My Desktop
Prepare & Submit Proposals
Prepare Proposals in FastLane
New! Prepare Proposals (Limited proposal types)
Proposal Status
Awards & Reporting
Notifications & Requests
Project Reports
Submit Images/Videos
Award Functions
Manage Financials
Program Income Reporting
Grantee Cash Management Section Contacts
Administration
Lookup NSF ID

Preview of Award 1812399 - Annual Project Report

Cover |
Accomplishments |
Products |
Participants/Organizations |
Impacts |
Changes/Problems

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1812399
Project Title:	NeTS: Small: Collaborative Research: Network-Centric Mobile Cloud Computing
PD/PI Name:	Wei Gao, Principal Investigator
Recipient Organization:	University of Pittsburgh
Project/Grant Period:	09/01/2017 - 09/30/2019
Reporting Period:	10/01/2017 - 09/30/2018
Submitting Official (if other than PD\PI):	Wei Gao Principal Investigator
Submission Date:	10/15/2018
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Wei Gao

Accomplishments

*** What are the major goals of the project?**

Mobile cloud computing (MCC) has been used to address the resource limitation of mobile devices by migrating expensive local computations to the cloud. However, transmitting data wirelessly from mobile devices to the cloud also consumes energy. Hence, the key problem of MCC is how to minimize the energy consumption while preserving the mobile application performance. Different from traditional solutions which focus on reducing the cost of wireless transmission solely from the application perspective, this project focuses on designing MCC schemes from a network-centric perspective, by investigating, formulating, and mitigating the impact of special characteristics of wireless networks on the energy efficiency of MCC. The proposed research could benefit end users with various mobile devices by extending their battery lifetime and improving their performance.

This project aims to improve the performance of MCC by mitigating the impacts of two special characteristics of wireless networks: the long-tail problem at the wireless interface and the quality variations of the wireless link. More specifically, this

project consists of three closely intertwined research thrusts: (i) reducing the amount of tail energy when transmitting the program states to the remote cloud, while ensuring that the performance requirements of mobile applications can be met; (ii) mitigating the impact of wireless link quality on both energy and performance, and minimizing the degradation of application performance when the wireless link quality is low; and (iii) exploiting the difference of wireless link quality among mobile users to further improve the energy efficiency of MCC via user cooperation. An experimental testbed will be developed to investigate the practical impact of wireless network characteristics on MCC and evaluate the proposed MCC schemes.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Based on the previous research accomplishments made by this project, in this reporting period we have focused on developing new mobile system and wireless networking technologies that facilitate efficient workload migration from mobile devices to the remote cloud. More specifically, our major research activities include the following:

First, we have developed new mobile system designs to enhance the efficiency of mobile code offload from resource-constrained mobile devices to the edge cloud, by improving the granularity of such code offload from the traditional process-level to a more fine-grained method level. Such improvement allows more precise identification on the memory contexts that are relevant to the corresponding remote execution of mobile programs, hence minimizing the amount of wireless data transmission for mobile code offload. To support such fine-grained mobile code offload, our basic approach is to parse the mobile application binaries offline in advance, and then apply this parsing result to selectively migrate heap data while allowing successful method execution remotely. We will also parse all the mobile OS kernel libraries as an one-time effort, and then reuse such parsing results over different mobile applications for more accurate identification of relevant memory contexts.

Second, we have designed and evaluated a new PHY wireless modulation technique, which transforms the available choices for wireless link rate adaptation from discrete to continuous, so that the link rate being chosen is always optimal for any channel condition and the wireless channel throughput is hence optimized under highly severe or dynamic channel conditions. This technique aims to address the current under-utilization of wireless spectrum in various mobile cloud scenarios, especially those at large public facilities such as massive transportation systems, shopping malls and museums, where the wireless network performance may experience serious degradation due to the long communication distance or complicated indoor layout. In these cases, our technique will be critical to ensure sufficient wireless network throughput for transmitting the mobile program data for mobile cloud computing.

