Abu Bakar

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Research Interests

I am a systems researcher who leverages battery-free computing to build **sustainable** and **intelligent** embedded systems. My research approach involves a comprehensive exploration of the entire battery-free **system stack**. I design **hardware platforms** that enable energy-efficient batteryless operation, develop **operating systems** that reliably execute programs under frequent power failures, devise **embedded machine learning** algorithms that work efficiently on resource-constrained hardware, and create **tools** to facilitate the application development process for makers and researchers. I leverage these systems to build health-sensing **wearables** and infrastructure-monitoring **devices**, and actively seek opportunities to apply them in user-interaction, accessibility, and environment-monitoring applications, with a primary focus on minimizing environmental impact.

My work has appeared in SenSys, IMWUT, ASPLOS, and BuildSys, and has twice been selected for research highlight in ACM GetMobile magazine. It has been featured in Forbes, Washington Post, Scientific American, ACM Tech News, Daily Mail, The Independent, and many others. I have received a **Best PhD Forum Presentation Award** and a **People's Choice Award**, and was named a **Cyber-Physical Systems (CPS) Rising Star** in 2022.

Education

Expected May 2024 — **Georgia Institute of Technology,** Atlanta, GA
Ph.D. in Computer Science
Thesis: Adaptive and Intelligent Battery-free Computing Systems
Advisor: Dr. Josiah Hester

2020 — **Northwestern University,** Evanston, IL
M.S. in Computer Science
Advisor: Dr. Josiah Hester

2016 — **National University of Computer and Emerging Sciences (NUCES),** Islamabad, Pakistan
B.S. in Electrical Engineering
Dean's honor list for five semesters

Awards and Honors

2023 — **Best PhD Forum Presentation Award** at SenSys 2023

2023 — **ACM SIGMOBILE research highlight** for "Protean: An Energy-Efficient and Heterogeneous Platform …"

2022 — **Cyber-Physical Systems (CPS) Rising Star Award** by University of Virginia

2022 — **ACM SIGMOBILE research highlight** for "REHASH: A Flexible, Developer Focused, Heuristic Adaptation …"

2020 — **Conference travel grant** by ACM for ASPLOS 2020

2018 — **Conference travel grant** by NSF for SenSys 2018

2017 — **People's Choice Award** for "Inverting HVAC for Energy Efficient Thermal Comfort …" at BuildSys 2017

2017 — **Conference travel grant** by ACM for BuildSys 2017

2016 — **Dean's honor list** for five semesters at NUCES

2016 — **Silver and bronze medals** for three semesters at NUCES

2014 — **Best Intern Award** at SysNet Lab

PUBLICATIONS

Conference Papers

C09 **Protean: An Energy-Efficient and Heterogeneous Platform for Adaptive and Hardware-Accelerated Battery-free Computing**
Abu Bakar, Rishabh Goel, Jasper de Winkel, Jason Huang, Saad Ahmed, Bashima Islam, Przemysław Pawełczak, Kasım Sinan Yıldırım, Josiah Hester.
ACM Conference on Embedded Networked Sensor Systems (**SenSys**). 2022.
ACM SIGMOBILE Research Highlight in GetMobile magazine 2023

C08 **Adaptive Intelligence for Batteryless Sensors Using Software-Accelerated Tsetlin Machines**
Abu Bakar, Tousif Rahman, Alessandro Montanari, Rishad Shafik, Fahim Kawsar.
ACM Conference on Embedded Networked Sensor Systems (**SenSys**). 2022.

C07 **FaceBit: Smart Face Masks Platform**
Alexander Curtiss, Blaine Rothrock, **Abu Bakar**, Nivedita Arora, Jason Huang, Zachary Englhardt, Aaron-Patrick Empedrado, Chixiang Wang, Saad Ahmed, Yang Zhang, Nabil Alshurafa, Josiah Hester.
ACM Conference on Pervasive and Ubiquitous Computing (**UbiComp**). 2022.
Published in PACM IMWUT, Volume 5, Issue 4
Fast Company 2022 Innovation by Design Award—Finalist in the Students category
Featured in Forbes, Washington Post, Scientific American, ACM Tech News, Engadget, and many others

C06 **REHASH: A Flexible, Developer Focused, Heuristic Adaptation Platform for Intermittently Powered Computing**
Abu Bakar, Alexander G. Ross, Kasım Sinan Yıldırım, Josiah Hester.
ACM Conference on Pervasive and Ubiquitous Computing (**UbiComp**). 2021.
Published in PACM IMWUT, Volume 5, Issue 3
ACM SIGMOBILE Research Highlight in GetMobile magazine 2022

