Erol Gelenbe: ISCIS and Beyond

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Abstract We celebrate the 30-th annual ISCIS (International Symposium on Computer and Information Sciences) that Erol Gelenbe started in 1986 and pursued uninterruptedly as a service to the Turkish Computer Science and Engineering Community. We also outline his scientific contributions over the last fifteen years covering half of the life-time of ISCIS. These include his innovative work on a new representation of Intermittent or Renewable Energy Sources, and *Energy Packet Networks* which are a convenient representation for the flow, storage and consumption of of electrical energy, both at the microscopic level (in electronic chips) and at the macroscopic level (e.g. in buildings or data centres). The discussion then turns to his work on ICT systems that parsimoniously use energy in order to achieve quality of service (QoS). His pioneering work on Autonomic Communications and the Cognitive Packet Network is also reviewed, followed by network security, Emergency Management Systems, Gene Regulatory Networks, and analytic models of computer systems and networks.

1 Introduction

The International Symposia on Computer and Information Sciences (ISCIS) was started in 1986 by Professor Erol Gelenbe to provide the Computer Engineering and Computer Science community in Turkey with a venue for their academic research, and to interact with their peers from abroad, and create a tradition of refereed international quality publications in this newly formed community. Since 1986, ISCIS has been held annually without interruption, with the 30-th held at Imperial College London in September 2015. In recent years, the Proceedings of ISCIS have been published by Springer.

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The first ISCIS was held at Bilkent University, Ankara, Turkey, with the active support of Professor Ali Doğramacı. Bilkent University was newly formed, and emphasised Computer Engineering, Electrical and Electronic Engineering and Industrial Engineering, as key areas for Turkey's future. Very quickly, several Turkish universities, including the Middle East Technical University, Boğaziçi University in Istanbul, Ege University in Izmir, Istanbul Technical and Yıldız Technical Universities. Sabancı University in Istanbul also participated in organising this annual event. In the early years ISCIS was actively supported by the Department Chairs Council for Computer Engineering, itself chaired by the late Professor Oğuz Manas of Ege University. Other active colleagues included Professors Erol Arkun and Cevdet Aykanat of Bilkent University, Professors Ugur Halıcı, Hakkı Toroslu and Adnan Yazıcı of the Middle East Technical University, Professors Ali Rıza Kaylan and myself of Bogaziçi University. ISCIS was hosted by these several times. Erol actively selected the venues and teams that would run the conference, and "transferred" the know how and procedures to make it all work, thus training colleagues young and old in the "art" of organising scientific events without any subsidies, including organisation, venues, refereeing and paper selection, and keeping down the costs. There were indeed problems, for lack of funds, speakers who were unable to attend, quality control issues during certain years, attempts to cancel the publication of proceedings by third parties due to foreign political pressure, such as North Cyprus). Since 1998, the venues have included sites in Europe, in Turkey and America:

- 29. ISCIS 2014: Krakow, Poland [20],
- 28. ISCIS 2013: Paris, France [84],
- 27. ISCIS 2012: Paris, France [82],
- 26. ISCIS 2011: London, UK [88],
- 25. ISCIS 2010: London, UK [89],
- 24. ISCIS 2009: North Cyprus [1],
- 23. ISCIS 2008: Istanbul, Turkey,
- 22. ISCIS 2007: Ankara, Turkey,
- 21. ISCIS 2006: Istanbul, Turkey [145],
- 20. ISCIS 2005: Istanbul, Turkey [160],
- 19. ISCIS 2004: Antalya, Turkey [11],
- 18. ISCIS 2003: Antalya, Turkey [159],
- 17. ISCIS 2002: Orlando, Florida, USA [38],
- 15. ISCIS 2000: Istanbul, Turkey,
- 14. ISCIS 1999: Ege University, Turkey,
- 13. ISCIS 1998: Ankara, Turkey.

