CSIM

IEEE Technical Committee on Communication Systems Integration and Modeling

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IEEE COMMUNICATIONS SOCIETY

ICC GLOBECOM

IEEE

CSIM E-Letter **Vol. 1, No. 1, November 2006**

CONTENTS

The Communication Systems Integration and Modeling technical committee focus its activities on simulation, analytical tools and measurement of communications links and networks within the IEEE. This committee is approved by the IEEE Communications Society and is governed by the constitution and bylaws of the IEEE as well as the other twenty Technical Committees in the Society.

Communication Systems Integration and Modeling

- JOIN US -

All conference attendees are welcomed to join us in the CSIM Committee meeting at Globecom 2006.
Location: **Russian Hill Room (Stanford Court)**
Date: **Thursday, November 30th**
Time: **12:15 - 14:00**

Future CSIM Meetings

Globecom 2006, Nov-Dec 2006, San Francisco, USA
ICC 2007, June 2007, Glasgow, UK
Globecom 2007, Nov 2007, Washington, D.C., USA

Globecom 2006 CSIM Committee Activities

TUTORIALS

T22: Roadmap to Cross-Layer and Cross-System Optimization for B3G
Topic: Wireless Communications
Date and Time: Friday 1 December, 9:00 – 12:00
Instructors: C. Skianis, NCSR 'Demokritos'; G. Kormentzas, University of Aegean

ACCESS '06 Business Forum

3G Planning and Optimization
Date and Time: Tuesday 28 November, 2006, 9:45am
Chairs: C. Skianis, NCSR 'D'; J. Zhang, Univ. of Bedfordshire

TECHNICAL SYMPOSIA (27 Nov – 1 Dec 2006)

Quality, Reliability, and Performance Modeling for Emerging Network Services
QRP-01: Control of Network Services
QRP-02: Network Design
QRP-03: P2P Networking and Traffic Engineering
QRP-04: Traffic Control for Network Services-I
QRP-05: Traffic Control for Network Services-II
QRP-06: Traffic Engineering
QRP-07: Traffic Modeling and Scheduling
QRP-08: Voice and Video Quality Control
QRP-P1: Topics in Quality, Reliability, and Performance Modeling

World Class Solutions: Networking the Globe
NGL-01: Information Highways and Infrastructures
NGL-02: Pricing and Cost
NGL-03: Services in the Global Era
NET-P1: Topics in Networking & Services

HOW TO JOIN CSIM COMMITTEE

Joining CSIM is easy. Simply send an email to csim-request@comsoc.org. In the body of the message put either subscribe name@domain.com or unsubscribe name@domain.com.
The mailing list, csim@comsoc.org is the communication channel with the CSIM. To post a message send e-mail to csim@comsoc.org.
For any question, please contact Nelson Fonseca at nfonseca@ic.unicamp.br

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A WORD FROM THE E-LETTER E-I-Cs

Charalabos Skianis
Steven Wright

This inaugural issue of the CSIM TC E-Letter arrives to complement and promote a highly active committee within COMSOC that sponsors its traditional workshop CAMAD, as well as special issues in the IEEE Communications Magazine and in the IEEE Journal on Selected Areas in Communications. CSIM is very active in ICC and in GLOBECOM and was one of the co-founders of MILCOM. CSIM has its roots on the Communications Systems Engineering Technical committee and has been chaired by:

2005	-	now	-	Nelson L.S. da Fonseca
2002	-	2005	-	Mike Devetsikiotis
2000	-	2002	-	Mohammad Ilyas
1999	-	2000	-	Hussein Mouftah
1996	-	1999	-	Guy Omydar
1994	-	1996	-	Bill Tranter

The goal of the E-Letter is to disseminate issues that focus on opinions, initiatives, scientific achievements and perspectives of communication systems integration and modeling.

The first issue of the E-Letter features, apart from its informative material on ComSoc related activities, a message from the committee chairs entitled 'The Technical Committee on Communication Systems Integration and Modelling' by Nelson L.S. da Fonseca and Fabrizio Granelli. The issue is further complemented by two perspective articles entitled 'On Internet Measurement Research' by Antonio Pescapè, Alberto Dainotti, and Alessio Botta and 'The Tangram-II Environment' by Edmundo de S. e Silva, Rosa M.M. Leão, Ana P.C. da Silva, Flávio P. Duarte Antonio A. de A. Rocha, Fernando J. S. Filho, Guilherme D. G. Jaime, and Richard R.Muntz.

We renew the invitation to everyone to become regular contributor by submitting proposals for columns, perspective articles and annotated bibliographies. Information for submissions can be found at the CSIM website:
http://dit.unitn.it/~granelli/csim/

Enjoy this issue!

Charalabos Skianis
Steven Wright
Editor-in-Chiefs E-Letter

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

GLOBECOM 2006

27 November - 1 December 2006
San Francisco, California, USA
The objective of this conference is to provide a platform for researchers and technologists to present new ideas and contributions in the form of technical papers, panel discussions, as well as, test-bed implementations and real-world evaluation of many ideas in wireless communications. IEEE Globecom 2006 will feature also two CSIM co-sponsored symposia:

- **Quality, Reliability, and Performance Modeling for Emerging Network Services**
- **World Class Solutions: Networking the Globe**

ICC 2007

24 - 28 June 2007
Glasgow, Scotland, UK
The Conference is aimed at addressing key themes on "Smart Communications Technologies for Tomorrow". The programme will feature a General Conference, ten Specific Symposia, Applications Sessions and Tutorials. IEEE ICC 2007 will feature also one CSIM co-sponsored symposium:

- **Communications QoS, Reliability and Performance Modelling**

CAMAD 2007

3 September 2007
Athens, Greece
CAMAD will be held jointly with PIMRC 2007 in Athens, Greece. It provides a forum for discussion of recent developments on analytical and simulation tools and techniques for the performance evaluation of communications systems.