C05 **BFree: Enabling Battery-free Sensor Prototyping with Python**
Vito Kortbeek, **Abu Bakar**, Stefany L. Cruz, Kasım Sinan Yıldırım, Przemysław Pawełczak, Josiah Hester.
ACM Conference on Pervasive and Ubiquitous Computing (**UbiComp**). 2021.
Published in PACM IMWUT, Volume 4, Issue 4
Featured in The Independent, TechTimes, TechXplore, Interesting Engineering, Hackster.io, and others

C04 **Time-sensitive Intermittent Computing Meets Legacy Software**
Vito Kortbeek, Kasım Sinan Yıldırım, **Abu Bakar**, Jacob Sorber, Josiah Hester, Przemysław Pawełczak.
ACM Conference on Architectural Support for Programming Languages and Operating Systems (**ASPLOS**). 2020.

C03 **The Betrayal of Constant Power × Time: Finding the Missing Joules of Transiently-Powered Computers**
Saad Ahmed, **Abu Bakar**, Naveed Anwar Bhatti, Muhammad Hamad Alizai, Junaid Haroon Siddiqui, Luca Mottola.
ACM SIGPLAN/SIGBED Conference on Languages, Compilers, and Tools for Embedded Systems (**LCTES**). 2019.

C02 **Inverting HVAC for Energy Efficient Thermal Comfort in Populous Emerging Countries**
Khadija Hafeez, Yasra Chandio, **Abu Bakar**, Ayesha Ali, Affan A. Syed, Tariq M. Jadoon, Muhammad Hamad Alizai.
ACM Conference on Systems for Energy-Efficient Built Environments (**BuildSys**). 2017.
People's Choice Award

C01 **Design of a Laser Tracker Using 2-DOF Stepper Controlled Platform**
Abu Bakar, Neelam Nasir, Mukhtar Ullah, Zeashan Hameed Khan.
IEEE Conference on Robotics and Artificial Intelligence (**ICRAI**). 2016.

Journal Articles

J03 **User-Centered Perspectives on the Design of Batteryless Wearables**
Arwa Alsubhi, Reza Ghaiumy Anaraky, Simeon Babatunde, **Abu Bakar**, Thomas Cohen, Josiah Hester, Bart Knijnenburg, and Jacob Sorber.
International Journal of Human–Computer Interaction (**IJHCI**). 2023.

J02 **Demystifying Energy Consumption Dynamics in Transiently Powered Computers**
Saad Ahmed, Muhammad Nawaz, **Abu Bakar**, Naveed Anwar Bhatti, Muhammad Hamad Alizai, Junaid Haroon Siddiqui, Luca Mottola.
ACM Transactions on Embedded Computing Systems (**TECS**). Volume 19 , Issue 6. 2020.

J01 **Inverted HVAC: Greenifying Older Buildings, One Room at a Time**
Samar Abbas, **Abu Bakar**, Yasra Chandio, Khadija Hafeez, Ayesha Ali, Tariq M. Jadoon, Muhammad Hamad Alizai.
ACM Transactions on Sensor Networks (**TOSN**). Volume 14, Issue 3-4. 2018.

Workshop Papers

W02 **Logic-based Intelligence for Batteryless Sensors**
Abu Bakar, Tousif Rahman, Alessandro Montanari, Jie Lei, Rishad Shafik, Fahim Kawsar
ACM Workshop on Mobile Computing Systems and Applications (**HotMobile**). 2022.

W01 **Making Sense of Intermittent Energy Harvesting**
Abu Bakar, Josiah Hester
ACM Workshop on Energy Harvesting & Energy-Neutral Sensing Systems (**ENSsys**). 2018.

Posters and Demo Abstracts

P02 **Harnessing Power from the Soil: Long-Term, Stable Power Production from Terrestrial Microbial Fuel Cells Integrated into Green Infrastructure**
Weitao Shuai, Bill Yen, Laura Jaliff, **Abu Bakar**, Jason Huang, Alexander Curtiss, Colleen Josephson, Josiah Hester, Pat Pannuto, George Wells.
Assoc. of Environmental Engineering and Science Professors (AEESP) Research and Education Conference. 2022.

P01 **The Energy Harvesting Mode Abstraction**
Abu Bakar, Josiah Hester.
ACM Conference on Embedded Networked Sensor Systems (**SenSys**). 2018.

WORK EXPERIENCE

2022 – Present **Georgia Institute of Technology,** Atlanta, GA
Graduate Research Assistant
- ✦ Led research on designing **battery-free health-sensing wearables** powered by users' physical activities.
- ✦ Designed small, light-weight, and portable harvesters that generate power from users' movements.
- ✦ Developed **signal processing algorithms** to extract physiological signals from PPG sensor data.
- ✦ Mentored six junior Ph.D. and Masters students in projects on energy harvesting, **embedded system** design, and signal processing.

