



ITC 30 in Vienna
4–7 September 2018
University of Vienna, Austria

Preface

**Proceedings of the
30th International Teletraffic Congress
ITC 30**

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(ITC 30 TPC Co-Chairs)

Volume Editors

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Proceedings of the 30th International Teletraffic Congress (ITC 30). The meeting is held during 4-7 September 2018 at the University of Vienna, Vienna, Austria. ITC 30 is technically co-sponsored by IEEE Communications Society (IEEE ComSoc) and the Information Technology Society within VDE (ITG VDE), and in cooperation with ACM SIGCOMM.



ITC is the first international conference in networking science & practice, first held in 1955.

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Welcome Message from General Co-Chairs

On behalf of the Organizing Committee, we are delighted to welcome you to the 30th International Teletraffic Congress (ITC 30) to be held on September 4-7, 2018, at the University of Vienna, Austria.

ITC was founded back in 1955 by enthusiastic scientists and engineers who were willing to deploy networks holistically. Since then, it has established a multi-decade tradition as the primary forum for presenting and discussing the latest technical advances in the broad areas of teletraffic models, network systems, and measurements. Its inherent roots in solid methodological foundations have allowed ITC to adapt constantly its technological focus without losing its original identity. Today, ITC continues to serve as a broad and lively community for researchers and practitioners dedicated to advancing the limits of knowledge in networking.

ITC 30 focuses on the future smart world and how to build it using recent advances in networking science & practice, including key challenges arising from the upcoming interconnection of massive numbers of devices, sensors, and human beings. To this end, cutting-edge papers spanning both theory and experimentation will be presented which will address all areas of networking, ranging from traffic engineering and control with application also to emerging softwarized/virtualized network paradigms, up to innovative wireless scenarios brought about by the emergence of 5G and IoT systems. Moreover, ITC 30 aims to bridge the gap between performance modelling and real-life operational aspects, including research works which leverage measurement data to provide a better understanding of the wired and wireless networks' operation under realistic conditions.

We are happy that Debasis Mitra (Columbia University, USA) discusses the future smart world in his keynote on "An Engineer's Perspective on Some Societal Problems". In Debasis' view, this engineer relies on models, analysis and model-based experimentation to explore some societal problems, including the role of knowledge, its nurture and impact in high-tech industries, the survival of Best Effort services in the Internet in an uncertain regulatory environment, as well as inter-organizational working for content delivery in an increasingly content-centric Internet.

As one of the highlights of ITC 30, the ITC 30 Networking Science Vision Day will be organized on Wednesday, September 5, 2018, presenting several top experts from the networking community who will offer their views and visions on the future smart world and the role of networking research in it. The key question is "Networking Science - Where Are We Heading To?", and Philippe Jacquet (Nokia Bell Labs, France) will focus his corresponding talk on "Wireless and the City". Despite being the place where the majority of the human population lives and interacts, cities are in general among the worst environments for radio communication. Hence, this talk reviews the theories of wireless networks at the scale of a full city. Alexandre Proutiere (KTH Stockholm, Sweden) considers "Data-driven Decisions in Communication Systems", surveying recent advances in the use of online learning methods on the design of optimal (and sometimes distributed) radio access protocols in wireless networks as well as enhanced resource allocation schemes for better Quality of Experience. Mikael Touati (Orange Labs, France) discusses "Networks and Market Mechanisms", in particular, mechanisms used to match, allocate or trade resources in markets and survey mechanisms with and without money, their use-cases, properties and solution concepts. Piet Van Mieghem (TU Delft, The Netherlands) overviews "Network Science and Telecommuni-

cations". From the perspective of telecommunications, his personal view on the history of Network Science and its fascinations is provided. Then, the epidemic spread on networks, a way of diffusing information in a network, is discussed. The sessions of the Vision Day will be chaired by Helmut Leopold, Head of the Center for Digital Safety & Security at the Austrian Institute of Technology (AIT), who will bring in his broad experience in the field and thus will additionally stimulate the discussions, which are complemented by the perspectives of young researchers as well as a session on doctoral dissertations.

