Integrated Models for Information Communication Systems and Networks:

Design and Development

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Preface

The text is divided into two broad sections. Section 1 deals with Networks and Information processes, while Section 2 is dedicated to chapters on Information Communication and Engineering. The first section consists of chapters one (1) through eight (8), with chapter one serving as an introductory piece. The second section is made up of the remaining eleven chapters from chapter nine to nineteen. Most of the chapters in this second part are in the field of communications with two in the area of artificial intelligence.

In *Chapter One*, the principles of modeling are visited with a special bias to Information Communication Systems and Networks (ICSN). The basic rubrics of models, modeling, and simulation; an understanding of which is indispensible for the comprehension of subsequent chapters are expoused. Various fundamental terminologies, the knowledge of which is necessary for understding the concepts of models, modeling, and simulation, are explained. The contributing authors also shed some light on model structures and the methodological basis of formalizing complex system structures is discussed. The chapter concludes with recommendations from the authors on how to avoid the most common errors usually made by researchers in the process of model design which is that of losing track of the original problem statement as well as by embarking on actual model design without having enough requisite information about the modeled system.

Chapter two reports on the numerical methods of multifractal analysis as it affects ICSN. In this very compelling chapter, the contributing authors present the theory of fractals and multifractals. A method based on multifractal data analysis at network layer level by means of *Wavelet Transform Modulus Maxima* (WTMM) is proposed for the detection of traffic anomalies in computer and telecommunication networks. Algorithm development methods for estimating multifractal spectrum are presented. The chapter also introduces WTMM as an informative indicator necessary to exploit the distinction of fractal dimensions on various parts of a given dataset. A novel approach based on the use of multifractal spectrum parameters is proposed for estimating queuing performance for the generalized multifractal traffic on the input of a buffering device, which shows that the multifractal character of traffic has significant impact on queuing performance characteristics.

The contributing authors in *Chapter three* present the results of an extensive doctoral research thesis on a deterministic approach for resolving the switched LAN's delay problem. In this interesting chapter, that actually challenges some basic assumptions met frequently in the literature, the authors assert the need for networks to be designed with specified maximum End-To-End delay since, if the maximum packet delay between any two nodes of a network is not known, it is impossible to provide a deterministic guarantee of worst case response times of packets' flows. They then go on to compare the two principal

approaches for determining the end-to-end response times of flows in ICSN and submitted on the superiority of the deterministic rather than stochastic approach.

Chapter four presents yet another doctoral thesis research findings on the specific area of e-Learning. This rather educative research was conducted in Western Africa with the participation of a specialized school for the blind. The contributing authors contend that finding suitable content via a mobile phone has become a rigorous task for voice-based online learners to achieve better performance. They opine that this is more acute for sight-impaired learners because existing voice-enabled applications in the domain of e-Learning lack the attributes of adaptive and reusable learning objects. As a *panacea* for this obvious deficiency in eLearning infrastructure, the authors propose a *Voice-Enabled Framework for Recommender and Adaptation Systems in E-Learning* (*VeFRA*). In their submission, they present a usability study result based on ISO 9241-11 specification of 4.13 on a scale of 5, which translates to *Good Usability*. This they assert offers a ubiquitous e-Learning platform for the visually impared to learn, granted the availability of telephony, without the necessity of Internet services.

In *Chapter five,* the subject of *fractality* is revisited albeit from a slightly different angle. In this very informative chapter that cannot but appeal to a specialized set of researchers, the contributing authors present their research findings on *Signals with an Additive Fractal Structure for Information Transmission.* They propose a new class of wideband signals with an additive fractal structure. A detailed study of this novel class of wideband signals possessing a high level of irregularity and unpredictability at the level of simple technical implementation is presented. Exhaustive methods of modifying the signal spectrum with additive fractal structure for increased efficiency of the frequency resource application are given. The authors submit in their conclusion that complex wideband signals with an additive fractal structure can be employed in radioengineering applications such as speech transmission over channels with AWGN.

Chapter six presents a model developed for increasing the efficiency of data transmission in ICSNs based on the TCP/IP protocol suite. Complex simulation models were proposed and simulated for analysis and multilevel modeling processes of data transfer in computer networks based on the protocols of TCP/IP, which fully and accurately allow for determining co-existing exchange factors such as formation of dataflow, network topology, network protocols function, and internet support, which influence efficiency of data transfer. The contributing authors lay claim to an increase in network efficiency of between 10% and 15% when their developed model is deployed.