Turning to Erol himself, it is hard to describe the scientific content of an ongoing career starting in the early 1970's for a highly productive researcher whose curiosity ranges widely in Computer Science, Applied Probability, Operational Research, Electrical Engineering and even Theoretical Biology. The variety of Erol's work over the past fifteen years is unknown to those who know him through some specific research area. Thus our brief review points to his work in several areas since the year 2000, such as energy efficiency of ICT [14] and autonomic communications [24] where Erol has authored influential papers.

2 Energy Packet Networks

Erol's first work published in 2015 analyses the link between the random nature of harvested energy, and the random nature of the data collection activities of a wireless sensor [58], leading to an original analysis of "synchronisation" between the two resources that in this case enable wireless communications: the data packets and the energy packets, first studied in a paper published in 2014 [57]. However in some earlier work he had introduced of a novel way to view energy as a "packet-based" resource that can be modelled in discrete units which he called Energy Packets [52, 53]. While Ohm's Law in the complex variable domaine is a good way to analyse the steady flow of electricity in RLC networks, there are areas where it is not the best model:

- At a nano-scopic level, say at the level of the flow of individual electrons, both the stochastic nature of the sources and the physical non-homogeneities which govern the medium (e.g. metal) imply that different models may be needed; thus Erol recently proposed a stochastic flow model that addresses the conveyance of energy and information by individual particles [56].
- At a more macroscopic level, when one deals with intermittent sources of energy so that energy must be stored in batteries or other storage units (such as compressed air cylinders) that can include conversion losses to and from the electrical storage, and energy usage itself is intermittent, models descended from G-Networks [34, 37] become useful [54, 5, 55].
- This approach has raised interesting questions about how such large networks may be analysed in the presence of flow of energy and flow of work [57, 61] and some recent interesting results regarding "product form solutions" for such multi-hop networks have also been obtained [99].

3 Energy in ICT and its Optimisation

However, Erol's concern for energy consumption for communications actually started a decade earlier [79, 39] in the context of Wireless Ad-Hoc Networks, contributing a technique to extend overall life of a multi-hop network by using paths that have the most energy in reserve, i.e. the most full batteries. This work was pursued in papers related to network routing and admission control based on energy considerations [115, 114, 97, 97, 102, 95, 101, 122, 156] and this resulted in a practical design for an energy aware routing protocol.

His research group's involvement with energy consumption in information technology was also developed through their participation in EU Fit4Green Project which resulted in a widely cited paper [14] regarding the energy optimisation of Cloud Computing servers and of software systems [151]

Although energy consumption by ICT is an important issue, it must be viewed as a compromise between the two aspects, where a reduction in energy consumption in the manner a specific system is being operated, for instance as a function of workload or of workload distribution, is "paid for" by a loss in performance or an increase in the response times experienced by users. This issue has been studied in several of Erol's recent papers [81, 151, 80, 85].

Similar problems arise in wireless communications, but of course at far lower levels of energy consumption. Here the purpose is to minimise the amount of energy consumed per correctly received packet or bit. Indeed, in the wireless case, increasing the transmission power is often possible. This will overcome noise, but it has the opposite (negative) effect if *all* cooperating transcievers raise their power level, resulting in greater wireless signal *interference* and hence larger error probabilities for all parties. This in turn will *lengthen* the time needed to correctly receive a data unit, and hence will also increase the net energy consumed per correctly received bit or packet [83, 149, 108, 68].

4 Autonomic Communications and CPN

Erol has been long intrigued with the adaptive control of computer systems and networks since the 1970's [109, 13, 12, 153, 76, 77], where the challenge is to deal both with the very large size of the systems encountered in computer science, the imperfection of the dynamic models that describe them, and the very large size of these dynamic models.

His most recent foray into this area, starting with early papers [126, 78, 65, 107] that describe the Cognitive Packet Network (CPN) routing algorithm both for wired and wireless networks that uses reinforcement learning to provide network Quality of Service (QoS) in an automatic manner, is a pioneering initiative in the field of Autonomic Communications [40]. He is also the co-author of a paper that made this field popular a few years later [24].

