The 23rd International Technical Conference on Circuits/Systems,
Computers and Communications (ITC-CSCC 2008)

Optimizing Coexistence System with Interference Temperature for Multi-user Environments

Joo-pyoung Choi[1] and Won-cheol Lee[2]
School of Electronic Engineering, Soongsil University
1-1, Sangdo-Dong, Dongjak-Gu, Seoul 156-743, Republic of Korea
Tel: +82-2-816-6606
E-mail: [1]pyoung424@amcs.ssu.ac.kr, [2]wlee@ssu.ac.kr

Abstract: We explore the coexistence potential of cognitive system based on interference temperature. The characteristic feature of this interference temperature metric would be their ability to adapt the transmit power and bandwidth of their communication scheme to maximize the QoS for the secondary users while minimizing the interference to the primary users. Considering generalized interference temperature model as a baseline [2], we investigate the throughput variation of the secondary user in the heterogeneous communication environment. Also we propose a certain coexistence scheme that allocates bandwidth and transmit power of secondary user without harming the primary user using the concept of interference temperature.

1. Introduction

Recently, many kinds of wireless systems becoming services for satisfying demand of high quality communication service. Along with this, when considering the increase of wireless network users and QoS(Quality of Service) of various users, cognitive radio techniques have been proposed as a means to implement efficient reuse of primary spectrum. That is, cognitive radios are promising solutions to the problem of overcrowded spectrum.

Also the FCC (Federal Communications Commission) has recommended that optimum coexistence of heterogeneous communication users could be realized by deploying interference temperature metric[1, 3].

In this paper, consider the following communication scenario which we will refer to as the interference channel.

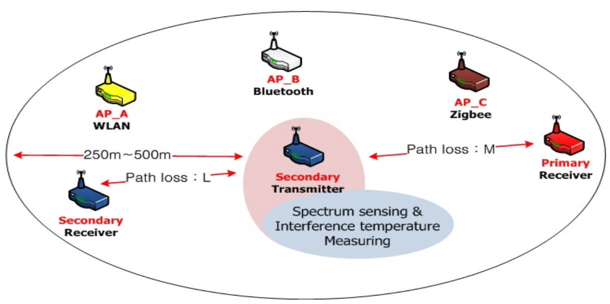

Figure 1. The interference channel with three primary users AP_A, AP_B, AP_C and secondary user.

2. Evaluation method

2.1 Calculation of secondary transmission power

As a means of quantifying and managing interference, interference temperature is defined as a measure of the RF (Radio Frequency) power available at a receiving. It is the temperature equivalent of the RF power available at a receiving antenna per unit of bandwidth, measured in units of Kelvin [2].

Let $T_I(f_c, B)$ be the interference temperature to the secondary user transmitter for channel c, with central frequency f_c and bandwidth B.

$$T_I(f_c, B) + \frac{MP_{se\_tx}}{kB} < TH_c \qquad (1)$$

Where M is path loss in transmission between secondary transmitter and primary receiver centered at frequency f_c. P_{se_tx} is the average interference power at the primary receiver in watts. Also TH_c is the interference temperature threshold and k is Boltzman's constant (1.38×10^{-23} Joules per Kelvin). In this paper, the interference temperature threshold and background noise temperature are set to each $7.83\times10^4 K$ and $122.15K$. Using above equation (1), the received signal power can be limited as

$$P_{se\_tx} < \frac{kB}{M}\left(TH_c - T_I(f_c, B)\right) \qquad (2)$$

Through the spectrum sensing technique, secondary transmitter computes above equation (1) and (2). Namely, it is initial coexistence processing from secondary transmitter viewpoint.

2.2 Calculation of secondary capacity

To guarantee the required SINR (Signal to Interference p lus Noise Ratio) level and QoS at the secondary user, we consider capacity of secondary user receiver.

$$C = B\cdot\log_2\left(1+\frac{L\cdot P_{se\_tx}}{kBT_I(f_c, B)}\right) \qquad (3)$$

Here, L is path loss in transmission between secondary transmitter and receiver pair. By computing above equation

(3), capacity of secondary receiver calculated at the secondary transmitter.

Consider the interference scenario shown in Figure 1, the defining assumption for these models is that the secondary transmitter has a priori knowledge of the primary user's interference temperature limits, bandwidth and path loss. From this assumption, equation (3) can be rewritten as

$$
\begin{aligned}
C &= B\cdot\log_2\left(1+\frac{L\cdot P_{se\_tx}}{kBT_I(f_c,B)}\right)\\
&= B\cdot\log_2\left(1+\frac{L\cdot\frac{kB}{M}\left(T_L(f_c,B)-T_I(f_c,B)\right)}{kBT_I(f_c,B)}\right)\\
&= B\cdot\log_2\left(1+\frac{L\cdot\left(T_L(f_c,B)-T_I(f_c,B)\right)}{M\cdot T_I(f_c,B)}\right)
\end{aligned}
\tag{4}
$$

Here, $T_L(f_c,B)$ is interference temperature limits. Figure 2 is the spectrum arrangement showing the interference temperature limits at the primary users.

