Oliver Michel

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I am a sixth-year Ph.D. candidate in Computer Science at the University of Colorado at Boulder. Here, I am working in the Networking and Security Research Group (NSR) advised by Professor Eric Keller. I received a Bachelor's degree in Computer Science from the University of Vienna, Austria advised by Professor Kurt Tutschku in 2013 and a Master's degree in Computer Science from the University of Colorado Boulder advised by Professor Eric Keller in 2015. During my undergraduate studies, I spent one year at the University of Illinois at Urbana-Champaign working with Professor Brighten Godfrey. My research interests span most areas of Computer Networking, and in particular, network monitoring, programmable data planes, and software-defined wide-area networks. I worked as an iOS Software Engineer for two years at Tupalo.com in Vienna, Austria and interned as a WAN Automation Engineer at Juniper Networks.

Personal Data

Name	Oliver Dominik Michel
Date of Birth	July 21st, 1988.
Citizenship	Germany
Academic Degrees	Master of Science (M.S.), Computer Science, UColorado Boulder Bachelor of Science (B.Sc.), Computer Science, UVienna

Education

Aug. 2013 – ongoing	Doctor of Philosophy (Ph.D.), Computer Science University of Colorado Boulder, CO, USA – Graduation expected in May 2019 – Thesis: Cloud-Scale Packet-Level Network Telemetry and Analytics
Aug. 2013 – May 2015	Master of Science (M.S.), Computer Science University of Colorado Boulder, CO, USA – GPA: 3.8/4 – 95%
Mar. 2009 – Jan. 2013	Bachelor of Science (B.Sc.), Computer Science University of Vienna, Austria/Medical University of Vienna, Austria – Specialization: medical informatics – GPA: 3.2/4 – 80% – Thesis: Adaptive Source Routing and Speculative Execution for Multi-homed Wireless Clients in Preclinical Medical Care, grade 4/4 – 100%
Aug. 2011 – Dec. 2011	Austria-Illinois Exchange Program University of Illinois at Urbana Champaign, IL, USA
Jul. 2008 – Feb. 2009	Rettungssanitäter, nationally registered EMT, Germany Academy of the German Red Cross NRW, Düsseldorf, Germany

Aug. 1999 – Jun. 2008	Abitur (high school diploma) Stiftisches Gymnasium Düren, Düren, Germany
Sep. 2006 – Oct. 2006	High School Exchange Program Mount Lebanon High School, Pittsburgh, PA, USA

Publications

Conference Proceedings

May 2018, HotCloud '18	Oliver Michel, John Sonchack, Eric Keller, Jonathan M. Smith. "Packet-Level Analytics in Software without Compromises". In *Proceedings of the 10th USENIX Workshop on Hot Topics in Cloud Computing* (HotCloud '18), Boston, MA, USA, 2018
May 2018, ATC '18	John Sonchack, Oliver Michel, Adam J. Aviv, Eric Keller, Jonathan M. Smith. "Scaling Hardware Accelerated Monitoring to Concurrent and Dynamic Queries With *Flow". In *Proceedings of the 2018 USENIX Annual Technical Conference* (ATC '18), Boston, MA, USA, 2018
Mar. 2018, SDN-NFV Sec. '18	Greg Cusack, Oliver Michel, and Eric Keller. "Machine Learning-Based Detection of Ransomware using SDN". In *Proceedings of the ACM International Workshop on Security in Software Defined Networks & Network Function Virtualization 2018* (SDN-NFV Sec. 2018). Tempe, AZ, USA, 2018
May 2017, SDS-2017	Oliver Michel, Eric Keller. "SDN in Wide-Area Networks : A Survey". In *Proceedings of the 4th IEEE International Conference on Software Defined Systems* (SDS-2017). Valencia, Spain, 2017
Apr. 2016, SDS-2016	Oliver Michel, Eric Keller. "Policy Routing using Process-Level Identifiers". In *Proceedings of the 3rd IEEE International Symposium on Software Defined Systems* (SDS-2016), Berlin, Germany, 2016
Nov. 2013, HotNets-XII	Matthew Monaco, Oliver Michel, and Eric Keller. "Applying Operating System Principles to SDN Controller Design". In *Proceedings of the 12th ACM Workshop on Hot Topics in Networks* (HotNets-XII), College Park, MD, USA, 2013
Oct. 2012, HotNets-XI	Ashish Vulimiri, Oliver Michel, P. Brighten Godfrey, and Scott Shenker. "More is Less: Reducing Latency via Redundancy". In *Proceedings of the 11th ACM Workshop on Hot Topics in Networks* (HotNets-XI), Redmond, WA, USA, 2012

