Towards Crowd-Shared Home Networks

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***Abstract*—**

I. Introduction

The Internet has crossed new frontiers with access to it getting faster and cheaper. New applications and services are being offered. Information and communication is of utmost importance during emergency response. The Internet plays a crucial role in enabling access to critical information that can save lives of people. Internet is now seen as critical infrastructure enabling remote health care, education, employment, e-governance, digital economy, and social networks.

In the reality of todays Internet, the vision of digital inclusion faces the challenge of a growing digital divide, i.e., a growing disparity between those with sufficient access to the Internet and those who cannot afford the access to universal services.

Access problems often result from sparsely spread populations living in physically remote locations it is simply not cost effective for Internet Service Providers (ISPs) to install the required infrastructure for broadband Internet access to 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 larger. A large exchange may accommodate many users and allow for competition between service operators; in contrast, a rural/remote broadband often does not offer economies of scale, raising the costs per user. This problem is widely and publicly recognized. For example, in 2012, 9.1 million homes in Europe still do not have fixed broadband coverage, more than 90% of which are in rural areas [BROAD2012]. Achieving ubiquitous mobile broadband coverage is also currently seen as not feasible by major operators as direct investment in local infrastructure may be uneconomic. For example in the UK, 3G coverage is far more patchy, ironically including major towns and cities [WAKE2012].

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 times their national average income [FILD2010]. This problem is also applicable to developed countries where many individuals find themselves unable to pass a necessary credit check or living in circumstances that are too unstable to commit to lengthy broadband contracts [SATH2012]. A recent survey in Nottingham, UK [NCC2012] revealed that affordability is cited as the primary barrier, explicitly so by over 22.7% of digitally excluded 16-44 year olds. According to the OECD, Spain has the most expensive broadband entry price among member nations. In New Orleans, USA, the poorer wards have broadband subscription rates between 0 and 40 percent [POOR]. We believe that leaving connectivity for all to be governed by market economics is a major impediment to achieving the full benefits of the Internet, and that basic Internet access should be made freely available to all due to its societal benefits, a sentiment recently expressed by Berners-Lee [FREE2010].

We see enabling benevolence in the Internet (act of sharing resources) as a potential solution to solve the problem of digital exclusion caused due to socio-economic barriers. Lowest Cost Denominator Networking (LCDNet) [UCAM2013] is a new Internet paradigm that architects multi-layer resource pooling Internet technologies to support new low-cost access methods that could greatly reduce a network operators direct investment in local infrastructure to support wider Internet access. LCDNet proposes to bring together several existing resource pooling Internet technologies to ensure that donors (users and network operators), who share their resources, are not affected and at the same time are incentivised for sharing their resources.

PAWS (Public Access WiFi Service) [PAWS] is based on LCDNet using 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 [SATH2012]. PAWS adopts an approach of community-wide participation, where broadband customers are enabled to donate controlled but free use of their high-speed broadband Internet by fellow citizens. Other initiatives have already explored sharing a users broadband Internet connection via wireless (e.g., FON). Although these methods are gaining worldwide acceptance, they are usually viewed as an extension of a users paid service accessible only to other customers of the same service. In contrast, PAWS will extend support free access to essential services to all. To protect the consumers paid service and the service provider revenue, it is essential to ensure that the free user traffic does not impact perceived performance of the bandwidth donor (customer). The PAWS service is therefore constrained to offer a LBE access to network resources (lower quality compared to the standard Internet service offered to paying users). Various methods are being considered, including enabling LBE QoS (in both layer 3 and 2) in the network.

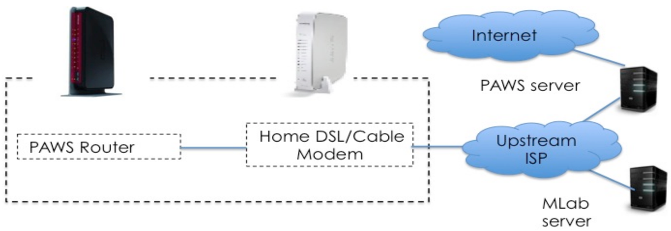

Fig. 1. PAWS network.