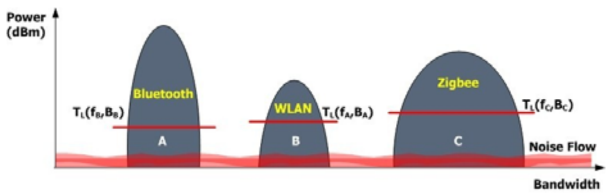

Figure 2. The interference temperature of the primary users.

For the secondary user's capacity to achieving the QoS for the secondary users but minimizing the interference to the primary users, we adjust the secondary transmitter bandwidth. Figure 3 shows the adaption process of secondary transmitter bandwidth.

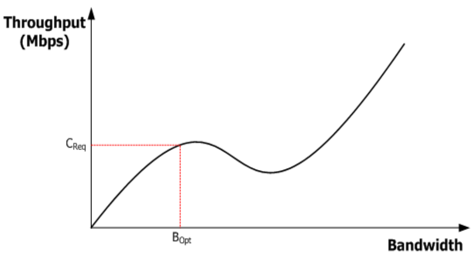

Figure 3. Adaption of bandwidth

Transmission possible power of the secondary transmitter could be calculated individually about the primary user. That is,

$$P_{se\_tx\_A} < \frac{kB_A}{M_A}\left(T_L(f_A,B_A)-T_I(f_A,B_A)\right) \tag{5}$$

$$P_{se\_tx\_B} < \frac{kB_B}{M_B}\left(T_L(f_B,B_B)-T_I(f_B,B_B)\right) \tag{6}$$

$$P_{se\_tx\_C} < \frac{kB_C}{M_C}\left(T_L(f_C,B_C)-T_I(f_C,B_C)\right) \tag{7}$$

where $P_{se\_tx\_A}$, $P_{se\_tx\_B}$ and $P_{se\_tx\_C}$ is the possible transmitter power of the secondary transmitter. This value satisfied transmission power constraints given by

$$P_{se\_tx\_select} = \min\left(P_{\max}, \min\left(P_{se\_tx\_A}, P_{se\_tx\_B}, P_{se\_tx\_C}\right)\right) \tag{8}$$

where $P_{se\_tx\_select}$ is the optimum transmission power at the secondary transmitter and $P_{\max}$ is the transmission power with no primary user communication environment.

Consider the interference scenario shown in Figure 1, the background noise and remaining interference power which excepts the primary user given by

$$P_I(f_c,B) = kBT_I(f_c,B) \tag{9}$$

The factor $T_I(f_c,B)$ is interference temperature of the primary users. That is

$$T_I(f_c,B) = \frac{1}{kB^2}\int_{fc-B/2}^{fc+B/2} S(f)\,df \tag{10}$$

The average power of the total bandwidth is

$$P_L(f_c,B) = \frac{1}{B_{Total}}\left(\sum_{l=1}^{L} B_l\cdot P_{se\_tx\_l}\right) \tag{11}$$

where L is the number of primary user. In this paper, primary user indexed with A (Bluetooth), B (WLAN) and C (Zigbee). Figure 4 showing the relationship of the minimum sensitivity level from respectively primary user and the transmission possible power at the secondary transmitter.

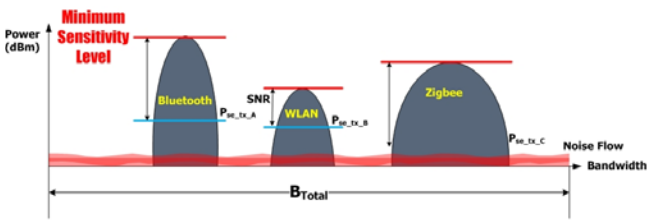

Figure 4. Relationship of the minimum sensitivity level and the transmission possible power.

From equation (9), (10) and (11), equation (4) can be rewritten as

$$C = B \log_2 \left(1 + \frac{L \cdot P_{se\_tx}(f_c, B)}{P_I(f_c, B) + P_L(f_c, B)} \right) \qquad (12)$$

3. Experimental data

To coexist with primary user, we carried out the realistic simulation by the concept of interference temperature that b ased on spectrum sensing technique in 2.4GHz ISM band. Also assuming that each user device's location and relative distances is known at the relation devices in free-space path loss environment. Each user is presumed to transmit as well as receive. Related spectrum allocation and parameters for simulation are showed in Figure 5 and TABLE I respectively.

