2016 International Teletraffic Congress (ITC 28) Report

The First International Conference in Networking Science & Practice

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ABSTRACT

The 28th International Teletraffic Congress (ITC 28) was held on 12–16 September 2016 at the University of Würzburg, Germany. The conference was technically cosponsored by the IEEE Communications Society and the Information Technology Society within VDE, and in cooperation with ACM SIGCOMM. ITC 28 provided a forum for leading researchers from academia and industry to present and discuss the latest advances and developments in design, modelling, measurement, and performance evaluation of communication systems, networks, and services.

The main theme of ITC 28, *Digital Connected World*, reflects the evolution of communications and networking, which is continually changing the world we are living in. The technical program was composed of 37 contributed full papers and 6 short demo papers presented in two parallel sessions, three keynote addresses and a demo session. The technical program of the ITC main conference was presented in the form of double-track sessions. Three workshops dedicated to timely topics were sponsored: Programmability for Cloud Networks and Applications, Quality of Experience Centric Management, Quality Engineering for a Reliable Internet of Services. ITC 28 Homepage: https://itc28.org/

1. INTRODUCTION

The evolution of communication and networking is continually changing the world we are living in. The digital connected world is triggered by the advances in telecommunications, the global penetration of the Internet, the massive deployment of mobile communications and optical fiber, the adoption of collaborative networking and social networks, the ever-increasing speed and flexibility of new communication technologies, networks, user devices, and applications, and various operational challenges arising from these developments.

ITC was originally established as the first international conference on networking science and practice. Since its inception in 1955, ITC has contributed to the evolution in communication and networking with state-of-the-art measurement studies, performance analyses of new technologies, recommendations for provisioning and configuration, and the advancement of new methodologies for network design and analysis. It gathers together a wide and lively community of researchers and practitioners dedicated to pushing the envelope in the area of networking. As such, ITC has provided a forum for leading researchers from academia and industry to present and discuss the latest advances and developments in design, modelling, measurement, and performance evaluation of communication systems, networks, and services. ITC's inherent roots in solid methodological foundations has allowed it to constantly adapt its technological focus without losing its original identity. ITC continues to serve as a broad and lively community for researchers and practitioners dedicated to advancing the limits of knowledge in networking. As such, ITC regularly organizes such events as congresses, specialist seminars and workshops for experts to gather and discuss the latest developments in design, modelling, and performance evaluation of communication systems, networks, and services.

ITC 28 has continued this tradition, while employing some new approaches to attract high-quality papers and researchers. The concept of *areas* was introduced into this offering of ITC. In particular, ITC 28 was structured into eight different areas, each of which addressed a hot topic in networking. Each area was chaired by two internationally well recognized experts in that area. The area chairs organized a smaller TPC per area. The idea was that the area chairs invited experts for their areas from the ITC community as well as other well-known experts worldwide. On the one hand, the concept was aimed at expanding the ITC community and attracting high-quality submissions. On the other hand, the subdivision into areas helped to improve the quality of the review process. The area chairs assigned the reviews to experts in their area and evaluated all papers in their domain.

In addition, a demo session was introduced into the ITC 28 program that cut thematically across the areas. The demo session was distinguished from the regular sessions only in the presentation format. "Demo papers" are papers whose content is best understood by an audience if the material is demonstrated rather than presented in a lecture style slide presentation. With the demo session, we aimed to provide a different kind of interaction among the participants, so as to make ITC more attractive for other communities. The eight different areas and the demo session are listed below along with the associated area chairs indicated in parentheses.

Smart cities and IoT (Alberto Leon-Garcia, Yanmin Zhu)
Cloud services & networking (Arup Acharya, Patrick Lee)
Mobile, wireless and 5G (Kin Leung, Thomas Hou)
Next generation and future Internet architectures (Michael Zink, Thomas Zinner)

Network & traffic management (Florin Ciucu, Peter Reichl)
Network design and optimization (Thomas Bauschert, Eric Wong)
Network measurements and analysis (Marco Mellia, Mark Squillante)
Networked applications (Zhu Li, Lea Skorin-Kapov)
Demonstration Session (Mark Berman, Michael Jarschel, Rick McGeer)
Descriptions of the areas and their main focus can be found online at https://itc28.org/.

2. SUBMISSION AND REVIEW PROCESS

ITC 28 attracted 116 international paper submissions across all areas, while 157 papers were registered. The 116 papers were submitted by authors from 33 different countries, out of which 20% were from the USA and Canada, 68% from Europe/Middle East/Africa, 11% from Asia/Pacific and the remainder from Latin America.

Each submitted paper was reviewed by at least three experts assigned by the area chairs and TPC chairs. All papers were single-blind reviewed. In special cases, when the discussion of reviewers did not converge, additional expert reviews were requested to come to a solicited decision. In total, there were 420 completed reviews for the submitted papers, i.e., an average of 3.6 reviews per paper. The area chairs and TPC members fostered discussions to facilitate the convergence of the reviewers' recommendations towards a final decision for each paper. In total, 300 discussion posts were provided for papers with diverging review scores. The area chairs provided a ranked list of papers with suggestions for papers to be accepted and rejected.

A full-day TPC meeting was held at the University of Würzburg, Germany, from 9.00 19.30 on May 3, 2016. The meeting was structured according to the areas. The area chairs presented the papers submitted to their area and the list of ranked papers. Based on the reviews and the recommendations from the area chairs, decisions were made as to which papers were to be accepted or rejected per area. In addition, for each area, a few reserve papers were identified. It should be noted that the reserve papers were also considered strong contributions. After the discussion of all areas, the reserve papers were discussed by the physically attending TPC members in Würzburg. The papers were evaluated and compared across different areas in order to identify the best papers from among the reserve papers. If an accepted paper was flagged as needing improvement, shepherding of such papers was initiated by the area chairs. Shepherding was led by the area chairs or a TPC member assigned to a particular area. Finally, 37 full papers were accepted out of the 108 full paper submissions, yielding an acceptance rate of 34%. In addition, 6 short demo papers were accepted. From among the authors of accepted papers, 28% were from USA and Canada, 61% from Europe/Middle East/Africa, 8% from Asia/Pacific and 3% from Latin America.

3. TECHNICAL PROGRAM

Given the accepted papers, the Technical Program Committee (TPC) chairs then grouped the papers according to their topics. As a result, an excellent technical program covering a wide range of topics was presented, consisting of 12 technical oral sessions and a demo session.

