Advanced Science and Technology Letters
Vol.41 (Sensor 2013), pp.9-12
http://dx.doi.org/10.14257/astl.2013.41.03

Robust Distributed Power Control for Cognitive Radio based Industrial Wireless Sensor Networks

Tran Minh Phuong and Dong-Seong Kim

Department of IT Convergence, School of Electronic Engineering
Kumoh National Institute of Technology, Gumi, South Korea
`{minhphuong27690,dskim}@kumoh.ac.kr`

Abstract. Cognitive radio sensor network (CRSN) has emerged as a promising solution to address the spectrum-related challenges of wireless sensor networks (WSN). Moreover, cognitive radio (CR) gives us a possibility to maximize the utilization efficiency of limited spectrum resources. In this paper, we propose an intelligent power control scheme to address the communication requirements in cognitive radio based industrial wireless sensor networks (CR-IWSN).

Keywords: Cognitive radio, industrial wireless sensor networks, throughput, energy efficiency, distributed power control algorithm.

1 Introduction

Cognitive Radio Sensor Networks (CRSN) was considered as a promising technique to overcome similar challenges observed in traditional wireless sensor networks [2], and has been integrated in current and future radio access networks through recent literatures [3]. Power allocation plays important role in multiuser spectrum sharing cognitive radio based industrial wireless sensor networks because of the channel interference in radio transmission and interference temperature regulation. Therefore, how to allocate the transmit power to sensor nodes with a view to satisfying the interference threshold and maximizing the SUs' utilities is an important task in the implementation of cognitive radio based industrial wireless sensor networks.

In this paper, we consider the underlay CR-IWSN where SUs and PUs communicate with their SBSs and PBSs, respectively. Our objective is to optimizing the throughput of SUs and energy efficiency that can be supported, subject to the following constrains:

- R1: Each SUs' required normalized $SINR$ must be above a predefined threshold.
- R2: The total amount of interference caused by all cognitive transmission to each PU must be maintained below a given threshold [1].

ISSN: 2287-1233 ASTL

2 System Model

We assume that M is the number of primary users (PUs) and N is the number of cognitive users (CUs). Let g_{ij} denote the interference channel gain between the ith SU and the jth PU. Also, let I_j be the maximum interference level limit tolerable at primary receiving point j. Then, the interference constraint can be written as

$$\eta_j = \sum_{i=1}^{N} g_{ij} p_i \leq I_j, \tag{1}$$

where p_i represents the transmitter power of the CR-Tx of link i.

The signal to interference-plus-noise ratio ($SINR$) of SU $i's$ signal at the SBS can be formulated as [4]:

$$SINR_i^s = \frac{h_{ii} p_i}{n_i + \sum\limits_{i \neq k} h_{ik} p_k + h_{i0} p_0}. \tag{2}$$

Let h_{ii} be the channel gain between SU i and its SBS, $h_{ik}p_k$ be the interference caused by other SUs, $h_{i0}p_0$ be the aggregate interference of PUs to the SBS and n_i be the channel noise power. The $SINR$ should be:

$$SINR_i^s \geq \gamma_i, \forall i, \tag{3}$$

where γ_i is the $SINR$ requirement at the CR-Rx of link i.

3 Distributed Power Control Algorithm

Each SU's transmission power level is obtained by solving the following optimization problem (P1):

$$\text{Max} \sum \mu_i \left(\gamma_i\right), \tag{4}$$

subject to (2) and (1), where $\mu_i(\gamma_i)$ is the utility function of the ith SU.

We use an ellipsoid to describe the uncertainty set for the interference caused by SU to the PBS and PUs to the SBS are respectively given by:

$$H = \left\{ \overline{H} + \varDelta H : \sum_{i} \left|\varDelta H_{ij}\right|^2 \leq \epsilon_0^2 \right\}, \tag{5}$$

$$F = \left\{ \overline{F}_i + \varDelta F_i : \sum_{i \neq k} \left|\varDelta F_{ik}\right|^2 \leq \epsilon_i^2 \right\}. \tag{6}$$

Let ϑ_i, λ_i, μ_i denote Lagrange multipliers corresponding to minimim and maximum $SINR$ constraints and local contraints, respectively. The Lagrange function of the convex equivalent of how to adjust transmit power levels is then

$$L(y,z,\vartheta,\lambda,\mu) = -\sum_i u_i\left(\frac{h_{ii}e^{y_i}}{e^{z_i}}\right) + \sum_i \vartheta_i\left(\gamma_i^{min}\frac{e^{z_i}}{h_{ii}e^{y_i}} - 1\right)$$
$$+\sum_i \lambda_i\left(\frac{1}{\gamma_i^{max}}\frac{h_{ii}e^{y_i}}{e^{z_i}} - 1\right) + \sum_i \mu_i\left[e^{-z_i}\left(n_i + \sum_{i\neq k} h_{ik}e^{y_k}\right) - 1\right]. \qquad (7)$$

