda 1$ and $\lambda 2$ (Fig.3).



http://doi.org/10.26594/register.v11i2.5679

ISSN 2502-3357 (online) | ISSN 2503-0477 (print)
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Fig. 3. MMPP-2 Traffic model

If $\lambda 1 = \lambda 2 = \lambda$, the MMPP-2 process becomes a Poisson process with rate λ. Moreover, if $\lambda 1 = 0$, the MMPP-2 process reduces to an IPP process.

3. Results And Discussion

3.1. Analytical Calculation of Jitter for MMPP-2

Consider two consecutive packets of traffic passing through a queue following the FCFS discipline, with a source S that is a Poisson source. The generation rate of the source changes depending on whether it is in state 1 ($\lambda 1$) or state 2 ($\lambda 2$) (i.e., an MMPP-2 traffic source), and the queue has an average service rate of μ. Let Tj be the sojourn time of packet j in the queuej. We consider that the sojourn times of packets j and j+1 are two independent random variables, Tj and Tj+1. We assume $\eta_1 = \mu - \lambda_1$ and $\eta_2 = \mu - \lambda_2$. According to Article [2], the probability density function of the sojourn time distribution for the MMPP-2 model is described as follows:

$$f_{Ti}(t) = C_1 R_1 e^{-R_1 t} + C_2 R_2 e^{-R_2 t} \quad (2)$$

With:

$$R_1 = \frac{1}{2}\left\{\eta_1 + \eta_2 + r_1 + r_2 + \sqrt{(\eta_1 - \eta_2 + r_1 - r_2)^2 + 4 r_1 r_2}\right\} \quad (3)$$

$$R_2 = \frac{1}{2}\left\{\eta_1 + \eta_2 + r_1 + r_2 - \sqrt{(\eta_1 - \eta_2 + r_1 - r_2)^2 + 4 r_1 r_2}\right\} \quad (4)$$

$$C_1 = \frac{{\lambda_2}^2 r_1 + {\eta_1}^2 r_2}{(\lambda_2 r_1 + \eta_1 r_2)(R_1 - R_2)} - \frac{R_2}{R_1 - R_2} \quad ,C_2 = 1 - C_1$$

We can therefore derive the average sojourn time, defined as:

$$E(Tint) = \frac{C_1}{R_1} + \frac{C_2}{R_2} = \frac{\eta_2 {r_1}^2 + \eta_1 {r_2}^2 + \eta_1\eta_2(r_1 + r_2) + r_1 r_2(\eta_1 + \eta_2)}{(\eta_2 r_1 + \eta_1 r_2)(\eta_1 \eta_2 + \eta_2 r_1 + \eta_1 r_2)}$$

With $\tau = E(Tint)$ and $\Delta = Ti{+}1 - Ti$

We consider the proposition cited in [1] and [7], which considers that packet i+1 enters the queue after packet i has already departed. This assumption can be expressed as follows:

$$P(Ti > \tau) = \int_{\tau}^{+\infty} f_{T_i}(u)\, du \approx 0 \quad (5)$$

Using equations Eq.1 and Eq.5, we obtain the following formula :

$$J = \int_{-\tau_k}^{0} -u f_{\Delta}(u)|_{-\tau_k<u<0} du + \int_{0}^{\infty} u f_{\Delta}(u)|_{u>0} du \quad (6)$$

Thus, after calculation, we obtain the analytical formula for jitter for the MMPP-2 model [17]:

$$J = \frac{{C_1}^2}{R_1} + \frac{{C_2}^2}{R_2} + 2\frac{C_1 C_2({R_1}^2 + {R_2}^2)}{R_1 R_2(R_1+R_2)} - \frac{{C_1}^2 e^{-2\tau R_1}}{R_1} - \frac{{C_2}^2 e^{-2\tau R_2}}{R_2} - 2e^{-\tau(R_1+R_2)}\frac{C_1 C_2({R_1}^2+{R_2}^2)}{R_1 R_2(R_1+R_2)} - {C_1}^2 \tau e^{-\tau R_1} - {C_2}^2 \tau e^{-\tau R_2} - \frac{C_1 C_2({R_1}^2 + R_1 {R_2}^2 \tau + R_2 {R_1}^2 \tau + {R_2}^2)}{R_1 R_2(R_1+R_2)} e^{-\tau R_2} - \frac{C_1 C_2({R_1}^2 + R_1 {R_2}^2 \tau + R_2 {R_1}^2 \tau + {R_2}^2)}{R_1 R_2(R_1+R_2)} e^{-\tau R_1} \quad (7)$$