This year's ITC technical program was composed of 37 contributed full papers and 6 short demo papers presented in two parallel sessions, three keynote addresses and a demo session. The technical program of the main conference was presented in the form of double-track sessions spanning three days, from September 13 to 15, 2016. The demo session, the three keynote speeches, and two selected sessions were presented as plenary sessions. Details on the workshops can be found in Section 6.

A brief overview of the main conference sessions is provided next. The session reports were compiled by the ITC 28 session chairs, who are indicated for each of the sessions.

1.A – Clouds and Data Center

(Session Chair: Andreas Timm-Giel, Hamburg University of Technology, Germany)
In session 1.A three papers were presented. The first paper, titled "Offering Resilient and Bandwidth Guaranteed Services in Multi-tenant Cloud Networks: Harnessing the Sharing Opportunities", was presented by Hyame Assem Alameddine from University of Concordia, Canada. The focus of the paper is on different options of how to share backup resources (bandwidth, virtual machines) in multi-tenant cloud networks. For a given embedding and protection plan design for each tenant, the objective followed here is to find the optimal bandwidth sharing allocation. The problem is formulated in the paper and as it is NP hard, a heuristic approach is presented and evaluated showing significant improvements.

The second paper, titled "Dynamic Virtual Network Traffic Engineering with Energy Efficiency in Multi-Location Data Center Networks" was presented by Mirza Mohd Shariar Maswood from the University of Missouri-Kansas. The focus of this paper is on the embedding of virtual networks with network bandwidth and processing demand at the end host considering energy efficiency. An MILP formulation is presented, which is solved at different time instances (review points). With this approach, insights on how different VN customers are affected in terms of resource allocation with north-south traffic in data centers are gained.

The third paper on "An Energy-Aware Embedding Algorithm for Virtual Data Centers" was presented by Manh Nam Tran from Hanoi University of Science and Technology in Vietnam. In this paper a virtual data center embedding algorithm is proposed together with an SND-based virtualisation architecture. The algorithm has the objective to be resource efficient in terms of CPU, memory and bandwidth, and to be energy efficient and flexible at the same time. Results are shown for the acceptance rate, resource-efficiency rate and power consumption, demonstrating superior behaviour of the proposed algorithm.

1.B – Traffic and Network Management

(Session Chair: Peter Reichl, University of Vienna)
Session 1.B focused on different facets of traffic and network management. Three papers were presented in the session. The first paper "Disaster Avoidance Control Against Tsunami" (by Phuong Nga Tran and Hiroshi Saito) investigates challenges in network disaster management on the relevant use case of tsunamis. Network operators aim at managing their network in case of tsunamis by proper prediction of the disaster and then to reduce the damaging effect of tsunamis on the network. The paper developed and evaluated heuristic algorithms to efficiently migrate service

(virtual) networks away from a disaster affected area to minimize traffic loss when a tsunami arrives. On the basis of the tsunami predicted information and network status, network operators can select a suitable algorithm for their disaster management action. The paper was presented by Phuong Nga Tran.

The second paper "Building a Low Latency Linux Software Router" (by Alexander Beifuß; Torsten M. Runge; Daniel Raumer; Paul Emmerich; Bernd E. Wolfinger; Georg Carle) was presented by Torsten Runge and Alexander Beifuß and focuses on technologies and architectures for network and traffic/service management. The authors argue that more routers will be CPU bounded in future due to flexible CPU based data plane devices where general purpose hardware in combination with software serves arbitrary needs. On commodity hardware the CPU typically becomes the bottleneck in packet processing. As a key contribution, a QoS concept for a Linux software router to prioritize latency-sensitive traffic at the incoming network interface is developed and investigated. The measurement results of a prototype implementation show that software routers are able to cope with real-time traffic and may improve the packet processing w.r.t. the latency of delay-sensitive traffic even under high traffic loads.

The third paper "Traffic-Driven Implicit Buffer Management - Delay Differentiation Without Traffic Contracts" (by Martin Karsten; Daniel S. Berger; Jens Schmitt) focuses on buffer and delay management of traffic. In particular, the problem of guaranteeing queueing delay bounds for multiple service classes without traffic contracts and without affecting the throughput rate for each class is investigated. A solution to this problem is given by decoupling throughput and delay management via traffic-driven implicit buffer management. The Delay Segment FIFO (DSF) packet scheduler is proposed which guarantees differentiated delay targets in the presence of unregulated throughput rates and satisfies a strict interpretation of network neutrality. The paper was presented by Martin Karsten.

The session was well attended with about 35 people. A "Best Question Award" was announced for the best question from the audience which stimulated lively discussions. Robert Bauer who also won the Best Student Paper Award received this Best Question Award from Peter Reichl.

2 – Wireless

(Session Chair: Michela Meo, Politecnico di Torino, Italy)
The three papers presented in session 2, devoted to Wireless, focused on different and timely technologies in wireless communications: software defined radios, multi-user MIMO and device-to-device communications. The first paper was titled "Self-Optimization of Software Defined Radios Through Evolutionary Algorithms", by Muhammed Zubair Basha Shaik, Andre Puschmann and Andreas Mitschele-Thiel and was presented by Muhammed Zubair Basha Shaik. The paper proposes a framework for optimizing radio transmission parameters in a software-defined radio environment. The peculiar and particularly interesting aspect of the proposed framework is that the choice of the parameters is done by using genetic algorithms. This allows the system to cope with situations with many parameters and several possible choices, situations that would not be treatable with optimization solutions. Since the paper also presents a prototype, it was selected to receive the best demo award of

ITC 28. Ryan E. Guerra presented the second paper of the session, entitled "Opportunistic Channel Estimation for Implicit 802.11af MU-MIMO", which was co-authored by Ryan E. Guerra, Narendra Anand, Clayton Shepard and Edward W. Knightly. The work focuses on multi-user MIMO channel coding and proposes a technique to estimate downlink channel conditions by using uplink transmissions. By not requiring the explicit transmission of channel sounding frames, the proposed solution greatly reduces channel sounding overhead. The proposed technique is shown to be quite effective in the presence of many users and when the channel conditions are stable. Finally, the last paper of the session, namely "DiVote: A Distributed Voting Protocol for Mobile Device-to-Device Communication", by Peter Danielis, Sylvia T. Kouyoumdjieva and Gunnar Karlsson, was presented by Peter Danielis. The paper proposes a protocol for distributed voting based on device-to-device communications. The idea is that users equipped with mobile devices can participate in distributed polls in given areas by exchanging simple information with other devices. The mobiles use the information they receive from other devices to derive local estimates of the global polling results. The solution is evaluated by extensive simulations.

