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Advances on Software Defined Wireless Networking

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Abstract

Software defined wireless networking is regarded as an emerging technology to enhance spectrum efficiency and improve the overall network performance. In this paper, we summarise the special issue on recent advances on software defined wireless networking. Specifically, this special issue publishes following findings: i) a novel context aware medium access control scheme for multichannel buffer-aided cognitive networks to reduce the delay by exploiting the packets' contexts; ii) a utility-based uplink scheduling algorithm that accommodates different performance metrics and adapts its decisions based on user-specified profiles by incorporating an intermediary layer between the MAC and network layer; iii) an opportunistic spectrum access (OSA) solution with stationary and nonstationary Markov multi-armed bandit (MAB) frameworks using index based algorithm (called QoS-UCB) which balances exploration in terms of occupancy and quality for transmission for stationary environments and discounted QoS-UCB (DQoS-UCB) for the non-stationary case. These methods have been formally analysed and evaluated using numerical results obtained from extensive simulations.

Keywords: Software defined networks, cognitive radio networks, wireless spectrum.

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1. Introduction

With the successful deployment of Wi-Fi and wireless cellular networks as well as advances in lightweight hand-held devices, the number of wireless subscriptions is increasing exponentially leading to exponential increase in data transfer. Advances in wireless networking technology allows smart objects/things to connect to the Internet making Internet of Things [1]. By 2020, over 30 billion smart things/ devices are expected to be connected through Internet of Things. These advances in devices and networking technologies offer several socioeconomic benefits. However, when several devices/things are connected wirelessly with each other, there will be congestion and will exist wireless spectrum scarcity problem. Recent studies have shown that almost all usable wireless spectrum bands are already allocated to some service providers or government bodies for long time and vast geographic area [2]. Meanwhile, most of the spectrum are underutilised or idle most of the time even in highly populated and busier cities [2]. This motivates us to investigate advance approaches to enhance the spectrum utilizations. There are different approaches for enhancing the spectrum such as opportunistic spectrum access using spectrum underlay and overlay [2], cognitive radio network [3], cognitive radio to network radio [4], software defined wireless networking [5,6] and wireless virtualization [7] for different applications including cognitive radio enabled vehicular networking [8] and dynamic spectrum access in smart grid [9].

This special issue aimed to theme innovative research achievements in the field of software defined wireless networking and communications. We were seeking original, innovative and unpublished papers related to the topics. Among several submitted papers, we accepted 4 high quality papers. We give many thanks to the reviewers for their time revising and providing useful comments to the authors and to the authors for their patience when some steps have been delayed because of the amount of received papers.

We have classified the accepted papers in the following topics:

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- Dynamic Spectrum Access & Cognitive Radio Networks
  1. Medium access control for multichannel cognitive radio networks
  2. Opportunistic spectrum access with QoS constraint
- Software Defined Vehicular Wireless Networks
  1. Scheduling in heterogeneous wireless vehicular networks
  2. Energy-aware software defined vehicular wireless networks

The rest of the paper is organized as follows. Section 2 presents about the accepted papers focused on dynamic spectrum access and cognitive radio networks. Accepted papers focused on software defined vehicular wireless networks are presented in Section 3. Finally, Section 6 presents our conclusions.

2. Dynamic Spectrum Access and Cognitive Radio Networks

This section includes the accepted papers focused on dynamic spectrum access and cognitive radio networks.

2.1. Medium access control for multichannel cognitive radio networks

Paper entitled "A Novel Buffer-Aided Medium Access Control for Multichannel Cognitive Radio Networks" by Mostafa Darabi and Behrouz Maham presents a context aware medium access control scheme for multichannel cognitive radio networks. Buffer plays a role while managing the delay more efficiently by exploiting the packets' context where i) delay sensitive packets in the primary and secondary networks are given a higher priority compared to delay tolerant packets; and ii) shorter packets in the primary and secondary networks are given a higher priority compared to longer packets for channel access and transmission. Numerical results obtained from simulation show that the proposed approach outperforms the existing approaches and improves the overall network performance by lowering waiting time of packets and increasing the throughput.

