ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow: Qinghua Wang
Visited Location : NTNU, Norway
Duration of Visit: one year

I - Scientific activity

(1 page at maximum)

During my tenure at NTNU, Norway, I was involved in the MELODY project which was responsible for the development of wireless medical, localization and communication applications using ultra-wideband technology. In this project, I spent most of my time on the research of medical localization based on radio frequency characteristics observed in an in-body and indoor environment. The challenges were non-line-of-sight radio measurements which could significantly degrade ranging and localization accuracies.

Because I didn't have too much experience on wireless communication before I started my ERCIM tenure, I had to spend lots of time on literature review and even readings of textbooks. This finally proved to be fruitful. At the end of my tenure, I already became familiar with wireless communication and could think holistically when I consider the research problems of wireless networking or wireless sensor networks which had been my doctoral thesis topic.

My scientific contribution during my tenure includes the proposition of a hypothesis test which is able to evaluate whether a set of measurements has been corrupted by non-line-of-sight radio propagation or not. If a set of measurements is corrupted, I have proposed two model-based ranging algorithms which could minimize the ranging error due to non-line-of-sight corruption. Incorporated with certain localization algorithms, my proposed ranging methods have the possibility of significantly improve the robustness of localization accuracy during noisy medical environments.

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. Q. Wang and I. Balasingham, "Wireless Sensor Networks - An Introduction," in *Wireless Sensor Networks: Application-Centric Design*, Tan Yen Kheng and Geoff V Merrett, Eds. InTech, 2010, ch. 1, pp. 1–14.
Abstract: This book chapter provides a detailed introduction to the history and current state of the art with regard to wireless sensor networks.

2. Q. Wang, T. Zhang, and I. Balasingham, "Characterizing the Traffic Load Distribution in Dense Wireless Sensor Networks," *Journal of Networks*, vol. 6, no. 2, 2011.

Abstract: Traffic load is not evenly distributed over the sensor nodes in a wireless sensor network (WSN). Understanding the traffic load distribution can guide the network-wide energy allocation, direct the design of routing algorithms, and optimize the node deployment in WSNs. In this article, we consider a dense WSN with nodes uniformly distributed in a disk sensing area, and find the expected traffic load distribution over the sensor nodes as a function of their distance from the sink. Further, the effects of network scale and routing strategy on traffic load distribution are also investigated. The expected traffic loads beared by individual sensor nodes are found to be in direct proportion to the radius of the network and in inverse proportion to the routing hop length, while independent of network density. In addition, a heuristic multipath routing algorithm is found to be capable of reducing the traffic load variance experienced by neighboring or symmetrically deployed sensor nodes. The results presented in this article are verified through extensive simulation experiments.

3. Q. Wang, "Traffic Analysis & Modeling in Wireless Sensor Networks and Their Applications on Network Optimization and Anomaly Detection," *Network Protocols and Algorithms*, vol. 2, no. 1, 2010.

Abstract: Wireless sensor network (WSN) has emerged as a promising technology thanks to the recent advances in electronics, networking, and information technologies. However, there is still a great deal of additional research required before it finally becomes a mature technology. This article concentrates on three factors which are holding back the development of WSNs. Firstly, there is a lack of traffic analysis & modeling for WSNs. Secondly, network optimization for WSNs needs more investigation. Thirdly, the development of anomaly detection techniques for WSNs remains a seldom touched area. Among these three factors, the understanding regarding the traffic dynamics within WSNs provide a basis for further works on network optimization and anomaly detection for WSNs.

