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Signal transmission model for the substations grounding grid

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ABSTRACT

The signal of the wireless sensor network in grounding grid, owing to energy loss, network congestion, path constraints and other factors, is easy to delay even partially losing. In order to ensure that the signal can be transmitted effectively in grounding grids for the substation, this paper presents a method based on traffic model of back-off balanced multiple sensor network cooperation model. As we all know, cognitive radio (CR) technology is adopted in multi-channel wireless networks to provide enough channels for data transmission. The MAC protocols should enable the secondary users to maintain the accurate channel state information to identify and utilize the leftover frequency spectrum in a way that constrains the level of interference to the primary users. We proposed a novel cooperation spectrum sensing scheme in which the secondary users adopt backoff-based sensing policy based on the traffic model of the primary users to maximum the throughput of the network. To obtain the full accurate information of the spectrum is a difficult task so that we propose the backoff sensing as a sub-optimal strategy. Since the secondary users sense only a subset of the channels in our proposed scheme, less time is spent to get the channel state information as more time is saved for the data transmission. And while dealing the signal data, I combine the intensity transfer method instead of the priority method. This can effectively reduce the network congestion, to ensure that the main information can be transfer well. It is also very useful to signal transmission for the Multi-sensor in Substations Grounding Grid (SGG).

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1. Introduction

As the SGG that the author is studying, is similar to the existing wireless sensor network, so in the establishment of the model of signal transmission, we no longer emphasizes grounding grid. In fact, the model is also practical for other wireless network. Allocating a fixed spectrum band to each wireless service has been proved to be inefficient since more than 90% of the spectrum is unused in most of the time while spectrum scarcity becomes a serious problem. As a result, cognitive radio (CR) is developed to solve the problems resulting from limited spectrum resources and low utilization of the spectrum. CR network (CRN) allows the unlicensed users dynamically access the licensed spectrum to enable communication or improve service quality while no transmission of the primary users processing. Although the basic idea of the CR technology is simple, it imposes new challenges to the design of the MAC protocol. One of the most difficult, but important, design problems is how the secondary users effectively detect the existence of the primary users.

Different sensing policies are proposed in Hang and Zhang (2008), Hsu, Wei, and Kuo (2007), Jia, Zhang, and Shen (2008), Han and Jean (2008) as possible solutions to this problem. Particularly, the authors in Hang and Zhang (2008) suggest the secondary users shall know the state of each channel of the primary network which is modeled as an ON–OFF source alternating between state ON (active) and state OFF (inactive), however, when there are many channels to sense, the reporting phase will take a large portion of the slot which cannot be ignored. Therefore, the efficiency can be quite low due to the fact that the data transmission occurs only in the negotiating phase. In (Hsu et al., 2007), the author use the statistical channel allocation to predict future spectrum usage and decide which channel to sense and access, but unfortunately, the complexity of this scheme increases quickly with the number of the licensed channels. The authors of Jia et al. (2008) adopt stopping rule for the spectrum sensing as hardware restrictions are taken into consideration. However, the sensing priority is not discussed problem in this work. In (Han & Jean, 2008), dissemination scheme for channel state information is studied with sensing priorities considered.

The backoff-based sensing strategy proposed in this paper is actually a sensing priority adjustment scheme based on the traffic model of the primary users. Meanwhile, using the intensity

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transfer method, we transfer the data directly. The length of the traffic is modeled with exponential distribution, which is simple but effective, especially for the on-line traffic.

The rest of the paper is organized as follows: Section 2 introduces the traffic model of the primary network and presents the proposed cooperative sensing scheme. This is followed by Section 3 which provides the performance of the proposed scheme with some numerical results obtained from the simulation for the SGG. Finally, the paper is concluded with Section 4.

2. Proposed channel sensing scheme

2.1. System model overview

We consider a licensed spectrum band divided into n data channels. Each licensed channel is time-slotted such that the primary users communicate with each other in a synchronous manner. Meanwhile, a number of ad-hoc network users, which are synchronized with the primary users, opportunistically access the licensed spectrum without imposing interference to the primary users. In this paper, we mainly focus on the scenarios where all secondary users utilize the licensed channels used by the same set of primary users. This implies that the licensed channel availability information sensed by each secondary user is consistent among all secondary users. The spectrum band is divided into N data channels index by i with $i = 1,2,\ldots,N$ and one control channel. Spectrum band of the control channel is pre-assigned and is disturbed from the primary users.