CPN related was a clear break with Erol's traditional research which has relied essentially on mathematical mdeling and simulation [30, 31, 103, 32, 116]. Related work [113, 150] suggests that decisions that have a "natural" appearance could also be incorporated in a similar manner, simulation systems where complex agent interactions occur, and agents take decisions based on their collective best interest. Similar questions have also been discussed with other methods in the context of search algorithms in dangerous environments [60].

The basic idea of CPN, amply tested in many experiments [91, 90, 86, 87, 93] is to use probe or "smart" Cognitive Packets (CPs) to search for paths and to measure QoS while the network is in operation. The search for paths is run via Reinforcement Learning using a Random Neural Network, based on the QoS objective of goal pursued by the end user. The CPs furnish information to the end user about the QoS offered by different paths, and in particular those actually being used by the end user, but in CPN it is the end user, which may be a representative decision maker for a QoS Class, that actually decides to switch to a new path or select a given path [92, 79, 49]. An extension to CPN that uses genetic algorithms to construct hitherto untested paths based on predicted QoS was also proposed [146].

More recent work has considered CPN for specific applications. For instance in [72] the issue of dealing with web access applications where the uplink may require short response times for Web requests, while the download may require high bandwidth and low packet loss for video downloads, is considered, and a specific system that supports these needs is designed, implemented and tested. Similarly, other recent work deals with the QoS needs of Voice, and a VoCPN system is designed and evaluated [157] on an experimental test-bed.

One of the interesting developments of CPN relates to novel energy aware routing algorithms [95, 96] that link to Erol's concern with energy savings. Other useful application concerns admission control [110] and denial of service defense [64, 94]. Other work that is unrelated to CPN but that proposes adaptive techniques for the management of wireless sensor networks in order to achieve better QoS are discussed in [104, 105, 147, 106], while adaptivity for the management of secondary memory systems is discussed in [162].

Of course, the Random Neural Network was reported in Erol's earlier work [33, 35, 36, 63, 62, 98, 70]. Some of its other applications can be found in [10, 9, 75, 19, 117, 18, 8, 66, 3, 4, 2, 132, 73, 74] and several papers reviewing this subject can be found in the papers of the special issue in [37].

4.1 Network Security

Erol's work on network security came through some work on the impact of Distributed Denial of Service (DDoS) Attacks on network QoS, and a proposal to use CPN as a way to detect DDoS, counter-attack by tracing the attacking traffic upstream and use CPN's ACK packets as a tool to give "drop orders" to upstream routers that are conveying the attacking traffic [94, 148]. This approach was also evaluated on a large network test-bed as a means to detect worm attacks and react to them by sending the users' traffic on routes that avoid the infected nodes [155, 154]. His work on security continued with more algorithmic issues [161], but recently moved to the analysis of signalling storms in mobile networks [128, 127, 7] and is currently one of the main centres of his attention.

5 Emergency Management Systems

Like many people around the world who have a personal experience of large scale disasters, Erol was deeply struck by what he saw in Turkey in 1999, right after the major earthquake that took place near Istanbul, in the areas around Izmit and Yalova. Although he was not present during the earthquake, he went to the sites just *after* the earthquakes with family members in order to to try to find two family members who were missing and who has in fact perished during the event. Finding, identifying, and transporting the bodies was a traumatic experience. He was impressed by the very rudimentary nature of technology that was being used to seek, locate and try to evacuate the victims. The destruction of roads, bridges, electrical power lines and telecommunication networks, meant that only rudimentary construction technologies could be used by the numerous family members and professional rescuers who flocked to the area in the days that followed the earthquake.

Since that time, Erol has devoted a part of his research effort to better understanding the ongoing research of emergency management technologies [123, 125], and developing a deeper understanding of the appropriate models and algorithms which are specific to this domain of research [67, 124, 22, 21]. Unfortunately, many aspects of emergency management have a significant overlap with tactical planning of military operations [71, 120, 121] whose purpose is to destroy the capabilities of an adversary but also to save the lives of friendly forces and evacuate the injured of both sides. In particular, his team has investigated different simulation approaches [71, 69, 25] that could be used to represent the extremely dynamic and fast changing "transient" events in an emergency, and then developed a novel agent based simulator named the Distributed Building Evacuation Simulator (DBES) [23] for evacuation planning and simulation. A constant concern of this work has been to develop decetralised techniques that do not require large and expensive infrastructures [28], and his team has organised a series of annual workshops related to the Pervasive Communications conferences of the ACM [111, 112, 26].