4. Q. Wang and T. Zhang, "Fair energy allocation in wireless sensor networks: theory and practice," in *Proc. of IEEE Global Communications Conference (GLOBECOM'10)*, Miami, FL, USA, December **1.** 2010.
Abstract: This paper deals with the energy allocation in multi-hop wireless sensor networks. Because the traffic loads are not evenly distributed in a multi-hop wireless sensor network, different sensor nodes usually experience different energy consumption rates. We present *Routing Independent Fair Energy-Allocation Scheme* (RIFES), which allocates the available energy resource to a sensor node according to its pre-estimated traffic load. Because traffic load is the dominating source of energy consumption, RIFES optimizes the network's lifetime by equalizing all individual nodes' expected energy exhaustion times.
Due to the fact that a node's real experienced traffic load may differ to its pre-estimated traffic load in practice, it is hard for RIFES to achieve its theoretical optimal performance. To bridge this gap between theory and practice, this paper also presents several distributed routing algorithms, the use of which prolongs the network's lifetime by balancing the real-experienced traffic loads among neighboring nodes.

5. Q. Wang and I. Balasingham, "Non-Line-of-Sight Error Mitigation for Range Estimation in Dynamic Environments," in *Proc. of 3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL'10), Special Session on UWB on Medical Applications*, Rome, Italy, November 2010.
Abstract: Localization is an important component in many applications such as the promising Ultra-Wideband (UWB) wireless sensor network for medical treatment. For the majority of localization technologies, it is essential to measure the ranges between a target and several reference nodes before the target can be localized. Existing range estimation techniques rely on the measurements of time-of-arrival (TOA) and received-signal-strength (RSS) which suffer from environmental change. Dynamic environment such as human mobility can cause non-line-of-sight (NLOS) measurements which will significantly degrade the accuracy of range estimation. Therefore, range estimation methods are desired to be robust to NLOS measurements. In this paper, it is proposed to use hypothesis tests to identify whether there are NLOS measurements mixed in with the measurement dataset. For those NLOS corrupted measurement datasets, a new range estimation method based on a Log-normal model is found to be capable of reducing the range estimation error. Another advantage of this new range estimation method is that NLOS measurements are not required to be excluded from its analysis. However, simulation results show that the range estimation accuracy can be further improved if NLOS measurements are excluded.

6. Q. Wang, I. Balasingham, M. Zhang, X. Huang, "Enhancing ranging quality in los-nlos condition using Gaussian mixture models". To be submitted.
Abstract: Ranging using radio-based measurements has been widely used for target tracking, localization and navigation purposes. Existing ranging techniques suffer from non-line-of-sight (NLOS) radio propagation in environments such as an indoor environment. Because NLOS radio propagation

travels extra distance than line-of-sight (LOS) radio propagation, ranging based on NLOS measurements could lead to significant errors. In this article, it is proposed to use hypothesis tests to identify whether there are NLOS measurements mixed in with the measurement data set. For those NLOS corrupted measurement data sets, a Log-Normal model based method and a Gaussian Mixture Model based method are used to enhance the quality of LOS range estimation. For both presented range estimation methods, NLOS measurements are not explicitly excluded from the final range estimation and thus they are suitable for scenarios when NLOS measurements cannot be labeled. Comprehensive simulation experiments as well as experiments using real-world data have been utilized to analyze the performance of the presented methods.

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. *1st Melody Project Workshop, Oslo, Norway, May 2010.*
2. *1st International Workshop of Melody Project, Trondheim, Norway, October 2010.*
3. *3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL), Rome, Italy, November 2010.*
4. *IEEE Global Communications Conference (Globecom), Miami, USA, December 2010.*

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 .

During my tenure, I visited two other ERCIM institutes as part of the research exchange programme.

1. Nov. 24 – Nov. 30, CTIF, Aalborg University, Aalborg, Denmark.
   During the visit, I had very good discussions with the security and networking research group in Aalborg University. I gave a talk which attracted about 20 participants. Although it was cold, I enjoyed the stay. Because it was warmed than Norway and they offered me free lunch.

2. Mar. 01 – Mar. 20, VTT, Finland
   During this visit, I had very good discussions with lots of researchers from different areas. Because it was a research institute instead of a university, I experienced a different research environment and it was very helpful. Basically, they were doing very practical things as I consider. Because they share locations with a local university, I also got the chance to visit the university there and it was a plus.