**Education**

PhD in Computer Engineering Spring, 2014

University of Maryland, College Park, MD GPA: 4.0/4.0

Advisor: Prof. Bruce Jacob (<http://www.ece.umd.edu/~blj/>)

B.Tech in Electronics and Communication Engineering Spring, 2005

Indian Institute of Technology (IIT), Guwahati, India GPA: 8.6/10

**Areas of Interest**

Computer Architecture, Machine Learning, Deep Learning Architecture, Memory Systems, Energy Efficient Architectures, Non-volatile Memory (PCM & SSD), High-Performance Computing, Distributed Systems

**Technical Skills**

**Programming Languages**: Verilog, VHDL, SystemC, C/C++, SystemVerilog, Perl, Linux/Unix based Shell Scripting (bash, tcsh), OpenMP, MPI

**CAD Tools**: Xilinx Synthesis Technology (ISE), Cadence Tools (Ncverilog, Simvision), Synopsis DesignWare Verification IP

**Architectural Simulators:** DRAMSim, MARSSx86 (PTLSim+QEMU), DiskSim

**Research Summary**

**Emerging Architecture Research:**

* Working on efficient compute and memory architecture for emerging applications like Deep Learning.

**Micro-architecture Research:**

* NVM based LLC: Proposed novel techniques to mitigate long NVM write latency (featured in ISCA-2018)
* Memory aware reordered source (MARS): to reshape the memory traffic for efficient memory bandwidth (filed patent)
* Adaptive Width Aware Core (AWAC): we used simple heuristics to intelligently provision resources in the core dynamically (part of work featured in IEDM'2017)

**Graduate Research Assistant:** University of Maryland, Department of ECE, College Park (Sep 2010 – May 2014)

My research focused on designing scalable and energy-efficient memory systems. As DRAM device gets bigger, we quantified and analyzed that the refresh operations pose a serious problem. To address refresh scalability, energy-efficiency and performance penalty, we proposed several practical methods to enable refresh reduction with available auto-refresh commands and coordinate the scheduling of refresh and low power modes to simultaneously improve energy and performance. These schemes require no or small changes in the DRAM device.

**Scalable DRAM Refresh:**

* Comprehensive evaluation and survey of DRAM refresh mechanisms, trade-offs, and penalties. We also clarify prevalent confusions with refresh options and timings available in JEDEC specified DDR devices. This study published in Transactions on Computers, 2015 ([Weblink](http://www.ece.umd.edu/~blj/papers/ieeetc64-XX.pdf)).
* Proposed simple modification in DRAM device to enable *refreshes reduction* with optimized auto-refresh commands rather than in-efficient row-level refresh commands. This work published in ISCA’15 ([Weblink](http://www.ece.umd.edu/~blj/papers/isca2015.pdf)).

**Energy Efficient Memory:**

* Proposed novel techniques to simultaneously minimize two important types of DRAM energy components: *background and refresh*. Our novel schemes called “*Coordinated Refresh*” schedule refresh operations and power down modes in such a way that energy consumption is reduced while improving performance. This work accepted in ISLPED’13 for presentation ([Weblink](http://www.ece.umd.edu/~blj/papers/islped2013.pdf)).

**High Capacity Memory:**

* Co-designed *parameterized simulation* infrastructure to study various emerging Non-volatile Memory (NVM) technologies, organization, and latencies. We simulated a range of workloads to understand performance tradeoffs when NVM used as part of the memory hierarchy. This study published in Intel Technology Journal (ITJ’13) ([Weblink](http://www.ece.umd.edu/~blj/papers/itj2013.pdf)) as well as in a Tech report ([Weblink](http://www.ece.umd.edu/~blj/papers/UMD-SCA-2010-12-01.pdf)).

**Accurate Memory Simulations:**

* Designed a set of techniques when applied in a full-system simulator gives *reliable, accurate and fewer variable* results. Our techniques implemented on [MARSSx86](http://marss86.org/~marss86/index.php/Home)integrated with [DRAMSim2](http://www.ece.umd.edu/~blj/papers/cal10-1.pdf) for case study to show reduce variability in simulations. This work published in a Tech report ([Weblink](http://drum.lib.umd.edu/handle/1903/12500)).