In *Chapter seven*, the contributing authors present the validation of a software architecture they call the *INTERPRETOR* as a dataflow model of computation for filtering, abstracting, and interpreting large and noisy datasets. They submit in their conclusion to the chapter on the non-triviality of the interpretation of large and noisy data. They contend that their developed architecture can be tailored and applied to different domains, which have the same issues associated with the interpretation of data. For future work, they suggest the development of a generic and reusable tool for proposed architecture.

In *Chapter eight*, the problem of modeling maintenance productivity measurement is addressed. This has been identified as a major area of concern for productivity engineers, based on the need for the establishment of productivity standards in virtually all functional areas of an industrial organization. This chapter identifies the approaches in integrated and systematic maintenance productivity measurement and creates models for optimizing total productivity in maintenance systems. It likewise discusses visual yardstick, utility, queuing systems, and simulations approaches for measurement of maintenance

productivity and highlights Markov chain approach for stochastic breakdowns in repairable systems. This chapter effectively concludes the first part of this text.

The second part of this text commences with *Chapter nine*. It essentially addresses issues concerned with the modeling of packet streaming services in ICSN. The chapter presents the result of researches into this very interesting and contemporary domain of study. The chapter gives a detailed discussion on the fundamental concepts of video streaming over wireless broadband access networks (BWAN). The contributing authors assert that all existing research in this area investigate the known types of errors separately. The lack of standard approaches to determining the effect of errors on transmission quality of services is mentioned. This very informative chapter promises to serve as a veritable reference material for those carrying out research in the area of quality estimation of video traffic over BWAN.

In *Chapter ten*, an investigation into the problem of mathematical modeling of video-sequences of digital half-tone images (DHTI) is visited. The fact that the computational rigor necessary for development of DHTI video-sequences of Markov type contributes in no small measure to the difficulty of their realization is particularly highlighted. It is postulated that the realization of a method of Markov Model DHTI construction and their statistically correlated video-sequences on the basis of the causal multi-dimensional multi-value MM is not computationally intensive. The authors submit that their proposed method is particularly effective when DHTI is represented by low-bit (4–8 bits) binary numbers. They conclude among others that the approach for MM construction of several statistically correlated DHTI video-sequences can be reduced to a formalized procedure of sequential elimination of the statistical redundancy between vicinity elements of the simulating image element belonging to the independent coordinates and all others. The results presented in this chapter are quite cutting-edge and should appeal to a specialized set of researchers in the domain of DHTI modeling.

Chapter eleven presents quite a fascinating contribution on the subject of Performance Analysis of Multi-Antenna Relay Networks over Nakagami-m Fading Channel. The performance of multi-antenna selective combining decode-and-forward (SC-DF) relay networks over independent and identically distributed (i.i.d) Nakagami-m fading channels is presented. The authors formulate the outage probability problem, optimize it with an approximated problem, and subsequently provide an analytic solution. They submit in their conclusion that the complexity of double antenna case versus single antenna case is not high and instead of increasing the number of relays, increasing the number of antennas is a practically better option.

A generic method for the reliable calculation of large-scale fading in obstacle-dense propagation environments is presented in *Chapter twelve*. The authors' aim in this chapter is to make an attempt at summarizing recent findings in the field of wireless channel modeling that provide a new method for reliable estimation of the statistical parameters of large-scale variations of the average received signal (shadow fading). They present an algorithmic solution that is theoretically based on pathloss estimation model and allows for a direct and reliable calculation of the deviation of the fluctuations of the average received signal in an obstacle-dense environment.

Chapter thirteen extends the concept of DHTI introduced in chapter ten by presenting the results of works in the *development of nonlinear filtering algorithms of digital half-tone images*. In this chapter, the authors are more concerned with solving the problem of algorithms and structures investigations for radio receiver devices with the aim of nonlinear filtering DHTI representing the time-discrete and value-discrete random Markovian process with more than two states. The contributing authors submit in their conclusion that qualitative and quantitative analysis of developed algorithms for nonlinear filtering

of static and dynamic DHTI show that filtering effectiveness increases with reduction in the SNR and with increase in the dimension of filtering process.