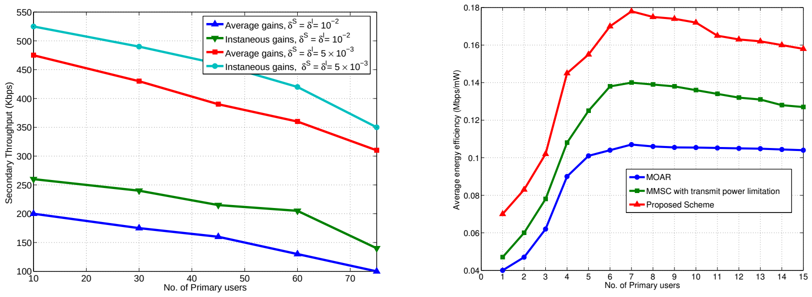
In order to make the aforementioned sum available at Tx_i, the proposed algorithm 1 can be adapted to the problem.

Algorithm 1: Robust Distributed Power Control.

```
Initialization: $t = 0$, $\beta > 0$,
    $y_i(0) > 0, z_i(0) > 0, \vartheta_i(0) > 0, \lambda_i(0) > 0, \mu_i(0) > 0$
At the SU:
At each iteration $t = 1, 2, ...$
The SU receives measure the $SINR$ and calculate the subgradient $\vartheta_i$ from
    SBS
Locally calculates its $y_i(t)$, $z_i(0)$, and its Lagrange multipliers. Update
    $\mu_i(t+1)$.
Feed back the information to SBS of the same link
At the SBS:
At each iteration $t = 1, 2, ...$
Estimate $h_{ii}$ and update $\lambda_i(t+1)$ Update transmision power
    $y_i(t+1) = \min\left\{y_i(t) - \beta\frac{\partial L}{\partial y_i}, y_i^{max}\right\}$
Broadcast $h_{ii}$ and $y_i(t+1)$
```

4 Simulation

In Fig. 1a, we show throughput of secondary versus the number of primary users for different values of $SINR$. As expected, throughput performance decreases as a QoS and the interference constraint violation probabilities become more stringent. Also, throughput of secondary users decreases with increasing number of primary users. Fig. 1b depicts the average energy efficiency of MOAR, MMSC with transmitted power limitation, and our proposed protocols. Although the energy of our proposed protocol reduces when the number of PUs is larger than 6, our proposed scheme still outperforms the MOAR, MMSC with transmit power limitation protocols.



(a) (b)

Fig. 2: Simulation results: (a) Throughput of SU verus the number of PUs, (b) Average Energy Efficiency of SU verus the number of PUs.

5 Conclusion

This paper considered dynamic spectrum access for CR-IWSNs under interference temperature and QoS constraints for each secondary link. We modeled uncertainty as a bounded distance between actual and nominal values, and showed that by using the protection value in our robust problem. By applying this new scheme, the sensors could share the spectrum without performance degradation and both of the throughput and energy consumption could be optimized.

Acknowledgments

This research was financially supported by the Ministry of Education, Science Technology (MEST) and National Research Foundation of Korea (NRF) through the Human Resource Training Project for Regional Innovation 2013 and Basic Science Research Program (NO. 2011-0025409).

References

1. Shah, G., Gungor, V., Akan, O.: A cross-layer qos-aware communication framework in cognitive radio sensor networks for smart grid applications. In: IEEE Transactions on Industrial Informatics, vol. 99 (2013)
2. Akan, O.B., Karli, O., Ergul, O.: Cognitive radio sensor networks. In: IEEE Network, vol. 23, no.4, pp. 3440 (July 2009)
3. Quang, P., Kim, D.-S.: Throughput-aware routing for industrial sensor networks: Application to isa100.11a. In: IEEE Transactions on Industrial Informatics, vol. PP, Issue: 99, (April 2013)
4. DallAnese, E., Kim, S.-J., Giannakis, G.B., Pupolin, S.: Power control for cognitive radio networks under channel uncertainty. In: IEEE Transactions on Wireless Communications, vol. 10, Issue: 10, pp. 3541 3551 (October 2011)