The Network Science Vision Day will be closed by the ITC 30 award session in which the ITC Rising Scholar Award and the Arne Jensen Lifetime Achievement Awards will be given to the recipients. The ITC Rising Scholar Award has been created in order to recognize young researchers with significant contributions to the ITC Community in the field of performance, traffic modelling, and control in communication networks and networking science. The Arne Jensen Lifetime Achievement Award is given to an individual who has provided an exceptional contribution to traffic modelling, control and performance, and dedication to the teletraffic community.

This year's ITC is arranged around four different areas: Performance Evaluation, Control and Optimization Chairs; Network Measurements and Big Data; Networking Architectures and Paradigms; and Wireless and Cellular Networks. The ITC technical program contains 18 full papers and 5 demo and poster papers across these areas. ITC 30 has a dedicated session with 5 accepted papers on doctoral dissertations which are related to the ITC topics in the field of performance, traffic modelling, and control in communication networks and networking science. The idea of the dissertation session is to give PhD students a forum to present their PhD to a larger audience during the ITC main conference. In addition, 2 PhD work-in-progress papers will be presented as part of the ITC conference. We would like to thank the chairs of the PhD session, Ramón Agüero (University of Cantabria, Spain), Thomas Bauschert (TU Chemnitz, Germany), Ognjen Dobrijević (University of Zagreb, Croatia), and Andreas Timm-Giel (Hamburg University of Technology, Germany).

In addition to the ITC conference, we also sponsor a workshop dedicated to "Network Calculus and Applications" (NetCal 2018). Network Calculus is a branch of queueing theory which aims at exploring the bounding behavior for queues. The workshop is composed of 10 original papers reporting mature or early-stage results in network calculus theory and its applications to different areas. Jean-Yves Le Boudec (EPFL, Switzerland) will give a keynote talk on "Network Calculus: From Integrated Services to Deterministic Networking". We would like to thank the workshop organizers for this successful event at ITC: Yuming Jiang (Norwegian University of Science and Technology, Norway), Jens Schmitt (University of Kaiserslautern, Germany), and Markus Fidler (Leibniz Universität Hannover, Germany).

We also thank ITC's International Advisory Committee (IAC) for their support of student travel grants and best paper awards. The IAC has graciously decided to offer a number of travel grants available to full-time students. We are also very grateful to IFIP TC6 WG6.6 for sponsoring additional student travel grants. ITC 30 has set up two prestigious awards: The Best Paper Award will be granted to the best contribution presented at ITC 30, while the Best Student Paper Award will be conferred upon the best paper whose first author is a full-time student at the time of submission of the paper and is the presenter. These awards will be selected based on the scientific merit of the publication as well as the quality of the oral presentation at ITC 30.

A successful conference requires dedication and engagement of many people. We would like to especially recognize the never-ending efforts of the three TPC Co-Chairs, Eitan Altman (INRIA Sophia-Antipolis, France), Giuseppe Bianchi (University of Rome Tor Vergata, Italy), and Thomas Zinner (TU Berlin, Germany), who have done a magnificent job in compiling this excellent technical program and who have put a lot of efforts and personal enthusiasm to make ITC 30 a lively and attractive event. Thank you so much!

Our thanks go to the Workshop Chairs, Chiara Buratti (University of Bologna, Italy) and Poul E. Heegaard (NTNU Trondheim, Norway), and to the Demo and Poster Chairs, Michael Jarschel (Nokia, Munich, Germany) and Corinna Schmitt (Universität der Bundeswehr München, Germany) for all their efforts. We thank Christopher Metter and Florian Metzger (both University of Würzburg, Germany), who have served as Web & EDAS Co-Chairs. Ravi R. Mazumdar (University of Waterloo, Canada) as Award Chair will lead the best paper award selection process. Prosper Chemouil (Orange Labs Networks, France) organized the student travel grant jury and reviewed the student travel grant applications. Our special thanks go to Michela Meo (Politecnico di Torino, Italy) as International Advisory Council Chair of ITC.