Simulation results show that the first channel assignment in the proposed scheme reduces the average waiting time for both the primary and secondary video and data packets of up to 50% and 40% compared to shortest queue rule and queuing channel assembling protocol. This help to enhance the throughput up to 45% in an average for primary and secondary networks compared to other approaches and first come first serve policy.

2.2. Opportunistic spectrum access with QoS constraint

Paper entitled "Efficient Learning in Stationary and Non-stationary OSA Scenario with QoS Guaranty" by Navikkumar Modi, et, al. present an opportunistic spectrum access (OSA) method using stationary and nonstationary Markov multi-armed bandit (MAB) frameworks where i) an index based algorithm called QoS-UCB balances the exploration in terms of occupancy and quality of service (in terms of signal to noise ratio for transmission) for stationary environments, and ii) a learning policy algorithm called discounted QoS-UCB (DQoS-UCB) for the non-stationary case. Proposed approaches outperform existing methods in terms of regret for a large variation range of the exploration coefficient values in stationary OSA scenario and in terms of policy including discount factor to weaken the confidence interval in non-stationary OSA scenario. Future research in this direction includes adaptive algorithm which can adapt discount factor according to the operating environment.

3. Software Defined Vehicular Wireless Networks

This section includes the accepted papers focused on dynamic software defined vehicular wireless networks.

3.1 Scheduling in heterogeneous wireless vehicular networks

Paper entitled "Multiple Interface Scheduling System for Heterogeneous Wireless Vehicular Networks: Description and Evaluation" by Cristian Roman, et al. presents a scheme MAC and Network layers of the reference model for reliable wireless communications for software defined vehicular network for vehicle to vehicle (V2V) communications and vehicles to infrastructure (V2I) for future vehicular transport networks. Specifically, a multi interface scheduling system aka MISS is proposed to achieve efficient bandwidth aggregation, or lower end-to-end packet delay. Numerical results show that safety critical traffic can benefit by prioritizing the resources for them when there are insufficient resources. Proposed approach adapts the parameters using software defined concept to give lower delay for safety traffic and/or video in vehicular networks. The algorithm is designed for a multi-queue, multi-radio access technology vehicular environment where the selection of access technology is based on the user perspective at the user end.

3.2 Energy-aware software defined vehicular wireless networks

Similarly, paper entitled "Software-Defined Management Model for Energy-Aware Vehicular Networks" by Elif Bozkaya and Berk Canberk present a software-defined management model for flow control and energy efficiency in vehicular networks to enhance the overall performance of the network. Problems, associated with network performance degradation because of broken network in

sparse traffic density and high energy consumption because of many RSUs which are not actively used, are solved to enhance the Quality of Experience of vehicular network users. SDN controller schedules RSUs by switching them on/off depending on the context of the vehicular network to reduce the total energy consumption. Numerical result obtained from simulation show that lower energy consumption and higher throughput while enhancing the Quality of Experience of vehicular network.

3. Conclusion

We have observed in this special issue that it has increased the interest of research community on starting new research lines related to software defined wireless networking and its application in different domains. We have classified the papers accepted in this special issue into 2 categories: software defined cognitive radio networks for low mobile users and software defined wireless vehicular networks for highly mobile users. Research on emerging software defined wireless networking will help to enhance the spectrum efficiency to support several applications including the vehicular networks, smart grid and broad band wireless communications.

References

[1] Book: S. Jeschke, C. Brecher, H. Song and Danda B. Rawat (Eds.), "Industrial Internet of Things: Cyber-manufacturing Systems," ISBN: 978-3-319-42559-7, Springer, 2016.

[2] Book: Danda B. Rawat, M. Song, and S. Shetty, "Dynamic Spectrum Access for Wireless Networks," Springer, ISBN:978-3-319-15298-1 Springer, 2015.

