2020-2021 Annual Report NSF NeTs Small RUI Grant

Federal Agency and Organization Element to Which Report is Submitted: 4900
Federal Grant or Other Identifying Number Assigned by Agency: 1816197

Project Title:

NeTS: Small: RUI: Bulldog Mote- Low Power Sensor Node and design Methodologies for Wireless Sensor Networks

PD/PI Name:

Nan Wang, Principal Investigator
Woonki Na, Co-Principal Investigator

Recipient Organization:

California State University-Fresno Foundation

Project/Grant Period:

10/01/2018 - 09/30/2021 (no cost extension to 03/31/2022)

Reporting Period:

10/01/2020 - 09/30/2021

Submitting Official (if other than PD/PI):

Submission Date:

10/01/2021

Signature of Submitting Official (signature shall by submitted in accordance with agency specific instructions):

1. Accomplishments

Project website has been created and linked under our college website.

From college website: http://fresnostate.edu/engineering/research/index.html
(Click one of the two banners)

Direct Link: http://fresnostate.edu/engineering/research/bulldogmote/index.html

1.1 What are the major goals of the project?

The major goals of the project are the design and implementation of the following components: (1) efficient low-power methodologies implemented throughout all WSN design layers from application to the physical layer, (2) a new WSN sensor node, the Bulldog Mote, created using various low power methodologies, and (3) energy harvesting technologies for sensor node architecture.

1.2 What was accomplished under these goals (you must provide information for at least one of the four categories below)?

Major Activities

1. The final version of the low power Bulldog Mote PCB has been made. Design of the mote system has been done. Simulation of WSN operation using the motes is carrying out.
2. Efficient low-power methodologies implemented throughout all WSNs' design layers from the application to the physical layer;
3. Low power WSN communication protocols have been developed and simulated. New RDC/LS-AODV low power design method was simulated and results are satisfied.
4. Energy harvesting technologies for sensor node architecture. Several energy harvesting technologies were studied and simulated. Solar and Wind based energy harvesting system are under testing for simulation and preliminary experiment results are being analyzed with 2nd PCB. Vibration, thermal and other energy harvesting technologies are being investigating for a possible addition of the energy sources.
5. Energy harvesting control architecture are being investigated for nonlinear control techniques such as fuzzy, sliding mode, neural network and so on. Also with additional energy storages using battery and ultra-capacitor, a control architecture is being tested using simulation study.

Specific Objectives

1. Multi-energy source based energy harvesting for a low power application, 3.3V~5V available 10W~50W power capacity, was developed and tested. The main objective is to develop an efficient energy harvesting system using multi-energy sources for the target voltages up to 50W power rating.
2. A larger WSN of 11 sensor nodes was built to measure ambient temperature, light, and humidity. The idea is to get this infrastructure working on a small scale and then scale up. This is the crux of the connection between the physical sensor nodes and the cloud connection. Low power Radio Duty Cycle method was tested on the structure.

Significant Results

1. A WSN network of 11 new Bulldog motes has been built and tested. Low power communication protocol was implemented on the network and good results was achieved.
2. The final version of Bulldog Mote PCB was manufactured and is currently under testing.
3. New low power communication protocols were developed and simulated.
4. One journal and three conference papers were published in peer referred journal and conferences.
5. Multiple control techniques have been developed, such as a linear controller (PI), a combination of linear and non-linear controllers (PI and Hysteresis switching control), and Fuzzy logic controller (FLC). A comparison between each controller was observed in both simulation and experimentally for Max. Power Point Tracking(MPPT) and Constant Current(CC)/Constant Voltage(CV) battery charging. The multi-source energy harvester was implemented on an SMD(Surface Mounted Device) PCB circuit prototype. Similarly, the Hysteresis switching control (HSC) was implemented as a mixed-signal design using SMD PCB.
6. A series of the electrochemical impedance spectroscopy (EIS_ experiment was carried out to explore the behavior of a commercial cylindrical cell at different SOC conditions. We found this type of commercial cell had a SOC dependent impedance response. After conducting impedance test at different operating conditions, experimental results showed that such SOC dependent impedance behavior existed in different temperatures and C-rates, which suggests the mass transport should not be the primary reason leading to this phenomenon.

Key outcomes or other achievements

1. A 11-node WSN has been formed and simulated.
2. The final version of bulldog mote PCB was designed and manufactured
3. New low power MANET communication protocols were simulated
4. Multiple control techniques for energy harvesting and comparison data
5. An impedance battery model was studied

*** Detailed information can be found in the attached file.**

1.3 What opportunities for training and professional development has the project provided?

1. Dr. Nan Wang, presented results and progress of the NSF Bulldog project in the LIVE WEBCAST: STEM-NET "CSU NSF Research at Undergraduate Institutions (RUI)" to the students and Faculty from 23 California State University Campuses, June 23rd 2021.
2. Dr. Nan Wang presented the NSF NeTs Bulldog Mote project to the freshmen majoring in Electrical and Computer Engineering, 01/2021

3. Dr. Nan Wang presented the NSF NeTs Bulldog Mote project to the first year graduate students in ECE200, 11/2020
4. Dr. Woonki Na and his students will present their paper in Energy Harvesting in IEEE Energy Conversion Congress & Expo, Vancouver, Canada, Oct. 10~14, 2021
5. Dr. Nan Wang and his students will present their paper in low power WSN protocol design in IEEE IEMCON 2021, Vancouver, Canada, Oct. 27-30, 2021

1.4 How have the results been disseminated to communities of interest?

(1) Dr. Nan Wang, presented results and progress of the NSF Bulldog project in the LIVE WEBCAST: STEM-NET "CSU NSF Research at Undergraduate Institutions (RUI)" to the students and Faculty from 23 California State University Campuses, June 23rd 2021.