Our Publicity Co-Chairs, Pedro Casas (AIT Vienna, Austria), Frank Restuccia (Northeastern University, Boston, USA), and Sheng Zhou (Tsinghua University, China), have done a great job in disseminating information about ITC 30 throughout the world. Our Publication Co-Chairs, Matthias Hirth (University of Würzburg, Germany) and Lea Skorin-Kapov (University of Zagreb, Croatia), very efficiently organized the publication process with the CPS publisher and took care of the technical sponsorship with IEEE ComSoc and ACM SIGCOMM.

We greatly appreciate everyone who submitted papers to the conference, particularly those who will be presenting their work at ITC 30. The IEEE, IEEE Communications Society, IFIP - International Federation for Information Processing, and the Information Technology Society within VDE (ITG VDE) kindly agreed to technically co-sponsor ITC 30, and ACM SIGCOMM helped us through their in-cooperation agreement. Last but not least we are very grateful for the financial support by the Faculty of Computer Science of University of Vienna, as well as the Austrian Electrotechnical Association (OVE) and the City of Vienna for their generous support with organizing the social events. And of course, we thank all members of the COSY Research Group of University of Vienna for the local arrangements.

Having finished all preparations, we are now looking forward to a wonderful scientific event in a magnificent city, and would like to cordially welcome all participants of ITC 30 here in Vienna!

Peter Reichl (University of Vienna, Austria)
Tobias Hoßfeld (University of Würzburg, Germany)

September 2018

Welcome Message from Technical Program Co-Chairs

On behalf of the Technical Program Committee, we are delighted to welcome you to ITC 30, the 30th International Teletraffic Congress. ITC 30 takes place between September 4th -7th, 2018 in Vienna, Austria.

ITC boasts a rich tradition since its founding in 1955 and has evolved into one of the most reputable networking conferences with a particular emphasis on rigorous methodology. Over more than 50 years ITC has provided a forum for leading researchers from academia and industry to present and discuss key technological and methodological advances in the design, performance evaluation and control of communication networks, protocols and applications and in traffic measurement and management. ITC 30 continues this tradition by featuring the theme "Teletraffic in a Smart World", which is well aligned with the proliferation of the Internet of Things and the corresponding challenges to networked systems and services.

In terms of organization, ITC 30 adopted the thematic "Areas" implemented by the previous ITC conferences. Each Area was run by an individual Technical Program Committee whose expertise best suited the Area's topics. ITC 30 was structured into four regular Areas and one Demo and Poster Session.

Area 1: Performance Evaluation, Control and Optimization

Chairs: Sem Borst (TU Eindhoven, The Netherlands),
Markus Fiedler (BTH Karlskrona, Sweden),
Bruno Tuffin (INRIA Rennes, France)

Area 2: Network Measurements and Big Data

Chairs: Oliver Hohlfeld (RWTH Aachen, Germany),
Fabián Bustamante (Northwestern Univ., USA),
David Malone (Hamilton Institute, Ireland)

Area 3: Networking Architectures and Paradigms

Chairs: Andreas Kassler (University of Karlstad, Sweden),
Stefano Secci (Sorbonne UPMC, France),
Roberto Bifulco (NEC, Germany)

Area 4: Wireless and Cellular Networks

Chairs: Steven Latre (University of Antwerp, Belgium),
Albert Banchs (UC3 Madrid, Spain),
Shiwen Mao (Auburn University, USA)

Demo and Poster Session

Chairs: Michael Jarschel (Nokia, Munich, Germany),
Corinna Schmitt (Universität der Bundeswehr München, Germany)

ITC 30 attracted 46 full paper submissions across all areas and 9 demo and poster submissions. The authors of the submitted papers were from 25 different countries, out of which 79% were from Europe, 8% from the USA and Canada, 13% from Asia/Pacific and Latin America.

Each submitted full paper was reviewed by at least three experts manually assigned by the Area and TPC chairs. In special cases, when the discussion of reviewers did not converge, additional expert reviews were requested. In total, there were 156 completed reviews for the 46 submitted full papers, i.e., an average of 3.4 reviews per paper. The area chairs and

TPC members fostered discussions to converge the reviewers' recommendations towards a decision. The area chairs provided a ranked list of papers with suggestions for papers to be either accepted, rejected, or further discussed. A full-day online TPC meeting was held on May, 7th, 2018. The purpose of the online meeting was to jointly discuss the lists provided by the Area Chairs, and especially to make final decisions accounting for the Areas altogether. The TPC decided to accept 18 out of the 46 submitted full papers, with the overall acceptance rate of 39.1%. The submitted poster and demo papers were reviewed by at least three experts manually assigned by the area chairs. Based on the reviewers' recommendations and further discussions the Area and TPC chairs decided to accept 5 out of 9 submitted papers resulting in an acceptance rate for posters and demos of 55.6%.

