

# Kiryong Ha

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RESEARCH INTERESTS	My research interests spans to software systems for mobile computing, cloud computing, and virtualization. I have been working on <i>Cloudlet</i> project, which is a new architectural element that arises from the convergence of mobile computing and cloud computing. It is an enabling technology for a new genre of resource-intensive interactive mobile applications.	
EDUCATION	<b>Carnegie Mellon University</b> Ph.D. in Electrical and Computer Engineering <i>Advisor:</i> <a href="#">Prof. Mahadev Satyanarayanan</a>	<i>Sep. 2011 – Dec. 2016</i>
	<b>Korea Advanced Institute of Science and Technology (KAIST), Korea</b> Masters of Science at Biosystems Department, <i>First in Class</i> <i>Advisor:</i> Prof. Doheon Lee and Prof. Kwang Hyung Lee	<i>Feb. 2007</i>
	<b>Korea Advanced Institute of Science and Technology (KAIST), Korea</b> Bachelor of Science Electrical Engineering (major) and Computer Science (minor)	<i>Feb. 2005</i>
WORK EXPERIENCE	<b>Facebook Inc., Seattle</b> <i>Research Scientist</i> I work on improving utilization of Facebook data centers (Details are available upon request).	<i>Mar. 2017 –</i>
	<b>Facebook Inc., Seattle</b> <i>Software Engineering Intern</i>	<i>2016 Summer</i>
	<b>Microsoft Research, Redmond</b> <i>Research Intern</i>	<i>2014 Summer</i>
	I improve performance of mobile application using Micro Datacenter. Specifically, I design and implement GPU state migration across data centers by reproducing OpenGL states. I worked closely with <a href="#">Lenin Ravindranath Sivalingam</a> , <a href="#">Eduardo Cuervo</a> , <a href="#">David Chu</a> , <a href="#">Alec Wolman</a> , and <a href="#">Victor Bahl</a> .	
	<b>Electronics and Telecommunications Research Institute (ETRI), Korea</b> <i>Researcher</i>	<i>Feb. 2007 – Sep. 2011</i>
	ETRI is the largest government funded research institute in Korea. I conduct research on ubiquitous computing platforms and participated on two research projects; 1) Context-Aware Platform and 2) Collaborative Virtual Machine Technology for SoD Service.	
RESEARCH EXPERIENCE	<b>Open Edge Computing, Graduate research at CMU</b> I have worked on the deployment of the Cloudlet proposing a standard of Cloudlet API with companies including Intel and Vodafone at <a href="#">Open Edge Computing</a> . In addition, to provide a systematic way to expedite cloudlet deployment, I implement <i>cloudlet features</i> at <a href="#">OpenStack</a> , an open source ecosystem for cloud computing. New APIs are designed and implemented with underlying core features such as rapid provisioning and handoff.	<i>Sep. 2015 – Dec. 2016</i>

- Source code at <https://github.com/cmusatyalab/elijah-openstack/>
- Media coverage: [InfoWorld](#)

**Cloudlet: Dynamic VM Handoff**, *Graduate research at CMU*

*Sep. 2014 – Aug. 2015*

For latency-sensitive mobile applications that offload computation to a cloudlet, even modest user mobility can result in significant network degradation. I propose VM handoff as a technique for seamlessly transferring VM-encapsulated execution to a more optimal cloudlet. Through aggressive fine-grain adaptation to WAN bandwidth and cloudlet load, the prototype implementation is able to perform handoff in roughly a minute, which is at least one order of magnitude faster than off-the-shelf live migration.

**Gabriel: Cloudlet-Powered Mobile Systems**, *Graduate research at CMU* *June. 2013 – May. 2014*

I design and develop *Gabriel* systems for wearable devices. *Gabriel* is an assistive system based on Google Glass devices for users in cognitive decline. It combines the first-person image capture and sensing capabilities of Glass with cloud processing to perform real-time scene interpretation. The system architecture is multi-tiered. It offers tight end-to-end latency bounds on compute-intensive operations, while addressing concerns such as limited battery capacity and limited processing capability of wearable devices.