3.A – Cellular

(Session Chair: Zhisheng Niu, Tsinghua University, China)
Three papers were presented in the session 3.A, all of them on user-BS/RRH association in heterogeneous cellular networks. In the first presentation, Farah Moety presented a joint work with her colleagues in Orange Labs Networks - Chatillon, on "Joint Optimization of User Association and User Satisfaction in Heterogeneous Cellular Networks". The key contribution of this paper is the reformulation of the Mixed Integer Linear Programming problem into a computationally tractable form. The results were quite interesting, and attracted four questions from the audience. The second presentation was made by Ying Loong Lee from Multimedia University in Malaysia who talked about the "Joint Resource Allocation and User Association for Heterogeneous Cloud Radio Access Networks" to improve energy efficiency. The questions from the audience were also mainly on the suboptimal algorithm itself and the energy saving gain. In the last talk, Abishek Sankararaman from UT Austin presented a paper on "Performance-Oriented Association in Large Cellular Networks with Technology Diversity", which takes a slightly different approach from the previous two talks. It considers multiple RATs rather than a single RAT in order to exploit the diversity of different RATs. In summary, all three talks are closely related, focusing on user association and joint resource allocations. The session was well attended with approximate 30 attendees.

3.B – Video Streaming

(Session Chair: Poul Heegaard, Norwegian University of Science and Technology, Norway)
Three papers were presented in the session 3.B on Video Streaming. Christian Moldovan (University of Duisburg-Essen) presented his work on Bridging the Gap Between QoE and User Engagement in HTTP Video Streaming, a very challenging topic and timely use case (of video streaming). A general model for bridging the gap between QoE and UE is very challenging, as also pointed out by questions from the audience. The second presenter was Jan Willem

Kleinrouweler (CWI, Amsterdam). He presented his work on resource sharing policies for DASH assisting network elements. His has developed a Markov model that can be used for the evaluation of different possible policies. He received some questions about the realism in the model assumptions. The last presenter, Philip Lundrigan (University of Utah), explained how to utilize nearby smartphones to improve video upstreaming performance. He received questions, among others, about incentives for allow sharing, and whether utilizing nearby smartphones helps if they are all connected to the same mobile operators. In summary, it was an interesting and engaging session with very good presenters, and many timely questions (and answers) to their work. This impression is based on the session chair's opinion, but also on the feedback from the audience provided directly to the session chair. It is worth noting that two of the presenters in the session (Kleinrouweler & Lundrigan) received a student travel grant, see Section 5.3.

4.A – Caching Strategies

(Session Chair: Hans van den Berg, TNO / University of Twente, The Netherlands)
Three papers were presented in this well focused session 4.A on caching strategies. The papers and presentations were of very high quality (all of them were nominated for the Best Paper Award) and triggered lively discussions. In the first presentation Andrea Araldo, PhD student at Universit ParisSud and Tlcom ParisTech, presented joint work with Györgi Dn (KTH) and his supervisor Dario Rossi (Tlcom PariTech) on "Stochastic Dynamic Cache Partitioning for Encrypted Content Delivery". The key contribution of the paper is a content-oblivious cache allocation algorithm, based on a perturbed stochastic subgradient method, that 'nearly' maximizes the overall cache hit rate. The main novelty lies in the fact that, to protect business-critical information, ISPs only need to measure the aggregated miss rates of the individual Content Providers and do not need to be aware of the objects that are requested, as in classic caching. The second presentation was provided by Damiano Carra (University of Verona, Italy) about the paper "Access-time aware cache algorithms" co-authored with a colleague from Inria and researchers from University of Verona, Akamai and Eurecom. This paper investigates the impact of caches limitations to serve requests fast enough. In particular, a new, hierarchical cache replacement policy was presented that takes these limitations into account. The policy is optimal when requests follow the independent reference model, and significantly reduces the hard-disk load, as shown also by realistic, trace-driven evaluations. The last presentation, by Nicolas Gast from Inria, France, was about the paper "Asymptotically Exact TTL-Approximations of the Cache Replacement Algorithms LRU(m) and h-LRU" co-authored by Benny van Houdt (University of Antwerp, Belgium). The authors propose time-to-live (TTL) approximations to determine the cache hit probability of two classes of cache replacement algorithms: the recently introduced h-LRU and LRU(m). These approximations only require the requests to be generated according to a general Markovian arrival process. The speaker provided both numerical (by trace-based simulation) and theoretical support for the claim that the proposed TTL approximations are asymptotically exact. The session was very well attended with about 40 people in the room.

4.B – Performance Analysis

(Session Chair: Markus Fiedler, BTH Karlskrona, Sweden)
This session provided contributions of a rather fundamental nature in terms of performance challenges and analysis methods. The first paper "Meeting soft deadlines in single- and multi-server systems" was presented by Esa Hyytiä, University of Iceland and Aalto University, Iceland. The key contributions consist of admission policies that take the risk of future deadline violations into account. These policies are proven to be optimal in the single server case; given in the form of efficient heuristics and dispatching policies in the parallel server case; and complemented by closed-form heavy traffic limits. Animations throughout the presentations contributed significantly to the understanding of the properties of the policies in the parameter space.

The second paper "Performance analysis of CoDel and PIE for saturated TCP sources" was presented by Michael Menth, University of Tübingen, Germany. It compared three strategies to deal with the well-known buffer-bloat phenomenon in routers, namely CoDel, the proposed modification CoDel-ACT, and PIE, in a systematic manner. In particular, demonstrations and discussions of the timely evolution of queuing delays and drop patterns helped the audience to understand the pros and cons of the different methods.

The third paper "Stochastic upper and lower bounds for general Markov fluids" was presented by Jens Schmitt, Universität Kaiserslautern, Germany. It addresses a gap in stochastic fluid flow modeling, namely to produce some sufficiently tight closed-form upper and lower performance bounds, which was reached through a martingale construction. From these general results, delay distributions for different scheduling schemes are obtained. The discussion phase touched upon, among others issues, the interpretability of the results.