CONFERENCE CALENDAR

CONFERENCE	LOCATION	INFORMATION
GLOBECOM 2006 IEEE Global Telecommunications Conference	27 November - 1 December 2006 San Francisco, CA USA	http://www.ieee-globecom.org/2006/
GLOBECOM 2007 IEEE Global Telecommunications Conference	26-39 November 2006 Washington DC, USA	http://www.comsoc.org/confs/globecom/2007/
ICC2007 IEEE International Conference on Communications	24-28 June, 2007 Glasgow, Scotland, UK	http://www.icc007.org/
ITC-20 20th International Teletraffic Congress	17-21 June 2007 Ottawa Canada	http://www.itc20.ca/
SPECTS 2006 International Symposium on Performance Evaluation of Computer and Telecommunications Systems	31st July – 2nd August, 2006 Calgary Canada	http://www.scs.org/confernc/summersim/summersim06/cfp/spects06.htm
MASCOTS 2006 Conference on Measurement and Simulation of Computer and telecommunications Systems	11-13 September, 2006 Monterey , CA, USA	http://www.cs.ucsc.edu/mascots06/
OPNETWORK 2006	August 28-Sept 1st, 2006 Washington DC, USA	http://www.opnet.com/opnetwork2006/
VALUETOOLS 2006	October 11-13, 2006 Pisa, Italy	http://www.valuetools.org/
WNS-2 ns-2: the IP Network Simulator	Oct10th, 2006 Pisa, Italy	http://www.wns2.org/

CSIM INTEREST GROUPS

Based on the research interests of CSIM members, there is an ongoing process of formulating several IGs led by experts and active researchers in each area. Detailed info about the IG charters, focus areas of each IG, and their activities are announced at http://dit.unitn.it/~granelli/csim/.

IG Membership: Membership is free. Information about how to join each IG will also be available at each IG will be available at the CSIM Web site.
New IG Proposal: Experts and Active researchers are encouraged to propose new IG to the chair of CSIM at nfonseca@ic.unicamp.br.

AWARDS

Distinguished Service Award – Given to a CSIM member for exemplary service to CSIM TC over a sustained period of time.

Eligibility: The nominee must have been a CSIM TC member for a sustained period of time.

Career Achievement Award – Given to a CSIM member for outstanding contribution over a sustained period of time or a breakthrough contribution.

Eligibility: The nominee must have exhibited outstanding contribution over a sustained period of time or a breakthrough contribution.

Conference Best Paper Award – Given to an outstanding conference paper with a topic consistent with the focus of the CSIM TC.

Eligibility: Any paper published in the proceedings of an IEEE ComSoc- and/or CSIM- sponsored congress/conference/workshop/symposium, in the two years preceding the nomination.

Selection process: The chair of the event from which a paper will be selected shall indicate not less than three consistent within the scope of the CSIM TC. The chair of the conference should select the papers among the ones best ranked. The chair of the conference shall not rank the selected papers when indicating them to the award subcommittee.

Best Paper Award – Given to an outstanding paper with a topic consistent with the focus of the CSIM TC.

Eligibility: Any paper published in an IEEE ComSoc journal/magazine or in the proceedings of an IEEE ComSoc-sponsored conference/workshop/symposium in the previous three years of the nomination. At least three papers should be considered for selection.

MESSAGE FROM THE COMMITTEE CHAIRS

November 2006

The Technical Committee on Communication Systems Integration and Modelling

Nelson L.S. da Fonseca and Fabrizio Granelli

Technical activities of IEEE Communications Society (ComSoc) are organized into Technical Committees, which are intended to "*define and implement the technical directions of the Society. As a fundamental element of the Society all members are invited - and encouraged - to participate in one or more of its technical committees. These committees - networks of professionals with common interests in communications - usually meet twice a year at major conferences*".

The IEEE Communications Society Technical Committee on Communication Systems Integration and Modeling (CSIM) is concerned with disciplines and modelling tools to facilitate the integration of information-transport equipment, subsystems, and networks into communications systems. The activities of the CSIM technical committee are focused on simulation, analytical tools and measurement of communications links and networks. Historically, CSIM has its roots on the Communications Systems Engineering Technical committee.

CSIM TC sponsors its traditional bi-annual workshop CAMAD, as well as special issues in the IEEE Communications Magazine and in the IEEE Journal on Selected Areas in Communications. It is very active in ICC and in GLOBECOM (providing technical sponsorship and TPC member to several symposia) and was one of TCs co-founders of MILCOM.

CSIM activities are mainly discussed during meetings held twice per year, in conjunction with ICC and GLOBECOM, the ComSoc flagship conferences. The other instruments for discussion and collaboration are the mailing list of the committee, csim@comsoc.org, where meetings and other initiatives are advertised, and the committee website, http://www.comsoc.org/~csim/, where all information related to CSIM activities is published. Useful information which can be found on the website includes minutes from previous meetings and agenda of forthcoming meetings, policies and procedures of the TC, useful links for experts working in CSIM-related areas.

Recent activities of the CSIM TC include:

- Organization of CAMAD 2006 (International Workshop on Computer Aided Modeling, Analysis and Design of Communication Links and Networks) as a standalone event after many years of co-location with ICC and GLOBECOM;
- CSIM co-sponsored and co-chaired two ICC 2006 (IEEE International Conference on Communications) symposia: "Communications Quality, Reliability and Performance" and "Next Generation Mobile Networks";
- CSIM is co-sponsoring and co-chairing two symposia at Globecom 2006 (IEEE Global Telecommunications Conference): "Quality, Reliability and Performance Evaluation for Emerging Network Services" and "World Class Solutions: Networking the Globe ";
- CSIM is co-sponsoring and co-chairing the "Communications QoS reliability and performance Modeling" Symposium at ICC 2007 (IEEE International Conference on Communications);

As one of the international leading groups of experts in the topics of modelling and integration of communication systems, CSIM issues awards to authors achieving significant results in those fields, in the form of best paper awards, to express the appreciation for top-level research results. In 2006, a best paper award was given to Leonardo Badia, Nicola Bui, Marco Miozzo, Michele Rossi and Michele Zorzi for the work "On the Exploitation of User Aggregation Strategies in Heterogeneous Wireless Networks" presented at CAMAD 2006 in June 2006.