For $\lambda_1 = \lambda_2 = \lambda$, The MMPP-2 process reduces to a Poisson process with a rate λ , therefore $\eta_1 = \eta_2 = \eta$

We will then have:

$R_1 = \eta + r_1 + r_2, R_2 = \eta$, $C_1 = 0$ and $C_2 = 1$.

Using these values and our jitter formula derived for the MMPP-2 model, we obtain the jitter formula for the Poisson model as follows:

$$J = \frac{1}{\eta} + - \frac{e^{-2\tau\eta}}{\eta} - \tau e^{-\tau\eta} \quad (8)$$

which matches the formula found in [7], thereby confirming the validity of our analytical jitter formula for the MMPP-2 model. If $\lambda_2 = 0$, the MMPP-2 process reduces to an IPP process with:

$$R_1 = \frac{1}{2}\left\{\eta_{ipp} + r_{on} + r_{off} + \sqrt{(\eta_{ipp} + r_{on} + r_{off})^2 - 4\eta_{ipp} r_{off}}\right\} \quad (9)$$

$$R_2 = \frac{1}{2}\left\{\eta_{ipp} + r_{on} + r_{off} - \sqrt{(\eta_{ipp} + r_{on} + r_{off})^2 - 4\eta_{ipp} r_{off}}\right\} \quad (10)$$

$$C_1 = \frac{\eta_{ipp} - R_2}{R_1 - R_2} \quad , \quad C_2 = 1 - C_1 \text{ and } \eta_{ipp} = \mu - \lambda ipp$$

3.2. Analysis of Jitter Behavior for Voice Traffic

Studies on audio traffic in packet-switched networks have provided values for the parameters r_{on}, r_{off} [15]. These values greatly depend on the sensitivity of codecs (encoders/decoders) to silence detection and on the validity of the Markovian approximation of the ON and OFF periods. Let t1 and t2 be the

ISSN 2502-3357 (online) | ISSN 2503-0477 (print)
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average durations of the active (ON) and inactive (OFF) periods, respectively. We then have $t_1 = \frac{1}{r_{on}}$ *and* $t_2 = \frac{1}{r_{off}}$.
According to the Article [18], the classical voice model uses codecs G711, G726, and G729 to encode the voice with the following values: $t_1 = \frac{1}{r_{on}}$=352ms et $t_1 = \frac{1}{r_{off}}$=650 ms.

Using our analytical formula for jitter in IPP traffic and the average durations of the active (ON) t_1 and inactive (OFF) periods t2 , we present Figure Fig. 4, which illustrates the variation of jitter for the IPP model as a function of the arrival rate λipp. The results show that jitter decreases as the arrival rate λipp increases. This behavior confirms that jitter is a decreasing function of the arrival rate, as observed in Article [7].