The PAWS testbed (Figure 1) is currently under deployment with 20 custom-made PAWS routers placed in a deprived community in Nottingham and another 10 routers in rural Scotland. The testbed currently serves as a small-scale open network measurement observatory in the UK that will allow researchers to gather data about network availability, reachability, topology, security, and broadband performance from distributed vantage points in socio-economically deprived urban and rural areas. A significant contribution of the testbed is that it currently serves as a crowd-shared access network (like FON) for under-privileged users in urban and rural communities. This provides the research community with a wealth of information on the needs of under-privileged users in terms of their access patterns and what do they use Internet access for. The testbed also provides researchers the opportunity to understand behavioral patterns of home broadband users in terms of how do they share their home broadband networks with the public, e.g., how often do they switch off their home access points and when (day/time) do they switch it off.

However, PAWS has faced ongoing deployment challenges such as limited coverage and most importantly due to home user sharing patterns. We have noticed that the PAWS routers were always not available mainly due to home users plugging off the PAWS router from the Ethernet socket of the home router and reusing the socket for their own use or because they did not want to share their Internet connection with the others for certain periods of the day or for other reasons such as economic constraints placed on home users in underprivileged areas where they are forced to conserve energy by turning off the routers at nights. Figure 2 presents a six-month view of the PAWS routers status (available/unavailable) logs demonstrating that not a single router was available continuously over the entire duration. These observed user behaviors have become serious challenges for the successful adoption of PAWS.

The underlying problem with PAWS or any crowd-shared network (such as FON) is that they serve as single point of Internet access to users within the coverage of the wireless router and hence have no provision to extend the coverage or to provide any redundancy during unavailability of the routers which is mainly due to the sharers sharing tendencies or policies. A potential solution to these problems would be to extend the PAWS network as a crowd-shared mesh network. Such a network would allow home broadband users to share part of their own broadband connection to the public for free while also connected to each other as a wireless mesh providing extended coverage. This also offers network redundancy to the Internet backhaul even when some sharers decide not to share their backhaul Internet connection for certain periods of time.

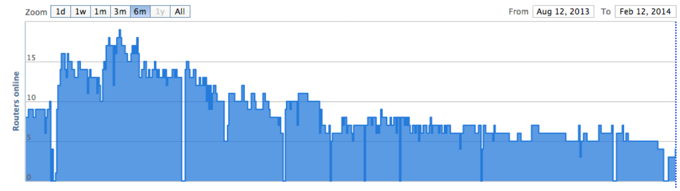

Fig. 2. PAWS routers availability.

II. Architecture

III. Evaluation

In this section, we quantify the benefits of using a wireless mesh in crowd-shared home networks for public Internet access. In Section III-A, we present the simulation environment, the modeling of router on/off periods, and the metrics used to evaluate the efficiency of the wireless mesh. Section III-B provides a comparative study of crowd-shared home networks with and without a wireless mesh based on our simulation results.

A. Simulation Environment

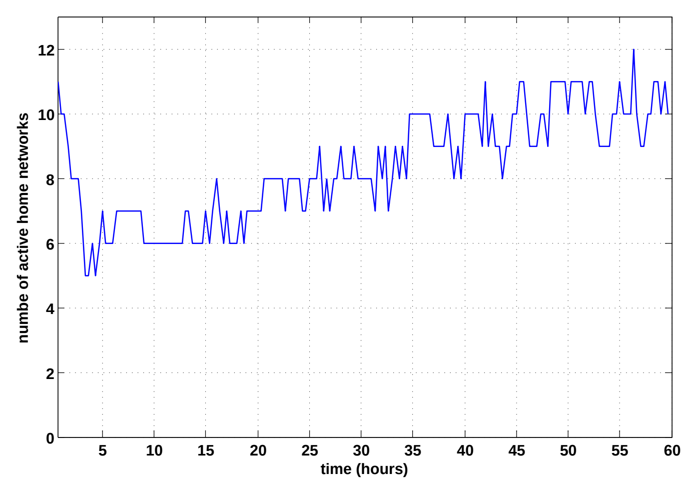

Fig. 3. Number of active home routers.

B. Simulation Results

Initially, we measure the shared bandwidth utilization and request acceptance rate with an arrival rate of 50 flows per minute over a 60-hour period. Fig. 4 illustrates a low utilization of the shared bandwidth without a wireles mesh during the whole period, although there is high demand for Internet access by guest users attached to the various home networks. In contrast, a wireless mesh allows to capitilize the unused capacity and accommodate a larger volume of guest user traffic. More precisely, according to Fig. 4 guest user traffic redirection through the wireless mesh results in the full utilization of the bandwidth shared by home network users. Furthermore, crowd-shared home networks with a wireless mesh can accommodate substantially higher guest user traffic, as depicted in Fig. 5. This stems from the high utilization of the shared bandwidth.