To enhance the integration of early-stage researchers a dedicated session on doctoral dissertations related to the ITC topics was newly established. The idea of the dissertation session is to give PhD students a forum to present their PhD to a larger audience during the ITC main conference. Each of the papers received at least three reviews. Based on the recommendations of the reviewers and additional discussions by the TPC chairs, 5 papers out of 5 submitted papers were accepted.

The ITC program is complemented by four invited papers highlighting teletraffic research in the area of next generation networks and wireless networks. Each of the paper received three reviews and was discussed by Area and TPC chairs.

The accepted papers are to be presented during the main conference in a single-track format. A selection of the best papers will be published by the international scientific journal Performance Evaluation in a special issue, after being subject to an additional refereeing process according to the journal's standards.

ITC 30 was possible thanks to the significant effort of many people to whom we would like to express our sincere gratitude. Researchers submitted interesting technical papers; TPC members and reviewers ensured a high quality of the reviewing process; keynote speakers have provided additional value to the conference. We are also grateful to the members of the International Advisory Council (IAC) of the ITC for their support. We further express our special thanks to all co-chairs of the various activities and committees, and to the sponsors. We finally thank all attendees, whose participation is always essential to the success of the conference.

Eitan Altman (INRIA Sophia-Antipolis, France)
Giuseppe Bianchi (University of Roma Tor Vergata, Italy)
Thomas Zinner (TU Berlin, Germany)

September 2018

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Area 2: Network Measurements and Big Data

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Steve Uhlig	Queen Mary University of London, UK
Zach Bischof	IJ, Japan

Area 3: Networking Architectures and Paradigms

Antonio Cianfrani	University di Roma 1, Italy
Bengt Ahlgren	RISE-SICS, Sweden
Christian Esteve Rothenberg	University of Campinas, Brazil
Danny Tsang	Hong Kong University of Science and Technology, China
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Thomas Bauschert	Tu Chemnitz, Germany
Torsten Braun	University of Bern, Switzerland
Wolfgang Kellerer	TUM, Germany
Zhenhua Liu	Lawrence Berkeley National Lab, USA

Area 4: Wireless and Cellular Networks

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Azzedine Boukerche	University of Ottawa, Canada
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US Navy Research Labs, USA
IMDEA Networks Institute, Spain
New York University, USA

Tuesday 4th September, 2018

- 09:00 – 10:30 Opening & **Keynote** by Debasis Mitra (Columbia University)
An Engineer's Perspective on Some Societal Problems
- 10:30 – 11:00 Coffee break
- 11:00 – 12:30 **Session 1: Performance Evaluation**
Evaluating Rare Events in Mission Critical Dispatching Systems by Esa Hyttiä; Rhonda Righter
Statistical Delay Bounds for Automatic Repeat Request Protocols with Pipelining by Mark Akselrod; Markus Fidler
Whittle Index Approach to Energy-Aware Dispatching by Samuli Aalto; Pasi Lassila
On Occupancy Based Randomized Routing Schemes in Large Systems of Shared Servers by Thirupathaiiah Vasantam; Ravi R Mazumdar
- 12:30 – 14:00 Lunch
- 14:00 – 15:30 **Session 2: Mobile Edge Computing**
Online Algorithms for Cost-Effective Cloud Selection with Multiple Demands by Youngmi Jin; Michiaki Hayashi; Atsushi Tagami
Performance Evaluation of Service Functions Chain Placement Algorithms in Edge Cloud by Lam Dinh-Xuan; Michael Seufert; Florian Wamser; Constantinos Vassilakis; Anastasios Zafeiropoulos; Phuoc Tran-Gia
A Popularity-Based Approach for Effective Cloud Offload in Fog Deployments by Marcel Enguehard; Giovanna Carofiglio; Dario Rossi
Time Constrained Service-aware Migration of Virtualized Services for Mobile Edge Computing by Peiyue Zhao; György Dán
- 15:30 – 16:00 Coffee break

Tuesday 4th September, 2018 (cont.)