Moreover, the committee is promoting the activation of Special Groups of Interest (SIGs) to enable small groups of experts to study a specific topic or problem as well as supporting current standardization activities. The latter include for example IEEE P1900 standardization activity of next-generation radio technologies and cognitive radio systems.

Current CSIM officers are Nelson L.S. da Fonseca (Chair, State University of Campinas, Brazil), Pascal Lorenz (Vice-Chair, University of Haute Alsace, France), and Fabrizio Granelli (Secretary, University of Trento, Italy).

For more information, visit the CSIM TC website: http://www.comsoc.org/~csim

We welcome your participation in CSIM activities. **Please, get involved!**

PERSPECTIVE ARTICLE November 2006

On Internet Measurement Research

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I. INTRODUCTION

Internet measurements are fundamental for the networking research community. Through them, we acquire more knowledge on the incredibly complex and ever-changing system the Internet is. By traffic analysis, topology discovery, study of routing dynamics, and measurement of links capacity, delay, etc. we can better understand how this system behaves and how it is evolving. Application of results leads to better control, optimization, and to the design of future network architectures. The analysis of measurements has been proved unvaluable not only for more traditional application fields like performance evaluation, but also for many others. In last years, for example, there has been a boost of network security research based on Internet measurements.

For research results to be significant and reliable, we need repeatable experiments, large data sets, comparable measures, confirmation of the found properties on more observation points and at different times [1]; moreover, we need accurate, up-to-date, and sanitized data. This is not always possible. From one side, there are questions related to the quality of the measurements: what to measure and with which methodology. For example, some traffic analyses simply need flow-level data, or are not significantly affected by packet sampling, while other kinds of studies might be. On the other side, two major obstacles to the large availability of data are security-privacy concerns and costs. Service providers do not want to disclose details on their networks (and how they perform), and they need to preserve their customers privacy. Furthermore, the costs to build and administer a measurement infrastructure and to make reliable and anonymized data available to the public are often very high.

However, the need for large availability of measurement data to all researchers is indisputable [2]. Recently, there have been several discussions on the development of a largescale community-oriented measurement infrastructure [3]. A lot of benefits would come from the adoption of a common framework, and a large-scale distributed infrastructure would yield up-to-date, statistically relevant, and comparable data, necessary to cope with the inherent diversity of the Internet. Also, costs would be much more affordable and clearly funded. However, the discussion of this matter arises more questions than answers [3], and the development of such infrastructure has not yet started. In the mean time, several efforts from different members of the research community to provide measurement data and tools are being made. Some notable examples are represented by the CAIDA (http://www.caida.org), NLANR (http://www.nlanr.org), and MAWI-WIDE (http://tracer.csl.sony.co.jp/mawi) projects which cover a broad scope, or by more specific projects as Crawdad (http://crawdad.cs.dartmouth.edu), which is devoted to build a community for wireless networks measurements. Smaller projects from other research groups [4] also make useful data available.

It has been noted that the networking research community is relatively younger than those of other scientific disciplines, as biology and astronomy, which have partially solved the problem of co-ordinatively sharing experimental data (sometimes with privacy issues involved too). This is a big challenge we still have to face. For example, which tools must be used to perform active network measurements? As regards passive measurements, some recent proposals argue that it would be much simpler to make ISPs and link administrators keep the data private, but allowing researchers to run tools on them to extract data innocuous with respect to privacy and security. But, which data (and how) must be collected [5] and archived? Moreover, measurement data often needs sanitization, which means removing outliers and anomalies caused by spurious data and errors in the various (hardware and software) processing phases. How to solve problems related to

the large amount of data to manage? Several sampling techniques have been developed, but their impact on different kinds of analysis (e.g. for anomaly detection) is still under investigation. Moreover, alternative techniques to reduce the amount of data resulting from measurements are being proposed.

While looking for general consensus on well-established procedures, the research community in parallel develops new measurement methodologies and techniques. New tools are proposed, evaluated, and improved. Also, as the time goes by, we deepen our knowledge on the various aspects related to data collection and analysis (as coping with large data sets, data sanitization, etc.). Further, the Internet is a moving target, causing new measurement requirements to continually arise.

In this article, we briefly give an overview of our contribution to the community regarding some of these aspects. First, with respect to traffic analysis and characterization, our contribution is methodological, because related to specific approaches to what to measure and how. Moreover, in our work in this field, we have faced several of the cited issues, and we sometimes came up with original solutions to cope with them. Second, we have developed, and we are still expanding, a set of tools for network measurements (both active and passive) and for the processing of measurement data sets. Third, we have started a measurement and data collection framework to make the measurement, obtained by using our tools, publicly available. In the next section we will discuss all of these points.

II. TOOLS AND DATA FOR NETWORKING

A. Traffic Measurement and Analysis at Packet-level Network traffic can be observed at different abstraction levels. It is possible to study aggregate traffic or, for example, to separate it into conversations, connections, flows, or packets. While still adopting a multi-level analysis approach, in our studies we focused our attention on packet-level. Packet-level traffic characterizations express traffic in terms of inter-packet time (IPT) and packet size (PS). There are several important advantages in such approach. First of all, it is very straightforward and concise. We do not need to make any assumptions regarding the kind of applications generating traffic, and the same methodology is easily extensible to study different application-level protocols and mixes of them. Moreover, observing traffic at packet-level allows working at the deepest point of view. And the analysis and modeling results can be applied in several contexts. Switching devices often operate on a packet-by-packet basis, and most network performance problems (e.g. delay, jitter, loss) happen at packet level. Packet-level models are also easily applicable to traffic emulation and simulation, which can be used to study network-related issues (measuring delay, jitter, packet loss etc.) or to test network equipment. Traffic at packet level remains observable after encryption made by, for example, end-to-end cryptographic protocols such as SSL or IPSec; this makes packet-level characterization and modeling robust approaches to traffic profiling for anomaly detection.