5 – Demo Session

(Session Chair: Michael Jarschel, Nokia Bell Labs, Germany)
The first ever demo session in the long history of the International Teletraffic Congress was held at ITC 28 in Würzburg. All demonstrations were first introduced to the plenary either in a 30 minute presentation for full paper demos or a 3 minute lightning talk for short paper demos. Additionally, the demos were shown live during a dedicated demonstration period in separate rooms.

The first of the full paper demos was presented by Zubair Shaik (TU Ilmenau). He demonstrated a framework for self-optimizing parameters for software-defined radios using evolutionary algorithms to maximize the throughput. Both the second and third full paper demo were presented by Rick McGeer (University of Victoria/US Ignite). In the first presentation, he showed PlanetIgnite, a general-purpose, Infrastructure-as-a-Service, self-assembling, lightweight edge cloud for distributed application configuration and deployment. He highlighted its simplicity by adding a new node and creating and instantiating an application live. His second presentation introduced LiveTalk, a framework for collaborative browser-based replicated-computation applications. LiveTalk permits multiple users separated across the wide area to interact with separate copies of a single application, sharing a single virtual workspace, using very little network band-

width. This was illustrated through a live collaboration with a colleague half way around the world.

The short paper contributions consisted of six papers. Robert Finze (University of Tübingen) showed how different high-performance zones in the university campuses in Baden-Württemberg can communicate directly through the optical 100 Gb/s high-speed network and how the legacy network is used for communication to the campuses. Steffen Gebert (University of Würzburg) showed the application of the SDN concept to Bring Your Own Device scenarios, offering personalized virtual networks that are set up and extended on demand. Francesco Bronzino (Rutgers University & WINLAB, USA) demonstrated an emergency alert system for vehicles assisting first responders that exploits users location awareness to support quick and reliable alert messages for interested vehicles deployed on the GENI testbed in the US. Rastin Pries (Nokia Bell Labs, Munich) presented an approach to 5G network slicing using the example of a health insurance provider offering individual services for the customers with the help of a network slice. Finally, Marcel Großmann (University of Bamberg) showed a fault tolerant, reliable and secure extension to interconnect several independent host with Hypriot Cluster Lab software (Docker on ARM powered single board computers) to achieve QoS-requirements.

In general, the session was received very well, as it offered an interesting mix of different fields and technologies that were shown live and will serve as a starting point for more of these sessions in future ITCs.

6.A – Softwarization

(Session Chair: Nguyen Huu Thanh, Hanoi University of Science and Technology, Vietnam)
The session 6.A consisted of three papers, which dealt with several issues in softwarization in Software-Defined Networking, Network Function Virtualization contexts. In the first paper, "Sector: TCAM Space Aware Routing on SDN," presented by Ali Tizghadam, the authors proposed a method to reduce the number of entries in the OpenFlow forwarding tables, thus improving the performance of SDN switches by merging flows under the considerations of flows' traffic demands for traffic engineering. The presenter and the participants discussed about the impact of flow dynamicity (flows dynamically join and leave the network) on the performance of the proposed algorithm. The second paper "Port Based Capacity Extensions (PBCEs): Improving SDNs Flow Table Scalability" presented by Robert Bauer also dealt with improving the scalability of the OpenFlow forwarding table by delegating flow processing tasks from an overloaded switch to other available switches. The proposed mechanism is interesting, which can also be applied in some NFV paradigms. Questions has been raised discussing about the complexity of the mechanism as additional control information should be added into the forwarded packets. In the last paper, "Performance Modelling of Softwarized Network Functions Using Time Discrete Analysis," presented by Steffen Gebert, the authors proposed an analytical queueing network model to evaluate softwarized/virtual network functions. Performance results were presented and discussed. The proposed method is meaningful to evaluate the performance of specific virtual network functions when embedded on physical machines. The presenter received some questions about more realistic arrival patterns of traffic, and also about the sta-

tionary conditions of the system. In conclusion, the three papers in the session discussed different and timely problems on softwarized network functions. It was an interesting and engaging session with good presenters, and interesting questions (and answers) to their work.

6.B – Information and Social Networks

(Session Chair: Michael Menth, University of Tübingen, Germany)
The session 6.B consisted of two papers on information centric networking (ICN) and one on social networks. The first presentation "Cache the Queues: Caching and Forwarding in ICN from a Congestion Control Perspective" by Dinh Nguyen (KDDI R&D Laboratories, Japan) pointed out that caching in ICN may be a way to reduce network congestion and a performance study underlined this claim. The second paper "Optimizing Time to Exhaustion in Service Providers Using ICN" presented by Ali Shariat (University of Toronto, Canada) suggested that caching in ICN reduces congestion and extends the time-to-exhaustion of available capacity in service provider networks. Already a limited fraction of ICN deployment may allow for substantially delayed capacity upgrades. The last study on "Binary Opinion Dynamics with Biased Agents and Agents with Different Degrees of Stubbornness", presented by Arpan Mukhopadhyay (INRIA, Paris & Bell Labs, France), considered agents in social networks exchanging binary opinions and finding consensus. Among others, the impact of bias and stubbornness of agents on consensus finding times was investigated.

7.A – Measurements

(Session Chair: Marco Mellia, Politecnico di Torino, Italy)
Three papers were presented in session 7.A on Network Measurements, covering hot topics such as privacy in the Internet and tracking activities, the usage of data science approaches to automatically identify possible malicious traffic, and novel tools to detect network neutrality violations in the wild. The first paper "IntegraTag: a Framework for High-Fidelity Web Client measurement" by Charles Thomas, Jeff Kline, and Paul Barford was presented by Charles Thomas. The second paper "CLUE: Clustering for Mining Web URLs" by Andrea Morichetta, Enrico Bocchi, Hassan Metwalley, and Marco Mellia was presented by Andrea Morichetta. The third paper "Testing for Traffic Differentiation with ChkDiff: The Downstream Case" by Riccardo Ravaioli, Guillaume Urvoy-Keller, and Chadi Barakat was presented by Riccardo Ravaioli. All three papers were very interesting, presenting measurements, algorithms and insights that the audience appreciated. All three presenters did a great job of presenting their works, as testified by the questions asked by colleagues attending the session who continued the discussion with authors after the session ended.