16:00 – 17:30 **Session 3.1: PhD Workshop**

Optimal Fairness and Quality in Video Streaming With Multiple Users by Christian Moldovan; Tobias Hoßfeld; Poul E. Heegaard; Lea Skorin-Kapov

Performance Evaluation of Container based Virtualization on Embedded Microprocessors by Vivian Noronha; Thomas Bauschert ; Ekkehard Lang; Maximilian Riegel

Session 3.2: Madness Session

WhatsAnalyzer: a Tool for Collecting and Analyzing WhatsApp Mobile Messaging Communication Data by Anika Schwind; Michael Seufert

Effects of Adaptive Streaming Optimizations on the Perception of 360° Virtual Reality Video by Joris Heyse; Maria Torres Vega; Tim Wauters; Femke De Backere; Filip De Turck

Exploring the Transmission Behaviour of Overwatch: The Source of Lag by Florian Metzger; Roman Heger

Deriving YouTube Playout Phases from Encrypted Packet Level Traffic by Stefan Geissler; Stanislav Lange; Florian Wamser; Tobias Hoßfeld

RB-OLITS: A Worst-case Reorder Buffer Size Reduction Method for 3D-NoC based on Ohm's Law-like Traffic Splitting by Zhenmin Li; Renshi Fan; Du Gao-ming; Yifan Cao; Zhonghai Lu; Gao Ming-lun

Evening Welcome Reception

Wednesday 5th September, 2018

- 09:00 – 10:30 **Session 4.1: Vision Day A**
Network Science and Telecommunications by Piet Van Mieghem
Networks and Market Mechanisms by Mikaël Touati
- 10:30 – 11:00 Coffee break
- 11:00 – 12:30 **Session 5: Young Researchers Session**
Online Resource Allocation in Dynamic Optical Networks by Ronald Romero Reyes; Thomas Bauschert
Optimization of Controller Placement and Information Flow in Softwarized Networks by Stanislav Lange
Synopsis of the PhD Thesis -Network Computations in Artificial Intelligence by Decebal Constantin Mocanu
Cognitive Real-time QoE Management of Video Streaming Services by Maria Torres Vega; Antonio Liotta
From Self-Sustainable Green Mobile Networks to Enhanced Interaction with the Smart Grid by Daniela Renga; Michela Meo
- 12:30 – 14:00 Lunch
- 14:00 – 15:30 **Session 4.2: Vision Day Session B**
Wireless and the City by Philippe Jacquet
Data-driven Decisions in Communication Systems by Alexandre Proutiere
- 15:30 – 16:00 Coffee break / Poster & Demo Session
- 16:00 – 17:00 ITC Award Session
- Evening Gala Dinner

