

# Oliver Michel

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I am a fourth-year doctoral student 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, software-defined wide-area networking, network management abstractions, programmable data planes, and low-latency networking. I worked as an iOS Software Engineer for two years at Tupalo.com in Vienna, Austria and recently interned as a WAN Automation Engineer at Juniper Networks.

## Personal Data

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

## Education

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|-----------------------|---|
| Aug. 2013 – ongoing   | Doctor of Philosophy (Ph.D.), Computer Science<br>University of Colorado Boulder, CO, USA   |
| Aug. 2013 – May 2015  | Master of Science (M.S.), Computer Science<br>University of Colorado Boulder, CO, USA<br>– GPA: 3.8/4 – 95%   |
| Mar. 2009 – Jan. 2013 | Bachelor of Science (B.Sc.), Computer Science<br>University of Vienna, Austria/Medical University of Vienna, Austria<br>– Specialization: medical informatics<br>– GPA: 3.2/4 – 80%<br>– 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<br>University of Illinois at Urbana Champaign, IL, USA  |
| Jul. 2008 – Feb. 2009 | Rettungssanitäter, nationally registered EMT, Germany<br>Academy of the German Red Cross NRW, Düsseldorf, Germany   |
| Aug. 1999 – Jun. 2008 | Abitur (high school diploma)<br>Stiftisches Gymnasium Düren, Düren, Germany   |

Sep. 2006 – Oct. 2006

High School Exchange Program  
Mount Lebanon High School, Pittsburgh, PA, USA

## Publications

### Conference Proceedings

- 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

- 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

- 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

### Projects

**Defragmenting the Cloud** Network virtualization is a widely used technique to overcome the ossification of networks. Being commonly applied in both data center as well as wide-area settings, network virtualization enhances network flexibility and enables innovation by making it easier to provide network programmability. However, mapping virtual resources (links and nodes) to physical (substrate) resources is a challenging problem and commonly referred to as the provably NP-hard virtual network embedding (VNE) problem. As virtual networks come and go over time, VNE algorithms tend to introduce resource fragmentation in the network leading to request rejection when resources would technically be available but cannot be assigned to the requested topology or other request constraints. In this project, we aim at (1) improving VNE algorithms by considering resource fragmentation, (2) design a defragmentation algorithm enabling the online reconfiguration of virtual networks to reduce fragmentation. In a second step, we investigate systems primitives to allow for reconfiguration of virtual networks. This work is based upon the work on Live Migration of Ensembles (LIME) as presented by our group at HotNets-XI and SoCC '14.

- Technologies: custom C++ simulation framework, Mixed Integer Programming algorithms, ALEVIN VNE simulation suite

**Policy Routing using Process-Level Identifiers** Enforcing and routing based on network-wide policies remains a crucial challenge in the operation of large-scale enterprise and data center networks. As current data plane devices solely rely on layer 2 – layer 4 identifiers to make forwarding decisions, there is no notion of the exact origin of a packet in terms of the sending user or process. In this project we ask the question: *Can we go beyond the MAC?* That is, can fine-grained process-level information

like user ids, process ids or a cryptographic hash of the sending executable be semantically used to make forwarding decisions within the network? We designed a system architecture and implemented an early prototype leveraging the P4 technology for protocol-independent packet processing and forwarding in conjunction with on-board tools of the Linux operating system. Using this system, we are able to make forwarding decisions within the network based on fine-grained process-level identifiers that are traditionally only available within a host's operating system.

- Technologies: Linux systems programming, P4

**Network Abstractions in the Application Layer** Many of today's applications (in particular data processing applications) use intra-application networks to connect computing elements. By making intra-application networks part of the network itself, we simplify applications by providing an abstraction of the network, freeing applications from the responsibility of maintaining their own internal topology management and forwarding systems. Also, moving the network edge into the applications allows the network management to leverage advances such as software-defined networking, providing a unified management across an entire path. For these networks, we are inspecting a new interface to the network based on intra-application channels told to the network rather than addresses.

- Technologies: Apache Storm, Dbus, Trema OF Controller, Apache Kafka, Click Modular Router
- Publications: "Extending the Software-defined Network Boundary", Poster, SIGCOMM 2014

**SDN Controller Architecture** While there is a broad variety of SDN controllers (both proprietary and open source) available, we investigate the commonalities between SDN controllers (often referred to as the network operating system) and traditional operating systems. We believe network application should be developed against an API that is similar to that of existing operating systems. That is that SDN applications should run independently from each other and not in a monolithic design (like today's controllers suggest it). Also applications should be able to take advantage of features that operating systems already provide (such as access control and process management). In this area, I am particularly interested in how such independent applications are composed and are granted access to the network configuration.

- Technologies: Linux Systems Programming, OpenFlow, libfuse, NFS, OpenVSwitch
- Publications: "Applying Operating System Principles to SDN Controller Design", Paper, HotNets-XII

**Low Latency Networking** Latency is an extremely important quality metric of computer networks. While network hardware can be designed and provisioned to provide low latency on average, heavy tails are pervasive in latency distributions of almost all classes of networks due to a variety of reasons. We investigate several techniques how to reduce this latency tail and provide networking at the speed of light with a more uniform latency distribution compared to what today's networks are able to achieve. Strategies such as redundant multi- or single-path routing, as well as adaptive source routing across wide-area networks showed extremely satisfactory early results.

- Technologies: Linux Systems Programming, Linux Tunneling, GENI Mesoscale Infrastructure
- Publications: "More is Less - Reducing Latency by Redundancy", Paper, HotNets-XI

## Work Experience

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|-----------------------|---|
| 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

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|---------------------|--|
| Aug. 2014 - ongoing | Emergency Medical Technician, University of Colorado Emergency Medical Services, Boulder, CO, USA                |
| Feb. 2009 - ongoing | Emergency Medical Technician, Fire Department, emergency medical services, ICU transfers, City of Düren, Germany |

## Internships

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|-----------------------|--|
| Jun. 2016 – Aug. 2016 | WAN Automation Software Engineering Intern, Juniper Networks Open-Lab, 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

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|-----------|--|
| 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

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|-----------------------|--|
| Oct. 2015             | 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

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|-----------------------|--|
| Programming Languages | C++, C+, Ruby, Python, Wolfram Language, Java Script, Objective-C, Bash, Java, JavaScript, PHP   |
| Technologies/Tools    | UNIX Systems, OpenFlow, P4, L <sup>A</sup> T <sub>E</sub> X, Ansible, Apple Cocoa & iOS, Mathematica, Click Modular Router, Ruby on Rails, OpenGL, CMake, Git, Subversion, dbus, systemd, UML, libvirt |

## Graduate Coursework

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

## Et cetera

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| 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) |
| 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