7.B – Caching

(Session Chair: Thomas Bauschert, TU Chemnitz, Germany)
Session 7.B consisted of three talks. The first presentation was given by Emilio Leonardi (Politecnico di Torino, Italy). He outlined a new performance evaluation technique for large scale caching systems called ModelGraft. It integrates elements of stochastic analysis within a Monte Carlo simulation approach and shows significant gains wrt

CPU time and memory consumption compared to a classical event-based simulation. The second paper, presented by Valentino Pacifici (KTH , Sweden), formulates the problem of content caching in a mobile backhaul as a binary integer programming problem and suggests a distributed approximation algorithm to solve the problem. The last presentation, given by Gerhard Hasslinger (Deutsche Telekom, Germany), deals with the performance evaluation of the new web caching strategy SG-LRU in terms of the achievable hit rate for realistic scenarios of large user populations. The score gated least recently used (SG-LRU) strategy combines the usual LRU policy with the flexibility to keep most important content in the cache according to a predefined score function.

8 – Virtualization

(Session Chair: Thomas Zinner, University of Würzburg, Germany)
The last session, session 8 of this year's ITC 28 featured two papers in the timely context of Network Function Virtualization.

Antonio Marotta (Karlstad University, Sweden) presented his work on "A Power Efficient and Robust Virtual Network Functions Placement Problem." In the paper, a robust optimization approach was used to solve a facility placement problem by placing network functions and functions chains in case of uncertain traffic demands with respect to energy consumption. Discussions included the limitations of the chosen evaluation approach with respect to scalability and how to investigate realistic topologies.

The second presenter was Mathis Obadia (Thales Communications & Security & Telecom Paristech, France). He presented his work on "Elastic Network Service Provisioning with VNF Auctioning." In the paper, a game theoretic approach including Multi-Unit Combinatorial Auctions to sell leftover VNF capacities for bids was developed. He received questions on how to include the presented approach in a real-world cloud stack and on expected timescales of the presented approach. In summary, it was an interesting and engaging session with very good presenters, and many timely questions (and answers) to their work.

4.   ITC 28 KEYNOTE SPEAKERS

ITC 28 had three excellent keynote speakers in the main program presenting their visions.

Nikhil Jain (Vice President of Technology, Qualcomm Technologies, Inc.) serves as vice president of technology for Qualcomm Technologies, Inc., where he is responsible for chips and technology that go into the wearable products. Prior to joining Qualcomm, Nikhil Jain served as a senior member of the technical staff and manager of wireless system engineering for Northern Telecom, where he played a key role in deploying the first CDMA networks in North America. His keynote was on the *Internet of Everything: Engineering Challenges and Opportunities.* When millions of devices come on to the network and start looking at what we do, and control things that we use, a new world with challenges and opportunity will emerge. How would engineering have to evolve to deliver this new world. Reducing cost, data integrity, personal security, making a simple user experience and integrating the value these devices create with our daily lives are some of the key challenges. The keynote talk be-

gan by giving some marque examples of devices that have changed life for the people of the world. Devices from Toq the smartwatch to Nest the thermostat have solved some of the above mentioned problems. The talk waved through the development of human achievements in getting the world of Internet of everything created. It addressed some of the key design and engineering problems solved and how the use model could scale to make an impact. Nikhil Jain talked about how the problems will become more complex in future and what are some of the key engineering questions that have to be solved.

Wolfgang Kellerer (Technical University of Munich (TUM), Germany) is full professor and head of the chair of Communication Networks in the department of Electrical and Computer Engineering at Technical University of Munich, Germany. Recently, he has been awarded with an ERC Consolidator Grant from the European Commission for his research project FlexNets "Quantifying Flexibility in Communication Networks." In his keynote *Towards Flexible Networking in Dynamically Changing Environments*, he points out that communication networks have emerged to become the basic infrastructure for all areas of our information society with application areas ranging from social media to industrial production and healthcare. New requirements include the need for dynamic changes of the required networking resources, for example, to react to social events or to shifts of demands over time. Providing the required flexibility to react to those changes and being cost efficient at the same time has recently emerged as a huge challenge in networking research. With Software Defined Networking (SDN) and Network (Function) Virtualization, three concepts have emerged in the networking research, which claim to provide more flexibility. However a deeper understanding of the flexibility vs. cost trade-off is missing so far in networking research. Wolfgang Kellerer focused on the challenges of flexible networking, proposed a definition for flexibility as a new measure for design space analysis and highlighted selected solution concepts. Presented research topics include the optimized placement of mobile core network functions, SDN in an industrial communication scenario as well as new concepts for SDN network virtualization based on a new network hypervisor concept.

Eitan Altman (INRIA Sophia Antipolis, France) is a researcher at INRIA (National research institute in computer science and control). In 2014 he received the ISAACS Award from the Society of Dynamic Games for his contribution in game theory. His keynote talk on *Dynamic Games for Analyzing Competition in the Internet* considers the global Internet which has enabled a massive access of internauts to content. At the same time it allowed individuals to use the Internet in order to distribute content. This introduced new types of competition between content over popularity, visibility, influence, reputation and user attention. The rules of these competitions are new with respect to those of traditional media, and they are determined by the way resources are allocated through network protocols (including (i) page rank in search engines and (ii) those protocols used in recommendation systems). Eitan Altman first presented an overview of some central competition issues both in the Internet as well as in other types of networks. Then, he presented dynamic game competition models in order to understand the impact of competition on network performance.

5.   ITC 28 AWARDS AND GRANTS

The Arne Jensen Lifetime Award is presented at ITCs to an individual for his/her lifetime achievement to the teletraffic community and and exceptional scientific contributions to traffic modeling, control and performance. The Arne Jensen Lifetime Award is granted by the International Advisory Committee (IAC) of the ITC.

The IAC has also set up three prestigious best paper awards for ITC 28. Each award consisted of 500 EUR. The IAC offered a number of travel grants that will be available to support full-time students for attending ITC 28. The amount of each student travel grant is 600 EUR.

