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Review on Traffic Modeling of Wireless Access Networks LTE &WiFi technologies

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Abstract: *Wireless access networks need to provide a certain level of quality of service. For analytical tractability and simplicity, most existing analytical performance models for computer networks have been designed using unrealistic working scenarios where the traffic model follows a Poisson process. Performance models should describe the key characteristics of the actual network traffic and provide acceptable accurate estimations of performance of the network. Accurate traffic modeling can be considered the most important component to estimate the network performance. The main goal of this paper is to show the literature work that studied the performance modeling of wireless access networks especially cellular network LTE technology and the WiFi technology. We classify the previous studies into three main categories. The first category shows approaches in the performance modeling of WLAN, the second category presents the previous studies of the performance of LTE cellular network, and the third category presents the literature of heterogeneous wireless access networks.*

***Key Word**: Wireless Access Networks, Traffic Modeling, Cellular Networks, WiFi Network*

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I. Introduction

The main goal of this paper is to show the literature work that studied the performance modeling of wireless access networks, especially the cellular network LTE technology and the WiFi technology. We classify the previous studied into three main categories. The first category shows the approaches in performance modeling of WLAN alone. We specifically focus on the traffic model used. In the second category we present the previous studies in the performance modeling of LTE cellular network and the analytical models introduced to investigate the LTE network performance metrics and the type of traffic used to verify the performance of the whole network. In the third category we present the literature work in heterogeneous wireless access networks modeling and performance evaluation. We focus on multi radio technologies namely LTE and WiFi technologies. Today, popular mobile multimedia applications such as HTTP video streaming , Cloud computing [1] and interactive gamesfeature high-frame transmission rates, enhanced frame density, high levels of burst-like packet loss, latency, jitter and stringent delay constrains to provide a smooth viewing experience. This requires new modeling techniques in order to provide the best possible QoS. With video streaming already consuming the main portion of bandwidth within wireless networks [2] and Variable-Bit-Rate (VBR) video traffic exhibiting noticeable burstiness over a wide range of time scales[3], Poisson Process would no longer be adequate for capturing the complex characteristics of traffic generated by today's internet applications. The rest of the paper organized as follow Section 2 shows briefly the most common traffic models. In section 3 the performance modeling of WLAN IEEE802.11 is presented. Section 4 shows the previous studies for cellular LTE technology. The literature on the heterogeneous wireless access networks modeling presented in section 5. In section 6 we conclude our work.

II. Data Modeling

Selecting the appropriate traffic model can lead to the successful design of wireless access networks. The more accurate is the traffic model the better is the system quantified in terms of its performance. Successful design lead to enhancing the overall performance of the whole of network. This section briefly introduces the most common traffic models for wireless access networks and its ability to measure the performance of current wireless networks with huge amount of demand. In general, the aim of traffic modeling is to provide the network designer with relatively simple means to characterize traffic load on a wireless access networks. Ideally, such means can be used to estimate performance and to enable efficient provisioning of network resources. Modeling a traffic stream emitted from mobile users or any network application using a stochastic process that behaves like real traffic stream from the point of view of the way it affects wireless access network performance or provides QoS to customer. The traffic model is the key for determining the performance of the wireless access networks. Traffic modeling in the evaluation methodology document should focus on capturing

the accents of the network applications which post special demand on the wireless access networks performance. Long rang dependency (LRD) is the key characteristic that needs to be captured, because the effect of high burstiness resulting from most of multimedia internet applications on both transport and buffering capabilities in the wireless access networks. Some real time network applications are bursty and dynamically change their bandwidth demands overtime (e.g. compressed video), while others require constant bandwidth (e.g. uncompressed video). Bursty applications produce VBR (Variable Bit Rate) traffic streams, while constant applications produce CBR (Constant Bit Rate) traffic streams. In the literature there are many approaches in traffic modeling classification in [4], the authors divided traffic models into stationary and non-stationary. Stationary traffic models can be classified into two classes: short range and long-range dependent. Traffic can be as above VBR OR CBR. CBR(smooth) traffic is easy to model and predict its impact on the performance of the network. In [5] they classify VBR traffic models into two main categories, the first category is bound (envelope) based source model; these models provide a bound or an envelope on the volume of source traffic characteristics. The bounding characterization can be deterministic or stochastic bound interval independent, bound interval dependent (BIND). The second category is unbound (exact) source model; these models characterize source behavior by describing their stochastic properties through suitable distribution function.
In Mohamed et all, [4] they compare the most traffic types and they found that ON/OFF traffic model introduced in [6] has rich parameters as can be seen from figure 1. Also ON/OFF model can seizure the traffic characteristics of most types of multimedia applications. Using Matrix-Exponential (ME) representations of the ON and OFF time distributions we can analytically model the ON/OFF model as a semi-markov process of the Markov Modulated (MMPP) type. Using Power-Tail distributions for the duration of the ON period, we can generate a wide range of network applications traffic.

