Computer Organization Laboratory

Toshiaki Miyazaki
Professor

Hiroshi Saito
Senior Associate Professor

Peng Li
Associate Professor

The following researches are progressed in Computer Organization Laboratory:

Toshiaki Miyazaki:
    has mainly three topics as follows:

- *Die-hard sensor network:* A wireless sensor network that has an autonomous function alternation mechanism among sensor nodes as well as ordinary wireless sensor network capabilities such as automatic network establishment. With this mechanism, we can realized self-organized and maintenance-free sensor network systems. Its applications include surveillance of disaster-hit region, and river and forest monitoring. We are developing not only sensor-node hardware but also protocols equipped to the sensor node.

- *Demand-addressable sensor network:* The aim of this research project is to construct a wide-area sensor network that interprets users' abstract sensing demands. The network then finds the sensors that hold the data which satisfies the demand, mashes up the collected data within the network along with useful information from other systems, and finally enables the user' s terminal to display it in real time. The sensor network itself has an environmental adaptability that allows each sensor node to consider its surroundings and the user-issued requests, and which will then dynamically change its role to actively acquire the desired sensing data autonomously.

- *Custom computing:* A research field to realize a dedicated hardware using programmable logic devices such as FPGAs (Field Programmable Gate Arrays) in order to solve a give problem effectively. We focused on acceleration of Time-Space Continuous Dynamic Programing (TSCDP) using FPGAs.

TSCDP is a way of recognition of air-drawn gestures and characters from a video stream. It can realize both time- and location-free (spotting) recognition. Spotting means prior segmentation of the input video, and it is not needed to perform TSCDP. However, TSCDP requires computation power. Thus, it is meaningful to accelerate TSCDP using FPGAs.

Hiroshi Saito:
Our research interests are design automation of asynchronous circuits, design automation of multi/many core systems, and applications of sensor networks.

- Asynchronous circuits are circuits where circuit components are controlled by pairs of local handshake signals instead of a global clock signal. Because of the absence of a global clock signal, asynchronous circuits are low power and low electromagnetic interference compared to synchronous counter parts which use global clock signals. We are developing design support environment to implement asynchronous circuits on commercial FPGAs, developing a transformation tool from a synchronous register transfer level (RTL) model to an asynchronous RTL model, and designing a low power asynchronous processor.

- Due to the advance of integration technology, current embedded systems consist of multi/many processing cores. This makes possible parallel execution of multiple applications. However, it makes embedded system design complex. To make system-level design easy, we are developing design support environment to implement a Simulink model into commercial field programmable gate arrays (FPGAs) through task partitioning, scheduling, and allocation.

- Our local area has heavy snow fall in the winter season which results in degradation of economic activities and traffic accidents. To reduce such problems, it is desirable to check snow fall at real time. We are developing a web system which shows snow depth of roads that are measured by a sensor network. The sensor network consists of sensor nodes with open source hardware Arduino and XBee module.

Peng Li:
My research interests mainly focus on wireless communication and networking, specifically wireless sensor networks green and energy-efficient mobile networks and cross-layer optimization for wireless networks. I also have interests on cloud

computing, big data processing and smart grid. These topics are studied from two aspects. First, new techniques and approaches will be proposed to enhance network system performance. Prototypes are developed to evaluate their feasibility. Second, new algorithms will be designed and evaluated using advanced theoretical methods, like convex optimization, stochastic optimization, game and auction theories.

Refereed academic journal

[miyazaki-201-031-01:2015] T. Hayashi, Y. Watanabe, A. Pham, T. Miyazaki, S. Matsufuji, and T. Maeda. A Novel Class of Zero-Correlation Zone Sequence Set Having a Low Peak-Factor and a Flat Power Spectrum. *IEICE Trans. Fund*, E98-A(12):2429–2438, 2015.