Technical Reports

Aug. 2015	Matthew Monaco, Oliver Michel, Alex Tsankov, and Eric Keller. "Yanc – Yet Another Network Controller". University of Colorado Technical Report, Boulder, CO, USA, 2015

Posters

Apr. 2018, NSDI 2018	Oliver Michel, John Sonchak, Adam J. Aviv, and Eric Keller. "Scalable, Hardware-Accelerated Network Analytics". Poster at the 15th USENIX Symposium on Networked Systems Design and Implementation (NSDI '18), Renton, WA, USA, 2018
Feb. 2018, NDSS 2018	Greg Cusack, Oliver Michel, and Eric Keller. "Machine Learning-based Fingerprinting of Network Traffic Using Programmable Forwarding Engines". Poster at the Network and Distributed System Security Symposium 2018 (NDSS '18), San Diego, CA, USA, 2018
Mar. 2016, NSDI 2016	Oliver Michel, Eric Keller. "Defragmenting the Cloud". Poster at the 13th USENIX Symposium on Networked Systems Design and Implementation (NSDI '16), Santa Clara, CA, USA, 2016
Aug. 2014, SIGCOMM 2014	Oliver Michel, Michael Coughlin, Eric Keller. "Extending the Software-defined Network Boundary". Poster at the ACM SIGCOMM 2014 Conference, Chicago, IL, USA, 2014
Apr. 2014, NSDI 2014	Michael Coughlin, Oliver Michel, Eric Keller, Adam J. Aviv. "Making the Live Network the Honeypot". Poster at the 11th USENIX Symposium on Networked Systems Design and Implementation (NSDI '14), Seattle, WA, USA, 2014
Oct. 2013, GEC18	Oliver Michel, Matthew Monaco, Eric Keller. "Applying Operating System Principles to SDN Controller Design". Poster and Demo at the 18th GENI Engineering Conference (GEC18), New York, NY, USA, 2013
Apr. 2013, NSDI 2013	Oliver Michel, David Stezenbach, Kurt Tutschku. "Multihoming and Adaptive Multipath Transmission using off-the-shelf Components in Preclinical Medical Care". Poster at the 10th USENIX Symposium on Networked Systems Design and Implementation (NSDI '13), Chicago, IL, USA, 2013
Mar. 2012, GEC12	Oliver Michel, Ashish Vulimiri, and P. Brighten Godfrey. "Adaptive Source Routing". Poster at the 13th GENI Engineering Conference (GEC13), Los Angeles, CA, USA, 2012

Presentations

Jun. 2018	Oliver Michel. "Packet-Level Network Analytics without Compromises". Peer-reviewed Talk at the 73rd North American Network Operators' Group Meeting (NANOG 73), Denver, CO, USA
Sep. 2017	Oliver Michel, Eric Keller, and Fernando M.V. Ramos. "Network Defragmentation in Virtualized Data Centers". Invited Talk, University of Lisbon, Portugal
Apr. 2014	Oliver Michel, Matthew Monaco, Eric Keller. "Applying Operating System Principles to SDN Controller Design". Invited Talk, University of Illinois at Urbana-Champaign, Champaign, IL, USA
Apr. 2013	Oliver Michel. "More is Less - Reducing Latency via Redundancy". Invited Talk, University of Colorado Boulder, Boulder, CO, USA

Nov. 2012	Oliver Michel. "Adaptive Source Routing and Speculative Execution for Multi-homed Wireless Clients in Preclinical Medical Care". Bachelor Thesis and public presentation at the University of Vienna, Austria
Oct. 2012	Ashish Vulimiri, Oliver Michel, P. Brighten Godfrey, and Scott Shenker. "More is Less - Reducing Latency via Redundancy". Talk at the 15th GENI Engineering Conference (GEC15), Houston, TX, USA

Research Experience

Positions

Jan. 2014 - ongoing	Research Assistant, Next Generation Networks Research Group, Department of Computer Science at the University of Colorado Boulder, Boulder, CO, USA
Oct. 2010 - Feb. 2013	Undergraduate Research Assistant, Institute for Distributed & Multimedia Systems - Chair of Future Communication at the University of Vienna, Austria