The contributing authors of *Chapter fourteen* present the results of performance analysis of traffic and mobility models on Mobile (MANET) and Vehicular Ad Hoc Wireless Networks (VANET). They established the importance of traffic and mobility models in evaluating the performance of communication networks, despite criticism and assumption from various works reported in the literature on transmission control protocol's weaknesses vis-à-vis MANET and VANET. The contributing authors submit based on simulation results that CBR and VBR performed better than TCP at both low and high mobility with high throughput of receiving bits, less end-to-end delay, and less packets dropped. In their informed opinion, most dropped packets were due to high end-to-end delay, time-to-live expiration of the routing protocol, and end of simulation time.

In *Chapter fifteen*, the rather specialized topic of quantum cryptography (QC) is presented. This cutting-edge approach to information security proposes a new method of generation random private key for quantum communication line users. The authors present Quantum Key Distribution (QKD)–a technology based upon quantum principles for generation random bit string used as privacy key between two remote users. They present salient concepts of quantum physics as they are employed vis-a-vis QC (e.g. the *Heisenberg uncertainty principle)* according to which measurement of a quantum system state changes its initial state. They maintain that the main advantage of QC is that legal users will know about eavesdropping activities. A generalized structure of the QKD systems with phase coding of photon states is proposed based on analysis of what is commercially available.

Chapter sixteen presents research results on load balancing in 3GPP LTE systems. The chapter reveals the research efforts of the contributing authors in resolving load-balancing issues of next generation mobile networks (NGN) through the instrumentation of soft computing. They contend that most available models have relied heavily on conventional mathematical models which does not adequately track some of the multifaceted challenges of NGNs. They thus propose in this chapter the use of soft computing, precisely the ANFIS model for dynamic QoS-aware load balancing in 3GPP LTE. They state that the adoption of ANFIS offers learning capability of neural network and knowledge representation of fuzzy logic for a load balancing solution that is cost effective and closer to human intuition. Results obtained from model validation using testing and checking datasets show that the ANFIS model is a robust tool for a dynamic load balancing scheme in 3GPP LTE.

In *Chapter seventeen*, the use of artificial intelligence (AI) for the resolution control problems is presented. Specifically, the contributing authors present the use of artificial neural network (ANN) for the control of a laboratory MAGnetic LEVitator (MAGLEV) system. They present a mathematical model for MAGLEV using the Lagrangian approach. They submit in the conclusion to the chapter that in terms of positioning accuracy, the ANN is very hearty but the dynamic accuracy was found to be inadequate.

In the penultimate *Chapter eighteen*, the contributing authors present a pre-assessment model of constitutive modelling of wind energy potential of selected sites in Nigeria. The chapter presents the result of a study on the availability of wind energy resources of a site using 21 years' (1987 - 2007) monthly average wind speeds for 18 locations in Nigeria to create a constitutive model. The resulting empirical model can be employed for determining the range of wind energy potential of a site and making a less rigorous decision on site selection for complete assessment.

In this concluding chapter of the text, *Chapter nineteen,* the contributing authors present a comparative framework of two algorithms for resource allocation in a wireless system with multiple users vying for wireless network resources. A means of improving system resource sharing indices using cross-layer optimization techniques is proposed. The results show that while the MC has a higher system capacity, the MWC reliably transmits realtime and non-realtime traffic within the requirements for this traffic class. The authors submit that the resource allocation scheme and scheduling done using cross-layer optimization in MWC has reduced the delay time for realtime and non-realtime traffic and done the same at least partially for best-effort traffic.

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Chapter 16
ANFIS Modeling of Dynamic Load Balancing in LTE

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ABSTRACT

Modelling of ill-defined or unpredictable systems can be very challenging. Most models have relied on conventional mathematical models which does not adequately track some of the multifaceted challenges of such a system. Load balancing, which is a self-optimization operation of Self-Organizing Networks (SON), aims at ensuring an equitable distribution of users in the network. This translates into better user satisfaction and a more efficient use of network resources. Several methods for load balancing have been proposed. While some of them have a very buoyant theoretical basis, they are not practical. Furthermore, most of the techniques proposed the use of an iterative algorithm, which in itself is not computationally efficient as it does not take the unpredictable fluctuation of network load into consideration. This chapter proposes the use of soft computing, precisely Adaptive Neuro-Fuzzy Inference System (ANFIS) model, for dynamic QoS aware load balancing in 3GPP LTE. The use of ANFIS offers learning capability of neural network and knowledge representation of fuzzy logic for a load balancing solution that is cost effective and closer to human intuition. Three key load parameters (number of satisfied user in the network, virtual load of the serving eNodeB, and the overall state of the target eNodeB) are used to adjust the hysteresis value for load balancing.