> The present paper introduces a novel method for the construction of a class of sequences that have a zero-correlation zone. For the proposed sequence set, both the cross-correlation function and the side lobe of the auto-correlation function are zero for phase shifts within the zero-correlation zone. The proposed scheme can generate a set of sequences of length $8n^2$ from an arbitrary Hadamard matrix of order n and a set of 2n trigonometric-like function sequences of length 4n. The proposed sequence construction can generate an optimal zero-correlation zone sequence set that satisfies the theoretical bound on the number of members for the given zero-correlation zone and sequence period. The auto-correlation function of the proposed sequence is equal to zero for all nonzero phase shifts. The peak factor of the proposed sequence set is $\sqrt{2}$, and the peak factor of a single trigonometric function is equal to $\sqrt{2}$. Assigning the sequences of the proposed set to a synthetic aperture ultrasonic imaging system would improve the S/N of the obtained image. The proposed sequence set can also improve the performance of radar systems. The performance of the applications of the proposed sequence sets is evaluated.

[miyazaki-201-031-02:2015] T. Miyazaki and Y. Kasama. Multiple Human Tracking Using Binary Infrared Sensors. *Sensors*, 15(99):DOI:10.3390/s150613459, 2015.

> To create a context-aware environment, human locations and movement paths must be considered. In this paper, we propose an algorithm that tracks human movement paths using only binary sensed data obtained by infrared (IR) sensors attached to the ceiling of a room. Our algorithm can estimate multiple human movement paths without a priori knowledge of the number of humans in the room. By repeating predictions and estimations of human positions and links from the previous human positions to the estimated ones at each time period, human movement paths can be estimated. Simulation-based evaluation results show that our algorithm can dynamically trace human movement paths.

[pengli-201-031-01:2015] Song Guo Huawei Huang, Peng Li and Weihua Zhuang. Software-Defined Wireless Mesh Networks: Architecture and Traffic Orchestration. *IEEE Network*, 29(4), 2015.

Summary of Achievement

In this article, we study how to apply SDN concept to a wireless mesh network that has been widely adopted by various applications. We first propose a novel architecture of SD-WMNs, and identify several critical challenges. Since wireless spectrum is a scarce resource that is shared by both data and control traffic in SD-WMNs, we propose three spectrum allocation and scheduling algorithms, namely FB-NS, NFB-NS, and NFB-S that orchestrate both control and data traffic. Finally, performance is evaluated via extensive simulations.

[pengli-201-031-02:2015] Peng Li Baoliu Ye Huawei Huang, Song Guo and Ivan Stojmenovic. Joint Optimization of Rule Placement and Traffic Engineering for QoS Provisioning in Software Defined Network. *IEEE Transactions on Computers*, 64(12):3488–3499, 2015.

To efficiently use TCAM resources, we propose a rule multiplexing scheme, in which the same set of rules deployed on each node apply to the whole flow of a session going through but towards different paths. Based on this scheme, we study the rule placement problem with the objective of minimizing rule space occupation for multiple unicast sessions under QoS constraints. We formulate the optimization problem jointly considering routing engineering and rule placement under both existing and our rule multiplexing schemes. Via an extensive review of the state-of-the-art work, to the best of our knowledge, we are the first to study the non-routing-rule placement problem. Finally, extensive simulations are conducted to show that our proposals significantly outperform existing solutions.

[pengli-201-031-03:2015] Song Guo Toshiaki Miyazaki Jiankun Hu Deze Zeng, Peng Li and Yong Xiang. Energy Minimization in Multi-Task Software-Defined Sensor Networks. *IEEE Transactions on Computers*, 64(11):3128–3139, 2015.

It is significant to design an energy-efficient sensor scheduling and management strategy with guaranteed quality-of-sensing for all tasks. To this end, three issues are investigated in this paper: 1 the subset of sensor nodes that shall be activated, i.e., sensor activation, 2 the task that each sensor node shall be assigned, i.e., task mapping, and 3 the sampling rate on a sensor for a target, i.e., sensing scheduling. They are jointly considered and formulated as a mixed-integer with quadratic constraints programming (MIQP) problem, which is then reformulated into a mixed-integer linear programming (MILP) formulation with low computation complexity via linearization. To deal with dynamic events such as sensor node participation and departure, during SDSN operations, an efficient online algorithm using local optimization is developed.

Simulation results show that our proposed online algorithm approaches the globally optimized network energy efficiency with much lower rescheduling time and control overhead.

[pengli-201-031-04:2015] Peng Li Toshiaki Miyazaki Hai Jin Zaiyang Tang, Song Guo and Xiaofei Liao. Energy-Efficient Transmission Scheduling in Mobile Phones using Machine Learning and Participatory Sensing. *IEEE Transactions on Vehicular Technology*, pages 3167–3176, 2015.

