ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow: Sang-Seon Byun
Visited Location : Norwegian University of Science and Technology
Duration of Visit: 1 Nov. 2007 ~ 31 Oct. 2008

I - Scientific activity

(1) Dynamic spectrum allocation in wireless sensor networks
I consider the centralized spectrum allocations for resource-constrained wireless sensor networks with the following goals: (1) allocate spectrum as fairly as possible, (2) utilize spectrum resource maximally, (3) reflect the priority among sensor data, and (4) reduce spectrum handoff. The problem is formulated into a multi-objective problem, where I propose a new approach to solve it using Modified Game Theory. In addition, cooperative game theory is adopted to obtain suboptimal solutions for the MGT in reasonable time. I 've found that our proposal can produce near optimal solutions that are very close to the LP bound with a factor of less than 2.

(2) Coalitional game theoretic power control for delay-constrained wireless sensors
I propose a coalitional game theoretic approach to the power control problem in resource-constrained wireless sensor networks, where the objective is to enhance power efficiency of individual sensors while providing the Qos requirements. I model this problem as two-sided one-to-one matching game and deploy deferred acceptance procedure that produces a single matching in the core, which is the set of actions a_N of all sensors such that no coalition of sensors has an action that all its members prefer to a_N. Furthermore, I show that, by applying the procedure repeatedly, a certain stable state is achieved where no sensor can anticipate improvements in there power efficiency as far as all of them are subject to their own QoS constraints. I evaluate this proposal by comparing with cluster-based coalescing and the social optimal solution. By numerical experiments, I show that the matching in the core outperforms the cluster-based coalescing, and produces better total system power efficiency than the social optimal.

(3) An inventory model for spectrum pooling
In order to comply with more opportunistic and transient service requirements, many researches have paid attention to an approach called spectrum pooling. If I imagine a scenario in which current wireless service providers (WSPs) manage the spectrum pool, the radio spectrum itself will be traded like a market-based scenario, and moreover, every WSP will likely require new strategies in order to make profits under such dynamic service requirements. Therefore, I deploy a probabilistic inventory model that helps WSPs to determine the economic order quantity and reorder point in order to achieve minimum total expected cost that includes ordering cost, holding cost, and stockout cost. This model may become beneficial for WSPs to manage and estimate economic aspects of the spectrum pooling while previous work concentrated on only detection and exploitation of unused spectra. By numerical experiments

and simulations, I show that better total expected cost and actual total cost are achieved when we apply the best order quantity and reorder point.

II- Publication(s) during your fellowship

- Journal papers

(1) Sang-Seon Byun and Chuck Yoo, “Minimum DVS gateway deployment in DVS-based overlay streaming,” Computer Communications, vol. 31, no. 3, Feb. 2008.

Abstract

DVS (Distributed Video Streaming) is an edge streaming architecture for providing smooth video delivery. It is to divide video among multiple streaming senders in order to effectively provide the required throughput. In P2P-based streaming, if some peers are connected with high speed physical link, it is highly probable that they receive the best quality streaming stably from an original source. On these peers, we can impose the role of DVS gateway, i.e., let them translate the original streaming to distributive form and relay to the other peers who cannot connect to the original source with enough bandwidth. In dedicated infrastructure-based streaming, DVS gateway may be recruited by a content delivery company as an infrastructure node, that is to say, this infrastructure node has enough bandwidth to receive the best quality streaming from the original source, and it thus able to relay the original streaming using the distributed streaming to usual subscribers.

In this paper, we consider a minimum DVS gateway deployment problem in DVS-based overlay streaming with satisfying bandwidth requirement of every peer or subscriber. We also consider the mandatory diversity and limitations of DVS gateways’ streaming capacity.

The mandatory diversity is beneficial to mitigate the degradation of quality when an available bandwidth decreases suddenly, and the streaming capacity of each DVS gateway may be limited and heterogeneous. Based on recent advances in modeling techniques in flow networks, we provide a mixed integer programming formulation of the minimum DVS gateway deployment problem, and show that this problem is NP-hard. Thus we propose Lagrangian Relaxation with reduction heuristic to obtain an approximated solution. Our theoretical simulation studies show that the results obtained by our method are close to the lower bound obtained using LP relaxation.

