Integrated Models for Information Communication Systems and Networks:

Design and Development

Aderemi A. Atayero
Covenant University, Nigeria

Oleg I. Sheluhin
Moscow Technical University of Communication & Informatics, Russia

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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.

Aderemi A. Atayero
Covenant University, Nigeria

Oleg I. Sheluhin
Moscow Technical University of Communication and Informatics, Russia

Chapter 1
Principles of Modeling in Information Communication Systems and Networks

Oleg I. Sheluhin
Moscow Technical University of Communication and Informatics, Russia

Aderemi A. Atayero
Covenant University, Nigeria

ABSTRACT

The authors present in this entry chapter the basic rubrics of models, modeling, and simulation, an understanding of which is indispensible for the comprehension of subsequent chapters of this text on the all-important topic of modeling and simulation in Information Communication Systems and Networks (ICSN). A good example is the case of analyzing simulation results of traffic models as a tool for investigating network behavioral pattarns as it affects the transmitted content (Atayero, et al., 2013). The various classifications of models are discussed, for example classification based on the degree of semblance to the original object (i.e. isomorphism). Various fundamental terminologies without the knowledge of which the concepts and models and modeling cannot be properly understood are explained. Model stuctures are highlighted and discussed. The methodological basis of formalizing complex system structures is presented. The concept of componential approach to modeling is presented and the necessary stages of mathematical model formation are examined and explained. The chapter concludes with a presentation of the concept of simulation vis-à-vis information communication systems and networks.

FUNDAMENTALS OF MODELS AND MODELING

A model is essentially the *re*presentation of an object, system or concept in a form different from that in which it occurs naturally. A model may likewise be defined as a tool, which helps in the explanation, understanding or perfection of a system. Modeling can be described as the process of substituting a test object (the original) for its image, description, or substitute object known as a model and providing a behavior close to that of the original within certain reasonable limits of assumptions and uncertainties. Simulation is

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usually performed in order to gain knowledge of the properties of the original object by studying its model, rather than the object itself.

The use of models is justified in cases when they are simpler in comparison with the option of creating the original object, or when the original object is better left uncreated for whatever reason. In the words of D.K. Nordstrom (2012), "Models are one of the principal tools of modern science and engineering…" Scientists and engineers devote a lot of time to design, build, test, compare, and revise models (Frigg and Hartmann, 2009).

A model may be the exact replica of an object (*albeit* on a different scale and from a different material) or depict certain characteristic properties of the object in an abstract form; i.e. a representation of a real system or process (Konikow and Bredehoeft, 1992). A model is thus essentially an instrument for forecasting the effect of input signals on a given object, while *modeling* is a method of improving the reasoning efficiency and intuitive capacity of specialists.

All models are but simplified *re*presentations or abstractions of the real world. An *abstraction* contains within itself the major behavioral traits of an object, but not necessarily in the same form or as detailed as in the object. Usually a large portion of the real characteristics of the object of study is disregarded, while such peculiarities that idealize a real event version are chosen. As a result, most models are abstract in nature.

The degree of semblance of a model to its object is called *isomorphism.* Two conditions must necessarily be satisfied for a model to be considered *isomorphic* (or similar in form) to the original object:

1. Existence of exclusive correspondence between elements of the model and the modeled object;
2. Maintaining the exact relationships or interactions between these elements.

From the foregone, we see that a model is essentially a physical or abstract object, with properties similar to those of the original object under study in certain defined ways. The specification of models depends on the particular problem of study as well as the available resources. The general requirements for models are as listed below:

1. **Adequacy:** This refers to the level of accuracy in replicating the properties of the original object.
2. **Completeness:** The ability of the model to deliver to the receiver all necessary information about the original object.
3. **Flexibility:** The ability to playout different situations in the whole range of conditions and parameters.
4. The *complexity* of developing the model must agree with the existing time and software constraints.

According to Tedeschi (2006), the design of the tests for adequacy for a particular model should of necessity evaluate weaknesses to be addressed. He further contends that a combination of several statistical analyses vis-à-vis the original conceptual purpose of the model is essential for determining its adequacy.

Since modeling s the process of creating a replica of an object and the subsequent study of the object's properties through the created replica (a.k.a. model), entails two major stages:

1. Model design;
2. Model evaluation/validation and conclusion derivations.

Model validation is concerned with ascertaining that a model performance in satisfactorily accurate vis-a-vis model design objectives; it is all about building the model right (Balci, 1997). It is pertinent to note here that a uniform procedure

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