In this paper, we study the tail energy minimization problem by exploiting the techniques of machine learning and participatory sensing. We design a client-server architecture, in which the training process is conducted in a server, and mobile devices download the constructed predictor from the server to make transmission decisions. A system is developed and deployed on real hardware to evaluate the performance of our proposal. The experimental results show that it can significantly improve the energy efficiency of mobile devices while incurring minimum overhead.

[pengli-201-031-05:2015] Song Guo Peng Li and Jiankun Hu. Energy-Efficient Cooperative Communications for Multimedia Applications in Multi-Channel Wireless Networks. *IEEE Transactions on Computers*, 2015.

The dramatic growth of mobile multimedia communications imposes new requirements on quality-of-service and energy efficiency in wireless networks. In this paper, we study the energy- and spectrum-efficient cooperative communication (ESCC) problem by exploiting the benefits of cooperative communication (CC) for mobile multimedia applications in multi-channel wireless networks. In a static network, it is formulated as a mixed-integer nonlinear programming problem. To solve this problem, we use linearization and reformulation techniques to transform it into a mixed-integer linear programming problem that is solved by a branch-and-bound algorithm with enhanced performance. To deal with the problem in dynamic networks, we propose an online algorithm with low computational complexity and deployment overhead. Extensive simulations are conducted to show that the proposed algorithm can significantly improve the performance of energy efficiency in both static and dynamic networks.

[pengli-201-031-06:2015] Peng Li and Song Guo. Incentive Mechanisms for Device-to-Device Communications. *IEEE Network*, 2015.

In this article we fill the gap by designing incentive mechanisms to encourage users to work under D2D mode. We consider two basic market types, open

markets and sealed markets, where users have information of all users or only their own, respectively. For open markets, we design a Stackelberg game based incentive mechanism that can achieve Nash equilibrium. For sealed markets, we design an auction based incentive mechanism that guarantees truthfulness.

Refereed proceedings of an academic conference

[hiroshis-201-031-01:2015] H. Saito T. Yoneda, M. Imai and K. Kenji. Dependable Real-Time Task Execution Scheme for a Many-Core Platform. In *Proc. DFTS*, pages 198–205, 2015.

This paper explores a new dependable real-time task execution scheme for a many-core system.

[miyazaki-201-031-03:2015] D. Baba, N. Suematsu, S. Nabeshima, and T. Miyazaki. Reconfigurable Sensor Network Emulator Virtualizing Integrated Large-Scale Sensor Network. In *IEEE International Conference on Computing, Networking and Communications (ICNC2016)*, pages 79–83, Feb. 2015.

In this study, we propose a reconfigurable sensor network emulator (ReSNE) that realizes a virtual large-scale sensor network environment by combining pseudo sensor/network devices and real ones. This is necessary as it is difficult to evaluate nationwide sensor networks using a real environment because of the need for a large number of real sensor nodes and related devices such as base stations, in addition to a large dedicated communication network. To emulate sensor network traffic, we also use a sensor data generator that generates sensed data packets in the network based on specific user-defined parameters. Furthermore, we develop an auto-configuration tool to enable us to set up the environment quickly. Here, we discuss details of the proposed ReSNE architecture and present some of the evaluation results obtained.

[miyazaki-201-031-04:2015] K. Anazawa, P. Li, T. Miyazaki, and S. Guo. Trajectory and Data Planning for Mobile Relay to Enable Efficient Internet Access after Disasters. In *IEEE Globecom2015*, page DOI:10.1109/GLOCOM.2015.7417170, Dec. 2015.

Our experiences in East Japan Earthquake show that disasters will cause a large-scale network interruption due to serious damage of existing network infrastructures. To enable Internet connection before network service restoration, which is usually time-consuming, we propose to use a mobile relay to

carry data for several isolated communities formed after disasters. Specifically, we consider that only one community has the Internet connection, and data from Internet need to be carried to other communities by the mobile relay. The data downloading performance of each community is evaluated by the utility of obtained data minus the penalty of corresponding latency. With the objective of maximizing the poorest performance among communities, we formulate a max-min problem to optimize the trajectory of the mobile relay and its carried data volume for each community. Due to the NP-hardness of this problem, we propose a genetic algorithm by representing the trajectories of mobile relay as chromosomes that evolve to approximate the optimal solution. The fitness of each chromosome is evaluated by optimizing the data volume carried for each community. Extensive simulations are conducted to show that our proposed algorithm significantly outperforms existing algorithms.

