ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow:	Liuguo Yin
Visited Location:	NTNU, Trondheim, Norway
Duration of Visit:	12 months, April 1st, 2007 -- March 31st, 2008

I - Scientific activity

(1 page at maximum)

During my staying at the Norwegian University of Science and Technology (NTNU), considerable research related to wireless sensor networks was carried out, which can be divided into two parts:

In the first part, I addressed the area of the energy consumption issues of wireless sensor nodes. As we know, the sensor nodes of a wireless sensor network typically work with small batteries for which replacement is very expansive and even impossible. Thus, minimizing the energy consumption of the sensor nodes is an important design consideration. The data transmission energy consumption is a critical part of energy consumption in wireless sensor nodes, which can be optimized by well allocating the channel coding rate, the modulation constellation size, and the transmission duration. Moreover, we have observed that for a wireless sensor network whose nodes are densely distributed, the measurements at individual sensor nodes are always spatially correlated. When the correlations between data measured by nearby sensor nodes are considered, the communication energy consumption may be further reduced. Based on this observation, we have proposed an optimization algorithm for minimizing the overall data transmission energy consumption. Compared to the optimized uncorrelated uncoded transmission scheme, the total energy consumption may be reduced by more than 83.5% for a correlation value of 0.6 and a transmission distance of 100 meters when using the results from the proposed optimization. This is significant with respect to increasing the lifetime of a wireless sensor network.

In the second part of my research work, I focus on the topic of energy-efficient routing for event-driven dense wireless sensor networks. In dense wireless sensor networks, the occurrence of an event may be detected by multiple sensor nodes. Then each of the event-detecting sensor nodes may immediately generate a report message for transmission to the sink node. For this application, the target of our routing algorithm is to maximize the energy efficiency of such multiple-to-one routing schemes, so as to maximize the duration before the first failed event-reporting to the sink node. Although this kind routing problem has been proven to be NP-complete, we have built a heuristic routing protocol for event-driven dense wireless sensor networks. The proposed routing protocol exploits a new cost function for energy balancing among sensor nodes and uses an iterative scheme with optimized data fusions to compute the minimum-cost route for each event-detecting sensor node, which is able to outperform the LEACH protocol and the PEGASIS protocol over 100-300% and 10-100% in network lifetime.

II- Publication(s) during your fellowship

Please insert the title(s), author(s) and abstract(s) of the published paper(s). You may also mention the paper(s) which were prepared during your fellowship period and are under reviewing.

1) Liuguo Yin, Changmian Wang, and Geir E. Øien. "Energy Consumption Optimization in Data Transmission from Correlated Sensor Nodes," *IEEE 4th International Symposium on Wireless Communication Systems (ISWCS 2007)*, pp. 26-30, 2007.

ABSTRACT

In this paper, we focus on the energy consumption issues of data transmission from correlated sensor nodes, and an optimization algorithm is proposed for minimizing the total energy consumption of the hardware and the physical link. We perform a detailed trade-off analysis of the circuit energy consumption, the transmission energy consumption, the transmission time, the QAM constellation size, and the channel coding rate over transmission distance and correlation values, thus a new optimized transmission schedule with much lower energy consumption is obtained. Compared to the optimized uncorrelated uncoded transmission scheme, the total energy consumption may be reduced by more than 83.5% for a correlation value of 0.6 and a transmission distance of 100 meters when using the results from the proposed optimization, which is significant with respect to increasing the lifetime of a wireless sensor network.

2) Liuguo Yin, Changmian Wang, and Geir E. Øien, "On the Minimization of Communication Energy Consumption of Correlated Sensor Nodes," Accepted by *Springer Wireless Personal Communications, special issue based on selected papers from the ISWCS'07 conference.*

ABSTRACT

Minimizing the sensor-node energy consumption is an important consideration in designing wireless sensor networks. In this paper, we focus on the energy consumption issues related to communication of data from correlated sensor nodes. An optimization algorithm is proposed for minimizing the overall energy consumption of the hardware and the physical link. We perform a detailed trade-off analysis of the circuit energy consumption, the transmission energy consumption, the transmission time, the modulation symbol size, and the channel coding rate, over a wide range of transmission distances and correlation values. Thus, a new optimized communication schedule with much lower energy consumption than our benchmark scheme is obtained. Compared to the optimized uncorrelated uncoded transmission scheme, the total energy consumption may be reduced by more than 83.5% for a correlation value of 0.6 and a transmission distance of 100 meters when using the results from the proposed optimization. This is significant with respect to increasing the lifetime of a wireless sensor network.