Education Activities:

Two PhD students have worked on the project. Some of the research results have been integrated with the education curricula at University of Tennessee and University of Pittsburgh. For example, we have added smartphone techniques to the contents of our undergraduate course “ECE1160: Introduction to Embedded System Design” and provided the students with the opportunity of working with the Android OS and off-the-shelf mobile devices.

Specific Objectives:

During the last reporting period, our research objectives are two-fold as described below:

Our first objective is to improve the efficiency of mobile code offload from resource-constrained mobile devices to the edge cloud. Current offloading schemes either require the programmer’s annotations, which restricts its wide application; or transmits too much unnecessary data, resulting bandwidth, and energy waste. Instead, a viable solution to this challenge is to enhance the granularity of such code offload, so as to avoid any irrelevant memory context from being transmitted to the edge cloud. Such fine-grained code offload, however, is challenging due to the complexity of mobile programs’ memory space at run-time.

Our second objective is to ensure that the wireless link connecting mobile devices to the remote cloud can always provide sufficient throughput for transmitting the mobile program data being remotely executed, even if the link condition is highly dynamic or severe due to link congestion or signal quality degradation. In practice, such wireless throughput could be particularly impaired over large-scale public network scenarios such as massive transportation systems, shopping malls and museums, due to the long communication distance and various types of wireless interferences that may seriously degrade the wireless signal quality.

Significant Results:

We have designed a new mobile code offload system, which addresses the aforementioned challenges and performs automated method-level workload offloading with least context migration. Our basic idea of achieving the least context migration while ensuring the offloading appropriateness is to identify the memory contexts that may be accessed by a specific application method prior to its execution, through offline parsing of the application executables. The parsing results will be stored as metadata along with the application executables at local mobile devices, and will be utilized by the run-time application execution to screen the thread stack and heap contexts to migrate only the relevant memory contexts to the remote cloud. In order to further improve the efficiency of such offline parsing and avoid unnecessary redundancy during parsing, we also pre-parse all the OS libraries that may be invoked by mobile application methods and then reuse these parsing results for different user applications. We have implemented the proposed system design over practical Android OS, and the experimental results over realistic smartphone applications show that our system can migrate 70 percent less memory contexts compared to existing schemes, while maintaining the same offloading effectiveness. To the best of our knowledge, we are the first to exploit the inner characteristics of application binaries for workload offloading in mobile clouds.

We also developed a new PHY-layer wireless modulation technique, named vMod (VLC-based modulation), which is a better solution towards rateless networking that always provides maximum wireless throughput over highly dynamic wireless links. Being different from existing rateless codes that regardlessly send and decode rateless data chunks with high communication and computation overhead, vMod transforms the available choices for link rate adaptation from discrete to continuous, so that the link rate being chosen is always optimal for any channel condition. The key technical contribution of vMod is that it can modulate an arbitrarily fractional number of data bits into a wireless data symbol, while preserving every individual symbol to be independent from others. In this way, it can provide any link rate that is supported by the channel condition. In order to encode a fractional number of data bits into a symbol that contains an integer number of constellation points, our key insight is to design a Variable-Length Code (VLC) and split the data bitstream into variable-length codewords, which are then mapped to constellation points in symbols. Hence, each symbol randomly carries a variable amount of data bits, and any link rate can be statistically achieved by adjusting the range and constitution of codeword lengths. We implemented vMod over USRP with GNURadio toolkit, based on a 5 GHz WiFi transceiver. Minimum modification is conducted over WiFi PHY and MAC. Based on this implementation, we evaluated vMod under dynamic channel conditions, and also compared vMod with existing rateless codes (Strider and Spinal codes). The experiment results show that vMod scales well with the dynamic channel conditions and improves the WiFi throughput by 30% over a single narrowband link, but consumes up to 95% less computation and communication overhead.

Key outcomes or Other achievements:

Our research activities in the last reporting period has resulted in one journal paper and one conference paper being published at top-tier venues.

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

Two PhD students have worked on the project, and the research results have been published at various top-tier journals and conference proceedings.