[miyazaki-201-031-05:2015] T. Miyazaki, P. Li, S. Guo, J. Kitamichi, T. Hayashi, and T. Tsukahara. On-demand Customizable Wireless Sensor Network. In *The 6th International Conference on Ambient Systems, Networks and Technologies (ANT-2015)*, pages 302–309, June 2015.

In this paper, we propose a wireless sensor network (WSN) whose behavior can be dynamically customized by injecting programs or roles specified by the user. To enable easy specification of the roles, a role-generation mechanism is also proposed. To realize the WSN, we introduce a reconfigurable wireless sensor node that has an ultra-low-power field-programmable gate array (FPGA) as well as a low-power microcontroller unit (MCU). By injecting several different roles into the sensor nodes, we confirmed that the behavior of the WSN can be changed on demand.

[pengli-201-031-07:2015] Peng Li Hai Jin Song Guo Xiaofei Liao Xiao Lei, Zaiyang Tang and Feng Lu. Energy Minimization for Cellular Network Interfaces with Dynamic Link Quality. In *The 24th International Conference on Computer Communications and Networks (ICCCN)*, 2015.

In this paper, we study to minimize energy consumption of the cellular network interface with a sequence of download/upload requests. Given accurate estimation of achievable link rate, we design a dynamic-programming (DP) based algorithm to obtain the optimal solution. Without the knowledge of dynamic link quality and future requests, an online algorithm is proposed to approximate the optimal solution. Finally, we conduct extensive simulations

using real traces to evaluate the performance of our proposals, and the results show that 29% energy can be saved by using our algorithm under typical network settings.

[pengli-201-031-08:2015] Toshiaki Miyazaki Peng Li and Song Guo. 'Relay Placement for Latency Minimization in Delay Tolerant Networks. In *IEEE International Conference on Communications (ICC)*, 2015.

In this paper, we study a relay deployment problem with the objective of minimizing communication latency among all nodes in DTN, which has been little studied so far. Upon the concept of latency graph that we propose to model the message delivery latency in DTN, the problem of relay placement for latency minimization (RPLM) is defined and proven NP-hard. To solve the RPLM problem, we propose a heuristic algorithm with low complexity, and conduct extensive simulations to show that it significantly outperforms other two existing schemes.

[pengli-201-031-09:2015] Song Guo Junji Kitamichi Takafumi Hayashi Toshiaki Miyazaki, Peng Li and Tsuneo Tsukahara. On-Demand Customizable Wireless Sensor Network. In *International Conference on Ambient Systems, Networks and Technologies (ANT)*, 2015.

In this paper, we propose a wireless sensor network (WSN) whose behavior can be dynamically customized by injecting programs or roles specified by the user. To enable easy specification of the roles, a role-generation mechanism is also proposed. To realize the WSN, we introduce a reconfigurable wireless sensor node that has an ultra-low-power field-programmable gate array (FPGA) as well as a low-power microcontroller unit (MCU). By injecting several different roles into the sensor nodes, we confirmed that the behavior of the WSN can be changed on demand.

Unrefeered proceedings of an academic conference

[hiroshis-201-031-02:2015] M. Imai H. Saito and T. Yoneda. Task Allocation Methods based on the Maximum Task Parallelism for Multi-core Systems with the DTTR Scheme. In *VLD2015-113*, pages 13–18, 2016.

[hiroshis-201-031-03:2015] T. Yoneda H. Saito and M. Imai. A Task Allocation Method for Duplication with Temporary Triple Modular Redundancy and Reconfiguration. In *DA Symposium 2015*, 2015.

[miyazaki-201-031-06:2015] M. Ohta, T. Okoshi, Y. Watanabe, and T. Miyazaki. Inducing of Rambling Activities by Using Inverse Perspective. In *IEICE Technical Report (HCP)*, volume 115(471), pages 5 – 10, March 2016.

[miyazaki-201-031-07:2015] S. Nabeshima and T. Miyazaki. Easily Behavior Customization Environment for Wireless Sensor Networks. In *IPSJ 78th National Convention*, volume 1T-01, March 2016.