(2) Sang-Seon Byun and Chuck Yoo, “Improving inter-destination synchronization in hierarchical reliable multicast,” Telecommunication Systems, vol. 37, no. 4, Apr. 2008.

Abstract

In hierarchical reliable multicast schemes, the number of repair proxies and their locations influence inter-destination synchronization. The inter-destination synchronization in multicast environments means the adjustment of the output timing among destinations over the Internet. Improving the inter-destination synchronization is beneficial to collaborative applications such as multi-conference system and multi-playing online game. In this paper, we propose a scheme to find the optimal locations of repair proxies that can improve inter-destination synchronization maximally in heterogeneous network environments. The simulation results show that if repair proxies are placed by the proposed scheme, delivery delay fairness of inter-destination can be improved by 0.05 maximally. In addition, we perform *t*-Test on the simulation results in order to verify that our optimal placement improves synchronization.

(3) Sang-Seon Byun and Chuck Yoo, “Locating repair servers in hierarchical reliable multicast networks to reduce the makesapn,” accepted for the publication in International Journal of Communication Systems.

Abstract

In hierarchical reliable multicast environment, *makespan* is the time that is required to fully and successfully transmit a packet from the sender to all receivers. Low makespan is vital for achieving high throughput with a TCP-like window based sending scheme. In hierarchical reliable multicast methods, the number of repair servers and their locations influence the makespan. In this paper we propose a new method to decide the locations of repair servers that can reduce the makespan in hierarchical reliable multicast networks. Our method has a formulation based on mixed integer programming to analyze the makespan minimization problem. A notable aspect of the formulation is that heterogeneous links and packet losses are taken into account in the formulation. Three different heuristics are presented to find the locations of repair servers in reasonable time in the formulation. Through simulations, three heuristics are carefully analyzed and compared on networks with different sizes. The results show that the our best heuristic is close to the lower bound by a factor of 2.3 in terms of makespan and by a factor of 5.5 in terms of the number of repair servers.

(4) Sang-Seon Byun and Ilangko Balasingham, "An inventory model-based spectrum pooling for wireless service provider and unlicensed users," under being reviewed for the publication in European Transactions on Telecommunications.

Abstract

In order to comply with more opportunistic and transient service requirements, many research literatures have paid attention to an approach called *spectrum pooling*. If we imagine a scenario in which current wireless service providers (WSPs) manage the spectrum pool, the radio spectrum itself will be traded like a market-based scenario, and moreover, every WSP will likely require new strategies in order to make more profits under such dynamic service requirements.

In this paper, we deploy *probabilistic inventory model* that helps WSPs to determine the *economic order quantity* and *reorder point* in order to achieve minimum *total expected cost* that includes ordering cost, holding cost, and stockout cost. This model may become beneficial for WSPs to manage and estimate economic aspects of the spectrum pooling while previous work concentrates on only detection and exploitation of unused spectra.

(5) Sang-Seon Byun and Ilangko Balasingham, "Coalitional game theory for wireless communications," under being reviewed for the publication in IEEE Signal Processing Magazine.

Abstract

Non-cooperative games depend on additional incentive or punishment in order to encourage players to be cooperative. However, *coalitional games* have a set of global actions, namely, *core*, which is preferred by all players to any other coalitional actions. Therefore, we can make all players cooperate without any reparative incentive or punishment. In this article, we discuss noticeable research efforts related to the coalitional game theory in three different wireless communication scenarios: (i) *wireless multi-hop networks*, (ii) *receiver cooperation for spectrum sensing* , and (iii) *power control for energy efficiency*. On each scenario, the main achievement resulted from the non-empty core is presented, and we summarize how the actions in the core can be found. By proving the existence of the non-empty core, we conclude that good performance can be obtained of the selfish and rational users can be cooperative in relaying and forwarding packets, spectrum sensing, and controlling transmission power. Furthermore, it is possible the coalitional game theory to be applied to other wireless scenarios such as dynamic spectrum allocations, correlated sensor networks, media access scheduling, multi-band/multi-user ultra wideband systems, etc.

