Work in Progress: A Channel Selection Algorithm for a TVWS mesh network

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Abstract—**The concept behind this work is to build mesh networks in the TVWS band for developing regions to improve internet access opportunities. The purpose is to solve a pertinent problem within the context, namely to find an optimal or almost optimal channel selection for the mesh. Both simulation as well as a trial network will be used to analyse performance.**

Keywords— **TVWS, mesh, channel selection, DSA, coexistence**

I. Introduction

Opportunistic use of the under-utilised television broadcast spectrum – so called TV White Space (TVWS) – is a promising alternative to alleviate the artificial spectrum shortage resulting from less than optimal spectrum allocation policies. Meanwhile, a prominent situation in South Africa and other developing countries is the dichotomy between the numerous internet access options in urban areas and the very limited internet access opportunity in more rural areas, where there is less commercial incentive for Internet Service Providers to invest in infrastructure.

TVWS appears to be an appropriate solution to provide low cost internet connectivity in lower density areas, which does not require significant infrastructure investments. TVWS also has superior propagation properties compared to higher frequency bands, has greater penetration, is less sensitive to obstructions, and experiences lower attenuation over large distances [1]. However, there are issues that must be considered by secondary users (SUs) when using the TV band. Regulation is stringent on the conditions for its use in order to guarantee the absence of any detrimental effects to the primary spectrum users. It is required that any node wishing to use the spectrum first query the spectrum database to acquire an up-to-date list of available channels within its geographical area, and only those channels can be considered for use. Additionally, coexistence with other SUs must be considered, which may be competing for the same channels, and may cause interference by transmitting on adjacent channels or even channels further away.

TVWS is traditionally used in a point-to-multipoint topology but to use the TVWS band in the most advantageous way within the context sketched, we suggest using it in a mesh configuration. Mesh networks have advantages in that they are more equipped for rapid rerouting and reconfiguration in response to changing network conditions, such as the loss of nodes or the emergence of other secondary spectrum users. The self-healing and self-configuration properties result in lower maintenance requirements and costs, a significant benefit when deployed in remote areas where minimizing costs is important.

Two of the most pertinent issues that arise are channel selection and routing. The two issues are clearly related, and must be determined in a way that optimises spectral efficiency and the percentage of offered traffic actually carried over the entire network. The main objective of this work is to develop a channel allocation (CA) algorithm to be used in conjunction with a routing algorithm to optimise the throughput of a TVWS mesh network in the presence of primary users and other possible dynamic secondary user interferers.

While there has been much interest in algorithms for dynamic spectrum access, in the TVWS arena, e.g. [2], and separately in mesh networks from a mathematical perspective [3]–[5], there is a marked lack of practical algorithms that combine the specific requirements of TVWS with practical details of how the algorithms can be implemented in a mesh network using currently available commodity hardware, how hidden terminal problem can be addressed during the channel switch-over process and how channel switching is to be coordinated across the mesh. The contribution provided by this work is a proposed algorithm for TVWS mesh that is firmly rooted in reality and will be tested in an actual network.

The rest of this paper gives only a very brief view of the intended work, models and methodology.