  The student encouragement award

[miyazaki-201-031-08:2015] N. Suematsu, D. Baba, and T. Miyazaki. Space-Time Distributed Database Using Geohash for Wide-area Sensor Networks. In *IPSJ 78th National Convention*, volume 1t-02, March 2016.

[miyazaki-201-031-09:2015] D. Baba, N. Suematsu, and T. Miyazaki. Integrated System Allowing Easy Setting of Large-scale Sensor Network Emulation. In *IPSJ 78th National Convention*, volume 1T-06, March 2016.

[miyazaki-201-031-10:2015] T. Okoshi, Y. Watanabe, M. Ohta, and T. Miyazaki. Context Extracting Method Using Appearing Order of Frequently-Appearing Patterns. In *IPSJ 78th National Convention*, volume 1W-06, March 2015.

[miyazaki-201-031-11:2015] N. Sagami and T. Miyazaki. Acceleration of Time-Space Continuous Dynamic Programming Algorithm Using an Array Processor. volume 1V-04, 2016.

[miyazaki-201-031-12:2015] K. Anazawa, P. Li, and T. Miyazaki. Data Transfer Method among Isolated Data Servers Using Multiple Mobile Relays. volume 6T-02, 2016.

[miyazaki-201-031-13:2015] Y. Igarashi and T. Miyazaki. Data Synchronization among Isolated Servers Using DTN and Message Ferry. volume 6T-03, 2016.

[miyazaki-201-031-14:2015] K. Anazawa, P. Li, and T. Miyazaki. An Online Algorithm for Trajectory Planning of Mobile Relay to Enable Communication after Disasters. In *IEEE student session in 2015 Tohoku-Section Joint Convention of Institutes of Electrical and Information Engineers, Japan*, volume 2A01, Aug. 2015.

Summary of Achievement

[miyazaki-201-031-15:2015] Y. Watanabe, M. Ohta, and T. Miyazaki. Similar Trajectory Classification Using a Graph Matching Method. In *IEEE student session in 2015 Tohoku-Section Joint Convention of Institutes of Electrical and Information Engineers, Japan*, volume 2A02, Aug. 2015.

[miyazaki-201-031-16:2015] S. Nabeshima and T. Miyazaki. Retargetable Scenario Compiler for Programmable Wireless Sensor Nodes. In *IEEE student session in 2015 Tohoku-Section Joint Convention of Institutes of Electrical and Information Engineers, Japan*, volume 2A03, Aug. 2015.

[miyazaki-201-031-17:2015] N. Suematsu, D. Baba, and T. Miyazaki. Evaluation of Large-scale Distributed Database System for Nation-wide Sensor Network. In *IEEE student session in 2015 Tohoku-Section Joint Convention of Institutes of Electrical and Information Engineers, Japan*, volume 2A04, Aug. 2015.

[miyazaki-201-031-18:2015] T. Miyazaki, P. Li, S. Guo, T. Hayashi, J. Kitamichi, and T. Tsukahara. Special Invited Talk: Implementation of Demand Addressable Sensor Network Realizing Demand-Driven Wide-Area Sensing(pages 11 – 16.

[miyazaki-201-031-19:2015] T. Miyazaki. Keynote Speech: How to deal with big sensor data? - A demand-driven large-scale sensor network approach. In *IEEE International Symposium on Big Data and Networking 2016*, Feb. 2016.

Research grants from scientific research funds and public organizations

[hiroshis-201-031-04:2015] H. Saito. Grant-in-Aid for Scientific Research (C), 2014-2016.

[miyazaki-201-031-20:2015] T. Miyazaki. Ministry of Education Scientific Research Fund, 2015-2017.

[miyazaki-201-031-21:2015] T. Miyazaki. Joint research with NTT innovation laboratories, 2015.

[miyazaki-201-031-22:2015] T. Miyazaki. Cross-ministerial Strategic Innovation Promotion Program (SIP), 2014–2018.

Academic society activities

[hiroshis-201-031-05:2015] H. Saito, 2015.

Steering Committee of IPSJ-SLDM

[hiroshis-201-031-06:2015] H. Saito, May 2015.

Technical Program Committee of ASYNC 2015

[miyazaki-201-031-23:2015] T. Miyazaki, 2012-1015.