(2) All project procedures and results have been published on our NSF NETs Bulldog Mote website.

(3) Dr. Nan Wang, Dr. Woonki Na and student assistants presented current progress and results of the projects in IEEE conferences.

(4) The project activities are disseminated during virtual Project day held on 12/2021

1.5 What do you plan to do during the next reporting period to accomplish the goals?

(1) Complete testing and debugging of hardware and software of the Bulldog sensor system

(2) Complete testing and debugging of hardware and software of the Energy Harvesting control system.

(3) Finish integration of the WSN system and carry out simulation on real world application.

2. Products

2.1 Conference and Journal papers

1. Arvindh Srinivasan and Nan Wang, “An Effective approach for implementing Image Segmentation using Low-Cost System On Chip”, in Proc. of the IEEE IEMCON 2021, October, 2021, Vancouver, Canada.

2. Cameron Lane, Calvin Jarrod Smith and Nan Wang, “LS-AODV: An Energy Balancing Routing Algorithm for Mobile Ad Hoc Networks”, submitted to the IEEE IEMCON 2021, October,2021, Vancouver, Canada.

3. H. Martinez, M. Marji,C. Lim,J. Kim, N. Wang and W. Na, " Sliding Mode Control Based Energy Harvesting System For Low Power Applications, " accepted for the presentation, IEEE Energy Conversion Congress & Expo, Vancouver, Canada, Oct. 10~14, 2021

4. Y. Xie, J. Kim, M. Lee, J. Park and W. Na," An Impedance Behavior Study of Commercial NCA Cylindrical Battery Cells at Different SOCs," published in the Journal of The Electrochemical Society, 2021, 168, 090548

2.2 Website Title: NSF NeTs Bulldog Mote Project at Fresno State.

URL： http:/fresnostate.edu/engineering/research/bulldogmote/index.html

Short Description of the Website

The Fresno State BullDog Project is supported by the NSF NeTs Grant #1816197, from 10/01/208 to 09/20/2021. This project aims to design a new low-power sensor node, the Bulldog Mote, using attractive low power techniques, such as energy harvesting, clock scheduling, and dynamic voltage scheduling, implemented through all WSN design layers.The impact of this project will be further strengthened by: (1) embedding low-power design technologies in substantial systems from major industry parties, (2) enhancing curriculum development with improved courses and senior projects, (3) disseminating research results through online tutorial, peer referred publications, and open-source website, (4) reaching out to K-12 students and underrepresented minority groups through open houses and summer camps, and (5) supporting women and minority students in research. Finally, subsequent comprehensive low-power design model and procedures will be developed for designers to create and improve designs of other embedded devices under tight power constrains.

3. Participants/organization

3.1 * What individuals have worked on the project?

- Nan Wang, Ph.D., Professor, PI
- Woonki Na, Ph.D., Associate Professor, co-PI
- Calvin Smith, Graduate Student, WSN Communication gateway and physical design
- Cameron Lane, WSN Protocol Designs
- Randy Saetern, Undergraduate Student, PCB design and Control
- Cheaheng Lim, graduate Student, Energy harvesting software design integration
- Honorio Martinez, graduate student, energy harvesting hardware and battery charging algorithm design integration
- Maen Marji, graduate student, energy harvesting hardware and software design integration

3.2 What other organizations have been involved as partners?

- Chungnam National University, Daejon, S. Korea

3.3 What other collaborators or contacts have been involved?

- Jonghoon Kim, Assistant professor, Electrical Engineering department, Chungnam National University, Daejon, S. Korea
- Yuanyuan Xie, Associate professor, Mechanical Engineering department, Fresno State University

4. Impacts

4.1 What is the impact on the development of the principal discipline(s) of the project?

- Enhanced ECE courses, such as senior design, embedded systems, wireless communications, networking, power systems and smart grid designs by adding up-to-date technical contents and projects.
- Improved involvement of underrepresented students in research projects.
- Enhanced learning experience of undergraduate and graduate students by involve them in real world projects.

4.2 What is the impact on other disciplines?

N/A

4.3 What is the impact on the development of human resources?

- Enhanced training and retention of the junior faculty.

4.4 What was the impact on teaching and educational experiences?

- Enhanced development of senior projects for undergraduate students
- Enhanced development of Final projects for graduate students
- Supported course projects and new labs

4.5 What is the impact on institutional resources that form infrastructure?

- The project will provide a method to design low power digital devices using various technologies. It can be used in teaching or device designs.

4.6 What is the impact on technology transfer?

- The project will provide a method to better monitor forest fire, landslides, and structure health.

4.7 What is the impact on society beyond science and technology?

- Attracted students from underrepresented groups to the FSU engineering department.
- Improved students' interest in enrolling to programs at Fresno State University.

4.8 What is the impact on society beyond science and technology?

- Bulldog motes have been selected to from a WSN to monitor Fresno City Air Quality

Actual or Anticipated problems or delays and actions or plans to resolve them

Because of the Covid-19 pandemic, all our courses were offered online and all faculty and students needed to work from home. This greatly affected the progress of the research projects without accessing to the labs and in person supervision of the students. We are doing our best to catch up the pace of the schedule but a delay of completion of the project was expected. We required a no-cost extension for 6 months.