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

Our research work in this project has resulted in two conference papers. These publications will help people better understand our novel techniques on exploiting system and network dynamics in mobile clouds, and further apply these techniques to improve the performance and energy efficiency of MCC applications in practice. We have also given seminar and summer camp talks to high school students to stimulate their interest in engineering majors.

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

In the next year of this project, we plan to build on our current research accomplishments, and further explore the possibility of providing satisfactory and reliable wireless network performance to mobile cloud computing. For example, we plan to further expand our existing design of vMod to multiple-access wireless networks and allow multiple wireless devices to access rateless networks simultaneously. We will also investigate the possibility of realizing such continuous link rates without PHY hardware modification. Such hardware design, on the other hand, also allows us to develop more efficient mobile software systems that support mobile code offload over highly heterogeneous mobile scenarios.

Products

Books

Book Chapters

Inventions

Journals or Juried Conference Papers

Haoyang Lu and Wei Gao (2018). Continuous Wireless Link Rates for Internet of Things. *Proceedings of the 17th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN)*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Yong Li and Wei Gao (2017). Minimizing Context Migration in Mobile Code Offload. *IEEE Transactions on Mobile Computing*. 16 (4), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses

Other Conference Presentations / Papers

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Websites

Project website
http://www.pitt.edu/~weigao/reporting/mcc_network_centric.html

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked

Name	Most Senior Project Role	Nearest Person Month Worked
Gao, Wei	PD/PI	3
Li, Yong	Graduate Student (research assistant)	3
Lu, Haoyang	Graduate Student (research assistant)	4

Full details of individuals who have worked on the project:

Wei Gao
Email: weigao@pitt.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 3

Contribution to the Project: Lead and manage the project

Funding Support: This project

International Collaboration: No
International Travel: No

Yong Li
Email: yli118@vols.utk.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Developed the fine-grained mobile code offload technique.

Funding Support: This project

International Collaboration: No
International Travel: No

Haoyang Lu
Email: haoyanglu@pitt.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: Developed the vMod technique, which turns the available choices of link rate adaptation from discrete to continuous.

Funding Support: This project.

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?
Nothing to report.

What other collaborators or contacts have been involved?
Nothing to report

Impacts

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

MCC can greatly benefit a large variety of mobile devices ranging from smartphones to embedded sensor devices, and from smart watches to wearable medical devices. The transformative nature of the proposed research is to completely redesign MCC from a network-centric perspective, and to turn various system modeling and formal analysis techniques into actionable distributed algorithms and design strategies that apply to practical mobile cloud systems. It will investigate the essential factors determining the energy efficiency of MCC that are tightly coupled with the special characteristics of wireless networks, and will inspire further theoretical and systematic studies that can open up new areas of research. To summarize, the research output will have the following impacts. First, it leads to a new design philosophy for MCC that is pivotal to practical integration of mobile devices into the cloud. Second, it introduces novel solutions to deal with the long-tail problem related to the wireless radio interface that is vital to energy-efficient MCC. Third, this work can spawn a new area of research on mitigating the impact of wireless link quality on MCC. Fourth, the techniques of cooperative wireless link selection in MCC are likely to foster further research along this direction. Finally, the developed testbed as a unique research facility will benefit the whole research community.

What is the impact on other disciplines?

The mobile cloud is a typical example of mobile computing systems with complex dynamics rooted in the system's execution. Being able to precisely characterize and appropriately exploit these dynamics to improve the system efficiency and adaptability has a direct and immediate impact on a large variety of ubiquitous computing and cyber-physical systems.

What is the impact on the development of human resources?

Many of the research results have been integrated into the undergraduate curricula at the University of Tennessee and University of Pittsburgh, by adopting many perspectives of the research results for undergraduate students' course projects and senior design topics. The project has supported two PhD students working on their dissertations. The involvement of the graduate and undergraduate students into this research will prepare them for leadership roles in computer science research, academia, and industry.

What is the impact on physical resources that form infrastructure?
Nothing to report.

What is the impact on institutional resources that form infrastructure?
Nothing to report.

What is the impact on information resources that form infrastructure?
Nothing to report.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.