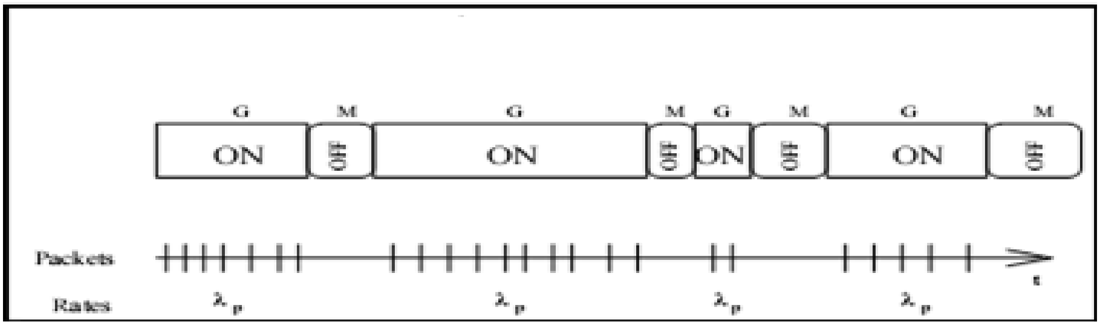

Figure 1: ON-OFF. Traffic Model

III. Wireless LANs Performance Modeling

WiFi networks became an important part of today'sInternet access technology [1]. For analytical tractability

and simplicity, most existing analytical performance modelsfor computer networks have been designed using the assumption of unrealistic working scenarios where the trafficmodel follows a Poisson process [5], [6]. For example, theauthors in [10] investigated the performance analysis of WiFinetworks with multiple access protocols with infrastructurenetwork architecture. Bianchi [7] presents a general WLAN model to study the behavior of 802.11 DCF. They used DTMC to define the exponential behavior of DCFalgorithm in saturation state.A lot of models are devolved based Bianchi model as in [8, 9].They developed a Markovian modelto random access protocol p-persistence Carrier SenseMultiple access/Collision Avoidance CSMA/CA with backoff estimation algorithm. In [11] Ping et all analyzed thethroughput of the ad-hoc WLANs. They enhanced thethroughput of multi hop ad-hoc network by controlling theoffered traffic load at the source, authors introduced a closedform solution of the throughput with ALOHA and theyevaluated their model by using simulation. In [12] the problemof the fair scheduling among WiFi stations is investigated.They proposed distributed fair scheduling protocol based onself-clocked fair queuing and IEEE802.11 medium accessprotocol.In [13] Gupta and Kumar investigated the capacity ofad-hoc WiFi networks. They estimated the capacity of ad-hocnetworks with randomly located stations. They estimated theoptimal throughput of the network under different conditions.The same in [14.15] they estimated the capacity of the networktaking into account the mobility of the nodes in ad-hoc.The authors in [22] experimentally study the performanceof two adhoc nodes with constant file size. They examinedthe impact of nodes orientations, wall partition and line ofsight blockage on the throughput of a link. Anandet allin [23] analyzed experimentally a public WiFi and studyuser behavior in infrastructure network. They used two-stateMarkov-modulated Poisson process with mean ON time 38seconds and off time 6 seconds. Also they investigated theeffect of offered load in network performance. Also, traffic modelswith Markov Modulated Poisson Process were used to modelcorrelation between multimedia traffic [15].On the other hand, authors in [33, 34] showed that the bursty behavior and self-similar characteristics of the adopted video encoding and compressing for interactive and streaming of network applications. Also the same characteristics for TCP traffic have been shown in [35] and they found that the Poisson Process is not sufficient for precise modeling of multimedia network traffic. The authors [36] introduced the versatile traffic models. They focused on MAC and physical layers for multiple simulation sessions by embracing multiple interrupted Poisson processes to yield ON/OFF traffic over wireless networks.

