ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow: Chung Shue Chen
Visited Location: CWI, The Netherlands
Duration of Visit: 1st June 2008 to 28th Feb 2009

I - Scientific activity

1. Construction and analysis of user unsuppressible protocol sequences for the collision channel without feedback.

   A recent revisit of the model of collision channel without feedback has motivated some interesting designs of periodic binary sequences. The protocol and system simplicity is especially attractive for applications in certain wireless sensor and ad hoc networks. Due to the lack of feedback link and user synchronization, the beginning of the protocol sequences cannot be well synchronized and non-zero relative time offsets are unavoidable. User unsuppressibility for individual service guarantees is desirable and emphasized.

   - Results of optimal protocol sequences that have *shift-invariant* or zero-variance throughput performance are reported in the Publication II.1 and II.4. (Please see the details presented in Section II, Publications and the Abstracts.)

   - Results of user unsuppressible protocol sequences in their *minimum* necessary lengths and the corresponding lower bounds are reported in Publication II.3 and II.6.

2. Design of routing protocols for the real-time packet delivery in wireless sensor networks.

   A two-hop information based routing protocol is proposed for real-time wireless sensor networks. Both packet delay performance and energy utilization efficiency are considered. It is to achieve low packet deadline miss ratio while maintaining system energy balance in supporting real-time service in wireless sensor networks.

   - Results of the 2-hop neighborhood information based routing protocol and performance evaluation are reported in Publication II.5.

3. Invited talks:

   - "User unsuppressible protocol sequence and its potential application to real-time systems," TRIO-LORIA, INRIA Nancy-Grand Est, France.
   - "Design and analysis of protocol sequences in collision channel without feedback," Dept of Mathematics, Vrije Universiteit, Amsterdam, the Netherlands.
   - "Constructions of protocol sequences for robust wireless accessing," State Key Laboratory of Industrial Control Technology, Zhejiang University, Hangzhou, China.

II- Publication(s) during your fellowship

1. **C. S. Chen**, W. S. Wong, and Y.-Q. Song, "Constructions of robust protocol sequences for wireless sensor and ad-hoc networks," *IEEE Trans. on Vehicular Technology*, vol. 57, no. 5, pp. 3053-3063, Sept. 2008.

Abstract - A class of periodic unipolar binary sequences is investigated for their potential applications in defining new protocols for distributed multiple accessing. Based on linear congruence sequences, one can show that, for any finite subset of these sequences, with the total proportional rate not exceeding a specific threshold, there cannot be enough collisions to completely block any particular sequence, no matter how they are shifted with respect to one another. This property can be exploited in certain applications, such as wireless sensor and ad hoc networks. A further investigation into how to enhance the allowable rate sum is conducted. New protocol sequences with interesting and useful properties are accordingly designed.

2. **C. S. Chen** and G. E. Øien, "Optimal power allocation for two-cell sum rate maximization under minimum rate constraints," in *Proc. IEEE Intl. Symposium on Wireless Communication Systems*, pp. 396-400, Oct. 2008.

Abstract - In this paper, we analyze the sum rate maximization problem in a two-cell wireless system under peak power and minimum service rate constraints. The optimal power allocation is found to be binary, in the sense that each base station power will have one out of only two possible discrete levels, and the result can greatly reduce the optimization and power control complexity required. A closed-form solution of the optimal assignment is reported. The new result provides a generalization of the binary power control (BPC) proposed in [1]. It is possible to apply the new result under the two-cell structure when clustering a larger network into groups of two cells. In a comparison with the full power transmission, it is shown that the proposed scheme outperforms in both the outage probability and sum rate performance generally.

3. **C. S. Chen**, K. Shum, C. W. Sung, W. S. Wong, and G. E. Øien, "User unsuppressible protocol sequences for collision channel without feedback," in *Proc. Intl. Symposium on Information Theory and its Applications*, pp. 1213-1218, Dec. 2008.

Abstract - A revisit of the model of collision channel without feedback (CCw/oFB) has motivated some interesting designs on periodic binary sequences. The protocol and system simplicity is particularly favorable for applications in certain wireless sensor and ad hoc networks. User unsuppressibility for individual service guarantee is desirable and emphasized here. We review some protocol sequences that are user unsuppressible (UU). Lower bounds of sequence length are obtained. Some corresponding sequence sets are identified.

4. K. Shum, **C. S. Chen**, C. W. Sung, and W. S. Wong, "Shift-invariant protocol sequences for the collision channel without feedback," to appear in *IEEE Trans. on Information Theory*, 2009.

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.

5. Y. Li, **C. S. Chen**, Y.-Q. Song, Z. Wang, and Y. Sun, "Enhancing real-time delivery for wireless sensor networks with two-hop information," *submitted*, 2009.

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 that in SPEED; however, our routing decision is made based on the novel 2-hop velocity integrated with energy balancing mechanism. Initiative drop control is embedded to enhance energy utilization efficiency while reducing packet deadline miss ratio. Simulation and comparison show that the new protocol has led to lower packet deadline miss ratio and higher energy efficiency than two existing popular schemes. The result has also indicated a promising direction in supporting real-time QoS for wireless sensor networks.

6. K. Shum, W. S. Wong, C. W. Sung, and **C. S. Chen**, "User irrepressible protocol sequences and disjoint difference family," *submitted*, 2009.

Abstract - We consider a non-blocking property, called user unsuppressibility, in wireless sensor network. The underlying network is modeled as a collision network without feedback. Two packets transmitted at the same time cause a collision. The objective is to guarantee with probability one that each data source can successfully transmit at least one packet within a period of time. The channel access is accomplished by assigning each transmitter a deterministic and periodical zero-one sequence, called protocol sequence. Each transmitter reads out its sequence and sends a packet if and only if the value is equal to one. We analyze the class of user-irrepressible protocol sequences with the minimum number of ones in each period, and define an equivalent combinatorial structure that we call the disjoint difference family. The advantage of this scheme is that it provides guarantee to bounded message delay and zero blocking probability without complicated time synchronization mechanism. In this paper, we derive lower bound on the minimum period, and present a construction method that meets this lower bound asymptotically.

III -Attended Seminars, Workshops, and Conferences

1. International Conference on Communications and Networking in China (CHINACOM), Hangzhou, China, 25-27 August 2008.
2. IEEE International Symposium on Wireless Communication Systems, Reykjavik, Iceland, 21-24 Oct. 2008.
3. International Symposium on Information Theory and its Applications, Auckland, New Zealand, 7-10 Dec. 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.