Current Projects

Scalable, Hardware-Accelerated Network Analytics With computer networks growing larger and becoming more complex, monitoring is an increasingly important part of network operation. While network devices usually support exporting statistics and traffic traces in a variety of formats, efficiently processing monitoring from various sources at scale and making decisions based on computations on this data remains a challenge. This is due to multiple reasons. (1) Many applications (*e.g.,* for debugging and traffic classification), require per-packet data such as timestamps. There is still a lack of efficient and scalable ways to gather per-packet data and thus often rely on flow records that only expose aggregated values. (2) There is no widely accepted and practical way for building monitoring applications using reusable, lightweight components that are easy to deploy and use on commodity servers. Most existing solutions require the extensive use of cluster computing technologies (significantly increasing capital expenditure (CAPEX) and operational expenses (OPEX)). Toward the goal of providing high-performance per-packet analytics in a practical, easy to operate environment, we propose an architecture and streaming framework in which monitoring applications can be built using reusable components that perform computations. Analytics applications in this framework are C++ applications that link against a library that provides processing primitives, as well as a runtime environment that provides high-performance, parallel computation. Through experiments, we identified that these applications are primarily I/O-bound due to frequent memory operations on small chunks of data, *i.e.,* per-packet data. To further improve processing performance, we propose selective hardware offload of analytics functions, that can be aggregated (while preserving per-packet information) before being processed in software. To implement this pattern, we leverage programmable *Smart NICs*, that can perform initial processing at very high data rates.

Defragmenting the Cloud Network virtualization is an extensively used approach to allow multiple tenants with different network architectures and services to coexist on a shared data center infrastructure. Core to its realization is the mapping (or embedding) of virtual networks onto the underlying substrate infrastructure. Existing approaches are not suitable for cloud environments as they lack its most fundamental requirement: elasticity. To address this issue, we introduce two new network primitives – *expand* and *contract* – which allow virtual networks to scale up and down. Mapping and scaling virtual networks over time, however, introduces fragmentation in the substrate network. This is akin to fragmentation in a file system where files are not laid out in contiguous physical blocks of the storage

device. We define metrics for fragmentation and show that this problem not only negatively impacts the revenue of the data center provider as the virtual network acceptance rate decreases, but also profoundly impacts network performance and reliability for tenants and their applications. Instead of further improving embedding algorithms to tackle this problem, in this work, we present a yet unexplored approach: leveraging network migration techniques to *defragment* the network. We introduce network defragmentation as a new management primitive and propose algorithms to materialize it. On average, using defragmentation leads to 20% reduction in path length and utilization and cuts the number of very long paths (longer than half of the network diameter) between 52% and 62%. Moreover, it doubles the number of servers utilized by 50% or less as a result of consolidating resource utilization.

Previous Projects

Policy Routing using Process-Level Identifiers

– "Policy Routing using Process-Level Identifiers". In *Proceedings of the 3rd IEEE International Symposium on Software Defined Systems* (SDS-2016)

Network Abstractions in the Application Layer

– "Extending the Software-defined Network Boundary", Poster, SIGCOMM 2014

SDN Controller Architecture

– "Applying Operating System Principles to SDN Controller Design", In *Proceedings of the 12th ACM Workshop on Hot Topics in Networks* (HotNets-XII)

Low Latency Networking

– "More is Less – Reducing Latency by Redundancy", In *Proceedings of the 11th ACM Workshop on Hot Topics in Networks* (HotNets-XI)

Work Experience

Jun. 2009 – Jun. 2011	iPhone-Software-Developer, Tupalo.com Internet-Services GmbH, Vienna, Austria
Jan. 2003 – ongoing	Founder, Owner, editum internet solutions, Hürtgenwald, Germany

Voluntary Work

Aug. 2014 – Dec. 2016	Emergency Medical Technician, University of Colorado Emergency Medical Services, Boulder, CO, USA
Feb. 2009 – May. 2013	Emergency Medical Technician, Fire Department, emergency medical services, City of Düren, Germany

Internships

Jun. 2016 – Aug. 2016	WAN Automation Software Engineering Intern, Juniper Networks OpenLab, Bridgewater, NJ, USA
Jun. 2013 – Jul. 2013	Visiting Researcher, Department of Computer Science, University of Colorado at Boulder, CO, USA

