WhiteMesh: Leveraging White Spaces in Multihop Wireless Topologies

TBA
Dinesh Rajan, and Joseph Camp

***Abstract*—**

I. Introduction

FCC adopted rules to allow unlicensed radio transmitters to operate in the white space freed from TV band since 2010 [1]. White space is popularly referred to unused portions of the UHF and VHF spactrum includes, but not limited to 54M-72MHz,76M-88MHz,174M-216MHz,470M-608MHz,and 614M-806MHz [2]. To use these band, FCC ruling requires white space devices(WSDs) to learn of spectrum availability at their respective locations from a database of incumbents. For example, in Dallas/Fort Worth, TX, 482M-488MHz band should be yielded for TV channels, in Chicago, IL 470M-482MHz band is reserved for TV channels. [3] These bands provides superior propagation and building penetration compared to licensed ISM Wifi bands like the 2.4 and 5GHz bands, holding rich poetntial for expanding broadband capacity and improving access for wireless users.

Wireless mesh network is able to provide broadband Internet access to large contiguous areas through less mesh nodes equipped with WSD due to the propagation characteristic of ISM bands. White space mesh is an economic way to provide backhaul internet service in rural area or other low density area employing the propagation characteristics. White space could also be used to improve the urban or high density area connectivity through lower interference channels.

Mesh deployment requires selecting the number and locations to place mesh nodes to cover the whole area and the nodes are inter-connected in order to access to Internet gateway points. Unfortunately, prior white space mesh placement research fails to address the compatibility of current existing devices, for instance, iPhone, Mac Laptop do not have white space radios to access white space gateway points. For a realistic mesh network, the end hop to the client need to be able to work in ISM Wifi band. To appreciate the multiband mesh deployment problem, it is important to understand the differences between white spaces and the popular ISM bands where Wifi devices operate. First, in FCC rules, users in white space band have to yield primary users.Before enter a white space channel, users have to detect the channel occupation. Second, white space band may suffer some unknown interference such as wireless Mic. Such devices may turn on at anytime without warning. Third, white space is cleaner than ISM bands since most of the TV stations have stopped using the bands. And also since in white space is in lower band, the coverage of these band is larger than higher frequency ISM band which could help to reduce the mesh nodes. According to these advantages and disadvantages, the balance between white space bands and ISM bands is possible to provide imporvement of mesh network.

This work focus on minimize the mesh nodes when gurantee the coverage and connectivity of the network. We present FIXME mesh node placement algorithms so as to minimize the deployed nodes, guarantee the coverage, and mesh node inter-connectivity.

The main contributions of our work are as follows:

- We formulate the hetergeneous mesh node placement problem as a FIXME problem.
- We propose a methodology to leverage the infulence of white space in mesh networks.
- We propose FIXME algorithms to minimize the numberof deployed mesh nodes.
- We perform extensive outdoor experiments from multiple environments and simulations to evaluate the proposed algorithms.

II. Multiband Adaptation

In this section, we first formulate the white mesh deployment problem with propagation, connectivity and QOS constrainr of multiband sceniario. We then propose FIXME white mesh deployment algorithms for multiband multihop networks. For comparison, we also propose FIXME baseline assignment methods based on existing solutions.

A. Problem Formulation

The objective of the mesh node placement problem in multiband scenario is to minimize the number of deployed mesh nodes and relay nodes with the constraint of full coverage of the target area and connectivity to the Internet existing users. The set fo potential mesh node accessing to Internet locations, M, is assumed know. Discrete locations for mesh nodes follows naturally from pratical constraints on deployment, such as the availability of wired connection store or other infrastructure for mesh node installation. The coverage area of the mesh network is discretized into small grid of coverage locations N. The center of each grid is the point output the received signal justifying the connection and channel capacity. Relay nodes R are defined as nodes do not have direcet Internet access but can connect to the mesh node and provide Wi-fi coverage of a number of grid. The vertex set of the input is defined as $V = M \cup N$,the union of coverage grid and the potential mesh nodes location. The solution of the problem could tell which mesh node will be built and where should a relay node be added. The set of chosen mesh nodes is represented as M_b. The output of the problem is the nodes location and number of wireless nodes $R \cup M_b$, the union of mesh nodes chosen from potential locations and the relay nodes.

B. Connectivity Constraint

The connctivity graph represented as $G = (V, E)$ could indicate the existence of usable links. This formulation encodes the signal quality of each link independently can represent the link quality diversity across bands. The links set, E, from the coverage grids to either relay nodes or mesh node, corresponding to the estimated or measured signal strength is abouve a signal strength threshold. More formally, the connectivity graph where both target coverage locations and potential mesh node locations form a unified connectivity graph. The mesh network have to satisfy the coverage of each grid through an edge E from either a mesh node or a relay node.

C. Propagation across Bands

For wireless networks, the received signal power of a node is represented as $P_{dBm}(d) = P_{dBm} - 10\alpha log_{10}(\frac{d}{d_0}) + \epsilon$. Pathloss exponent α in outdoor environments range from 2 to 5, higher frequency has a heavier pathloss. [4]. The propagation of frequency becomes an important characteristic since the pathloss exponent varies with channel frequency. The propagation difference makes the performance of radios vary from band to band in the same location. Specifying each link individually enables us to encode non-uniform propagation. In other words, each grid can be covered by an arbitrary node. The propagation alternation brings the advantages of providing more possible path for multihop network without increase interference of their neighbors.

D. Capacity Constraint

Wireless bandwidth is shared among all clients and mesh nodes, as a result, it is offen desirable to limit the number of potential sharers of the scarce wireless spectrum. The link E II-B could gurantee the minimum bandwidth sharing for the client, however, it could not represent the quality of the service. Our formulation enforces this by imposing a maximum degree b_v on the connectivity of a mesh node, represented the downlink/uplink capacity of the mesh node to clients. More complete capacity of formulations in other research take into account on-demands and fairness [5], but we do not get into these scenarios in this paper.

To employ the propagation advantages brings a NP-hard problem to arrive the optimal solution [5]. To approach the optimal solution we have FIXME frameworks to solve part of the problem subject to time fairness of each node.

III. White Mesh Algorithms

References

[1] FCC, "White space," http://www.fcc.gov/topic/white-space, 2012.

[2] Wiki, "White space(radio)," http://en.wikipedia.org/wiki/White_spaces_(radio)#United_States, 2013.

[3] B. W. Consulting, "Tv white space," http://www.broadband-mapping.com/tv-white-spaces.html, 2013.

[4] J. Camp, J. Robinson, C. Steger, and E. Knightly, "Measurement driven deployment of a two-tier urban mesh access network," in *Proceedings of the 4th international conference on Mobile systems, applications and services*. ACM, 2006, pp. 96–109.

[5] S. Arkoulis, E. Anifantis, V. Karyotis, S. Papavassiliou, and N. Mitrou, "On the optimal, fair and channel-aware cognitive radio network reconfiguration," *Computer Networks*, 2013.