ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow:	Chung Shue Chen
Visited Location:	NTNU, Trondheim, Norway
Duration of Visit:	September 1st, 2007 to May 31st, 2008

I - Scientific activity

1. Design of robust multiple access schemes and routing protocols for wireless sensor and ad hoc networks.

Technological advances in recent years have enabled the fabrication of miniaturized sensors or actuator devices with built in information processing and communication capabilities. One challenging issue to address is how to design efficient multiple access protocols in terms of transmission reliability, QoS guarantees, energy utilization efficiency, and system simplicity. In addition to the problem of having to accommodate a large number of devices, there is also the issue that a sensor network topology can change dynamically and the nodes have restrictive power consumption and low complexity requirements.

Here, we focus on the MAC, routing protocol designs and their performance:

- Results in MAC are reported in the papers listed in the Publication II.3 and II.5. (Please see the details presented in Section II, Publications and their Abstracts.)
- Results in routing protocol design are reported in the papers listed in Publication II.2 and II.4.

2. Design of multi-link resource allocation schemes for network capacity optimization

Radio resource management is important in enhancing spectrum utilization efficiency in broadband wireless services. Multi-cell binary power control (BPC) is promising in the network capacity optimization. In this project, we investigate the performance of BPC and conduct a comparative study to the best known non-binary optimization. Performance under imperfect channel knowledge is highly concerned for practical reasons. The result is reported in the paper presented in Publication II.1.

Besides, we consider individual performance guarantee with minimum rate requirement under power constraints. It is observed that the system optimization complexity can be greatly reduced generally. In some cases, the optimal power allocation solution will fall into a binary or discrete sense. The result is under preparation and will be submitted soon.

II- Publication(s) during your fellowship

1. **C. S. Chen**, M. Kaynia, G. E. Øien, and A. Gjendemsjo, "Cooperative multi-cell power control under imperfect channel knowledge: a comparative performance study," in *Proc. COST2100 Workshop on MIMO and Cooperative Communications*, Norway, June 2008.

Abstract: Radio resource management is important in enhancing spectrum utilization efficiency in broadband wireless services. Multi-cell binary power control (BPC) in full-reuse networks is a promising candidate in system optimization for this purpose. While the BPC scheme is inherently simple, the sum rate maximization by cooperative BPC across cells/links is almost as good as the best achievable non-binary solution. For practical use, the issue of imperfect channel knowledge should however also be considered. In this paper, we conduct an investigation and analysis of the performance of BPC and compare it to the best known non-binary optimization, as well as to full-power transmission. Performance under two different link gain measurement error models is reported. Clearly, with perfect channel knowledge, BPC usually has system capacity lower than that from the optimized non-binary allocation, although the loss is marginal. However, more interestingly, when measurement errors occur, BPC achieves a better and more robust performance. Simulation results show that it is less sensitive to the negative impacts of the link gain measurement errors. When looking at the simple full power scheme, comparisons show that although it is severely suboptimal when perfect channel state knowledge or moderate channel state error levels are considered, it can actually outperform BPC and also GP-based optimization in some scenarios with severely erroneous channel knowledge.

2. **C. S. Chen**, Y. Li, and Y.-Q. Song, "An exploration of geographic routing in *k*-hop based searching for wireless sensor networks," in *Proc. International Conference on Communications and Networking in China* (CHINACOM), Hangzhou, China, August 2008.

Abstract: We explore the asymptotic performance of existing geographic routing with a utilization of *k*-hop neighborhood information. The reachability from source to sink improves as we integrate more information into the routing decision. It is observed that the average number of hops required decreases significantly from the 1-hop to 2-hop based searching. This indicates an attractive tradeoff between the performance enhancement and system complexity. As simple greedy forwarding is insufficient in lossy wireless environment, we propose a new metric incorporating advance in distance and link quality to handle unreliable communication links. Simulation result has verified its effectiveness and superiority over the conventional simple greedy method. Besides, a generalization to *k*-hop based routing and the resulting performance are presented. Results show that with the multi-hop based searching, in both the deterministic and probabilistic lossy radio models, there is a good improvement in the number of transmissions required from end to end, which can indicate potential improvement in the routing delay and energy efficiency in transmissions.

3. **C. S. Chen**, K. Shum, C. W. Sung, W. S. Wong, and G. E. Øien, "User un-suppressible protocol sequences for collision channel without feedback," *submitted*, 2008.

Abstract: A revisit of the model of collision channel without feedback (CCw/oFD) has motivated some interesting designs on periodic binary sequences. The protocol and system simplicity is particularly favourable for applications in certain wireless sensor and ad hoc networks. User un-suppressibility for individual guarantee is desirable and emphasized here. We review some protocol sequences that are user unsuppressible. Lower bounds of sequence length are obtained and used to evaluate the performance of those sequences.

4. Y. Li, **C. S. Chen**, Y.-Q. Song, Z. Wang, and Y. Sun, "A two-hop based real-time routing protocol for wireless sensor networks," in *Proc. IEEE International Workshop on Factory Communication Systems* (WFCS), pp. 1-10, Dresden, Germany, May 2008.

Abstract: A two-hop neighborhood information based routing protocol is proposed for real-time wireless sensor networks. The approach of mapping packet deadline to a velocity is adopted as SPEED; however, our routing decision is made based on the novel 2-hop velocity. Energy-efficient probabilistic drop is embedded to enhance energy utilization efficiency while reducing packet deadline miss ratio. In case packet deadline requirement is not stringent, a new mechanism is included to release nodes which are frequently chosen as forwarders. Improvement on energy consumption balance throughout the network is observed. The true characteristics of physical and MAC layers are captured in the simulation. A real lossy link model is drawn from extensive experiments through Mica2 Motes. Simulation results show that the new protocol has achieved lower packet deadline miss ratio and higher energy efficiency.

5. K. Shum, **C. S. Chen**, C. W. Sung, and W. S. Wong, "Shift-invariant protocol sequences for collision channels without feedback," *submitted*, pp. 1-20, 2007.

Abstract: We consider collision channel in which collided packets are considered unrecoverable. For each user, the transmission of packets follows a specific periodical pattern, called the protocol sequence. Due to the lack of feedback, the beginning of the protocol sequences cannot be synchronized and non-zero relative offsets are inevitable. The variation in relative offsets yields variation in throughput. In this paper, we investigate the protocol sequence set which is optimal in the sense that the throughput variance is zero. Such protocol sequences are said to be shift-invariant (SI). The characterizing properties of SI protocol sequences are presented. We also prove that SI sequences are identifiable, meaning that the receiver is able to determine the sender of each successfully received packet without any packet header. A general construction of SI sequences that meets the lower bound on sequence length is given. Besides, we study the least periods of SI sequences, and show that the least periods must be distinct in some cases. The throughput performance is compared numerically with other protocol sequences.

III -Attended Seminars, Workshops, and Conferences

1. IEEE International Symposium on Wireless Communication Systems (ISWCS), 16-19 October 2007, Trondheim, Norway.
2. IEEE Global Telecommunications Conference (Globecom), 26-30 November 2007, Washington D.C., USA.
3. COST2100 Training School: Wireless Network Optimisation, 4-6 February 2008, Wrocław, Poland.
4. GETA Winter School: Signal Processing Advances in Wireless Communications - Cognitive Radio, Ruka, Finland, 11-13 February, 2008.

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.