Thursday 6th September, 2018

- 09:00 – 10:30 **Session 6: Wireless and Cellular Networks**
Performance Evaluation of Scheduling Schemes for D2D Communications by Antonia Maria Masucci; Philippe Olivier; Alain Simonian
Can Decentralized Status Update Achieve Universally Near-Optimal Age-of-Information in Wireless Multiaccess Channels? by Zhiyuan Jiang; Bhaskar Krishnamachari; Sheng Zhou and Zhisheng Niu
Limited by Capacity or Blockage? A Millimeter Wave Blockage Analysis by Ish K Jain; Rajeev Kumar; Shivendra Panwar
Enabling a Win-Win Coexistence Mechanism for WiFi and LTE in Unlicensed Bands by Ilenia Tinnirello; Domenico Garlisi; Fabrizio Giuliano
- 10:30 – 11:00 Coffee break
- 11:00 – 12:30 **Session 7: Network Measurements**
Can WebRTC QoS Work? A DSCP Measurement Study by Runa Barik; Michael Welzl; Ahmed Mustafa Elmokashfi; Thomas Dreibholz; Stein Gjessing
LENTA: Longitudinal Exploration for Network Traffic Analysis by Andrea Morichetta; Marco Mellia
TimeWeaver: Opportunistic One Way Delay Measurement via NTP by Ramakrishnan Durairajan; Sathiya Kumaran Mani; Paul Barford; Robert Nowak; Joel Sommers
A Heuristic Approach to Assess the Traffic Matrix of an ISP exploiting Segment Routing Flexibility by Antonio Cianfrani; Marco Polverini; Trupti Nalawade
- 12:30 – 14:00 Lunch
- 14:00 – 15:30 **Session 8: Network Architectures and Paradigms**
A Semi-Virtualized Testbed Cluster with a Centralized Server for Networking Education by Mark Schmidt; Andreas Stockmayer; Florian Heimgaertner; Michael Menth
Performance Implications of Packet Filtering with Linux eBPF by Dominik Scholz; Daniel Raumer; Paul Emmerich; Alexander Kurtz; Krzysztof Lesiak; Georg Carle
Impact of TCP BBR on CUBIC Traffic: A Mixed Workload Evaluation by Habtegebrel Haile; Anna Brunstrom; Karl-Johan Grinnemo; Per Hurtig; Eneko Atxutegi; Fidel Liberal; Åke Arvidsson
Application-Agnostic Offloading of Datagram Processing by Oliver Hohlfeld; Jens Helge Reelfs; Jan R uth; Florian Schmidt; Torsten Zimmermann; Jens Hiller; Klaus Wehrle

Thursday 6th September, 2018 (cont.)

15:30 – 16:00 Coffee break

16:00 – 17:30 **Session 9: Application Scenarios and Farewell Session**

Improving Mobile Video Quality Through Predictive Channel Quality Based

Buffering by Jan Willem Kleinrouweler; Britta Meixner; Joost W

Bosman; Hans van den Berg; Rob van der Mei; Pablo Cesar

Network-level Cooperation in Random Access IoT Networks with

Aggregators by Nikolaos Pappas; Zheng Chen

International Workshop on Network Calculus and Applications (NetCal 2018)

Friday 7th September, 2018

- 09:00 – 09:15 Opening
- 09:15 – 10:15 **Keynote** by Jean-Yves Le Boudec (EPFL, Switzerland)
Network Calculus, from Integrated Services to Deterministic Networking
- 10:15 – 10:30 Coffee Break
- 10:30 – 12:30 **Session I: Applications**
Latency and Backlog Bounds in Time-Sensitive Networking with Credit Based Shapers and Asynchronous Traffic Shaping by Ehsan Mohammadpour; Eleni G Stai; Maaz Mohiuddin; Jean-Yves Le Boudec
Multi-interface Communication: Interface Selection under Statistical Performance Constraints by Sounak Kar; Amr Rizk; Markus Fidler
Energy Management in Wireless Communications with Energy Storage Imperfections by Sami Akin
Stochastic Guarantees for Rate-Adaptive Streaming by Mark Akselrod; Markus Fidler; Ralf Lübben
- 12:30 – 13:30 Lunch
- 13:30 – 15:00 **Session II: Service and Arrival Characterizations**
A Fluid-Flow Interpretation of SCED Scheduling by Jorg Liebeherr
A General Per-Flow Service Curve for GPS by Almut Burchard; Jorg Liebeherr
Integrating Fractional Brownian Motion Arrivals into the Statistical Network Calculus by Paul Nikolaus; Sebastian Henningsen; Michael A. Beck; Jens Schmitt
- 15:00 – 15:15 Coffee Break
- 15:15 – 16:45 **Session III: Analysis Techniques**
The Case for a Network Calculus Heuristic: Using Insights from Data for Tighter Bounds by Fabien Geyer; Georg Carle
On Kernels and Queues: When Network Calculus Meets Analytic Combinatorics by Anne Bouillard; Céline Comte; Élie de Panafieu; Fabien Mathieu
Network Calculus for Mean Delay Analysis through a Network by Fabrice M. Guillemin; Ravi R Mazumdar; Catherine Rosenberg; Yu Ying
- 16:45 – 17:00 Closing

ITC 30 Sponsors



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