- Conference

(1) Sang-Seon Byun, Ilangko Balasingham, and Xuedong Liang, "Dynamic spectrum allocation in wireless cognitive sensor networks: Improving fairness and energy efficiency," in proc. IEEE VTC, Sep. 2008.

Abstract
This paper considers the centralized spectrum allocations in resource-constrained wireless sensor networks with the following goals: (1) *allocate spectrum as fairly as possible*, (2) *utilize spectrum resource maximally*, (3) *reflect the priority among sensor data*, and (4) *reduce spectrum handoff*. The problem is formulated into a multi-objective problem, where we propose a new approach to solve it using modified game theory (MGT). In addition, cooperative game theory is adopted to obtain approximated solutions for MGT in reasonable time. The results obtained from numerical experiments show that the proposed algorithm allocates spectrum bands fairly with well observing each sensor's priority and nearly minimal spectrum handoffs.

(2) Sang-Seon Byun and Ilangko Balasingham, "Power control for mission critical wireless sensor networks using repeated coalitional games," in proc. IEEE MILCOM, Nov. 2008.
Abstract
In this paper, we propose a coalitional game theoretic approach to the power control problem in resource-constrained wireless sensor networks, where the objective is to enhance power efficiency of individual sensors while providing the QoS requirements. We model this problem as two-sided one-to-one matching game and deploy deferred acceptance procedure that produces a single matching in the core, which is the set of actions a_N of all sensors such that no coalition of sensors has an action that all its members prefer to a_N. Furthermore, we show that, by applying the procedure repeatedly, a certain stable state is achieved where no sensor can anticipate improvements in their power efficiency as far as all of them are subject to their own QoS constraints. We evaluate our proposal by comparing them with cluster-based coalescing and the local optimal solution obtained by maximizing the total system energy efficiency, where the objective function is non-convex.

(3) Xuedong Liang, Ilangko Balasingham, and Sang-Seon Byun, "A multi-agent reinforcement learning based routing protocol for wireless sensor networks," in proc. IEEE ISWCS, Oct. 2008.
Abstract
In this paper, we present MRL-QRP, a multi-agent reinforcement learning based routing protocol with QoS support for wireless sensor networks. Sensor node cooperatively computes QoS routes using distributed value function - distributed reinforcement learning algorithm (DVF-DRL).Global optimization can be achieved by only using locally observed network information and limited exchanging of state values within immediate neighboring nodes. The impact of network traffic load, sensor node mobility and density on the network performance is investigated. Simulation results show that MRL-QRP performs well in respects of QoS metrics and fits well in highly dynamic environments.

(4) Hessam Moussavinik, Sang-Seon Byun, and Ilangko Balasingham, "Towards robustness in multiband/multiuser IR-UWB: Overcoming unknown NBI via FEC and subband scheduling," under being reviewed for the publication in proc. ICACT 2009.
Abstract
Impulse radio-ultra wideband (IR-UWB) communication is a strong candidate for short-range biomedical wireless sensor networks (BWSN). In this paper, we propose a multiband/multiuser IR-UWB scheme, which is robust against unknown narrowband interference (NBI), by deploying multiband signaling with FEC coding and subband scheduling. We deploy a TPC encoder with Hamming $(n; k; d)^2$ product code of $(k/n)^2$ code rate and minimum Hamming distance of d^2. In addition,we propose a fair subband scheduling that is required to provide each sensor with uniform opportunity of avoiding the unknown NBI. We cast the problem of finding the fair subband schedule into a multi-objective integer programming, and plan to solve it using Nash bargaining solutions (NBS).

III -Attended Seminars, Workshops, and Conferences

(1) IEEE Vehicular Technology Conference, 21-24 Sep. 2008, Calgary, Canada.
(2) Annual Workshop of SAMPOS Project, 2-3 Oct. 2008, Oslo, Norway.
(3) VERDIKT Conference of The Research Council of Norway, 29-30 Oct. 2008, Bergen, Norway.

IV – Research Exchange Programme (12 month scheme)

- No