As regards traffic characterization, we applied this approach in the study of traffic of different applications (HTTP, SMTP, IM, Worms, network games) and it showed some invariant properties with respect to time (time invariance) and to the observed network (space invariance), when sampling large and highly heterogeneous populations of clients and servers (to make our results partially independent from both network conditions and end-to-end congestion control) [6]. We are still expanding the categories of traffic to study, and we are experimenting on the usefulness of packet-level characterization for traffic fingerprinting and profiling, with possible applications in the context of classification and network security. As for traffic modeling, in [7] we developed a packet-level model based on Hidden Markov Models (HMM) which jointly modeled IPT and PS, taking into account mutual dependencies and time structure (by means of autocovariance). Preliminary results showed also that the model has interesting prediction capabilities.

B. Measurement Tools

1) ***Plab***: To capture and analyze traffic we developed Plab, a software platform written in C, based on the Libpcap library (http://www.tcpdump.org), running on FreeBSD, Linux, and MacOS-X. We wrote Plab because we needed a measurement tool which allowed us to focus analysis on packet-level statistics, while still being able to look at network traffic at different levels. By capturing live traffic, or by analysis of trace files in tcpdump format, Plab is currently able to split traffic into different kinds of sessions. Depending on user-specified parameters, a session can be identified by:

- all packets sent and received by a host (*host mode*);
- all packets identified by source and destination IP and ports with a default timeout of 60 seconds (*flow mode*);
- all packets exchanged by 2 hosts related to a specific service (e.g. TCP port 80), with a user definable timeout (*conversation mode*).

Given one of the above modes, sessions are assigned an ID, and for each session the IPT between packets flowing in the same direction are calculated, along with PS. We call such data packet-level data series. Moreover, higher-level measures related to the sessions are stored, as the arrival time of each session, its duration, packet and bytes transmitted for each direction, etc. IPT and PS looking at the aggregate traffic as a whole are also calculated. Also, many processing and filtering capabilities have been implemented, as the ability to decode optional TCP headers as the MSS, or to filter packets or entire sessions based on several criteria. Berkeley Packet Filter syntax (tcpdump-style) is supported at the end of the command line. We added also specific features which are useful for data sanitization. In our studies, we discovered that in some publicly available traffic traces there are some spurious data probably due to hardware/software errors. Among them, for example, we found full chunks of packet sequences duplicated inside the traces. Checks based on packets timestamps inconsistencies, allow removing such duplicates. Data sets extracted by Plab are dumped into text files which can be directly imported under software environments for time series processing and statistical analysis such as Matlab (http://www.mathworks.com) or R (http://www.r-project.org). Plab is open-source and is available at our site (http://www.grid.unina.it/software/Plab).

2) ***Statistical Library***: Once measurement data has been collected, several approaches can be adopted in the analysis of network traffic and Internet measurements in general. Besides more general techniques of statistical analysis, which look at processes from a stochastic point of view by studying marginal distributions, covariances, scaling properties, etc., techniques from the fields of Signal and Image Processing and from Information Theory are successfully used to investigate Internet phenomena and to highlight interesting behaviors. In our studies, we usually work under the Matlab and Octave (http://www.octave.org) environments. In this context, in addition to tools made available by the research community, we developed a number of Matlab functions useful for statistical analysis. Most of them have been written with the explicit purpose to ease the analysis of time series extracted from network traffic traces and active measurements. There are tools to extract, display (also by means of diagrams), and compare statistical properties, or for example, to build packet and byte rate time series sampled with different periods starting from IPT and PS. We also developed scripts which implement an entropy-based technique to heavily reduce large data sets while preserving main statistical properties. Tools for statistical fitting, based on Expectation Maximization, can be used as an aid to build analytical models starting from empirical data. They can then be applied, for example, into traffic emulation contexts (see next subsection). More details on the Statistical Library are available at http://www.grid.unina.it/Traffic/Tools/statools.php, from which it can be freely downloaded.

3) ***D-ITG***: Distributed Internet Traffic Generator (D-ITG) is a platform capable to produce IPv4/IPv6 traffic by accurately replicating appropriate stochastic processes. By specifying the distributions of Inter Departure Time (IDT) and packet size random variables, it is therefore possible to specify different renewal processes for packet generation. We plan to add support for more complicated stochastic processes (taking into account temporal structures and dependencies) in the future. By using characterization and modeling results from literature and from our analysis (Sections II-B.1, II-B.2), DITG is able to replicate statistical properties of traffic as it is generated at the application layer (e.g Telnet, VoIP - G.711, G.723, G.729, Voice Activity Detection, Compressed RTP - DNS, network games). This is obviously done using the right layer-4 protocols. We currently support TCP, UDP, DCCP, ICMP, and we also developed a beta version supporting the new SCTP protocol. Moreover, it is possible to set the TOS (DS) and TTL IP header fields. Besides being a traffic generator, D-ITG can be used as an active measurement tool: oneway-delay (OWD), round-trip-time (RTT), packet loss rate, jitter, and throughput, can be measured and analyzed using the various components of the D-ITG platform: (i) sender; (ii) receiver; (iii) decoder; (iv) log server. The support of different operating systems (Windows, Linux, Linux Familiar) allows to use the distributed platform for

experimentation in complex and heterogeneous environments, by using several senders and receivers. As regards the problem of experiment repeatability, D-ITG allows to use the same random numbers generation seed to perform identical experiments on the same scenario or to study different scenarios under the same traffic generation conditions. D-ITG is able to reach high (receiver and sender) data rates. More precisely, with two Linux boxes connected with a Gb Ethernet the maximum achieved data rate is 612 Mbps. A multithread implementation of D-ITG is currently released as open-source for all supported platforms (http://www.grid.unina.it/software/ITG).

4) ***Hynetd***: In most situations, active and passive measurements can not leave out of consideration knowlegde of network topology. Hynetd[8] (Hybrid Network Topology Discovery) is a tool based on a hybrid methodology that effectively combines active and passive approaches to discover network topologies at router level, starting from the IP address space to explore and SNMP community names. The adopted approach aims to guarantee a high level of completeness and accuracy and to improve the efficiency of the discovery process (both in terms of discovery duration and traffic overhead). Released as open-source (http://www.grid.unina.it/software/TD), Hynetd runs under the Linux operating system.

C. Data

In this subsection we give a very brief overview of the measurement data we started to make available to the community (http://www.grid.unina.it/Traffic/Traces).