II. The Channel Selection Problem in TVWS Mesh Networks

A. Description

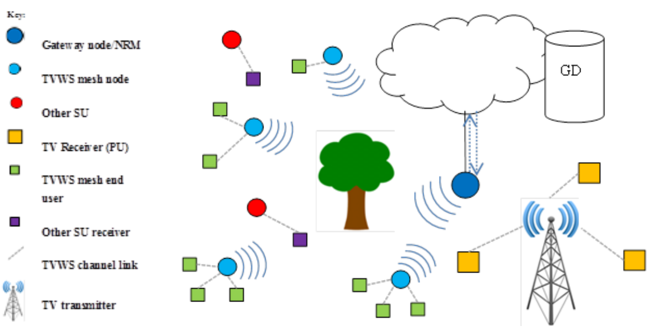

Figure 1: Illustration of the TVWS ecosystem

Figure 1 above illustrates the situation in which the network is envisaged to work. This shows a gateway node (the internet connection point for the other mesh nodes), customer premise equipment, and other interference sources and obstacles (the tree). The gateway is also the node that first performs the database query. All nodes start by doing a spectrum scan for unused channels in their coverage area and gauge interference levels. A channel manager (CM) node chooses a channel for the beacon broadcast based on occupancy measurements per channel. Terminal nodes start in *ad hoc* mode, receive the beacon and perform network subscription and registration procedures. The CM then gathers information from all the other nodes, runs the CA algorithms and shares the assignment information with the mesh nodes. The mesh consists of nodes denoted first tier, second tier and so forth. The first tier nodes communicate directly with the CM. The first tier nodes then act as CM for second hop nodes, the second for the third etc. In each case the intermediate CMs forward the necessary control packets to the nearest primary CM for scheduling of the dependent nodes. All nodes are also equipped with Wi-Fi, which is an included channel in the scheduling or used as a fall-back option. Once the first channels are assigned and communication paths exist the same channels are used for control and data packaged together, so there is no need for a dedicated control channel.

B. Situational Assumptions and Constraints

- Nodes are stationary so their location only needs to be shared once.
- Network changes such as node additions or removals are infrequent (compared to packet transmission rate).
- Time slots are separated by an interval longer than the coherence time of the channel i.e. channel properties are constant during a single time slot.
- Information elements in control packets: currently assigned channels, geo-location of other nodes in the network, and transmit power settings.
- Devices in the network can be accurately synchronised as they all contain on-board GPS devices.
- Power supply is not a limiting factor and nodes transmit at the highest allowed power level (20 dBm).

Constraints to be considered in formulating the model and solution are:

- Hardware: We have selected to use the Doodle labs down-converted TVWS cards on Mikrotik boards as the platform, since they are relatively inexpensive and the platform lends itself to development. The hardware has shortcomings in terms of processing power and speed of reconfiguring, the number of interfaces, the sensing mechanism and spectrum scanner, as well as filters and adjacent channel rejection ratio, which has a strong impact on the protection ratios.
- The use of the Geolocation spectrum database is mandatory. Access to the database may be difficult and it may not be completely accurate.

For communication to take place between two nodes they must be within communication range of each other, must use the same channel and the same channel bandwidth. Additionally, interference must be suitably low on the link.

C. Model

The network can be modelled as a graph where each vertex is a node interface. Each edge is characterised by a tuple of currently assigned channel, and a flow measure that is dependent on the physical distance between its end nodes, the attenuation on the channel and interference experienced from other nodes. A channel assignment schedule is defined over a certain number of time slots for a set of links concurrently active. SINR must be above a certain threshold for successful transmission and decoding, or to minimize the probability of a dropped packet. In addition, protection ratio requirements for primary users must be met to ensure quality factor 4 or 5 TV viewing [6]. These form the constraints on the optimisation problem, which is to find a feasible schedule of channels on links for a set of time slots so as to maximize the overall network capacity. A new optimization algorithm will be employed to carry out the optimization every time a new channel allocation is required, with measures to trade-off the losses incurred while making changes with the gains of a more optimal channel allocation.

D. Methodology

The algorithm is to be tested with the simulation tool Network Simulator 3 (NS3) by generating traffic based on various statistical models and applying the algorithm to various different mesh topologies. The ratio of carried traffic to offered traffic will be measured and compared with the results of other candidate algorithms, used on the same simulation instance. An actual trial network is also being built to do important “real world” tests to confirm practicability.

III. Expected Outcomes

In this work an algorithm will be developed that makes smarter channel allocation decisions in TV white space mesh networks. A protocol for formation of the mesh over selected channels will be developed to ensure that as the mesh grows or changes the constraints are still met and channels are assigned such that overall network capacity is optimised or, if required, specific per-user QoS requirements are met.

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