Framework for Generating and Designing Spectrum Awareness Modules for Opportunistic Networking

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***Abstract*—For improved spectrum utilization in opportunistic network (OppN), spectrum awareness (SA) metrics can be generated from the synthesis and analysis of both static and dynamic network parameters. However, there are several techniques and algorithms for evaluating network parameters. Hence, a standardized framework is needed for generating SA towards improved spectrum consumption. To the best of our knowledge, no such framework currently exist in literature. In this work, therefore, we propose a novel approach for constructing, justifying and improving SA modules for OppN. Our approach maps different SA metrics to network parameters, which we define as SA integrals. We derive the constant of proportionality (SA constant) between the metrics and the integrals as a function of reliability, computational complexity and latency. The derived SA constants can be used to justify and compare SA techniques and algorithms. Based on the results obtained from the modeling and simulation of an adhoc cognitive radio network, using QualNet, we illustrate the applicability of SA constant as an index $(0.0 < SA\ constant < 1.0)$ for quantifying the level of SA derivable from any specified SA module.**

***Index Terms*—Big Spectrum Data, Cognitive Radio, Performance Evaluation, Spectrum Awareness**

I. Introduction

Spectrum situational awareness (SSA) in cognitive radio network (CRN) has the potential for improving spectrum utilization; intelligent decision making for spectrum utilization and sharing, based on SSA, yields optimum network resource consumption [1]. Therefore, the design of CRN for maximum SSA requires standard analytical benchmarks for investigating and comparing network performance and scalability. In order to generate SSA benchmarks, however, modular forms of the techniques and algorithms are required. Currently, there are a number of ongoing research projects exploring not only single-parameter-based SSA techniques but also the hybrid equivalents. According to some research works, hybrid parametric SSA techniques, for generating spectrum awareness from multiple combinations of network parameters, perform better than the single parameter techniques [2] [3]. Hence, in order to justify hybrid SSA techniques, standardized single-parameter SSA performance and scalability models and modules must be available.

Of all the challenges posed by network resource utilization, spectrum allocation and consumption are two of the vital network design variables. This is due to the fact that spectrum availability is limited by nature and different networks and applications compete for access. The number of channels available in a network is limited by Nyquist-Shannon theorem, network application demand, government policies and regulations. It therefore becomes paramount for opportunistic users to be able to explore the dynamic network resources for improved utilization and performance. As a result, we define spectrum awareness (SA) as the amount of useful knowledge available to a network user about its spectrum environment [4]. Thus, the SSA models can be used to predict spectrum availability for improved spectrum utilization.

SA models are useful in generating modular frameworks for optimizing spectrum utilization. For instance, if a user is able to accurately predict the receivers of an ongoing transmission and the duration of transmission over a particular channel, that user would definitely know when to avoid using the channel and look for an alternative means in case it has data to be transmitted. Hence, modeling the dynamic state of CRNs using intelligent data is a suitable approach for exploiting unused network resources. Analytical and empirical models of the dynamics of networks, based on network performance metrics, are therefore needed.

Reliability, computational complexity, and latency are key performance metrics that are considered when modeling the SA capability network users [5]. They are necessary in order to capture the effects of sacrificing one network resource for another and also to determine the true performance of a network in different scenarios. However, improving the overall performance of a network at the expense of limited network resources is not desirable. Hence, network design models must include all possible performance-determining factors. For instance, a valid SA model would be able to predict the behavior of a network both during and after data transmission for static and dynamic network reconfiguration respectively. Therefore, SA models are best generated by both parametric [6] and non-parametric [5] analysis of measured, estimated and predicted network parameters. Measured SA data have high latency and as the size of a network increases, more measurements are required. The accuracy of estimated and predicted variables, on the other hand, generally increases with the size of a network (measured by the number of users). Hence, as in [6], combining measured, estimated and predicted data would help to improve SA data accuracy, reduce computational complexity and minimize the overall data transmission latency.

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