1) *Traffic Traces*: As regards traffic traces, we used Plab and Tcpdump to passively capture traffic from the access link of our University network. The UNINA network has a main /16 address space plus few /24 networks and is connected to the rest of the Internet through a link running at about 200 Mbps. Using Plab, we were able to capture full layer-4 headers (e.g. TCP optional headers) without storing payload data for privacy issues. Moreover IP addresses were anonymized, preserving subnet membership, using the tcpdpriv tool from MAWIWIDE. Besides trace files, we also make available time series of IPT and PS extracted from traffic. Some of this data, being related to aggregate traffic captured in absence of network anomalies, has also been used for anomaly detection studies.

2) *Data Traces*: Data traces related to measurements of delay, jitter, packet loss, and throughput, have been obtained by using D-ITG to perform active measurements in various heterogeneous small-scale networks and in a large scale wireless network. With heterogeneous we mean:

- mix of different access network technologies, (Ethernet, 802.11, UMTS, GPRS, ADSL, etc.) and intermediate links.
- Transport protocols (TCP, UDP, DCCP, ..)
- Different end-point hardware (palm-tops, smart phones, laptops, workstations)
- Different end-point operating systems

Also, thanks to a joint research framework [9] with the Network Group of the Deutsche Telekom Laboratories (Berlin), we collected measurements made over a large-scale wireless network sited in Berlin: MagNets multi-hop backbone running on 802.11a/b/g.

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PERSPECTIVE ARTICLE *November 2006*

The Tangram-II Environment

Edmundo de S. e Silva, Rosa M.M. Leão, Ana P.C. da Silva, Flávio P. Duarte
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I. INTRODUCTION

During the last thirty years a number of tools have been developed to analyze the performance and/or the dependability of systems. Some of these tools have been tailored to specific applications, such as reliability/availability and queueing systems, and others allow the specification of general models. During these three decades one could witness the increase in the sophistication of the user interface as well as advances in both analytical and simulation model solution techniques.

With the growth of the Internet, the need for collecting measurements to understand the complex processes that compose its traffic also grew. Therefore a huge effort has been placed on the development of new measurement techniques capable of collecting a large variety of statistics useful to construct models targeted to traffic engineering.

The purpose of this paper is to describe some of the features of the TANGRAM-II tool that has been evolving for more than a decade. The main contributions of the tool are: the development of an integrated environment that includes a unique modeling paradigm for model specification, model solution using analytical solvers or simulators and, experimentation via traffic generators; novel analytical solution methods, and techniques for fluid simulation; new algorithms for active measurements. The applicability of such an environment and its modeling capabilities are shown through simple examples.

II. AN OVERVIEW OF TANGRAM-II

TANGRAM-II [2], [1] is a modeling tool that integrates different environments for developing and analyzing computer and communication models. The tool was designed to support research, application development, and education in performance evaluation by providing the ability to construct a full range of simple to complex models and both analytical and simulation solution methods.

The main purpose of a modeling tool is to provide the necessary support to the analyst to create an abstraction of the system under study and to help answer questions about the system behavior. First, the analyst has to estimate the range of values for the system parameters. These values can be acquired from measurements collected from real systems, via an experimentation laboratory setup, simply "guessed" from past experience, or by comparison against similar systems.

Once the analyst has performed the necessary measurements, she can extract the parameter values from the measurements to feed the model, for instance, to obtain the distribution of a random variable that matches the collected data. The model is then constructed and solved via simulation or an analytical technique. The results obtained from the model undergo another analysis step to provide the answers to the questions faced by the analyst. The whole process is interactive in nature.

TANGRAM-II was built to help the analyst through the modeling steps. The environment includes modules to conduct active measurements in a computer network and collect useful statistics to aid in parameterizing a model. Besides solution methods available in the literature, we incorporated original techniques we developed aiming at providing a rich set of options to the modeler. These include techniques for transient analysis, and for solving a class of non-Markovian models; algorithms for calculating measures useful for traffic analysis and experimentation and those used for active measurements. The tool's fluid simulator has also distinct features from others that allow the construction of generic building blocks for different application domains. The same modeling paradigm is employed both for analytical and simulation models and is carried through the measurement and

experimentation modules.

In addition to its modeling capabilities, TANGRAM-II incorporates multimedia tools (a distributed whiteboard and the video/VoIP Freemeeting tool) and the traffic engineering environment. The multimedia tools are useful for developing a model collectively by a group of users and to conduct real network experiments. The traffic engineering environment provides the means to perform network measurements. Figure 1 illustrates the main components of the TANGRAM-II environment.

III. THE MODELING ENVIRONMENT

The modeling environment of TANGRAM-II allows the user to build and solve models, guiding the analyst through a sequence of steps in the model construction: from the representation of each object, until the measures of interest are obtained via analytical solvers or simulators. The tool includes a library of common objects that can be instantiated and connected to build a new model. New objects are developed using a template object that contains several attributes, such as: declarations, events, messages and initialization. The object's behavior is determined, following the tool's paradigm, from the actions that take place when one of the defined events occurs and how the object reacts when a message is received. The TANGRAM-II paradigm is quite powerful with respect to the ease with which one can specify objects with complex behavior.

Each object has a (possibly empty) set of state variables whose values define its current state. Other types of variables can also be defined for an object such as parameters, and constants. The state variables can change as the result of actions associated with events or a message that is received. Events occur spontaneously when the associated conditions are satisfied. The interval between events is a random variable with a given distribution. When an event occurs, one of a set of actions is executed according to a given probability distribution. The actions are specified in a C-like language (a subset of C constructs) and can alter the current state of the object and/or result in one or more messages being sent to other objects that are connected to the sender. Objects react instantaneously to received messages and, as a consequence, new messages can be sent to other objects, and/or the state variables of the object may be altered. Messages can be broadcast to all objects connected to a channel or directed to a specific object. The sender can include data to a message that is then evaluated by the receiver.

From an analytical model, measures of interest can be obtained from functions of the state variables. Among the measures of interest are: marginal distributions, distributions of functions of state variables, conditional distributions, etc. Another way to calculate measures of interest is via the reward attribute.