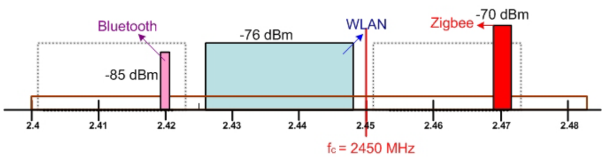

Figure 5. Spectrum allocation with multi-user environment.

TABLE I. Simulation parameters.

Parameter	WLAN	Bluetooth	Zigbee	Secondary user
Center Frequency (MHz)	2437	2423.5	2475	2450
Bandwidth (MHz)	22	1	2	Variable
Transmit power(dBm)	14	0	0	Variable
Required BER	10^{-5}	10^{-5}	10^{-5}	10^{-5}
Required SNR(dB)	8.4	2	2.5	7.56
Distance of each service users				
Primary receiver ⇔ Secondary transmitter			15m	
Secondary transmitter ⇔ Secondary receiver			6m	
Secondary receiver ⇔ Primary transmitter			WLAN : 400m Zigbee : 500m Bluetooth : 300m	
Primary transmitter ⇔ Primary receiver			WLAN : 300m Zigbee : 120m Bluetooth : 80m	

The interference temperature limit and background noise te mperature are set subject to satisfying the required BER(Bit Error Rate) of primary as 10^{-5}. Furthermore, secondary user also requires 10^{-5} BER. As we increase bandwidth of secondary user until satisfying 52Mbps, we can calculate th e interference temperature and the capacity according to det ermined bandwidth. To achieve the optimized bandwidth an d transmit power of secondary user satisfying required capa city, we applied the optimization algorithm methods.

4. Evaluation result

The bandwidth and transmit power of secondary user can be chosen by considering the SINR (i.e., 52Mbps) in secondary receiver. Allowable capacity can be derived according to the bandwidth of secondary user as shown in Figure 6. Optimized parameters of secondary user through the simulation results are listed in TABLE Ⅱ.

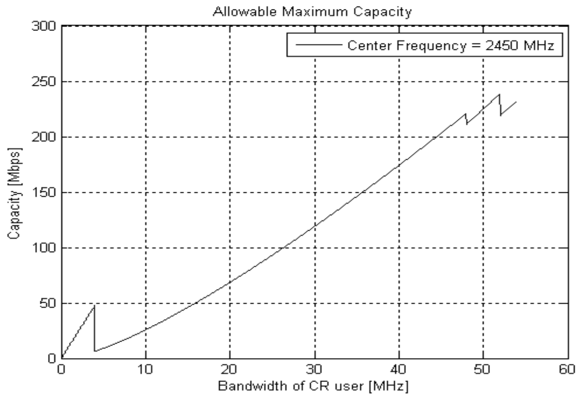

Figure 6. Allowable capacity according to bandwidth of secondary user.

TABLE Ⅱ. Optimized parameter of secondary user.

Parameter	**Optimized value**
Center frequency	2450 MHz
Bandwidth	16.5 MHz
Transmit power	WLAN : -20.75 dBm Zigbee : -23.44 dBm Bluetooth : -8.75 dBm

According to the TABLE Ⅱ, the secondary user flexibly utilize the frequency band for coexisting with primary user.

In this paper, we have investigated how to optimize the transmit power and bandwidth of secondary user while minimizing the interference influence of each user in multi-user channel environment. Numerical results revealed that the proposed schemes can achieve near-optimal bounds for coexistence between the primary user and secondary user.

Acknowledgment

This research is supported by Foundation of ubiquitous c omputing and networking project (UCN) Project, the Minist ry of Knowledge Economy (MKE) 21st Century Frontier R &D Program in Korea and a result of subproject UCN 08B3 -B2-32T

References

[1] Federal Communications Commission, "Facilitating opportunities for flexible, efficient, and reliable spectrum use employing cognitive radio technologies," ET Docket 03-108, Notice of Inquiry and Proposed Rulemaking and Order, 2003.

[2] Clancy, T., and Arbaugh, W. "Measuring interference temperature," *Virginia Tech Symposium on Wireless Personal Communications 2006*.

[3] Paul J. Kolodzy, “Interference temperature : a metric for dynamic spectrum *utilization,” International Journal of Network Management*, vol. 16, pp. 103 ~113, Mar. 2006.

[4] S. Haykin, "Cognitive radio: Brain-empowered wireless communications," *IEEE journal on selected areas in communications*, vol. 23, no. 2, Feb. 2005.