[3] Journal Article: Haykin, Simon. "Cognitive radio: brain-empowered wireless communications." IEEE journal on selected areas in communications 23.2 (2005): 201-220.

[4] Journal Article: M. Song, C. Xin, Y. Zhao, and X. Cheng, "Dynamic Spectrum Access: From Cognitive Radio to Network Radio," *IEEE Wireless Communications Magazine*, Feb. 2012.

[5] Journal Article: Danda B. Rawat and Swetha Reddy, "Software Defined Networking Architecture, Security and Energy Efficiency: A Survey," IEEE Communications Surveys and Tutorials, Vol. x, No. x, October 2016

[6] Conference: Danda B. Rawat and Swetha Reddy, "Recent Advances on Software Defined Wireless Networking," Proc. of IEEE SoutheastCon 2016, Norfolk, VA, March 30 - April 3, 2016.

[7] Conference: Danda B. Rawat and Nimish Sharma, "Wireless Network Virtualization for Enhancing Security: Status, Challenges and Perspectives," Proc. of *IEEE SoutheastCon 2016*, Norfolk, VA, Mar. 30 – Apr..3, 2016.

[8] Conference: D. Rawat, Y. Zhao, G. Yan, and M. Song, "CRAVE: Cognitive Radio Enabled Vehicular Communications in Heterogeneous Networks," *Proc. of IEEE RWW*, Jan. 2013.

[9] Conference: C. Bajracharya and D. B. Rawat, "Opportunistic Spectrum Access Enabled Heterogeneous Wireless Networking for Smart Grid", Proc. of *the IEEE Consumer Communications and Networking Conference* (*CCNC 2016*), 9-12 Jan. 2016, Las Vegas, NV, USA.

Biographies

Danda B. Rawat is an Associate Professor in the Department of Electrical Engineering & Computer Science at How`ard University, Washington, DC, USA. Rawat's research focuses on wireless communication networks, cyber security, cyber physical systems, Internet of Things, big data analytics, wireless virtualization, software-defined networks, smart grid systems, wireless sensor networks, and vehicular/wireless ad-hoc networks. Dr. Rawat is the recipient of NSF Faculty Early Career Development (CAREER) Award in 2016. He is the Founder and Director of the Cyber-security and Wireless Networking Innovations (CWiNs) Research Lab. He received the Ph.D. in Electrical and Computer Engineering from Old Dominion University, Norfolk, Virginia. He is a Senior Member of IEEE and member of ACM and ASEE.

Min Song served as Program Director with the NSF from October 2010 to October 2014. Through his outstanding contributions in promoting NSF's international engagement and leadership, Min received the prestigious NSF Director's award in 2012 for collaborative integration and the successful launch of ground-breaking international initiatives. Min's research interests include design, analysis, and evaluation of wireless communication networks and systems, network security, cyber physical systems, and mobile computing. During the past 15 years, Min has secured more than $3.4 million in research funding from NSF, DOE, NASA, and private Foundations, and published more than 160 technical papers. He was the recipient of NSF CAREER award in 2007.
Min's professional career comprises more than 27 years in government, academia, and industry. As an NSF Program Director in the Division of Computer and Network Systems, Min initiated three new programs: Enhancing Access to the Radio Spectrum (EARS), Wireless Innovation between Finland and US (WiFiUS), and US-Japan Big Data and Disaster (BDD) research program, and managed 10 programs in the field of wireless communications and wireless networking.

ChunSheng Xin received the Ph.D. degree in computer science and engineering from the State University of New York at Buffalo, Buffalo, NY, USA, in 2002. He is an Associate Professor with the Department of Electrical and Computer Engineering, Old Dominion University, Norfolk, VA, USA. He has received several grants from the National Science Foundation to support his research. His research interests include cybersecurity, cognitive radio networks, wireless communications and networking, cyber-physical systems, and performance evaluation and modelling. He has also served on the Technical Program Committee and the Organization Committee of numerous conferences. He has been an external consultant on cybersecurity for industry.