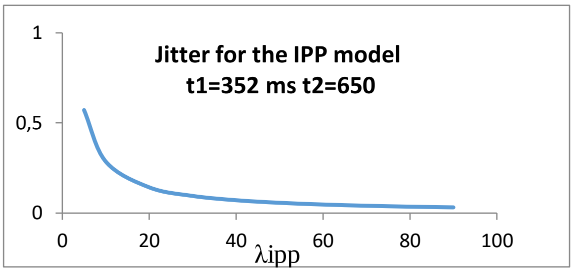

Fig. 4. Jitter variation as a function of λipp

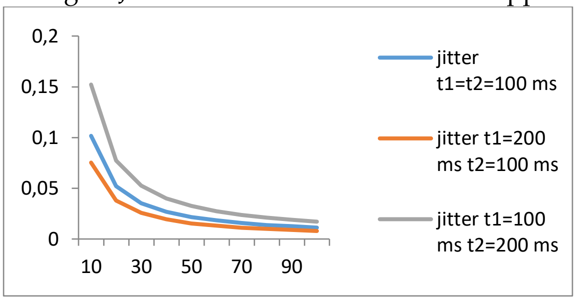

Fig. 5. Jitter variation as a function of durations t1 and t2

Using our analytical formula for jitter in IPP traffic, Fig. 5 shows that as the average duration of the active (ON) period increases relative to the OFF period, the jitter decreases. Conversely, an increase in the average duration of the OFF period results in an increase in jitter.

3.3. Analytical Calculation and Validation of Jitter for the MMPP-N Model

According to Article [2], the probability density function of the inter-arrival time distribution for the MMPP-N model can be expressed as follows:

$$f_{Tint}(t) = C_1R_1e^{-R_1t} + C_2R_2e^{-R_2t} + C_3R_3e^{-R_3t} + \cdots + C_NR_Ne^{-R_Nt} \quad (11)$$

Thus, after performing the calculations and using Eq. (6), we obtain the jitter formula for the MMPP-N model as follows:

$$J= \sum_{i=0}^{n} \frac{C_i^2}{R_i} + 2\sum_{\substack{0\le i,j\le n\\ i\ne j}} \frac{C_i C_j(R_i^2+R_j^2)}{R_iR_j(R_i+R_j)} - \sum_{i=0}^{n} \frac{C_i^2e^{-2\tau R_i}}{R_i} - 2\sum_{\substack{0\le i,j\le n\\ i\ne j}} \frac{C_i C_j(R_i^2+R_j^2)}{R_iR_j(R_i+R_j)} e^{-\tau(R_i+R_j)} - \tau\sum_{i=0}^{n} C_i^2e^{-\tau R_i} - \sum_{\substack{0\le i,j\le n\\ i\ne j}} \frac{C_iC_j(R_i^2+R_iR_j^2\tau+R_iR_j^2\tau+R_2^2)}{R_iR_j(R_i+R_j)}\left(e^{-\tau R_i} + e^{-\tau R_j}\right) \quad (12)$$

If $C_1 = 1$ and $C_2 = C_3 = C_N = 0$, the MMPP-N process reduces to a Poisson process and the inter-arrival time distribution for the MMPP-N model will be:

$$f_{Tint}(t) = R_1e^{-R_1t}$$

Using these values and our jitter formula derived for the MMPP-N model, we obtain the jitter formula for the Poisson model:

$$J= \frac{1}{R_1} + -\frac{e^{-2\tau R_1}}{R_1} - R_1e^{-\tau R_1} \quad (13)$$

This corresponds to the formula found in Article [7], thereby confirming the validity of our analytical jitter expression for the MMPP-2 model

4. Conclusions

http://doi.org/10.26594/register.v11i2.5679

ISSN 2502-3357 (online) | ISSN 2503-0477 (print)
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Analytical calculations are at the heart of any performance evaluation of telecommunications networks. In this paper, we focused on the calculation of jitter, presenting the analytical jitter formulas for the IPP, MMPP-2 and MMPP-N traffic models and an overview of related works on jitter and its behaviour. The obtained results may serve as the basis for further studies using these formulas and SDN concepts, in order to evaluate the performance of 5G and to deploy new algorithms and applications for the traffic optimization in 5G and beyond. Our next paper will be dedicated to validating these jitter formulas through simulations on NS-2/NS-3 for various types of traffic and networks, to observe the behavior of this parameter and its influence on 5G/6G services.

Author Contributions

H. Magri: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, visualization, writing – original draft, and writing – review & editing. M. Rachdi: Supervision and validation. M. Azzouazi: Supervision and validation.

Declaration of Competing Interest

We declare that we have no conflict of interest.

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