In our proposed cognitive radio-based multi-channel MAC protocols, each secondary user is equipped with two transceivers. The first transceiver is devoted to operating over the dedicated control channel. The secondary users use their control transceivers to obtain the sensing results of the un-used licensed channels from other secondary users, and to negotiate with the other secondary users through the contention-based algorithms, such as IEEE 802.11 distributed coordination function (DCF) and Carrier Sense Multiple Access (CSMA) protocols. The second transceiver consists of a SDR module such that it can tune to any one of the n licensed channels to sense for spare spectrum, receive/transmit the secondary users' packets. For convenience, we call the first transceiver the control transceiver and the second transceiver the SDR transceiver, respectively, in the rest of this paper. Each time slot is divided into sensing phase and negotiating phase. Sensing phase is used for channel sensing and information reporting while negotiating phase for data transmission and resources allocation among secondary users. Four types of packets are introduced into our scheme for exchanging control messages:

(1) C-RTS/C-CTS: contention and spectrum reservation during the negotiating phase.
(2) T-RTS/T-CTS: notify the other secondary users the completion of the transmission.
(3) D-RTS/D-CTS: negotiate with the receiver node and initial the transmission.
(4) RP: notify the other secondary users the sensing results.

2.2. Traffic model

Traditionally, we assume that the primary user transmission request arrival is a Poisson stream, while the service time for each primary user is exponentially distributed. Thus, applying M/M/1 queuing model, we can model each channel as a Markov chain as shown in Fig. 2, where the variable in the circle represents the number of the primary user waiting for spectrum resources. The transition probability, denoted by $q_{i,j}$, of the Markov chain can be written as:

$$q_{i,j} = \Pr\{S(t+\Delta t) = j | S(t) = i\} = \begin{cases} \lambda\Delta t + O(\Delta t), & i = j-1 \\ \mu\Delta t + O(\Delta t), & i = j+1 \\ O(\Delta t), & |i-j| \geqslant 2 \end{cases} \quad (1)$$

Thus, we are able to derive the probability transition matrix for the Markov chain

$S_j(t)$, denoted by Q, as follows:

$$Q = \{q_{i,j}\} = \begin{bmatrix} 1-\lambda & \lambda & 0 & \cdots & \\ \mu & 1-\lambda-\mu & \lambda & 0 & \cdots \\ 0 & 2\mu & 1-\lambda-2\mu & \lambda & 0 \\ \cdots & \cdots & & & \end{bmatrix} \quad (2)$$

Since the channel will be busy when $S_i(t) \geqslant 1$, we can simplify this Markov model to an ON/OFF channel usage model alternating between state ON (active) and state OFF (inactive). An ON/OFF channel usage model specifies a time slot in which the primary user signals is or isn't occupying a channel. The secondary users can utilize the OFF time slot to transmit their own packets. Suppose that each channel changes its state independently. Let α_i be the probability that ith channel transits from state ON to state OFF and β_i: be the probability that ith channel transits from state OFF to state ON, where $1 \leqslant i \leqslant N$. Then, the channel state can be characterized by a two-state Markov chain as shown in Fig. 1. The probability transition matrix is derived as follows:

$$Q = \{q_{i,j}\} = \begin{bmatrix} 1-\alpha_i & \alpha \\ \beta & 1-\beta_i \end{bmatrix} \quad (3)$$

Let $P(n)$ denotes the probability that the transmission on ith channel lasts for n time slots, thus, we are able to derive that $P(n)$ is geometrically distributed:

$$P(n) = (1-\alpha_i)^{n-1}\alpha_i \quad (n \geqslant 1) \quad (4)$$

Based on Eq. (4), the mathematic expectation, denoted by $E[P(n)]$, of the traffic length can be derived as:

$$E[P(n)] = \sum_{n=1}^{\infty} nP(n) = \frac{1}{\alpha_i} \quad (5)$$

2.3. Intensity transfer method for the data

Through the reasoning above, we can take the model as a controller which is concerned with predicting the values of one output or response variable Y for a set of more inputs or predictor variables X. In data processing, we use intensity transfer method. The so-called intensity transfer method is as below. When the control system is accurate input, the exact input value put the linguistic variable value acquired from the former conditional statements to the next linguistic variable value. In most cases, we can consider the fuzzy controller above as a double input and single output controller simply. Wherein, an input is for the deviation, setting it to X_1. Another input for the rate of change of the deviation, which is set to X_2. The output variable is Y, and their linguistic variables are respectively set to A_{i1}, B_{i2} and Y_i. As the initial variables. Therefore,

$$X_1 = \{A_{11}, A_{21}, \ldots, A_{j1}\}$$

$$X_2 = \{B_{12}, B_{22}, \ldots, B_{n2}\}$$

$$Y = \{Y_1, Y_2, \ldots, Y_r, \ldots, Y_m\}$$

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