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Evolving Hypernetworks based Channel Prediction for Secondary Access in Cognitive Radio Ad hoc Networks

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Learning is a fundamental aspect of a Cognitive Radio (CR) and is necessary for ensuring interference-free coexistence with primary networks. In CR ad hoc networks, learning has to stem from a CR node's individual environment sensing capability and from in-network cooperation among peers. One important aspect of learning about the environment for a CR device is to acquire information about primary networks and their operation. This aspect has been considered in the scope of a "Radio Environment Map" concept as well as in the specification of IEEE 802.22 standard.

We present a proposal that is aimed to enable CR devices operating in an ad hoc network to classify spectrum opportunities according to application requirements and to predict primary users' channel access behaviour. A spectrum sensing algorithm can only provide information if a channel is free or busy but cannot tell how long it will remain in that state. However, for user applications, certain quality of service guarantees are necessary which can only be ensured when a wireless channel can be accessed sufficiently. Therefore classification and prediction of channels become very important for CR ad hoc networks. We investigate an Evolving Hypernetworks [1] based approach where spectrum opportunities are classified according to applications' requirements. It is understood from literature that different application types e.g. voice, data, video require different levels of channel requirements. We associate these requirements of applications with the spectrum sensing results in order to develop a hypernetwork that can be used to predict the channel state and the approximated level of quality of service that can be achieved.

We map the spectrum sensing results onto a binary time series which is then used as the basic dataset for the evolutionary hypergraphs. Different parameters of the hypergraphs such as history window, hypergraph complexity and wights can be used to control the learning. Hypergraph based channel prediction can be used by CR nodes individually, as well as collectively to develop an abstract view of the RF environment.

In order to test the concept on hypernetworks based channel state prediction, we have carried out preliminary analysis in a discrete event simulator using a CR specific model [2]. The main trade-off in the hypernetworks based approach is the computational complexity with respect of efficiency and accuracy of prediction. If the computational complexity is ignored, other parameters of the hypernetowrks based technique can provide from 60 to 90 precent accurate prediction of the next state of the channel. This information enables CR nodes to perform pre-emptive channel handovers. An multi-hop ad hoc network can be considered an extension of several single-hop communications, therefore we simulated a single secondary link under influence of multiple primary users' communication (figure-1). Table-1 shows the performance results for an 802.11b medium access protocol with 3 primary users channels and different duty-cycles of primary users. Each primary user uses a single channel and the three are not synchronized in their channel usage. The duty cycle is considered as the percentage of channel usage by primary networks.

References:

[1] B. T. Zhang : *HyperNetworks: A Molecular Evolutionary Architecture for Cognitive Learning & Memory, IEEE Computational Intelligence Magazine vol. 3, Aug. 2008.*

[2] S. N. Khan, M. A. Kalil, A. Mitschele-Thiel: *Crsimulator: A Discrete Simulation Model for Cognitive Radio ad hoc Networks in Omnet++ , IFIP/IEEE Wireless and Mobile Networking Conference (WMNC2013) , Dubai, UAE, April 2013*

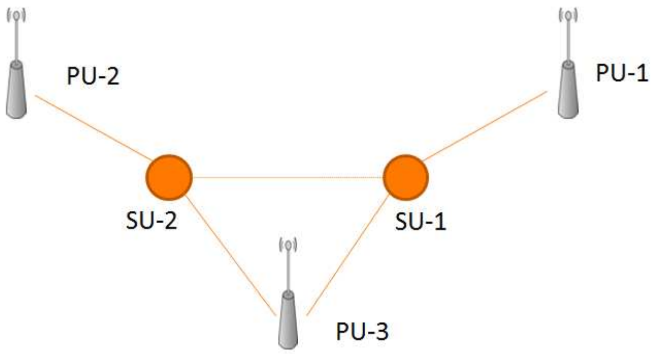

Figure-1

Sensing Delay	*PU-OFF*	*PU-50% DC No prediction*	*PU-75% DC No prediction*	*PU-50% DC Hypernets Prediction*
0	*6.5Mbps*	*3.2Mbps*	*1.6Mbps*	*4.3Mbps*
10ms	*6.1Mbps*	*3Mbps*	*1.3Mbps*	*4Mbps*

Table-1: Achievable datarates with 802.11b MAC.