**Work Experience**

***Research Scientist,*** Intel Labs, Intel, Bangalore (December 2015 --)

* Focusing on Architectures for newer applications like Deep Learning
* Research on design and architectural techniques for STTRAM based LLC
* Adaptively changing OoO core width/ports based on simple heuristics
* Memory aware reordering of the memory traffic to get high bandwidth efficiency

***Senior Hardware Engineer,*** Oracle (formerly SUN Microsystem), Santa Clara (June 2014 – December 2015)

* Worked on performance modeling, projection and design space exploration of SPARC processors
* Responsible for modeling and maintaining memory-controller and database-accelerator modules
* Architectural explorations for future processors and debugging performance issues during bring-up

***Research Assistant,*** Memory Systems Research Lab, Dept. of ECE, in University of Maryland (Sep 2010 – May 2014)

* DRAM low power modes and refresh mechanisms
* Novel applications of persistent memory
* Reliable full-system simulation infrastructure

***Graduate Intern,*** Intel Corporation, Hillsboro, USA (June 2013 – August 2013)

* Quantified speed versus accuracy tradeoffs in memory modeling at several levels of abstraction (constant, analytical, queue-based, detailed etc.)
* Implemented and integrated a memory model, which is 10x faster than the cycle accurate DRAMSim2 and is within 10% of accuracy
* These models are targeted to obtain approximate timing and power behavior of a system early in its design phase
* Technical Mentor: Emily Shriver, Strategic CAD Labs (SCL)

***Senior ASIC Engineer****,* LSI Corporation, India (Jan 2009 - July 2010)

* Co-implemented DDR2/3 *memory controller* and its PHY layer at 65nm process technology.
* Developed the crucial and challenging part of the optimized *DDR3 training sequence* and write leveling algorithm.
* Created *SystemVerilog and VMM* based automated test benches.

***ASIC Design and Verification Engineer****,* Nevis Networks, India (July 2005 - June 2006, May 2007-Jan 2009)

* Involved in design and verification of DRAM Control module in a 96-core Network Processor Chip.
* Performed entire *FPGA prototyping* of memory controller using Xilinx’s Vertex-4 based board and created synthesizable verification code.
* Led the SystemC modeling and Full-Chip Verification environment integration

***Design Engineer****,* STMicroelectronics, India (June 2006 - May 2007)

* Responsible for modeling, *RTL, and verification* of a couple of modules in Wireless USB Medium Access Control (MAC) Chip design.

***Summer Intern****,* Kyungpook National University (KNU), Daegu, South Korea (May 2004 - July 2004)

* Studied various *speech enhancements* and speech recognition techniques, and implemented Dynamic Time Warping (DTW) on TI-DSK 6711 using Simulink

**Graduate Class Projects**

**CMSC714 (High-Performance Computing):**

* Accelerated scientific codes up to 20x times on 64 core distributed cluster, using OpenMP and MPI constructs.
* Implemented 4 parallel versions of an irregular graph algorithm ( BFS) and compared their performance on real computer vision application

**CMSC818B (Distributed File System):**

* Designed in memory and client-server based file system from scratch by using FUSE calls.
* Developed database files systems using SQLite, added file/directory versioning.
* Implemented PAXOS and Authentication algorithms

**Other Projects**

* ENEE645 (Compiler Optimization): Implemented Loop Forward Propagation optimization in LLVM
* ENEE699 (Parallel Algorithms): Developed parallel versions of several graphs, sorting and tree algorithms
* ENEE644 (Computer Aided Design): Designed a CAD tool to manipulate and synthesize sequential circuits represented by Finite State Machines (FSM).

**Publications**

Kunal Korgaonkar, Ishwar Bhati, Huichu Liu, Jayesh Gaur, Sasikanth Manipatruni, Sreenivas Subramoney, Tanay Karnik, Steven Swanson, Ian A. Young, and Hong Wang, "Density Tradeoffs of Non-Volatile Memory as a Replacement for SRAM based Last Level Cache," *Proc. 45th International Symposium on Computer Architecture (ISCA 2018). Los Angeles, CA, June 2018.*

Kaushik Vaidyanathan, Daniel H Morris, Uygar E Avci, Ishwar S. Bhati, Lavanya Subramanian, Jayesh Gaur, Huichu Liu, Sreenivas Subramoney, Tanay Karnik, Hong Wang, and Ian A Young. "Overcoming interconnect scaling challenges using novel process and design solutions to improve both high-speed and low-power computing modes," *Electron Devices Meeting (IEDM), 2017 IEEE International*

Ishwar Bhati, Zeshan Chishti, Shih-Lien Lu, and Bruce Jacob, “[Flexible auto-refresh: Enabling scalable and energy-efficient DRAM refresh reductions](http://www.ece.umd.edu/~blj/papers/isca2015.pdf),” *Proc. 42nd International Symposium on Computer Architecture (ISCA 2015)*. Portland, OR, June 2015.