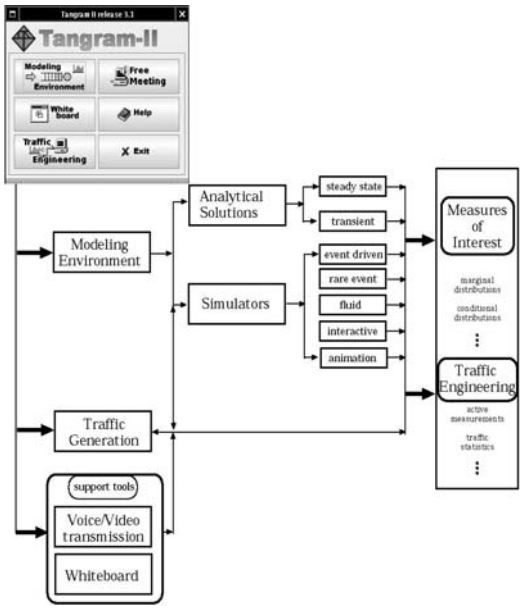

Fig. 1. The TANGRAM-II environment

Each object may have associated with it a reward attribute. TANGRAM-II allows two types of rewards to be defined: a rate reward and an impulse reward. A rate reward has a given name, a set of conditions and associated values. Let $\mathcal{R}$ be a specified reward for an object, $\mathcal{S}_c$ be the set of object states that satisfy condition $\mathcal{C}$ associated with $\mathcal{R}$, and let $r_{\mathcal{S}c}$ be the corresponding value assigned to $\mathcal{R}$. Then, $\mathcal{R}$ gains $r_{\mathcal{S}c}$ Units of reward per time unit the object spends in the set $\mathcal{S}_c$.

On the other hand, impulse rewards are associated with transitions in the model, and are useful to count events. Let $\mathcal{E}$ be an event of an object, p_i the probability of executing action i of $\mathcal{E}$ and $\rho_{\mathcal{E},i}$ the impulse reward associated with the reward attribute $\mathcal{I}$. Then $\mathcal{I}$ gains $\rho_{\mathcal{E},i}$ reward units each time action i of event $\mathcal{E}$ is executed. Impulse rewards can also be associated with messages that are sent or received by an object.

The rewards described above are associated with an object and so the conditions and values have their

scope limited to the set of state variables, events and messages of that object. However, one can also declare global rewards, and include the (time varying) cumulative value of the rewards just as any other variable in assignments to state variables, or in condition and action statements.

Rate and impulse rewards are a powerful approach to obtain measures of interest. One can specify complex conditions with rewards, and values that are constant expressions, dependent on state variables or on the cumulative values of other rewards. The simulators make extensive use of the concept of rewards and they are the manner by which the modeler specifics the measures to be calculated.

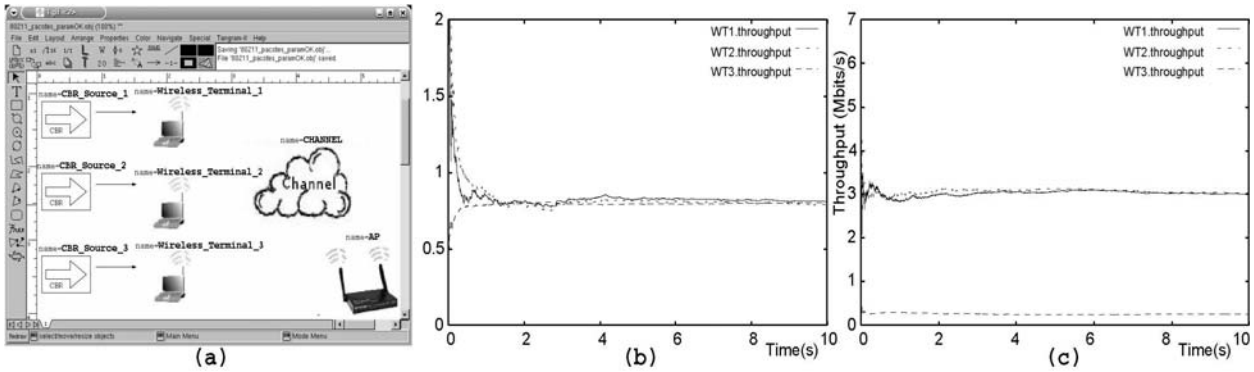

Fig. 2. WLAN IEEE 802.11 simulation

Figure 2(a) illustrates an example which represents a model of a WLAN IEEE802.11. It consists of three wireless terminals (WT) communicating to each other via an access point (AP). We simulate the basic DCF (Distributed Coordination Function) method which is based on the CSMA/CA mechanism. All intrinsic characteristics of the IEEE802.11 standard, such as DIFS, SIFS, Backoff and ack transmission times, were represented in the model. Other two objects complete the WLAN model: (i) the object channel which simulates the wireless channel error (any error model may be described, we used a Gilbert-Elliot model); (ii) the object source which represents an application generating CBR traffic.

We investigate the anomaly inherent to the IEEE802.11 protocol when there are wireless terminals using different transmission rates. Figures 2(b) and 2(c) show the throughput computed for the three wireless terminals. We consider that the terminals WT1 and WT2 transmit at 11Mbps and WT3 transmits at 1Mbps. One can note from Figure 2(b) that the throughput estimated for WT1, WT2 and WT3 is below 1Mbps (despite the 11Mbps transmission capacity assigned to terminals WT1 and WT2). Figure 2(c) illustrates the throughput obtained considering the solution proposed in [3] to mitigate the anomaly problem. In that work the congestion window size is inversely proportional to the wireless terminal transmission rate. Therefore, WT3 has a larger backoff time on the average than WT1 and WT2, and then the terminals achieve a throughput that is proportional to their transmission rates.

IV. TRAFFIC ENGINEERING

The TANGRAM-II traffic engineering environment includes methods for calculating measures useful for traffic model as well as an extensive set of tools for experimentation and collecting parameters from the Internet.

