Chapter 9

VillageLink: A channel allocation technique for wide-area white space networks

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Abstract
Internet connectivity is available to merely 39% of the world's population. Lack of internet access is primarily restricted to developing regions; however, many remote communities in the developed world are currently disconnected as well. The main cause of limited Internet penetration stems from the fact that more than three billion people live in rural areas. These areas are hard to connect via copper cables, fiber optic or cell phone base stations due to high deployment cost and low population density which renders these techniques economically infeasible. Rural areas are also hard to reach via cheap license-free solutions such as WiFi, as these technologies, operating in 2.4 or 5GHz bands, have a very limited connectivity range. In the 50–800MHz band, a large block of frequencies has recently been freed due to the analog to digital TV transition. This spectrum, called white spaces, promises to deliver an affordable means of providing wide area coverage. It is extremely attractive for rural areas as the propagation range is an order of magnitude higher signal propagation over the wide white space band, and the economic necessity of a resource-efficient, unlicensed, distributed solution for rural areas renders wide area white space networks uniquely challenging to realize. In a white space network a number of frequency selective effects will be present due to the topology, vegetation and antenna design. Because of the highly complex nature of electromagnetic propagation and the difficulty in accurately modeling fading, the analytical solution that provides a clear picture of frequency quality in white spaces is not practical. Frequency profile, however, is extremely important as it can be used as a basis for channel assignment in a white space network. However, even when frequency propagation information is available, channel allocation in a white space network is very hard. In a network where the span of available channels is not large, such as in WiFi networks, channel allocation can be cast to a graph coloring problem. In white spaces, the wide range of available channels leads to drastic differences in propagation among channels. These differences stem from the variation of free space propagation over frequencies, but also from antenna properties, as in practice antennas do not perform uniformly over a very wide span of white space frequencies. Finally, frequency assignment in such a wide band network has to satisfy conflicting goals: maximize useful transmission by allocating frequencies with superior propagation properties and minimize interference by allocating frequencies that propagate over a shorter radius. In this chapter we successfully address the above challenges by designing a lightweight frequency profiling methodology to evaluate channel quality and a novel channel allocation method that assigns operating frequencies to base stations with the goal of minimizing the impact of interference over the useful signal levels in a network. We compile these contributions into a practical channel profiling and allocation scheme for wide area white space networks called VillageLink. We test VillageLink's frequency probing mechanism on a long-distance software-defined radio white space link we deployed and confirm that antenna effects and the environment are a significant reason for high propagation diversity among white space channels. Through simulations we evaluate VillageLink's channel allocation. We show that our frequency-aware channel allocation leads to up to twice as much network capacity than an alternative heuristic based on interference avoidance, and that with its high performance, efficient resource usage and distributed nature, VillageLink represents a practical solution for wide area white space coverage in rural areas.