Ishwar Bhati, Mu-Tien Chang, Zeshan Chishti, Shih-Lien Lu, and Bruce Jacob, “[DRAM Refresh Mechanisms, Penalties, and Trade-Offs,](http://www.ece.umd.edu/~blj/papers/ieeetc64-XX.pdf)” *IEEE Transactions on Computers*, vol. 64, 2015.

Ishwar Bhati, Zeshan Chishti, and Bruce Jacob, ["Coordinated refresh: Energy efficient techniques for DRAM refresh scheduling,"](http://www.ece.umd.edu/~blj/papers/islped2013.pdf) Proc. 2013 International Symposium on Low Power Electronics and Design (ISLPED 2013). Beijing China, September 2013.

Jim Stevens, Paul Tschirhart, Mu-Tien Chang, Ishwar Bhati, Peter Enns, James Greensky, Zeshan Chishti, Shih-Lien Lu, and Bruce Jacob, ["An Integrated Simulation Infrastructure for the Entire Memory Hierarchy: Cache, DRAM, Nonvolatile Memory, and Disk,"](http://www.ece.umd.edu/~blj/papers/itj2013.pdf) Intel Technology Journal (ITJ), vol. 17, no. 1, 2013.

**Patents**

Ishwar Bhati and Zeshan Chishti, “Coordinating Power Mode Switching and Refresh Operations in a Memory Device,” US patent granted, 2015

Ishwar Bhati, Zeshan Chishti, and Shih-Lien L. Lu, “Techniques to Reduce Memory Cell Refreshes for a Memory Device”, US patent granted, 2016

Ishwar Bhati, Udit Dhawan, Jayesh Gaur and Sreenivas Subramoney, "Techniques to Reduce Memory Cell Refreshes for a Memory Device", US patent granted, 2018

Two other patents filed in the US PTO

**Ph.D. Thesis**

Ishwar Bhati, “[Scalable and Energy-Efficient DRAM Refresh Techniques,](http://www.ece.umd.edu/~blj/papers/thesis-PhD-ishwar--refresh.pdf)”Ph.D. thesis, May 2014.

**Technical Reports**

B. Jacob, Ishwar Bhati, M.-T. Chang, P. Rosenfeld, J. Stevens, P. Tschirhart, Z. Chishti, S.-L. Lu, J. Ang, D. Resnick, and A. Rodrigues, "[A Journaled, NAND-flash main-memory system,](http://www.ece.umd.edu/~blj/papers/UMD-SCA-2010-12-01.pdf)" University of Maryland Systems and Computer Architecture Group Technical Report, 2014.

Mu-Tien Chang, Ishwar Bhati, Jim Stevens, Paul Tschirhart, Peter Enns, Daniel Gerzhoy, Zeshan Chishti, James Greensky, Shih-Lien Lu, and Bruce Jacob, ["Producing Reliable Full-System Simulation Results: A Case Study of CMP with Very Large Caches,"](http://drum.lib.umd.edu/handle/1903/12500) Institute for Systems Research (ISR) Technical Report UMD-ISR-TR-2012-07, 2012.

**Relevant Graduate Courses**

Computer Architecture (A+), Algorithms (A), Computer Aided Design (A), Compiler Optimizations (A+), High Performance Computing (A), Distributed File Systems (A), Distributed Systems (A+), Parallel Algorithms (A), CMOS VLSI Design (A), Exascale Computing (A)

**Honors and Awards**

* Jacob K. Goldhaber Travel award to attend LPDDR3 and DDR4 workshops organized by JEDEC, Sep 2012
* Merit Scholarship, granted to one student per year, ECE deptt., IIT Guwahati, August 2003

**Activities**

* Volley Ball Team, Inter-IIT (2002 - 2003)
* Student volunteer for SPIC MACAY and IIT Guwahati’s Technical festival “Techniche”.

**Personal Information**

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