5.1   Arne Jensen Lifetime Award

The Arne Jensen Lifetime Award was created in memory of Arne Jensen, Founder of the International Teletraffic Congress (ITC) and Chair of the International Advisory Council (IAC) from its inception in 1955 until 1991. The Award is presented at ITCs to an individual who has provided exceptional contribution to traffic modeling, control and performance, and dedication to the teletraffic community. The International Advisory Council (IAC) of the International Teletraffic Congress (ITC) is pleased to announce that the recipient of the 2016 Arne Jensen Lifetime Award is Prof. Dr.-Ing. Phuoc Tran-Gia (University of Würzburg, Germany) for his huge contribution to teletraffic research and exceptional dedication to the ITC organization and community. He finished his PhD in 1982. He earned the professorial qualification at the University of Stuttgart in 1988 with the thesis: "Discrete-Time Analysis of Performance Models in Computer and Communication Systems.'. In the same year, he was offered a professorship at the University of Würzburg and, since then, he holds the Chair of Communication Networks (Informatik III) in the faculty of Mathematics and Computer Science.

5.2   Best Paper Awards

ITC 28 has set up three prestigious awards: Best Paper Award, Best Student Paper Award, Best Demo Award. These awards are offered both on the scientific quality of the paper and the presentation of the oral contribution or demo presentation. From the accepted papers, a list of nominees was selected by the TPC. A jury chaired by the award chair, Prosper Chemouil, designated the recipient of the award in each category after all presentations were made. The award committee included the following members: Prosper Chemouil (Orange Labs Networks, France) as award chair, Hans van den Berg (TNO, The Netherlands), Tobias Hoßfeld (University of Duisburg-Essen, Germany), Yutaka Takahashi (Kyoto University, Japan). Each award consists of 500 EUR and an award certificate.

ITC 28 Best Paper Award.

Access-time Aware cache Algorithms by Giovanni Neglia (INRIA Sophia Antipolis Mediterranee, France); Damiano Carra (University of Verona, Italy); Mingdong Feng and Vaishnav Janardhan (Akamai Technologies, USA); Pietro Michiardi (EURECOM, France); Dimitra Tsigkari (Inria Sophia Antipolis Mditerrane, France)

Abstract — Most of the caching algorithms are oblivious to requests' timescale, but caching systems are capacity constrained and in practical cases the hit rate may be limited by the cache's impossibility to serve requests fast enough. In particular the hard-disk access time can be the key factor capping cache performances. In this paper, a new cache replacement policy is presented that takes advantage of a hierarchical caching architecture, and in particular of access-time difference between memory and disk. The policy significantly reduces the hard-disk load, as shown by realistic, trace-driven evaluation.

ITC 28 Best Student Paper Award.

Port Based Capacity Extensions (PBCEs): Improving SDNs Flow Table Scalability by Robert Bauer and Martina Zitterbart (Karlsruhe Institute of Technology, Germany)

Abstract — Software-defined networks (SDNs) come with great promises regarding flexible operation of networks. A key component within SDN-switches is the flow table which holds the rules that determine how data streams are handled. The flow table, however, is a scarce resource with a rather limited rule capacity. To soften this well-known hassle, PBCE (Port Based Capacity Extension) provides the possibility to delegate flows to a so-called extension switch (e.g., neighboring switch) in order to utilize flow table resources of this switch. This paper presents a PBCE delegation architecture for OpenFlow-based SDNs along with a basic mechanism for flow table capacity outsourcing. A prototypical implementation and first promising performance results demonstrate the feasibility of the approach.

ITC 28 Best Demo Award.

Self-Optimization of Software Defined Radios Through Evolutionary Algorithms by Zubair Shaik; André Puschmann; Andreas Mitschele-Thiel (Ilmenau University of Technology, Germany)

Abstract — A framework for building software-defined radios is presented that are able to self-optimize their parameters using evolutionary algorithms. The framework has been implemented using the DEAP library for Python, which is based on the Genetic Algorithms (GAs). The paper discusses the overall system architecture and presents a system prototype that has been employed to optimize radio transmission parameters in an unknown radio environment in order to maximize the achievable throughput. Preliminary results are presented that have been obtained through over-the-air experiments in which different power parameters, modulation, coding schemes, etc., are optimized in an unknown radio environment.

5.3   Student Travel Grants

ITC 28 has received 23 applications for student travel grants (STG). The STG committee consisting of Prosper Chemouil (Orange Labs Networks, France) as award chair, Luigi Fratta (Politecnico di Milano, Italy) and Tobias Hossfeld (University of Duisburg-Essen, Germany) evaluated the applications and the advisor's recommendations. Congratulations to the recipients of the ITC 28 student travel grants (in alphabetical order):

- Jan Willem Kleinrouweler, Centrum Wiskunde & Informatica, The Netherlands
- Ying Loong Lee, Multimedia University, Malaysia
- Philip Lundrigan, University of Utah, US
- Thi-Minh Nguyen, UPMC Sorbonne University, France
- Manh Nam Tran, Hanoi University of Science and Technology, Vietnam

Aggregated STG Reports

After the conference, the STG recipients reported the benefits of having attended ITC 28, in terms of impact on his/her own research, of overall technical knowledge increase, and on technical exchanges and potential collaboration with other attendees. An aggregated report including quotations from the STG recipients is given below.

During ITC, there were a lot personal interactions and discussions between the students and the ITC attendees. One STG recipient discussed about "[. . .]Open vSwitch which is a software switch implementation that also provides an OpenFlow interface to allow for software defined networking. The current version only includes limited possibilities for quality of service. [. . .]Andreas Kassler showed me how I can use their traffic control implementation in my system, and also benefit from better traffic management. Furthermore, we discussed how I could adjust the switch implementation to suit my needs, specifically for DASH streaming. As part of my PhD, I would like to add an evaluation of my system through the means of user experiments." With Samira Tavakoli, he "[. . .]discussed the possibilities (and pitfalls) of performing a crowdsourcing study, that will take place in the near future." Åke Arvidsson "[. . .]recognized that my system could not directly be transferred to be used in cellular network. We had an interesting discussion on the particularities of cellular network, and brainstormed how my system could be adjusted to fit this use case as well."

A second STG recipient is working towards his PhD in "Software-Defined Networking, Network Function Virtualization and Green ICT. [. . .]The keynote talks including (1) "Internet of Everything: Engineering Challenges and Opportunities" and (2) "Towards flexible networking in dynamically changing environments" were very interesting, especially the talk of Prof. Wolfgang Kellerer in his Keynote. This gave me some ideas of implementing SDN/NFV platform by using mix SDN/NFV design and trading off between "quality of flexibility" and the energy-consumption in my research work. [. . .]The paper of Robert Bauer, "Port Based Capacity Extensions (PBCEs): Improving SDNs Flow Table Scalability", is a good one with the idea of the outsourcing-like flow capacity of a SDN switch by using extension SDN switches. Additionally, I also liked the demo "Demonstrating a Personalized Secure-By-Default Bring Your Own Device Solution Based on Software Defined Networking" by Steffen Gebert which showed the flexible security of mobile devices (BYOD) by using SDN technology."