Summer 2023 **Accenture — Future Technologies R&D Group,** Atlanta, GA
Research Intern
- ✦ Designed a **self-powered infrastructure monitoring system** to detect anomalies/faults through vibrations.
- ✦ Developed Artificial Neural Network (ANN) models to analyze machine vibration data.
- ✦ Converted ANN model to Spiking Neural Network (SNN) model to be deployed on a low-power embedded device.

2018 – 22 **Northwestern University,** Evanston, IL

Graduate Research Assistant

- Led a team to design a **low-power, plug-and-play hardware platform** with adaptive machine learning capabilities, consisting of sensors, harvesters, and microcontrollers (MCUs) for rapid prototyping of energy-harvesting battery-free applications.
- Developed energy-efficient **operating systems** with **bare-metal programming** on MSP430 and ARM MCUs.
- Collaborated with a team to build a smart face mask platform that harvested energy from breathing inside the mask, movements, and sunlight, to measure physiological signals during COVID.
- Mentored five undergrad and Masters students in projects on **firmware development, hardware design,** and **PCB development**.
- Published **six research articles** in top computer systems venues and presented at conferences and workshops.

Fall 2021 **Nokia Bell Labs — Pervasive Computing Group,** Cambridge, UK

Research Intern

- Implemented Tsetlin Machine(TM), a first-of-its-kind **logic-based ML algorithm**, on battery-free devices.
- Optimized TM architecture to boost **energy efficiency by 14x**. Achieved **12x lower inference latency** against binary neural networks.
- Designed encoding techniques for compressing TM models by up to **99%**.
- Developed **firmware** for a low-power MCU to adapt TM's model complexity at run-time under varying energy levels.
- Published two **research articles** and filed one **patent** application (in process).

2016 – 18 **LUMS School of Science and Engineering,** Lahore, Pakistan

Research Assistant

- Developed and deployed an energy-efficient smart HVAC system using sensors and distributed air-conditioning units (window ACs, heaters, fans) and achieved **6% energy savings**.
- Developed a server that pulled data from deployed sensors and controlled appliances via smart switches.

Summer 2014 **National University of Computer and Emerging Sciences — SysNet Lab,** Islamabad, Pakistan

Undergraduate Research Intern

- Worked on wirelessly powering battery-free sensor nodes across a building using laser deployed at a distance of up to 100m.

TEACHING EXPERIENCE

Georgia Institute of Technology

Spring 2023 **Teaching Assistant — C7470 Mobile and Ubiquitous Computing**

- Designed lab exercises and graded assignments for a class of 50 undergrad and grad students.
- Led in-class exercises on Arduino application development and activity recognition.
- Advised four groups working on smart orthotics and tangible gaming projects.

Northwestern University

Spring 2022 **Co-Instructor — CE465 Internet-of-things Sensors, Systems, and Applications**

- Led lectures and graded assignments for a class of 30 undergrad and grad students.
- Assigned research papers for reading and led in-class discussions focusing on ideas, strengths, and weaknesses of the papers.

Spring 2021 **Teaching Assistant — CE346 Microprocessor System Design**

- Designed and graded lab exercises and assignments for an undergrad class of over 40 students.
- Conducted weekly office hours to assist students with assignment-related queries.

Spring 2020 **Teaching Assistant — CE346 Microprocessor System Design**

- Designed and graded lab exercises and assignments for an undergrad class of over 30 students.
- Conducted weekly office hours to assist students with assignment-related queries.

Information Technology University

Spring 2017 — **Teaching Assistant — CS365 Data Communication & Networks**
- ✦ Designed and graded quizzes and assignments for an undergrad class of over 50 students.
- ✦ Conducted weekly office hours to guide students through numerical exercises on the core concepts of data communication networks and assist with assignment-related queries.

LUMS School of Science and Engineering

Fall 2016 — **Teaching Assistant — CS677 Internet of Things**
- ✦ Advised and graded course projects for a class of over 40 grad students.

National University of Computer and Emerging Sciences

Fall 2015 — **Teaching Assistant — CS214 Programming Fundamentals**
- ✦ Designed and graded quizzes and assignments focused on object-oriented programming in C++ for a class of over 100 undergrad students.
- ✦ Conducted weekly office hours to assist students with assignment-related queries.