INTRODUCTION

Mobile communication systems are unpredictable and stochastic in nature due to a number of factors such as constantly changing propagation channels, random mobility of users and sudden changes in network load. This renders conventional mathematical tools less effective for system modelling of communication systems. Thus communication systems can be best modelled by adopting soft computing which exploits the tolerance for imprecision, partial truth and uncertainty to achieve robustness, low solution cost and tractability. One of such soft computing platforms is the Adaptive Neuro-Fuzzy Inference System (ANFIS). ANFIS is an architecture which can serve as a basis for constructing a set of fuzzy if-then rules with appropriate membership functions to give the

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specified input/output pairs model (Jang, 1993). ANFIS modelling have been utilized in a number of applications such modelling of Microarray Cancer Gene Expression Data (Wang, 2005), Speed Control of Induction Motor (Kusagur, Kodad, & Ram, 2010), and for Optimization of Multiple Response Systems (Cheng, Cheng, & Lee, 2002). This chapter proposes the use of ANFIS modelling for dynamic load balancing for the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE).

The 3GPP LTE is Self-Organizing Network (SON). Self-Organizing Network operation was introduced to enhance system performance by improving network operations and maintenance. SON operations are also promising in reducing both CAPital EXpenditure (CAPEX) and OPerational EXpenditure (OPEX). Load balancing is a SON operation which aims at ensuring an equitable distribution of cell load among eNodeBs in order to improve the overall system capacity of the network (ETSI TS 136 300, 2011), (M. of WINNER, 2005). To this end, several algorithms have been proposed. In (Lobinger, Stefanski, Jansen, & Balan, 2010), a load balancing algorithm aimed at finding the Optimum Handover (OH) offset value between the overloaded cell and a possible target cell was proposed. Another approach, which is based on a network formulation of heterogeneous services with different quality of service requirements was proposed in (Wang et al, 2010). A utility-based load-balancing framework was used to develop an algorithm called Heaviest-First Load Balancing (HFLB) in (Wang et al, 2010). However, these methods and algorithms are not computationally efficient because they involve the use of iterative processes. Moreover, the need to minimize load overhead due to excessive handover and Ping-Pong effect needs to be taken into consideration. Also, to make a more informed and informed load balancing decision, there is a need to consider not only the load of the serving cell, but other indicators such as the overall state of the serving cell and the number of satisfied users in the entire network must be taken into account. These challenges points to the need for a robust and cost effective approach.

OVERVIEW OF 3GPP LTE

The Long Term Evolution (LTE) started in 3GPP (Third Generation Partnership Project) release 8 and continued in release 10 with the objective of meeting the increasing performance requirements of mobile broadband (Dahlman, Parkvall, & Skold, 2011). LTE is a new radio-access technology geared towards higher data rates, high spectral efficiency, very low latency, support of variable bandwidth, simple protocol architecture, and support for Self-Organizing Networks (SON) operation. Release 10, otherwise known as LTE advanced is a fourth generation (4G) specification that provides enhanced peak data rates to support advanced services and applications (100 Mb/s for high mobility and 1 Gb/s for low mobility). LTE is the radio access network for Evolved Packet System (EPS), which has a core network known as Evolved Packet Core (EPC). The overall architecture of the EPS is shown in Figure 1.

The LTE radio access network consists of evolved Node Bs (eNodeBs) and no centralized controller (for normal user traffic). Due to the absence of a network controller, it is said to have a flat architecture. This structure reduces system complexity and cost and allows better performance over the radio interface. The eNBs are interconnected by the X2 interface. The S1-MME interface connects the eNBs to the key control plane of the core network-the MME, while the S1-U interface connects the eNBs and the S-GW. Intra-LTE load balancing is usually accomplished over the X2 interface.

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