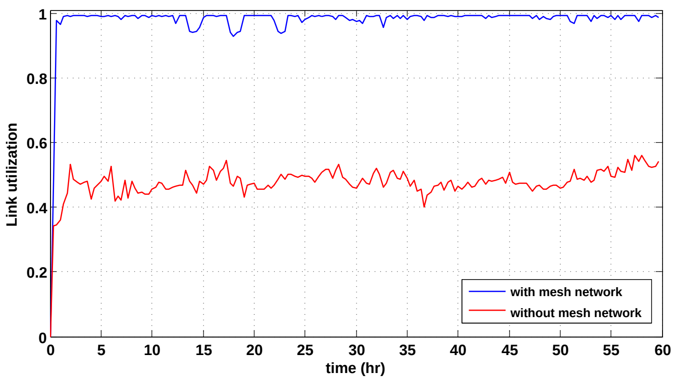

Fig. 4. Shared bandwidth utilization.

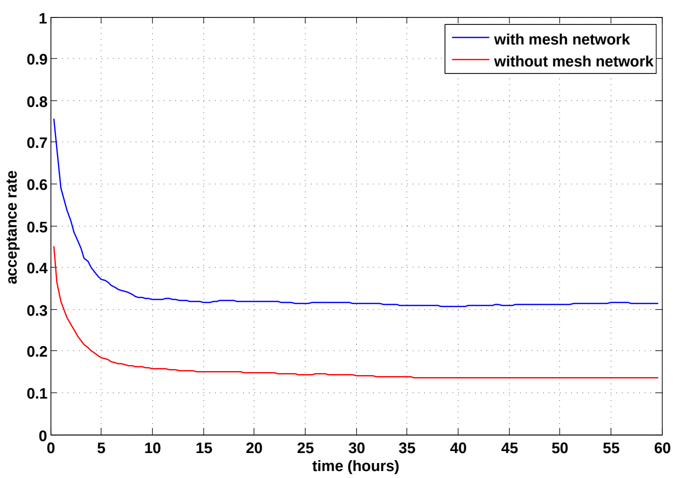

Fig. 5. Guest user traffic acceptance rate.

We further measure the shared bandwidth utilization with a wide range of guest user traffic demands. In this respect, Fig. 5 illustrates the shared bandwidth utilization with diverse flow arrival rates, ranging from 10 to 100 flows per minute. This simulation result corroborates the efficiency of the wireless mesh for various traffic loads, as the shared bandwidth utilization always remains very high. Without the presence of a wireless mesh, Fig. 5 shows poor bandwidth utilization, especially with low guest user traffic demand. In this particular case, the inability to redirect guest user traffic to home networks with available bandwidth results in wasting most of the shared bandwidth. Eventually, our simulation results show the significant benefit that a wireless mesh can bring in crowd-shared home networks, by effectively pooling shared resources across the interconnected home networks.

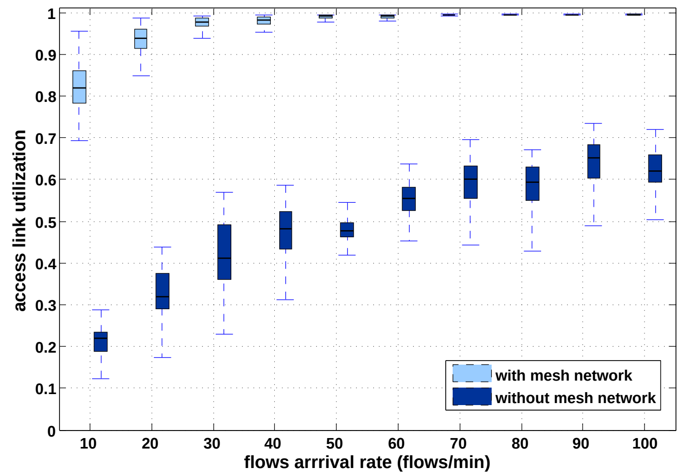

Fig. 6. Shared bandwidth utilization vs. flow arrival rate.

IV. Conclusions

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References

[1] A. Sathiaseelan and J. Crowcroft, LCD-Net: lowest cost denominator networking, ACM SIGCOMM CCR Vol. 43, No. 2, pp. 52-57, April 2013.