His team studied fast decision algorithms based on learning a wide range of problem instances and their optimal rescuer and rescue vehicle allocations [118, 29, 119], and selecting in real-time the allocation that best matches the current observed emergency situation. They also studied low-cost, light-weight and disruption tolerant techniques that can offer robust communications in emergency environments [131], and many ofthese methods actually span both the military and the civilian doman [158, 130, 144, 129, 27]. More recent work has been devoted to autonomic routing techniques based on ideas derived from CPN or from directional techniques so that the management of evacuees can be carried out without the intervention of any centralised decision making agent [16, 16, 15, 17, 59, 143]

6 Gene Regulatory Networks

Erol's interest in Gene Regulatory Networks [44], a very important topic in health sciences, started fortuitiously during a visit in the mid 2000's to the well known French gene splicing centre, the Genopole in Evry, near Paris. He had been invited there by a friend, Gabriel Mergui who was then the Genopole's industrialisation and marketing director and who knew about Er's interests in the interface between biology and computer science [51], to give a seminar (on his work in general) and to meet other colleagues.

At the Genopole, he met Professor Gilles Bernot who had known Erol when Gilles was an Assistant at the Laboratoire de Recherche en Informatique, co-founded by Erol at the Université de Paris Sud in Orsay, south of Paris, towards 1978-79. As we say in Turkish "nereden nereye" – as an expression of surprsie about the fortuitious chains of events .. "from where to where". At the Genopole, Gilles (whose background is in Formal Methods in Computer Science) was heading a group the specialised on the formal specification and simulation of Gene Regulatory Networks ... and he handed to Erol some of the early papers on graph models of gene regulatory networks (GRNs). On his return to London, Erol jumped into the subject and came up with the basic model that was published in the previously cited paper [44] and various conferences such as [41]. This initial paper took some time to attract interest from biologists, but it did attract interest in two directions.

It gave rise to an interesting development regarding the use of Erol's GRN model to detect anomalies in genetic data that can help detect or point to predisposition to certain diseases [135, 138, 140, 134, 136, 141]. Typically, this line of work involved using Erol's GRN model to represent a set of gene interactions, including some measure of the time scale of these interactions through appropriate time constants, and then estimating the parameters from measured micro-array from known "normal" (i.e. non-disease) data [139, 137], for instance using a learning algorithm similar to some earlier work [35, 70]. Once this phase of model identification is complete, the model can be used for comparison with other micro-array data, to determine whether this other data shows an anomaly or a propensity for some disease such as cancer [142, 133]. Another line of collaboration also emerged with biologists [152] regarding difficult problems of protein interaction networks. Interestingly enough, Erol also investigated how some of the underlying chemistry could be modelled [47].

7 How About Analytical Models?

In fact, in all of the areas we have listed, Erol's work has been driven by the use, or invention, of appropriate probability models [100]. However, an interesting development has been Erol's incursion into the literature on Statistical Physics with his theoretical papers on analytical solutions for chemical master equations [46], and the related issue of stochastic modeling in gene regulatory networks [45]. Another multi-disciplinary link he has been able to make links the behaviour of adversarial biological populations (such as germs and cells) to viruses in software or in computer networks [42]. His recent work has also linked particle motion in non-homogenous media [50, 6], where he has studied both the time it takes for a set of particles to attain a target, and the energy that is consumed in the process, which is related to the random motion of packets in a very large multi-hop sensor network [43].

Finally in my list of unusual analytic results, let me mention his work where he considers an (economic) market composed of N English auctions [48] where customers arrive according to a random process, select some auction and bid for a product with a probability that may depend on the current value that has been attained by that product, leave the marketplace if they are successful in purchasing the product, and may go to some other auction (or may leave the market) if they are unsuccessful. This analysis leads to a closed form expression for the equilibrium prices of all the products in the market.

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