IV. LTE Performance Modeling

In [37] The authors present a study LTE networks with CBR and VBR traffic. They used FBM traffic model to model VBR traffic [38]. In [39] Researchers studied the behavior of LTE network with cognitive radio taking into account recurrent failures with M/M/1 queuing model and with primary subscribers interruption[40.41] . In [42] authors presents a multi-discipline model for dynamic optimization.The behavior of LTE networks through vehicular communication in transportation are studied in [43, 44, 45 , 46, 47]. In [49, 50] the author investigate the performance of medium access control of mobile networks analytically taking into account energy consumptions, also they present model to describe the behavior for a group of communication over the network.

In [51], authors show the behavior of integration of different dense accesspoints and expect the behavior of network based on user level performance. A queuing model as illustrated in figure 2 was present to study the vehicular communication with Poisson arrival process [52].

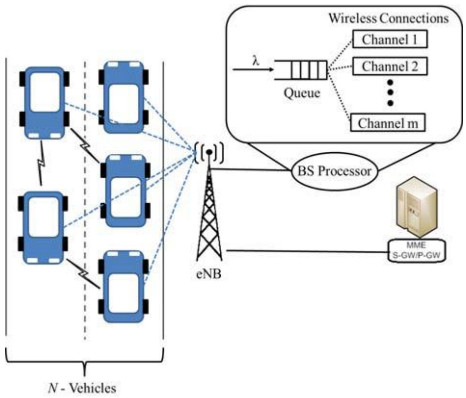

Figure 2 vehicular communication queuing model [52]

The authors in [54] present the model as illustrated in figure 3. They the Quality of service(QoS) for the subscribers using the with multiple cases.

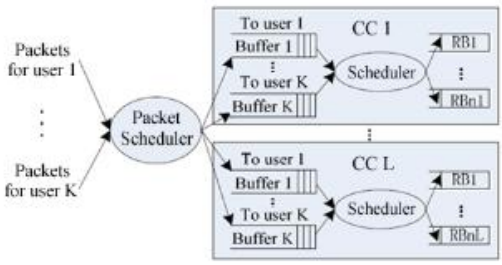

Figure 3: DQS For LTE network [54]

Authors in [55] present the behavior of LTE mobile with limited bandwidth using queuing theory. They use exponential arrival and solve the system using semi-Markov process.In [56] authors described the arrival behavior of LTE mobile network and show the self-similar characteristics of the arrival traffic. Gerhard in [57] studied the behavior of medium access control layers of LTE mobile network and derive a mathematical model for transmission rates based on channel conditions. In [58]Hossam and others study the bandwidth allocation in LTE networks based on user information. In [59] Theauthor presenttherelays impact on mobile network. They studied the whole systems with markovprocess.WANG et all in [60, 61] use DTMPmodel to allocate user resources based on the size of queue and flow arrival. They assume in [61] that all resources are equally shared among active users. The authors in [62] present a mathematical modelfor assessing the LTE network using Markov birth and death process .The authors in [63] present a basic rule for dimension and planning LTE mobile using 15 eNodeBbased on various performance metrics.

Konstantin in [64] studied the LTE network using queueing model illustrated in figure4they obtained a mathematical formula for loss probability based on Poisson process arrival process and exponential service time.

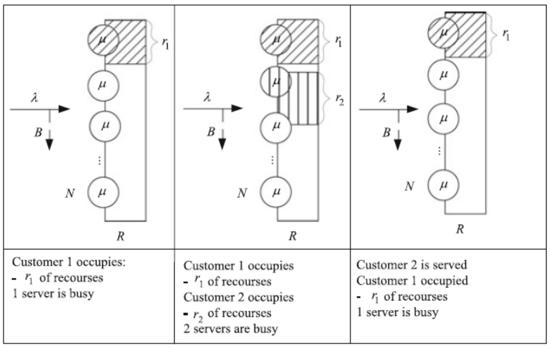

Figure 4: General Queuing Model [64]

In [65] Nailaet all present the performance of LTE medium access control scheduler with DTMC queueing model

using lognormal for constant traffic types and exponential distributions for the video applications.Spaeyin [66] studied the impact of admission control with quality of service in LTE mobile network. The authors in [67] used Markov process to assign the optimum resources and limited the user data. The authors in [68, 69] show the behavior medium access control layer of LTE network using crosslayertechnique for optimum allocation based on queueing theory. They model each state in the network with Markov chain and get the time spent by a user in each session.The previous studies in [70, 71. 72. 73]use the process sharing queueing model to study the performance of the evolved nodeB and they calculate the bandwidth of the based on the inbound and outbound conditions.