"During the demo session of the conference," another STG recipient "talked with Marcel Großmann and Andreas Eiermann about their work on bringing Docker to Raspberry Pis. Without knowing they would be in attendance at the conference, I had been following their work because I want to use Docker on Raspberry Pis for some of my own research. I had a great time talking with them about their research and I was able to ask them practical questions about using Docker with Raspberry Pis. [. . .]I also talked with Rick McGeer about his work with PlanetIgnite, GENI, and distributed computing. His work and demonstrations helped me to think about my own research and how I can apply it more broadly. Rick and I had a long discussion about my current research (building easy to deploy IoT sensor networks for in-home experiments) and how some of the principles of PlanetIgnite could be applied. [. . .]This conference was a great experience."

For another recipient, "[. . .]It was a great chance for me to meet many professors, researchers and research students from a lot of countries. In fact, the conference ITC 28 focused on the latest changes and developments of communication system, network and service, and specially there are many sessions related to Network Function Virtualisation that I am working on."

Finally a last recipient had a meaningful technical exchange after his presentation with the session chair, Prof. Zhisheng Niu from Tsinghua University, China. "[. . .]Prof. Niu has pointed out a very important issue of my study, whereby my study did not address the problem that could arise due to the instantaneous wireless channel variations, which may degrade the performance of the algorithm proposed in my study. [. . .]Throughout the ITC conference, I have been exposed to many interesting topics, particularly software-defined networking (SDN) and network function virtualization (NFV), which are currently intensively investigated in the area of cellular communications. [. . .]These studies have given me several important insights about the nature, features and mechanism of SDN and NFV that may be useful to my future study on SDN and NFV for cellular networks." The keynote talk given by Nikhil Jain "[. . .]gave me the motivation to explore the IoT topics as my future research in view of its vast potentials in the future. [. . .]Overall, I have gained much benefit from the ITC conference in terms of research knowledge, networking and presentation skills."

6. ITC 28 WORKSHOPS

On the first day of the congress, September 12, 2016, a half-day workshop on Programmability for Cloud Networks and Applications (PROCON) took place. On the final day of the congress, September 16, there are two full-day workshops: (1) 2016 International Workshop on Quality of Experience Centric Management (QCMan) and (2) Workshop of COST Action ACROSS on 'Quality Engineering for a Reliable Internet of Services'.

The PROCON Workshop and QCMan 2016 Workshop had an open call for papers. All papers were reviewed by at least 3 experts. The acceptance rates of both workshops were 46.15% and 46.67%, respectively. The accepted papers are published in the ITC proceedings and available via the ITC library, as well as IEEE Xplore and ACM DL. The ACROSS workshop invited experts who gave talks on various topics.

6.1 PROCON Workshop

The continuous growth of Internet content, applications and services has resulted in ever more demanding requirements of computing power, scalability, data processing, data storage, energy consumption and transfer speed. To meet this, one solution is the use of the cloud paradigm for applications and services. The cloud paradigm describes the hosting of services and execution of tasks in the cloud. The cloud offers with this principle the promise of almost unlimited and scalable resources. Thus, more and more application providers adopt their applications and move their solution to the cloud. From the scientific point of view, the cloud paradigm covers a broad range of distributed computing principles as well as related application paradigms, networking approaches or architecture models. The PROCON Workshop covered the scientific areas around Cloud

Networks, Programmability inside Networks, Cloud and Fog Computing principles, Software Defined Networking, Network Function Virtualization, and Software Engineering approaches for Highly Distributed Applications.

PROCON 2016 provided a single-track and one-day program, including a keynote, a demonstration, five full papers and one short paper presentation. The keynote talk was given by Robert Birke, IBM Zurich Research Laboratory, Switzerland. His research focuses on virtual resource management for large scale data centers, aiming at optimizing the application latency, system throughput, and resource efficiency, particularly energy. His talk reflected the IBM view on contemporary cloud architectures, and discussed existing and upcoming challenges in this area. The demonstration at the workshop is presented by CNIT, University of Catania and Telecom Italia as a joint presentation with demonstration. It is entitled with "An SDN/NFV Telco Operator Platform for Multipoint Video Live Streaming: Design and Prototyping."

A total of 20 papers were registered for the workshop, out of those 13 papers were finally submitted and 7 paper were withdrawn. Papers submitted to PROCON Workshop underwent a rigorous review process. Each paper received three or more independent reviews (on average 3.5 reviews), and was discussed among the workshop chairs. In certain cases, when the reviews did not match, additional expert reviews were solicited. Based on the reviews and extensive discussions of the co-chairs, 6 full papers and one short paper were finally selected for the workshop program, resulting in an acceptance rate of 46.15%.

6.2   QCMan 2016

The 4th International Workshop on Quality of Experience Centric Management (QCMan 2016) aimed at providing an international forum for researchers exploring this rapidly evolving domain of QoE Centric Management. However, this QoE centric management is greatly challenged in todays Internet by (i) the stringent QoE requirements of the supported services and applications (e.g., timing constraints, loss intolerance) and users (e.g., unpredictability of user behavior, request for high quality services), (ii) the plethora of service consumption possibilities (e.g., for video: live vs. on-demand, managed vs. over-the-top), (iii) the inherent complexity of services and applications which can be offered to users in several ways to reach the same QoE level, and (iv) the difficulty in assessing the quality as perceived by the end user also due to insufficient insight in the psychological and sociological factors of the service and application consumption.

Current research aspects are reflected in the technical program of QCMan 2016, which consisted of five full and two short paper presentations and was complemented with both a motivating keynote and a panel discussion. The panel discussion focused on discussing challenges of managing QoE for immersive media-rich applications. The panelists were Michael Jarschel (Nokia Bell Labs, Germany), Markus Fiedler (BTH Karlskrona, Sweden), Alexander Raake (TU Ilmenau, Germany), Dominik Strohmeier (Mozilla, Germany).