IEEE Sendai Section, Executive Committee Member

[miyazaki-201-031-24:2015] T. Miyazaki, 2015.

Steering Committee Member, IEICE Technical Group for Function Integrated Information System (FIIS)

[miyazaki-201-031-25:2015] T. Miyazaki, 2015.

Steering Committee Member, MCSoC-15 (IEEE 9th International Symposium on Embedded Multicore Systems-on-Chip)

[miyazaki-201-031-26:2015] T. Miyazaki, 2014 – present.

IEICE Senior Member

[miyazaki-201-031-27:2015] T. Miyazaki, 2014 – present.

IPSJ Senior Member

[miyazaki-201-031-28:2015] T. Miyazaki, 2012 – present.

IEEE Senior Member

Patent

[miyazaki-201-031-29:2015] T. Miyazaki, P. Li, and S. Guo. Information Management System in Disaster Area, and Service Equipment and Terminal for the System (Submitted AP2015-207660), October 2015.

Summary of Achievement

Advisor for undergraduate research and graduate research

[hiroshis-201-031-07:2015] K. Yoshimi. A Design Method for Low Energy Asynchronous Circuits with Bundled-data Implementation, University of Aizu, 2015.

Graduation research

[hiroshis-201-031-08:2015] J. Furushima. Design of a Low Energy Asynchronous MIPS Processor on FPGA, University of Aizu, 2015.

Graduation research

[hiroshis-201-031-09:2015] T. Urakawa. Design of a Low Energy Asynchronous Inverse Discrete Cosine Transform Circuit on FPGA, University of Aizu, 2015.

Graduation research

[miyazaki-201-031-30:2015] Naoki Akiyama. Graduation Thesis: Formal Method to Define Deadlock-free Sensor Node Behavior, University of Aizu, 2015.

Thesis Advisor: T. Miyazaki

[miyazaki-201-031-31:2015] Yusuke Igarashi. Graduation Thesis: Efficient and Stable Data Synchronization of Isolated Servers in Delay Tolerant Network Using Message Ferry, University of Aizu, 2015.

Thesis Advisor: T. Miyazaki

[miyazaki-201-031-32:2015] Seichi Adachi. Graduation Thesis: Distributed Database System Using Geohash and HBase for a Large-scale Wireless Sensor Network, University of Aizu, 2015.

Thesis Advisor: T. Miyazaki

[miyazaki-201-031-33:2015] Kazuya Anazawa. Graduation Thesis: Data Transfer Methods among Isolated Servers Using Mobile Relays, University of Aizu, 2015.

Thesis Advisor: T. Miyazaki

[miyazaki-201-031-34:2015] Daisuke Baba. Master Thesis: Customizable Emulation System Dedicated to Large-scale Sensor Network, University of Aizu, 2015.

Thesis Advisor: T. Miyazaki

[miyazaki-201-031-35:2015] Shun Nabeshima. Master Thesis: Behavior Customization Environment Applicable to Different Types of Wireless Sensor Nodes, University of Aizu, 2015.

> Thesis Advisor: T. Miyazaki

[miyazaki-201-031-36:2015] Naoki Suematsu. Master Thesis: Scalable Distributed Database System Enabling Effective Sensor Data Access Using Time and Space Information, University of Aizu, 2015.

> Thesis Advisor: T. Miyazaki

Advisor of a student club or circle

[hiroshis-201-031-10:2015] Triathlon Club

Other significant contribution toward university planning, management, or administration

[hiroshis-201-031-11:2015] Member of Academic Affair Committee in the Undergraduate School

[hiroshis-201-031-12:2015] Member of Curriculum Subcommittee

[hiroshis-201-031-13:2015] Member of Curriculum Working Group

Did you participate in Public Lectures, and/or Open Campus? (Yes or No) If yes, please describe what you did.

[hiroshis-201-031-14:2015] Joining open campus on August and October

Research achievement that can be used for University-Industry collaboration and its characteristics.(for UBIC's information)

[hiroshis-201-031-15:2015] Electronic design automation tools for asynchronous circuits

[hiroshis-201-031-16:2015] Electronic design automation tools for reliable multi-core systems

Summary of Achievement

[hiroshis-201-031-17:2015] A support system for snow removal using Arduino and sensor
    network