A large set of TANGRAM-II modules is dedicated to traffic modeling and analysis. For instance, the user has the ability to create fluid-flow traffic models, obtain first and second order descriptors analytically or from a trace. Traffic descriptors such as the auto-covariance function $\mathrm{Cov}(t,\tau)=E[IR(t),IR(t+\tau)]-E[IR(t)]^2$ and the index of dispersion for counts $\mathrm{IDC}(\tau)=\mathrm{Var}[N(\tau)]/\mathrm{E}[N(\tau)]$ for a given time lag τ (where $IR(t)$ is the traffic rate (instantaneous reward) at t and $N(\tau)$ is the process that counts the amount of traffic transmitted during $(0,\tau)$. The user can create a performance model using the traffic source under study and analyze the impact of the traffic on the resources during an observation period.

The modeling process is not complete without carefully choosing the parameter values for the model under construction. Obtaining such values may not be an easy task and many tools exist that support collecting statistics from computer systems. This includes tools to measure basic computer components such as disks, hardware and software performance

monitoring systems, and tools for collecting measurements over the Internet.

TANGRAM-II provides an environment to perform active measurements which includes a traf┐c generator and a module to calculate statistics. It is important to note that the packet generation module in TANGRAM-II is not only useful as a supporting facility to active probing but is also useful to provide an artificial load for other purposes. For instance, the user can generate traffic according to the same traffic model used in a performance model. This traffic could be send to specific equipment such as a router or a WWW server.

Among the statistics that can be specified and automatically obtained are: jitter, distribution of packet losses, RTT, one-way delay and the bottleneck capacity of a path. It is interesting to note that, in order to estimate some of the metrics, probes may be generated in different directions between two points (one-way, two-way or round-trip), and employing different traffic generation patterns/models (CBR, Markovian, packet pair, or from a trace).

The computation of the one-way delay is based on time stamps collected at the source and at the destination of the probes. If the clocks of the transmitter and receiver are perfectly synchronized, then the one-way delay of a packet probe is simply the difference between two time stamps for a packet: one issued at the time the probe is transmitted and the other at the arrival time at the destination. However, unless special equipment is used both at the transmitter and receiver (such as GPS - Global Positioning System), the two clocks involved in the measurement are not synchronized. The difference in time between two unsynchronized clocks is called clock offset and the difference in the rate at which each clock advances is the clock skew.

In TANGRAM-II some techniques were implemented to remove the clock skew and the offset. Accurately estimating the one-way delay requires additional issues to be addressed, besides determining the skew and offset between the clocks. For instance, clock updates are not uncommon during the measurement period. Furthermore, received packets may not get time stamped immediately upon arrival. These problems cause inaccuracies in the process of calculating the one-way delay. All these issues are addressed in TANGRAM-II.

Figure 3 presents the one-way delay measured between machines at UFRJ (Federal University of Rio de Janeiro) and UMass (University of Massachusetts, Amherst) and a set of known distributions parameterized from the measured one-way delay trace.

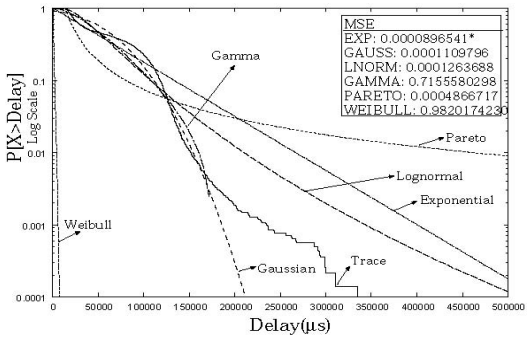

Fig. 3. Distribution of one way delay from UMASS to

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CALL FOR CONTRIBUTIONS

Call for Contributions per Annotated Bibliographies for

The Communications Systems Integration and Modeling Technical Committee

E-Letter

Editors in Chief: Charalabos Skianis, Steven Wright

IEEE Communications Society

The E-letter of the Communications Systems Integration and Modelling Technical Committee of the IEEE Communications Society is an electronic publication that welcomes submissions of annotated bibliographies.

A considerable barrier to entry into a new field of research is to become aware of the existing literature on the topic. The Internet and search engines -such as IEEExplore and, more recently, Google Scholar- have made access conference proceedings and journals immensely easier than it used to be.

However, speed and ease of access, by themselves, do not solve the problem of understanding the state of the art in a given field. Some form of intelligence is needed to filter the raw data represented by the very large number of available publications. Such intelligence may be acquired, in due time, by reading and attending conferences - or it may come from experts already working in the field.

To help fellow engineers and researchers to gain easier access to new fields of activities, the E-Letter of the Communications Systems Integration and Modelling Technical Committee (CSIM) invites experts in the field to submit annotated bibliographies on topics of their choosing.

It is expected that the annotated bibliographies could be of various kinds – from tutorial level bibliographies on the general field of multimedia communications to bibliographies on very specialized subtopics.

If technically feasible, we will adopt an open approach to bibliographies development. Instruments such as wiki are, in fact, making very easy to build knowledge repositories in a collaborative fashion, as shown, for instance, by the astounding success of wikipedia.org. Initial contributions could, therefore, if the original author agrees, be placed on a CSIM wiki to be integrated by comments and modifications made by the community at large. The E-letter will periodically publish selected annotated bibliographies.

Possible topics for annotated bibliographies include, but are not limited to:

- Modeling and Simulation techniques for Integrated Communication Systems
- Simulation techniques for large-scale Networks
- Validation of Simulation Models with Measurements
- Wireless, Mobile, Ad hoc and Sensor Networks
- Integration of wireless/cellular networks and the Internet
- Next Generation Internet
- Autonomic Communication Systems
- Traffic Engineering and Analysis
- Overlay and Virtual Networks
- Cross-Layer Protocol Design
- Network Monitoring
- Internet Traffic Modeling
- Network Measurements
- Simulation and Fast Simulation Techniques
- Modeling, Design of Wireless Ad Hoc Networks
- Network Optimization and Resource Provisioning

Annotated bibliographies will be subject to peer review and, upon acceptance, published in an upcoming issue of the E-Letter. All authors should consider the general nature of the E-Letter's readers. Annotated bibliographies should not have been previously published and must not be submitted for publication as well.

Submission guidelines are as follows: length should be no more than 3000 words (four double column pages).