- Source code at <https://github.com/cmusatyalab/gabriel/>
- Media coverage: [CBS 60 Minutes](#), [Computer World](#), [Tech Times](#), [Gizmag](#), [Engadget](#), [Popular Science](#)

**Cloudlet: Rapid VM Provisioning for Cloudlet Offload**

*Graduate research at CMU*

*June. 2012 – May. 2013*

A cloudlet is a new architectural element that arises from the convergence of mobile computing and cloud computing. In this work, I design and implement *Rapid VM synthesis* that enables just-in-time provisioning of a cloudlet at the edge of the Internet. I demonstrate a prototype system that is capable of provisioning a cloudlet with a non-trivial VM image in 10 seconds using realistic mobile applications. This speed is achieved through a series of optimizations including deduplication, VM introspection, pipelining, and demand fetching.

- Source code at <https://github.com/cmusatyalab/elijah-provisioning>

**Impact of Mobile Multimedia Application on Cloud Consolidation**

*Graduate research at CMU*

*Sep. 2011 – May. 2012*

In mobile context, new classes of multimedia applications are emerging that are both resource-intensive and interaction-intensive (e.g., Apple's Siri or Augmented Reality application). For these applications, end-to-end network bandwidth and latency matter greatly when cloud resources are used to augment the computational power and battery life of a mobile device. I present quantitative evidence that this crucial design consideration to meet interactive performance criteria limits data center consolidation. Then, I propose as an architectural solution, that is a seamless extension of today's cloud computing infrastructure.

**Collaborative Virtual Machine Technology for System on-Demand**

*Government Research Project at ETRI*

*Mar. 2008 – Sep. 2011*

This project aims to develop a framework that provides “networked computing environments” by virtualization of remote computing resources and peripherals over IP network. My contribution focuses on designing and developing resource virtualization and I/O data transmission protocols over network. I implement a virtual device management module that works with QEMU-DM and the corresponding client software working on iPhone, Android and Linux.

**Context-aware Platform**

*Government Research Project at ETRI*

*Mar. 2007 – Feb. 2008*

This project set forth to create a context-aware system based upon health information. Our team

develop wearable healthcare monitoring devices in the forms of a wrist-watch, chest-band, and necklace. Using the vital signals such as ECG, PPG gathered from the wearable device, I devise vital signal processing algorithms to noninvasively calculate heart rate and blood pressure.

