ROAR- Real-time Opportunistic Spectrum Access in Cloud based Cognitive Radio Networks

Sachin Shetty
Tennessee State University
Nashville, TN
Email: sshetty@tnstate.edu

Danda Rawat
Georgia Southern University
Statesboro, GA
Email: drawat@georgiasouthern.edu

***Abstract*—In this paper, we present the development of Real-time Opportunistic Spectrum Access in Cloud based Cognitive Radio Networks (ROAR), a research infrastructure based on cloud-based cognitive radio network. ROAR will provide opportunistic spectrum access to wireless users through analysis of sensed spectrum information for a wide range of bands by leveraging the vast computation, storage and networking resources available on cloud computing platforms. We present the design of experiments to support ongoing research projects, including secure dynamic spectrum access design, cognitive radio enabled opportunistic spectrum access in highly mobile vehicular networks, and interference mitigation techniques and wireless resource management schemes.**

I. Introduction

Breakthroughs in wireless technologies are needed to resolve the nontrivial technical challenges to providing the pervasive wireless connectivity necessary to support trillions of human and machineto- machine communications. Cognitive radio (CR) technology is an attractive solution in which wireless devices (i.e., unlicensed users) are allowed to access unused spectrum bands (i.e., white spaces) by using dynamic spectrum-sharing algorithms coupled with radio regulations [8]. In CR systems, unlicensed users are able to maintain high quality services by recognizing radio environments near the users terminal while guaranteeing that licensed users remain free from any harmful interference [4].

Over the past decade, Opportunistic Spectrum Access (OSA) based approaches in Cognitive Radio Networks (CRN) have been proposed to mitigated the spectrum scarcity problems plaguing future wireless systems [4], [8]. Spectrum overlay is one of the popular OSA approaches which requires an unlicensed CRN user to dynamically identify the spectrum opportunities in licensed bands based on geographic location [8]. However, it is possible that the unlicensed user may not be able to sense for spectrum opportunities optimally all the times which could result in false detection. In addition, the existing approaches are also unable to provide real-time OSA across diverse RF bands (e.g., 9kHz - 6GHz), including cellular, IEEE 802.11 a/b/g/n, IEEE 802.15.4, DSRC/WAVE and Bluetooth networks.

Cloud computing is an ubiquitous technology adopted by commercial and military enterprises to support services by leveraging access to on-demand computing, storage and networking resources. The wide-spread adoption of services implemented on cloud computing infrastructures has the potential to address the spectrum overlay challenges [5]–[7].

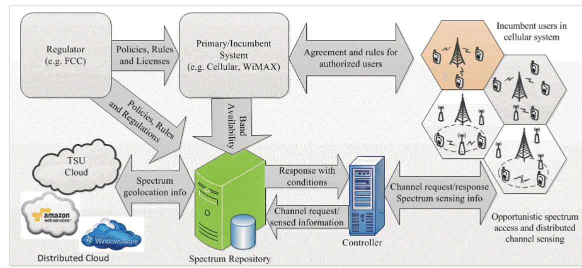

Fig. 1. ROAR Architecture

Unlicensed users sense the channels and report the spectrum occupancy information to a cloud service. The cloud service is responsible for maintaining a spectrum map for each network based on the sensed information. Alternatively, each licensed network can lease its licensed spectrum (a.k.a. authorized dynamic spectrum access) to secondary users through a cloud assisted spectrum server. The cloud service asista unlicensed users by providing access to spectrum channels which satisfy the Quality of Service and ensures efficient use of the CRN resources.

In this paper, we present the development of Real-time Opportunistic Spectrum Access in Cloud based Cognitive Radio Networks (ROAR), a research infrastructure to support cloud-based CRN. The ROAR project, funded by the NSF CRI program, is a collaborative effort between Georgia Southern University and Tennessee State University ROAR will aid the analysis of sensed spectrum information for a wide range of bands by leveraging the vast computation, storage and networking resources available on cloud computing platforms. ROAR will enable experimental investigations in ongoing projects, such as, secure dynamic spectrum access design, cognitive radio enabled opportunistic spectrum access in highly mobile vehicular networks, and interference mitigation techniques and wireless resource management schemes.

II. ROAR Architecture

Fig. 1 illustrates the various system components in the ROAR architecture which contribute to the implementation of the real-time OSA approaches in a cloud-based CRN. Following is a brief description of the key system components.

Development of Unlicensed User Model: The unlicensed user model aids the wireless device based on Software Defined Radio (SDR) technology to correctly report idle spectrum bands for the current geographical location to the cloud-based spectrum service and tunes radio parameters (transmit power, channel, modulation, etc) based on the band information provided by the service.

Development of Spectrum Map: The cloud-based spectrum service can select the best channel for the unlicensed user based on the availability of a spectrum map which contains real-time spectrum occupancy information for various geographical regions. The spectrum map will be developed by incorporating FCC's [1] spectrum usage regulations and policies.