Annotated bibliographies should be submitted in pdf format by e-mail to the E-Letter Editor C. Skianis at skianis@iit.demokritos.gr.

Deadlines:
Our deadline for receiving annotated bibliographies articles is 60 days prior to the cover date.

CALL FOR CONTRIBUTIONS

Call for Perspective Articles for

The Communications Systems Integration and Modeling Technical Committee

E-Letter

Editors in Chief: Charalabos Skianis, Steven Wright

IEEE Communications Society

Present and future generation networks are offered as a combination of highly diversified technologies in the access, backhaul and core (e.g., wireless, mobile, fixed lines) enabling provision of heterogeneous services. For that reason communication systems integration and modelling exploits important innovations in technical parallel fields, from the physical layer up to the application layer. A beneficial aspect of this phenomenon is that it is pulling together an extremely diverse group of experts specializing in technical converging areas. Even though such an ever-evolving environment promotes interdisciplinary fusion, however, teachers, researchers and professionals of the discipline need access to the most current information about the concepts, issues, trends and technologies in this emerging field. The **E-Letter** of the **Communications Systems Integration and Modeling Technical Committee** wishes to become a fast medium that provides a comprehensive coverage of the most important definitions, concepts, issues, trends and technologies in the field of multimedia communications technology. To this aim, the **E-Letter** of the Communications Systems Integration and Modeling Technical Committee welcomes submissions of Perspective Articles. Perspectives are articles written from the point of view of an expert in the multimedia technology field. They should focus on a particular technology or technology-related issue and how that technology or technology-related issue is being implemented and is impacting the multimedia arena. The E-Letter is seeking perspective articles on the subject of multimedia as it applies to the broad spectrum of multimedia communications. Also manuscripts for short essays and opinions may be considered.

Possible topics include, but are not limited to:

- Modeling and Simulation techniques for Integrated Communication Systems
- Simulation techniques for large-scale Networks
- Validation of Simulation Models with Measurements
- Wireless, Mobile, Ad hoc and Sensor Networks
- Integration of wireless/cellular networks and the Internet
- Next Generation Internet
- Autonomic Communication Systems
- Traffic Engineering and Analysis
- Overlay and Virtual Networks
- Cross-Layer Protocol Design
- Network Monitoring
- Internet Traffic Modeling
- Network Measurements
- Simulation and Fast Simulation Techniques
- Modeling, Design of Wireless Ad Hoc Networks
- Network Optimization and Resource Provisioning

Selected articles will be peer-reviewed and, upon acceptance, published in an upcoming issue of the E-Letter. All authors should consider the general nature of *E-Letter's* readership. Manuscripts should not have been previously published and must not be submitted for publication elsewhere. The **basic format to follow** is:

- Introduce the technology or issue being discussed.
- Discuss the technology's current or future impact on multimedia communications.
- Discuss pros and cons of the technology/issue.
- Discuss what the author is doing regarding this technology/issue.

Other Guidelines are as follows:

- Length should be no more than 2,000 words (three double-column pages).
- Articles should contain no more than 3 Figures. Figures and tables count for 300 words.
- Articles must contain no more than six references.
- Articles should be submitted in a .pdf format by e-mail to the E-Letter Editor C. Skianis at skianis@iit.demokritos.gr.

Deadlines:

Our deadline for receiving completed articles is 60 days prior to the cover date.

CALL FOR CONTRIBUTIONS

Call for Columns for

The Communications Systems Integration and Modeling Technical Committee

E-Letter

Editors in Chief: Charalabos Skianis, Steven Wright

IEEE Communications Society

The **E-Letter** of the **Communications Systems Integration and Modeling Technical Committee** features columns written by recognized experts in all the technological fields related to Communications Systems Integration and Modeling. Columns should give to all the communications systems community partners a possibility to voice their views on the issues, challenges, and opportunities facing industry and academia in connection with the field of Communications Systems Integration and Modeling. Columns featured by the E-Letter of the Communications Systems Integration and Modeling Technical Committee are intended to become a fast medium that provides a comprehensive coverage of the most important issues, concepts, definitions, trends and techniques in the field. To this aim, the E-Letter is looking for a group of insightful and diligent volunteers to serve as regular (or sporadic) columnists on the 2006-2007 term. Columns will be considered on all the aspects of Communications Systems Integration and Modeling. The E-Letter offers an unparalleled opportunity for potential columnists to express thoughts and opinions to a community-wide audience provided that the following instructions are followed.

What does it mean to be a columnist for the E-Letter?

It means keeping informed about Communications Systems Integration and Modeling issues, as well as news and scientific headlines. It means thinking about the issues that matter to readers in the context of the Communications Systems Integration and Modeling community. It means undertaking substantial research. It means writing clearly and effectively (perhaps provocatively) to demonstrate an opinion piece that can be easily followed.

What is a column for the E-Letter?

Columns are very brief articles in form of opinions, short essays, or news written from the point of view of an expert. Even though a column is, in essence, a timely and relevant piece of opinion writing, each good E-Letter column should relate an opinion to the most relevant topics of the Communications Systems Integration and Modeling community. Also controversial issues can make for a great column, but only if they sound interesting for the Communications Systems Integration and Modeling community.

Who can be a columnist for the E-Letter?

Well known experts, skilled practitioners, professionals and researchers are welcome to submit ideas for E-Letter columns. Also contributions from Chairs or members of the various Interest Groups of the Communications Systems Integration and Modeling Technical Committee, as well as from any member of ComSoc, discussing issues related to the activities of their groups, are greatly appreciated. The real and final qualification is having something interesting to say about Communications Systems Integration and Modeling and its surrounding community, and a willingness to put in the necessary time and effort.

Selected columns will be evaluated by the E-Letter Editors and, upon approval, published in an upcoming issue of the E-Letter. The basic format to follow is:

- Length should be no more than 700 words in length (one double-column page).
- Columns should contain no Figures.
- Columns should contain no References.
- Columns should be submitted as plain text (ASCII) by e-mail to E-Letter Editor C. Skianis at skianis@iit.demokritos.gr.

Deadlines:

Our deadline for receiving columns is 15 days prior to the cover date.