Jul. 2012 – Aug. 2012	Undergraduate Research Intern (NSF REU), Information Trust Institute, University of Illinois at Urbana-Champaign, IL, USA
Jan. 2012 – Mar. 2012	Visiting Researcher, Department of Computer Science, University of Illinois at Urbana-Champaign, IL, USA
Sep. 2009	Medical Center of the Albert-Ludwig University Freiburg, Department for heart and vascular surgery, transplant center, Freiburg, Germany
Jan. 2009	St. Marien-Hospital Düren, Department of Anesthesiology and surgical intensive-care medicine, Düren, Germany
Oct. 2008 – Dec. 2008	Fire Department, emergency medical services, ICU transfers, City of Düren, Germany
Aug. 2008	Medical Center of the RWTH Aachen University, Department of plastic-, hand- and burn-surgery, burn/trauma center, Aachen, Germany
Sep. 2005	Spymac Network Germany GmbH, Düsseldorf, Germany
Apr. 2004	Clanotopia IT-Service Ltd., Essen, Germany

Awards and Fellowships

Mar. 2018	Best Technical Poster Award, NDSS 2018
Aug. 2013	Dean's Outstanding Merit Fellowship, University of Colorado Boulder, CO, USA
Jun. 2011	Joint Study Scholarship of the Rector of the University of Vienna, Austria

Teaching Experience

Fall Semester 2015/2016/2017	Guest Lecturer, Advanced Networking, (ECEN5013), Prof. Eric Keller, University of Colorado at Boulder, CO, USA
Aug. 2013 - Dec. 2013	Teaching Assistant, Introduction to Computer Systems (CSCI2400), Prof. Richard Han, University of Colorado at Boulder, CO, USA
Mar. 2012 - Jun. 2012	Teaching Assistant, Undergraduate Networking (VO Network Technologies), Prof. Kurt Tutschku, University of Vienna, Austria

Technical Skills

Programming Languages	C++, C, Ruby, R, Objective-C, Java Script, Wolfram Language, Bash, Java, PHP
Technologies/Tools	Linux Systems, OpenFlow, P4, LaTeX, Ansible, Apple Cocoa & iOS, Mathematica, Kernel-Bypass Networking, Click Modular Router, Stream Processing, PostgresSQL, Ruby on Rails, CMake, Git

Graduate Coursework

2015	Design and Analysis of Algorithms (CSCI5454) Natural Language Processing (CSC5832)
2014	Advanced Networking (CSCI7000/05) Advanced Database Systems (CSCI5817) Computer Graphics (CSCI5229) Network Analysis (CSCI5352)
2013	Advanced Computer and Networked System Security (CSCI7000/12) Research Topics in Datacenter Scale Computing (CSCI7000/14)
2011	Advanced Computer Networks (CS538 – University of Illinois)

Et cetera

Conference Attendances	SIGCOMM 2011 (2011, Toronto, Canada), GEC 13 (2012, Los Angeles, CA), SIGCOMM 2012 (2012, Helsinki, Finland), HotNets-XI (2012, Seattle, WA), NSDI 2013 (2013, Chicago, IL), HotNets-XII (2013, College Park, MD), NSDI 2014 (2014, Seattle, WA), SIGCOMM 2014 (2014, Chicago, IL), 2nd P4 Workshop (2015, Palo Alto, CA), 1st P4 Developer Bootcamp (2015, Palo Alto, CA), NSDI 2016 (2016, Santa Clara, CA), ONS 2016 (2016, Santa Clara, CA), SDS 2016 (2016, Berlin, Germany), P4 Developer Day 2016 (2016, Palo Alto, CA), SDS 2017 (2017, Valencia, Spain), SIGCOMM 2017 (2017, Los Angeles, CA), NSDI 2018 (2018, Seattle, WA), NANOG 73 (2018, Denver, CO), HotCloud 2018 (2018, Boston, MA), ATC 2018 (2018, Boston, MA)
Travel Grants	GEC18, NSDI '14
Associations	ACM, USENIX, IEEE
Languages	German (native language), English (fluent), Latin (Latinum)

References

- Eric Keller, Professor, University of Colorado Boulder, CO, USA – eric.keller@colorado.edu
- Richard Han, Professor, University of Colorado Boulder, CO, USA – rhan@colorado.edu
- Didier Bousser, Senior Director, Routing Business Unit, Juniper Networks, CA, USA – dbousser@juniper.net
- Kurt Tutschku, Professor, Blekinge Institute of Technology, Sweden – kurt.tutschku@bth.se
- Philip Brighten Godfrey, Professor, University of Illinois at Urbana-Champaign, IL, USA – pbg@illinois.edu
- Ernst Schuster, Professor emeritus, Medical University of Vienna, Austria – ernst.schuster@meduniwien.ac.at