Selecting Optimal Spectrum Channel: In addition, to availability of a storage platform capable of accommodating real-time spectrum updates, there is a need for a distributed computing system which can implement OSA algorithms and provide real-time spectrum occupancy information to unlicensed users. The cloud-based spectrum service is also responsible to ensure fairness among users and balance the spectrum usage across the heterogeneous bands.

III. Research Experiments on ROAR

The testbed to realize ROAR comprises of RF Vector Signal Generator (signal source: 9 kHz to 6 GHz), Real-Time Spectrum Analyzer (3 Hz to 8.4 GHz), multiple NI USRP-2922 SDR and commercial cloud computing resources. The experiments Below is the list of experiments that will be conducted on the ROAR testbed.

Creation and Maintenance of Spectrum map database: Spectrum sensing algorithms will be implemented on the NI USRP-2922 SDR to scan a range of spectrum channels and provide occupancy information, location and time to the cloud-based spectrum service. The real-time spectrum analyzer will also scan the channels which are beyond the range of the SDR and report the occupancy information to the cloud service. The vector signal generator will be responsible for generating signals which emulate the arrival of the licensed user or noise, which will also be relayed to the cloud service. The cloud service will be responsible for creating and maintaining the spectrum map for every network. The spectrum map entries will also be verified for compliance with FCC policies and regulations

Real-time Opportunistic Spectrum Access in Cloud-based CRN: With the availability of the up-to-date spectrum map, the next step is to develop a algorithm implemented on a real-time distributed programming framework (Storm or Spark) which can accurately find spectrum opportunities in the cloud based storage in a timely fashion. The search algorithm also incorporates admission criteria for unlicensed users based on their geolocation, demand and operator's system capacity. The experimental validation of the algorithm will involve evaluating the ability to provide optimal channel in a timely fashion when the unlicensed users request data rates ranging from tens of Kbps to several hundred Gbps. In addition, to the speed of the response, we will also evaluate the ability of the algorithm to adapt to real-time changes in the spectrum environment due to arrival of licensed user or noise.

Performance evaluation of ROAR: We have identified several criteria to quantify the performance of the ROAR architecture. The latency between the submission of sensed spectrum opportunity and the receipt of the spectrum channel from the cloud-based service will be measured for different scenarios. The scenarios will involve varying the number of unlicensed users, data rates, noise level, and licensed user occupancies. The experimental results will provide an insight on the processes or configurations which make a significant contribution to the latency. We will also experimentally evaluate the ability of Storm [3] and Spark [2] framework to provide real-time opportunistic spectrum access for the aforementioned scenarios.

IV. Conclusions

In this paper, we presented the description of experiments for ROAR, a real-time opportunistic spectrum access testbed for cognitive radio networks. ROAR is based on a cloud-based cognitive network for real-time opportunistic spectrum access across diverse RF bands (e.g., 9 kHz - 6 GHz) including cellular, IEEE 802.11 a/b/g/n, IEEE 802.15.4, DSRC/WAVE and Bluetooth networks. The availability of ROAR will facilitate the experimental investigations in a number of other research projects, including secure dynamic spectrum access design, cognitive radio enabled opportunistic spectrum access in highly mobile vehicular networks, primary user security emulation, energy management techniques for mobile devices, cross-layer based protocol design, security for cyber-physical system design, interference mitigation techniques and wireless resource management schemes.

V. Acknowledgments

This work was supported in part by the National Science Foundation (NSF) under grant CNS-1405670. Any opinion, finding, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF

References

[1] Federal communications commission (fcc), second memorandum opinion and order, et docket no fcc 10-174. http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-174A1.pdf.

[2] Spark streaming. https://spark.apache.org/streaming/.

[3] Storm: The hadoop of real-time processing. http://tech.backtype.com.

[4] Simon Haykin. Cognitive radio: brain-empowered wireless communications. *Selected Areas in Communications, IEEE Journal on*, 23(2):201–220, Feb 2005.

[5] Danda B. Rawat, Sachin Shetty, and Khurram Raza. Secure radio resource management in cloud computing based cognitive radio networks. In *Proceedings of the 2012 41st International Conference on Parallel Processing Workshops*, ICPPW '12, pages 288–295, Washington, DC, USA, 2012. IEEE Computer Society.

[6] Danda B. Rawat, Sachin Shetty, and Khurram Raza. Geolocation-aware resource management in cloud computing based cognitive radio networks. In *International Journal of Cloud Computing*, 2013.

[7] Sachin Shetty and Danda Rawat. Cloud computing based cognitive radio networking. In *Cognitive Radio Technology Applications for Wireless and Mobile Ad Hoc Networks*, IGI Global, 2013.

[8] Qing Zhao and B.M. Sadler. A survey of dynamic spectrum access. *Signal Processing Magazine, IEEE*, 24(3):79–89, May 2007.