V. Data Offloading

Future Wireless Access networks are envisioned to be dense, heterogeneous, with diverse ranges of coverage, data rates and cognitive radio capabilities. Such systems will need to support high traffic loads as well as throughput, so as to meet the increasing demand of wireless users for multimedia applications as reported in Cisco forecast paper [2]. The 4G networks are not substantial enough to support massively connected devices and have a lot of limitations like no support for bursty traffic, latency, heterogeneity, etc. [74, 75]. Different access networks technologies will combine to form heterogeneous networks which present a single 5G network [76]. How to design such a new access network however is still under debate. There are trends towards adoption of software radio and a growing presence of general purpose platforms in wireless access networking, which allow signal processing, network processor class packet processing, wire-speed computation and server-class virtualization capabilities for software radio realizations of 3G and 4G wireless stacks. The goal of Resource Allocation (RA) is to distribute the available bandwidth and power efficiently and fairly while satisfying individual user Quality of Service (QoS) requirements. Extensive work on RA has been presented in literature with different objectives and algorithm complexities [77, 78, and 79]. 3GPP introduced a new standards for trusted and non-trusted access networks from operator point of view, they require additional security mechanisms, provide connections of policy and charging rules functions to gateway functions which define the Access Network Discovery and Selection function(ANDSF) [80]. The ANSDF enables operators to store policies for discovery and selection of radio access technology in a server and communicate them to the user via push or pull methods. Several solutions proposed to handle enormous data traffic in mobile networks, such as Long Term Evolution (LTE). Installing more base stations, deploying heterogeneous networks with Wireless Fidelity (WiFi) for dual-mode devices [81], However small cells and WiFi access points have drawn significant attention from mobile operators due to their potential to improve indoor coverage and capacity and offloading traffic from macro cells in a cost-effective manner. WiFi is a promising solution for cost-effectively adding mobile network capacity by leveraging low-cost access points and free licensed spectrum. WiFi is a mature and widely adopted technology in mostmobile devices. There are several possibilities to offload LTE traffic. Authors of [82] in their work which deals with the offloading to Femto cells and WiFi access points has shown that it is more efficient to use WiFi offloading than Femto cells offloading because we need high density of femto cells than WiFi for the same offloading. According to [83] a small base station (SBS) is installed onboard the vehicle; called a mobile SBS (mobSBS) which has WIFi antenna to access city wide WiFi coverage. Mobile users communicate with the mobSBS instead of the distant Macro base station (macroBS). In order to have efficient offloading in terms of bandwidth utilization, which is achieved through adapting a history-based, approach that reduces offloading demands overhead caused by non-incessant WiFi coverage. Many work done to offloading cellular traffic via WiFi to improve user experience (such as higher throughput and delay), the majority of this studies proposed offloading schemes based on delay-tolerant networking [84-88]. The goal of these schemes is to offload the data traffic from the cellular networks to WiFi to reduce the user's cost and the load of cellular networks [84]. In [85] and [86] the authors proposed delay-tolerant networking-based WiFi offloading technique. They reduce the cellular network data by up to 40% and 50%. The authors in [87] studied delay-tolerant networking-based WiFi offloading from the economic view; they modeled a game theoretic framework. Authors in [88] proposed a WiFi offloading technique which exploits mobility prediction to enhance its efficiency. However, most of these studies are based on the normal traffic assumption and they didn't include burst traffic, also they assume that the users will become aware of their throughput which they will receive when using the access technology.

VI. Conclusion

The main objective of this paper is to provide a comprehensive survey on the recent work concerning wireless access network performance modeling. Each application has different effect on the performance of access networks in particular LTE and WiFi networks and the integration between them. We classify the models based on the technology used. The paper introduces three approaches for the wireless access networks performance models. The first approach for WiFi access points performance. The second approach for the fourth generation mobile technology LTE access networks. Last approach presents the work done in the offloading from LTE networks to WiFi access network to improve the performance of cellular technology. Most of the models used unrealistic traffic models to represent the network application traffic and did not consider the bursty traffic. The research challenge is how to integrate the bursty traffic in the wireless access networks performance model for accurate performance modeling and efficient design for these networks.

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