The program was complemented by the keynote "Whats the number? Monitoring IP-based video with standardized QoE models", given by Alexander Raake, who is a professor and head of the Audiovisual Technology Group at TU Ilme-nau. The keynote emphasized efforts in QoE management by exploring the complete model development cycle – from model creation in user studies over ITU standardization to ISP-level deployment – and its challenges; based on lessons he and his team learned while creating and standardizing the IPTV quality model now recommended by the ITU.

A total of 19 papers were registered, 15 papers were finally submitted and 4 paper were withdrawn. All submitted papers underwent a rigorous review process with 3-4 reviews per paper. Based on these reviews, 5 full papers and 2 short papers were selected for publication, resulting in an acceptance rate of 46.67%. The technical contribution of these full papers fell within three topic areas. The first area comprises new insights for video streaming techniques. The first paper investigates the current implementation of the YouTube streaming algorithm. Drawbacks of the algorithm are investigated and the optimization potential is quantified using user- and network centric metrics (YouTube Can Do Better: Getting the Most Out of Video Adaptation). More generic insights on the impact of bandwidth fluctuations on the QoE in video streaming are highlighted in the paper (Impact of Variances on the QoE in Video Streaming).

In the second area, application-awareness and application-network interaction are discussed. The first paper provides insights into cloud service placement and the impact of the network design on the QoE. Further, a mechanisms based on application-aware network infrastructure clustering is proposed and investigated (Application-Aware Infrastructure Clustering for Cloud Service Placement to Enhance User QoE). A generic approach for comparing application-network interaction mechanisms is presented in the second paper (Towards a Framework for Comparing Application-Network Interaction Mechanisms). The third area features a paper on new QoE management solution taking personal aspects of QoE into account. Based on multi-agent technology a personalized QoE management is proposed.

Both short papers provide new insights into the impact of delays on the user perceived application quality in the context of two fundamentally different application types. The first short paper considers an online gaming use case of Minecraft, and provides an assessment of the impact of network latency on the QoE of casual gamers (Insensitivity to Network Delay: Minecraft Gaming Experience of Casual Gamers). The second short paper considers an enterprise environment use case within a SAP system, and features a correlation of response times and subjective user ratings on the perceived application performance using machine learning (Correlating QoE and Technical Parameters of an SAP System in an Enterprise Environments).

7.   OVERALL ASSESSMENT

An extensive, anonymous survey of participants was carried out. In total, 55 responses were collected to evaluate the quality of the sessions, keynote speeches, workshops, local organization, logistics, networking opportunities, social activities.

According to the participants, the best keynote was given by Nikhil Jain with 95% rating good or excellent. Approximately 76% of all respondents participated in the keynotes.

The technical sessions and workshops were mainly evaluated as "Good" or "Excellent". The top rated sessions were (i) Session 7.A: Measurements, (ii) Session 7.B: Caching, (iii) Session 4.A: Caching Strategies. This also reflects the

current interest in caching when considering ITC 28 submissions and the ITC 28 follow-up Elsevier Computer Networks Special Issue on "Softwarization and Caching in NGN".

Over 90% of respondents said that there was enough time for questions, technical sessions and networking opportunities. About 90% rated the conference dinner, the social event residence tour and the city tour as "Excellent". On a 5-point scale (1: 'poor', 2: 'fair', 3: 'neutral', 4: 'good', 5: 'excellent'), the conference venue and Würzburg as hosting city were evaluated on average 4.5. The registration process and the lunch was scored with 4.4. Thus, the ITC 28 logistics were "good" to "excellent". Finally, 21% of the respondents plan to visit the ITC next year. Additionally, 53% are planning to "likely" visit the conference.

8. OUTLOOK TO ITC 29

The ITC 29 conference in 2017 will be held at the University of Genoa, Italy from September 4 to September 8. The 29th event of the series will feature the topic of ubiquitous, software-based, and sustainable networks and services.

The ongoing "softwarization" process in networks, along with hardware capability and new services, is setting the pace for a tighter integration between computing and telecommunications technologies. At the same time, 5G and IoT are coming on the scene and will produce an unprecedented growth in wireless access and data generation. According to some estimates, there might be 25 billion connected things by 2020. The exponential growth of IoT nodes, flexibility in service provisioning, and programmability, are making networks more complex to manage and operate. In addition, network design presents new challenges, raised by ultra-low power consumption requirements of IoT nodes and by the use of less energy-efficient general-purpose hardware. The new paradigms will affect and shape the statistical features of teletraffic, along with its performance analysis and control. ITC 29 is organized into five areas and a demo session, which will cover quite a few relevant aspects. Additionally, a Demo Session will be organized.

Area 1: Networking, Cloud/Fog/Ubiquitous Computing, and Applications (incl. energy, multimedia, security, privacy). *Chairs: Roberto Bruschi (CNIT, Italy) and Steve Uhlig (QMUL, UK)*

Area 2: Future Internet Architectures (incl. SDN, NFV, HPC, ICN, CCN). *Chairs: Marco Canini (KAUST, KSA) and KK Ramakrishnan (UC Riverside, USA)*

Area 3: Wireless Networks and Applications (incl. 5G, IoT). *Chairs: Antonio Capone (Politecnico di Milano, Italy) and Jianwei Huang (Chinese University of Hong Kong, HK)*

Area 4: Measurements and Big Data Analytics (incl. monitoring, DPI, debugging, fault-tolerance, reliability, forensics, simulation, QoE). *Chairs: Pedro Casas (AIT Vienna, Austria) and Dario Rossi (Telecom Paris-Tech, France)*

Area 5: Performance Evaluation, Control, and Optimization (incl. queueing, game theory, machine learning). *Chairs: Rudesindo Nez-Queija (CWI, The Netherlands) and Zhi-Li Zhang (U. Minnesota, USA)*

Demo Session: *Chairs: Artur Hecker (Huawei, Germany), Rick McGeer (SAP Americas Labs, USA), and Chuan Wu (Univ. of Hong Kong, HK)*

The ITC 29 Conference Co-Chairs are Franco Davoli (University of Genoa, Italy) and Nikhil Jain (Qualcomm Technologies, USA). The TPC Co-Chairs are Raffaele Bolla (University of Genoa, Italy) and Florin Ciucu (University of Warwick, UK).

9. ACKNOWLEDGMENTS

Contact Information

More information on ITC, past and future conferences, award recipients, as well as access to the ITC Digital Library is available at http://itc-conference.org/.