#### PUBLICATIONS

- [1] Kiryong Ha, Yoshihisa Abe, Zhuo Chen, Wenlu Hu, Brandon Amos, Rohit Upadhyaya, Padmanabhan Pillai, and Mahadev Satyanarayanan. Live migration for edge computing. 2016 (Under submission).
- [2] Wenlu Hu, Ying Gao, Kiryong Ha, Brandon Amos, Padmanabhan Pillai, and Mahadev Satyanarayanan. Quantifying the impact of edge computing on mobile applications. In *APSys*, 2016.
- [3] Zhuo Chen, Lu Jiang, Wenlu Hu, Kiryong Ha, Brandon Amos, Padmanabhan Pillai, Alex Hauptmann, and Mahadev Satyanarayanan. Early implementation experience with wearable cognitive assistance applications. In *WearSys*. ACM, 2015.
- [4] Mahadev Satyanarayanan, Pieter Simoens, Yu Xiao, Padmanabhan Pillai, Zhuo Chen, Kiryong Ha, Wenlu Hu, and Brandon Amos. Edge Analytics in the Internet of Things. *IEEE Pervasive Computing*, 2015.
- [5] Wenlu Hu, Brandon Amos, Zhuo Chen, Kiryong Ha, Wolfgang Richter, Padmanabhan Pillai, Benjamin Gilbert, Jan Harkes, and Mahadev Satyanarayanan. The Case for Offload Shaping. In *HotMobile*. ACM, 2015.
- [6] Mahadev Satyanarayanan, Zhuo Chen, Kiryong Ha, Wenlu Hu, Wolfgang Richter, and Padmanabhan Pillai. Cloudlets: at the leading edge of cloud-mobile convergence. In *MobiCase (Invited)*. Springer, 2014.
- [7] Kiryong Ha, Zhuo Chen, Wenlu Hu, Wolfgang Richter, Padmanabhan Pillai, and Mahadev Satyanarayanan. Towards Wearable Cognitive Assistance. In *MobiSys*. ACM, 2014 (acceptance rate: 14 %).
- [8] Zhuo Chen, Wenlu Hu, Kiryong Ha, Jan Harkes, Benjamin Gilbert, Jason Hong, Asim Smailagic, Dan Siewiorek, and Mahadev Satyanarayanan. QuiltView: a Crowd-Sourced Video Response System. In *HotMobile*. ACM, 2014.
- [9] Kiryong Ha, Padmanabhan Pillai, Wolfgang Richter, Yoshihisa Abe, and Mahadev Satyanarayanan. Just-in-Time Provisioning for Cyber Foraging. In *MobiSys*. ACM, 2013 (acceptance rate: 16 %).
- [10] Pieter Simoens, Yu Xiao, Padmanabhan Pillai, Zhuo Chen, Kiryong Ha, and Mahadev Satyanarayanan. Scalable Crowd-Sourcing of Video from Mobile Devices. In *MobiSys*. ACM, 2013 (acceptance rate: 16 %).
- [11] Mahadev Satyanarayanan, Grace Lewis, Edwin Morris, Soumya Simanta, Jeff Boleng, and Kiryong Ha. The Role of Cloudlets in Hostile Environments. *IEEE Pervasive Computing*, 2013.
- [12] Kiryong Ha, Padmanabhan Pillai, Grace Lewis, Soumya Simanta, Sarah Clinch, Nigel Davies, and Mahadev Satyanarayanan. The Impact of Mobile Multimedia Applications on Data Center Consolidation. In *IC2E*, 2013 (acceptance rate: 21 %).
- [13] Yu Xiao, Pieter Simoens, Padmanabhan Pillai, Kiryong Ha, and Mahadev Satyanarayanan. Lowering the barriers to large-scale mobile crowdsensing. In *HotMobile*. ACM, 2013 (acceptance rate: 31 %).
- [14] Soumya Simanta, Kiryong Ha, Grace Lewis, Edwin Morris, and Mahadev Satyanarayanan. A Reference Architecture for Mobile Code Offload in Hostile Environments. In *MobiCase*, 2012.
- [15] Soumya Simanta, Grace Lewis, Edwin Morris, Kiryong Ha, and Mahadev Satyanarayanan. A Reference Architecture for Mobile Code Offload in Hostile Environments. In *WICSA/EICSA 2012*, Helsinki, Finland, 2012.

- [16] Kiryong Ha, Grace Lewis, Soumya Simanta, and Mahadev Satyanarayanan. Cloud Offload in Hostile Environments. Technical Report CMU-CS-11-146, CMU School of Computer Science, 2011.
- [17] Kyuchang Kang, Kiryong Ha, and Jeunwoo Lee. Android-based SoD Client for Remote Presentation. In *ICACT*. IEEE, 2011.
- [18] Kiryong Ha, Dongho Kang, Hyungjik Lee, Kyuchang Kang, and Jeunwoo Lee. SoD: Framework for on-Demand Computing in Home Environment. In *ICCE*. IEEE, 2011.
- [19] Kyuchang Kang, Dongoh Kang, Kiryong Ha, and Jeunwoo Lee. Android phone as wireless usb storage device through usb/ip connection. In *ICCE*. IEEE, 2011.
- [20] Kiryong Ha, Youngsung Kim, Junyoung Jung, and Jeunwoo Lee. Experimental Evaluations of Wearable ECG Monitor. In *EMBS*. IEEE, 2008.
- [21] Junyoung Jung, Kiryong Ha, Jeunwoo Lee, Young Kim, and Daeyoung Kim. Wireless Body Area Network in a Ubiquitous Healthcare System for Physiological Signal Monitoring and Health Consulting. *IJSIP*, 2008.
- [22] Dong oh Kang, Kiryong Ha, and Jeonwoo Lee. A context aware system for personalized services using wearable biological signal sensors. In *ICCAS*. IEEE, 2008.
- [23] Kiryong Ha, Inho Park, Jeonwoo Lee, and Doheon Lee. Automated blog design system with a population-based artificial immune algorithm. *Artificial Immune Systems*, pages 324–335, 2007.