3) Liuguo Yin, Changmian Wang, and Geir E. Øien, "Minimum cost routing with optimized data fusion for event-driven dense wireless sensor networks," *Submitted to IEEE PIMRC 2008.*

ABSTRACT

In this paper, we propose MICRO (MInimum Cost Routing with Optimized data fusion), an energy-efficient routing protocol for event-driven dense wireless sensor networks. The proposed routing protocol is an improvement over PEGASIS, which exploits a new cost function for energy balancing among sensor nodes and uses an iterative scheme with optimized data fusions to compute the minimum-cost route for each event-detecting sensor node. Compared to the previously suggested PEGASIS routing protocol, the MICRO protocol substantially improves the energy-efficiency of each route by optimizing the trade-off between minimizing the total energy consumption of each route and balancing the energy state of each sensor node. It is demonstrated that the MICRO protocol is able to outperform the LEACH and the PEGASIS protocols with respect to network lifetime by 100 - 300% and 10 - 100%, respectively.

4) Changmian Wang, Liuguo Yin, and Geir E. Øien, " Adaptive Route Configuration for Increased Energy Efficiency in Wireless Sensor Networks," *Submitted to CONET 2008.*

ABSTRACT

In this paper, we discuss a certain route configuration problem via optimization theory. The problem is potentially relevant for designers of both wireless sensor and wireless ad hoc networks with multihop and link adaptation capability. We consider the optimal bit error rate (BER) and transmission rate allocations subject to overall BER and delay constraints for a designated route. The pivot of the problem lies in the delay constraint, which divides the problem into two cases - the loose delay and the tight delay case. In the former, analytical solutions are obtained by applying the Karush-Kuhn-Tucker (KKT) theorem. Specifically, we discover in this case that for a given target BER, the optimum solutions are only related to the hop lengths in the route. When the delay constraint is tight, there exists a mapping which can be used to reduce the dimension of the problem by a factor of two; however, a numerical optimization algorithm has to be used to find the optimum. The problem can however be shown to be a convex optimization problem, which ensures that any local minimum will be global. Simulation results show that by optimally configuring a chosen route, substantial energy savings could be obtained, especially under tight delay constraints.

III -Attended Seminars, Workshops, and Conferences

Please identify the name(s), date(s) and place(s) of the events in which you participated during your fellowship period.

1) Workshop on Mathematical Modelling and Analysis of Computer Networks, June 21/22, 2007, INRIA-ENS, Paris, France.

2) IEEE 4th International Symposium on Wireless Communication Systems (ISWCS'07), October 16-19, 2007, Trondheim, Norway.

3) Second CROPS workshop, December 4-5, 2007, Helsinki, Finland.

IV – Research Exchange Programme (12 month scheme)

Please identify the name(s), date(s) and place(s) of your Research Exchanges during your fellowship period and detail them .

First Research Exchange:

Scientific contact: Prof. Dr. Francois Baccelli <Francois.Baccelli@ens.fr>
Dates: 17th June 2007 -- 23rd June
Place: INRIA-ENS, Paris, France
Detail:

- Gave an informal talk entitled 'Principle and Applications of Low-Density Parity-Check (LDPC) Codes';
- Discussed with Prof. Baccelli on the problems of the sensor-node energy consumption optimization and the energy-efficient routing algorithms;
- Attended the workshop on mathematical modelling and analysis of computer networks.

Second Research Exchange:

Scientific contact: Prof. Dr. Rob van de Mei <R.D.van.der.Mei@cwi.nl>
Dates: 18th February 2008 – 26th February 2008
Place: CWI, Amsterdam, Netherlands
Detail:

- Performed a presentation entitled 'Energy-Optimized Data Transmission and Routing for Dense Wireless Sensor Networks';
- Held numerous discussions with Prof. Mei and his group members on developing a mathematical model for analyzing the performance MICRO routing scheme; from which we have obtained the main idea on building the model and some important results such as the formula for estimating the location of relay nodes in the network area. A good paper may be expected on this topic.