Towards switched-homing for Internet access

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Abstract

Most home networks are single-homed, i.e. connected through a single link to the Internet. This solution, while easy to deploy, lacks resilience because of its single point of failure. BGP-based multihoming is suitable for entreprise networks, but impossible for home networks. We encourage the IETF and researchers to explore an alternative called **switched-homing** where a small network can switch from one Internet link to another. This paradigm can increase network resilience and provide energy savings by switching to a lower consumption link at appropriate times. We show that such switches can be smooth using modern transport protocols like QUIC and Multipath TCP, and discuss future work.

CCS Concepts

• **Networks** → **Network design principles**.

Keywords

Green networking, Fault-tolerance, Multi-homing

ACM Reference Format:
Paul-Edouard Bertrand Van Ouytsel, Matthieu Baerts, and Olivier Bonaventure. 2025. Towards switched-homing for Internet access. In *Applied Networking Research Workshop (ANRW 25), July 22, 2025, Madrid, Spain.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3744200.3744771

1 Introduction

Nowadays, almost all end-user networks are single-homed. These networks are attached to one border router which is connected to one Internet Service Provider (ISP). This single-homing approach works, but it does not provide redundancy. If the router or the access link fails, the network remains isolated until the failure has been solved. A possible solution can be found in multihoming, which consists in having two or more different access links to different ISPs. However, this solution is seldom used by home networks, as it requires registering an AS number and using BGP. Researchers and the IETF have discussed various solutions including `shim6` [16], LISP [6, 18], HIP [15] in the network layer. At some point, there was hope that IPv6 could make multihoming easier given that each IPv6 host must be able to use several IPv6 addresses [4]. However, IPv6 multihoming remains very difficult today [8, 9, 14].

Despite these difficulties, we believe it is time to reconsider how networks are connected to the global Internet. Nowadays, most end-users rely on Wi-Fi instead of Ethernet. A key benefit of Wi-Fi is that many devices can act as access points. Most users are equipped with a smartphone which can also act as a secondary Internet access point. We call this approach **switched-homing** and define it as a paradigm where a network with Internet access has one or more secondary Internet gateways, with only one active at a time. Depending on the situation, a switch to one of the secondary gateways can be performed. The switching procedure consists in stopping the activity of the current gateway and moving all connected devices to the new one. To the best of our knowledge, this concept hasn't been explored in literature yet. We first discuss the benefits of such an approach in Section 2 and then explore in Sections 3 and 4 how Internet protocols need to be adapted to preserve connectivity while switching between ISPs.

2 Motivation

In most homes, the router and the associated Wi-Fi network remain active all day, even if the load is very low during certain periods. Our measurements over twenty devices and related work [1] indicate that an access router consumes between 7 and 15 Watts. This energy consumption is stable and does not depend on network load. Multiplied by the number of such access routers, this becomes a significant energy

ANRW 25, July 22, 2025, Madrid, Spain

ACM ISBN 979-8-4007-2009-3/25/07
https://doi.org/10.1145/3744200.3744771

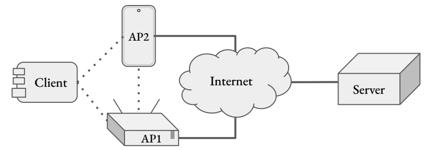
consumption. For example, in France, a study revealed that home access routers across the country consumed a total of 3.3 TWh in 2022. In comparison, during the same year, the networks of French ISPs consumed 4.1 TWh and French data centers consumed 2.1 TWh of electricity [1]. Switching off home access routers during the night has the potential to reduce their energy consumption by roughly one-third, which would correspond to about 1 TWh for France. However, switching off the access router implies that the various Internet of Things devices deployed at home lose their connectivity. This is problematic, as these devices are becoming more common [5]. Switched-homing can address both connectivity and energy savings.

The ability of recent smartphones to access 4/5G networks and act as Wi-Fi hotspots makes them ideal candidates for switched-homing. When using the smartphone as an access point, we expect an increase in the power consumption of the device. We have performed measurements on a Fairphone 5. In a first scenario, the smartphone is idle and connected to a Wi-Fi access point, resulting in an average power consumption of **38 mW**. In another scenario, the Android's Wi-Fi hotspot feature is enabled, as well as the cellular connectivity to the 5G network. Additionally, a device connected to the Wi-Fi hotspot sends pings to a public server. In this situation, the device consumes on average **1506 mW**. When acting as an access point, the smartphone consumes significantly more than when idle. Yet, this consumption is still 5 to 10 times lower than the power used by routers during idle periods [1], meaning switched-homing has the potential to save energy.

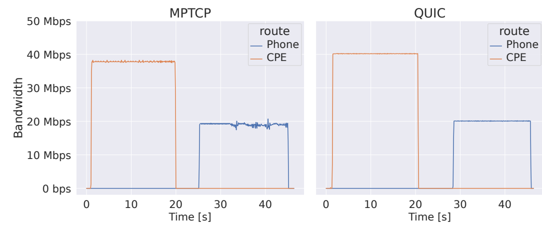
3 Experiments with switched-homing

An important aspect to consider for switched-homing is the ability to maintain connections despite changes of public IP addresses. With TCP, both client and server are expected to keep the same address during a connection. This, however, is not the case for more recent protocols such as MPTCP [7] or QUIC [13]. Indeed, MPTCP allows for multiple paths to be used while QUIC supports connection migration. In this section, we explore how these two protocols react in the context of switched-homing. For this, a virtual environment, using Linux namespaces, enables us to perform our tests in a fully controlled and reproducible environment [2]. To make the simulation more realistic, we use Linux traffic control to limit the bandwidth of the customer premises equipment (CPE) to 40 Mbps and the smartphone to 20 Mbps.

The testbed, shown in Figure 1a, consists of 5 different hosts. The CPE is represented as AP1 and the smartphone as AP2. When the smartphone detects the home access gateway is down, it creates a hotspot using the same name and credentials. The client is then able to switch to the new access



(a) Testbed used for the experiments



(b) Migrations using MPTCP & QUIC

Figure 1: Experiments

point when available. This mechanism has been verified with real hardware, and reproduced in the virtual environment. More specific real life aspects such as range are left for future works.

For the QUIC tests, the client performs an HTTP3 GET request to the server using `aioquic`. We slightly modified this library to trigger a connection migration whenever an access point change is detected [17]. The server relies on Cloudflare's `quiche` to handle HTTP3 requests. Meanwhile, the MPTCP tests use `iPerf3` and `mptcpize` to generate traffic.

Figure 1b shows the results of our experiments in the virtual setup. A connection is initiated by the client using the CPE as an access point. After 20 seconds, the switching procedure triggers. We simulate the process of searching for the new access point and connecting to it by adding a 5-second gap where the client is not connected to any access point. As can be seen in the plots, both MPTCP and QUIC are able to handle the access point switching. This experiment was repeated several times and always yielded similar results.

4 Conclusion

We have shown that the switched-homing paradigm has potential in terms of energy savings and network resilience. However, there are still ways in which this solution could be improved. Indeed, the transition from one access point to the other is not entirely seamless. When switching, hosts lose connectivity, search for the new access point, authenticate and acquire a new IP address. Some solutions already exist to make the process smoother, such as the 802.11r [10], 802.11v [12] and 802.11k [11] amendments to the 802.11 standard, which can be used to make the Wi-Fi transition smoother. Additionally, while QUIC migration and MPTCP can withstand the switching process, their deployment in the wild is still rare [3] [19].

Acknowledgements

This publication is supported by the Walloon Region as part of the FRFS WEL-T strategic axis.

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