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Software-defined wireless mesh networks for internet access sharing

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ABSTRACT

Universal access to Internet is crucial, and as such, there have been several initiatives to enable wider access to the Internet. Public Access WiFi Service (PAWS) is one such initiative that takes advantage of the available unused capacity in home broadband connections and allows Less-than-Best Effort (LBE) access to these resources, as exemplified by Lowest Cost Denominator Networking (LCDNet). PAWS has been recently deployed in a deprived community in Nottingham, and, as any crowd-shared network, it faces limited coverage, since there is a single point of Internet access per guest whose availability depends on user sharing policies.

To mitigate this problem and extend the coverage, we use a crowd-shared wireless mesh network (WMN), at which the home routers are interconnected as a mesh. Such a WMN provides multiple points of Internet access and can enable resource pooling across all available paths to the Internet backhaul. In order to coordinate traffic redirections through the WMN, we implement and deploy a software-defined WMN (SDWMN) control plane in one of the CONFINE community networks. We further investigate the potential benefits of a crowd-shared WMN for public Internet access by performing a comparative study between a WMN and PAWS. Our experimental results show that a crowd-shared WMN can provide much higher utilization of the shared bandwidth and can accommodate a substantially larger volume of guest traffic.

1. Introduction

The Internet has evolved into a critical infrastructure for education, employment, e-governance, remote health care, digital economy, and social media. However, the Internet today is facing the challenge of a growing digital divide, *i.e.*, an increasing disparity between those with and without Internet access [60]. Access problems often stem from sparsely spread populations living in physically remote locations, since it is simply not cost-effective for Internet Service Providers (ISPs) to deploy the required infrastructure for broadband Internet access in these areas. Coupled with physical limitations of terrestrial infrastructures (mainly due to distance) to provide last mile access, remote communities also incur higher costs for connection between the exchange and backbone network when using wired technologies, because the distances are longer. Ubiquitous mobile broadband coverage is currently not feasible, since direct investment in local infrastructure is uneconomic [55]. Addressing digital exclusion due to socio-economic barriers is also important. The United Nations revealed the global disparity in fixed broadband access, showing that access to fixed broadband in some countries costs almost 40–100 times their national average income [34].

The reluctance of network operators (who are economically motivated) to provide wired and cellular infrastructures

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to rural/remote areas have led to several initiatives to build large-scale, self-organized, and decentralized community wireless networks that use WiFi mesh technology (including long distance), due to the reduced cost of using the unlicensed spectrum [51]. These community wireless mesh networks have self-sustainable business models, which provide more localized communication services, as well as Internet backhaul support via peering agreements with traditional network operators who see such networks as a way to extend their reach at a lower cost. There are also community-led wireless initiatives such as crowd-shared wireless networks, in which home broadband owners share a portion of their home broadband with friends, neighbors, or other users either for free or as part of a service offering by the ISP (*e.g.,* [6,53]).

Public Access WiFi Service (PAWS) [53] is a community-led crowd-shared WiFi service that uses a set of techniques that make use of the available unused capacity in home broadband networks and allowing Less-than-Best Effort (LBE) access to these resources, based on the Lowest Cost Denominator Networking (LCDNet) paradigm [58]. PAWS adopts an approach of community-wide participation, where home broadband subscribers are enabled to donate controlled but free use of their high-speed broadband Internet to fellow citizens. PAWS was deployed with 20 custom-made PAWS routers placed in a deprived community in Nottingham and was also trialed out in rural Wales. PAWS is essentially a crowd-shared access network (similar to FON [5]) for under-privileged users in urban and rural communities. PAWS has been facing ongoing deployment challenges, such as limited coverage, stemming from user sharing patterns. In particular, during the PAWS trial deployment, it was observed that home users did not share their broadband connection over periods at which either the whole bandwidth or all the ports of the home router were needed (*i.e.,* PAWS uses an access point connected to the home router for Internet access sharing). Essentially, PAWS is a crowd-shared network with a single point of access per guest, and as such, Internet access sharing is highly dependent on user sharing policies (*i.e.,* the periods at which user share their Internet connection).

To mitigate this problem, we investigate the potential benefits of extending PAWS or any crowd-shared wireless network to a wireless mesh network (WMN) by interconnecting wireless home routers. As such, a crowd-shared WMN provides extended coverage via multiple points of access for each guest. We particularly consider crowd-shared WMNs in residential areas, taking advantage of the dense deployment of wireless home routers. The main challenge in the management of such a WMN lies in the coordination of guest traffic redirections, such that the shared bandwidth is efficiently utilized. More precisely, traffic redirection requires the assignment of guest flows to gateways and the selection of paths (through the WMN) that provide sufficient capacity and low delay. Furthermore, decisions for traffic redirections should be also based on user sharing policies, when these are disclosed in advance. Given the amount of information that has to be collected before flow assignments can be made, we deem a centralized control plane as a more suitable approach to WMN management for Internet access sharing, since all information can be conveyed to a centralized controller facilitating the coordination of traffic redirections. In this respect, we leverage on software-defined networking (SDN) principles for the control plane design.

Along these lines, our contributions are the following:

- We present the design and implementation of a SDN control plane for the coordination of guest traffic redirections through the WMN.
- We develop an algorithm for the assignment of gateways to flows that require redirection, taking into account the flow demands, the residual bandwidth in the access links and the WMN, as well as, the advance knowledge of sharing policies.
- We generate a model for user sharing patterns based on the router on/off periods captured from the PAWS deployment in Nottingham.
- We quantify the benefits of a crowd-shared WMN for Internet access sharing using a deployment of our SDN control plane in Athens Wireless Metropolitan Network (AWMN) [4], *i.e.,* one of the community networks of the CONFINE project [2,3,24]. Community Lab, https://community-lab.net/ In this respect, we perform a comparative study between a WMN and a crowd-shared network with limited coverage (*i.e.,* one access point per guest).

This paper extends our previous study on software-defined WMNs, at which the efficiency of a crowd-shared WMN was assessed using simulations [18]. The remainder of the paper is organized as follows. In Section 2, we provide an overview of the software-defined WMN (SDWMN) control plane. Section 3 elaborates on techniques for guest traffic redirection. In Section 4, we discuss the implementation of the SDWMN and its deployment in AWMN. In Section 5, we present our evaluation results and discuss the benefits of a crowd-shared WMN for Internet access sharing. Section 6 discusses related work. Finally, Section 7 highlights our conclusions.

2. Software defined crowd-shared wireless mesh networks

The underlying problem with PAWS or any crowd-shared network is that they serve as single point of Internet access to guests within the coverage of the wireless router and hence, they have no provision to extend the coverage when no bandwidth is being shared. Based on our experience from the trial PAWS deployment, PAWS routers were not available for certain periods, because sharers needed all the bandwidth of their broadband connection or due to other reasons, such as economic constraints placed on home users in underprivileged areas where they are enforced to conserve energy by turning off the routers at nights. These observed user behaviors entail significant challenges for the successful adoption of PAWS.

A potential solution to this problem is to extend the PAWS network as a crowd-shared WMN. Such a network would allow home network users to share part of their own broadband connection with the public for free while also connected to each other as a WMN providing extended coverage (Fig. 1). Extending PAWS to a crowd-shared WMN departs from the norm: multiple users from different ISPs form part