HONORS AND AWARDS

- Fellowship from [Facebook Ph.D Fellowship](#) 2015
- Best Demo Award at [HotMobile 2014](#) 2014
- Microsoft Research Ph.D. Fellowship Finalist 2014
- Travel Grant Award: [MobiSys 2013](#), [APSys 2012](#)
- Fellowship from [Korea Foundations for Advanced Studies](#) 2011
- Fellowship from [Kwanjeong Educational Foundation](#) 2006
- KAIST Full-scholarship for undergraduates/graduates 2000 – 2007

ACTIVITIES

- Journal/Conference Reviewer:
  - 2017 IEEE Computer
  - 2017, 2016, 2015, 2014 IEEE Pervasive Computing
  - 2015 IEEE Transaction on Mobile Computing
  - 2015 IEEE Transactions on Parallel and Distributed Systems
  - 2014 UbiComp
  - 2011, 2010, 2009 IEEE EMBS
- Program Committee Member:
  - [2015 MobiSys PhD forum](#)
  - [2017 MoReal: 1st Workshop on Mobile Virtual Reality and Augmented Reality member](#)
- Demo and Poster Co-Chair for [2017 HotMobile Workshop](#)

TEACHING AND MENTORING

- Teaching Assistance: [CMU 15-821/18-843: Mobile and Pervasive Computing](#)** 2015 Fall  
Instructors: Mahadev Satyanarayanan and Dan Siewiorek  
Design and mentoring class projects. Grade Quiz.
- Teaching Assistance: [CMU 18-746/15-746 Storage Systems](#)** 2015 Spring  
Instructors: Greg Ganger and Garth Gibson  
Evaluate programming projects. Grade midterm and final.

## Mentoring

- Samuel Platt (*CMU Undergrad*): Improving Web service using Cloudlets 2016 Fall
- Rohit Upadhyaya (*CMU Master*): Mobile Edge Computing with containers 2015 Fall
- Aravind Selvan (*CMU Master*): Callback-based Database Caching on Cloudlets 2015 Fall
- Junjue Wang, Xinkai Wang (*CMU Ph.d and Master students in CSD*) 2015 Fall  
3D Virtual Tour With Google Street View and Cardboard, [Video Demo](#)
- Varun Saravagi, Harsha Rastogi (*CMU Master student in Software Engineering*) 2015 Fall  
Virtual Tour using Google Street View Caching on Cloudlets, [Video Demo](#)
- Ying Gao (*CMU Master student in Software Engineering*) 2015 Summer  
Performance analysis of code offloading engine (COMET) using Cloudlet
- Varun Saravagi (*CMU Master student in Software Engineering*) 2015 Summer  
Code partitioning for JavaScript. Co-mentor with [Padmanabhan\(Babu\) Pillai](#)
- Ishan Vashistha and Abhinav Kuruvadi (*CMU Master students in MSIT-Mobility*) 2014 Fall  
Achieving parallelism in ESVM-based object detection algorithm for real-time Google Glass applications. Co-mentor with [Ishan Misra](#).
- Parth Mehta (*CMU Master student in Software Engineering*) 2013 Summer  
Suspend/resume of GPU state for migration in virtual environment
- Zhuo Chen, Junchen Jiang, and Brandon Taylor (*CMU SCS Ph.d students*) 2012 Fall  
Rendering Mobile Browser using Cloudlet
- Da-Yoon Chung (*CMU SCS undergrad*) 2012 Summer  
Analysis on Cloud Game Streaming to a mobile device

## INVITED TALKS

- [MSR Student Summit on Mobility, Systems, and Networking](#) 2/1/2016
- [IBM F2C2 workshop](#) 7/29/2013
- [CMU SDI/ISTC Seminar](#) 6/20/2013
- CMU KVM/QEMU workshop: Tutorial on libvirt and virt-manager 6/3/2013
- [CMU SDI/ISTC Seminar](#) 3/21/2013
- CMU PDL Aug. 2012

## REFERENCES

**[Prof. Mahadev Satyanarayanan](#)**  
Carnegie Mellon University  
[satya@cs.cmu.edu](mailto:satya@cs.cmu.edu)

**[Prof. Daniel Siewiorek](#)**  
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[dps@cs.cmu.edu](mailto:dps@cs.cmu.edu)