Fall 2014 — **Teaching Assistant — EE112 Programming for Engineers-II**
- ✦ Designed and graded quizzes and assignments focused on object-oriented programming in C++ for a class of over 100 undergrad students.
- ✦ Conducted weekly office hours to assist students with assignment-related queries.

Spring 2014 — **Teaching Assistant — EE110: Programming for Engineers-I**
- ✦ Designed and graded quizzes and assignments focused on C programming for a class of over 100 undergrad students.
- ✦ Conducted weekly office hours to assist students with assignment-related queries.

MENTORSHIP

Graduate Students

2021 – Rishabh Goel, Ph.D. Robotics, Georgia Institute of Technology

2023 Sabeen Liaquat, M.S. Computer Science, Georgia Institute of Technology (Now Software Engineer at Amazon)

2023 Rayan Dabbagh, M.S. Computer Science, Georgia Institute of Technology (Now Software Engineer at Amazon)

2023 Srihari Subramanian, M.S. Computer Science, Georgia Institute of Technology

2023 Rahul Katre, M.S. Computer Science, Georgia Institute of Technology

2023 Ryan Tougas, M.S. Electrical and Computer Engineering, Georgia Institute of Technology

2023 Vivek Kumar Singh, M.S. Electrical and Computer Engineering, Georgia Institute of Technology

2022 – 23 Julia Persche, M.S. Biomedical Engineering, Northwestern University (Now Product Designer at Cionic)

2020 – 21 Alexander Ross, M.S. Electrical Engineering, Northwestern University (Now Research Assoc. at MunichImaging)

2020 – 21 Eugene Choe, B.S./M.S. Computer Engineering, Northwestern University (Now Firmware Engineer at Samsung)

2019 – 20 Julian Richey, B.S./M.S. Computer Engineering, Northwestern University (Now ASIC Design Engineer at Amazon)

2019 – 20 Jackson Schuster, B.S./M.S. Computer Engineering, Northwestern University (Now Software Engineer at Microsoft)

Undergraduate Students

2021 – 23 Jason Huang, B.S. Computer Engineering, Northwestern University

2023 Aaron Wu, B.S. Electrical Engineering, Georgia Institute of Technology

2022 Alejandra Almonte, B.S. Mechanical Engineering, Northwestern University

Service and Leadership Experience

2022 – Present **Paper Reviewer**
- CHI 2024
- IMWUT 2022, IMWUT 2023
- SenSys 2023 (Secondary Reviewer)

2023 – Present **Member — Leadership Council — Ka Moamoa Lab**
- Coordinated with the lab director in setting short-term goals for the lab and mentored junior PhD students.

2022 **Coordinator — Group Meeting — Ka Moamoa Lab**
- Organized and occasionally led weekly group meetings of 20+ people at Ka Moamoa Lab.

2019 – 20 **Treasurer — Toastmasters International — Northwestern University**
- Managed finances for the university club including student memberships.

2019 **Organizer — Graduate Student Seminar Series — Northwestern University**
- Organized biweekly seminars for the Computer Engineering department where students presented recent research papers in their fields.

2016 **Finance Secretary — National Solutions Convention (NaSCon) — NUCES**
- Managed finances of **USD 50,000** to conduct 50 events during the annual 3-day university-wide mega-event.
- Led a team of 8 people to manage the budget and expenses of 50 social and technical events that included talks, workshops, seminars, gaming, robotics, and coding competitions.
- Served as a liaison between the university and sponsors.

2015 – 16 **Chairperson — IEEE Student Branch — NUCES**
- Managed a team of 10 people and organized robotics competitions, workshops, and seminars focusing on research and technology trends in industry and academia.

2015 **President — IEEE FAST Electrica — NUCES**
- Organized the annual 3-day university-wide tech event that included 26 competitions, workshops, and seminars.
- Supervised a team of 60 people who were a part of operations, logistics, sponsorship, marketing, photography, and event management teams.

2015 **President — IEEE Robotics Club — NUCES**
- Organized workshops on robotics and maintained a maker space for students build robots.

Skills

Programming: C/C++, Assembly, Python (PyTorch, Pandas, SciPy, NumPy, Matplotlib), VHDL, Verilog, Bash, GDB, Make, HTML, CSS

Hardware: ARM Cortex, nRF52x, TI MSP430, STM32, Arduino, Teensy, FPGA, PCB Design, Beaglebone, Raspberry Pi, UART, I2C, SPI

Software: Keil, Eclipse, Mbed, SEGGER J-Link, Ozone, Arduino, Proteus, Eagle, LTspice, RTOS, Git, MATLAB, Jupyter Notebook

Lab Equipment: Oscilloscope, Logic Analyzer, Energy Profiler, Digital Multi Meter, Soldering Iron

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