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fP2P–HN: A P2P-based route optimization architecture for mobile IP-based community networks

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ABSTRACT

Wireless technologies are rapidly evolving and the users are demanding the possibility of changing their point of attachment to the Internet (i.e. Access Routers) without breaking the IP communications. This can be achieved by using Mobile IP or NEMO. However, mobile clients must forward their data packets through its Home Agent (HA) to communicate with its peers. This sub-optimal route (lack of route optimization) considerably reduces the communications performance, increases the delay and the infrastructure load. In this paper, we present fP2P–HN, a Peer-to-Peer-based architecture that allows deploying several HAs throughout the Internet. With this architecture, a Mobile Node (MN) or a *Mobile Community Network* (i.e. a NEMO) can select a closer HA to its topological position in order to reduce the delay of the paths towards its peers. fP2P–HN uses a Peer-to-Peer network to signal the location of the different HAs. Additionally, it uses flexible HAs that significantly reduce the amount of packets processed by the HA itself. The main advantages of the fP2P–HN over the existing ones are that it is scalable, it reduces the communications delay and the load at the HAs. Since one of the main concerns in mobility is security, our solution provides authentication between the HAs and the MNs. We evaluate the performance of the fP2P–HN by simulation. Our results show that the fP2P–HN is scalable since the amount of signalling messages per HA does not increase, even if the number of deployed HAs increases. We also show that the average reduction of the communication's delay compared to Mobile IP/NEMO is 23% (with a minimum deployment) and the reduction of the load at the HA is at least 54%.

1. Introduction

Wireless technologies have rapidly evolved in recent years. IEEE 802.11 is one of the most used wireless technologies and it provides up to 54 Mbps of bandwidth in an easy and affordable way. In the current Internet status, a user can be connected through a wireless link but he cannot move (i.e. change his access router) without breaking the IP communications. That's why IETF designed Mobile IP [29], which provides mobility to the Internet. With "mobility", a user can move and change his point of attachment to the Internet without losing his network connections.

In Mobile IP, a Mobile Node (MN) has two IP addresses. The first one identifies the MN's identity (Home Address, HoA) while the second one identifies the MN's current location (Care-of Address, CoA). The MN will always be reachable through its HoA while it will change its CoA according to its movements. A special entity called Home Agent (HA), placed at the MN's home network will maintain bindings between the MN's HoA and CoA addresses.

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The main limitation of Mobile IP is that communications between the MN and its peers are routed through the HA. Unfortunately, packets routed through the HA follow a sub-optimal path. This reduces considerably the communications' performance, increases the delay and the infrastructure load. In addition, since a single HA may be serving several MNs and forwarding several connections, the HA itself may become the bottleneck of the whole system and represents a single point of failure in Mobile IP-based networks [1].

Mobile IPv6 [30] solves this limitation by allowing MNs to communicate with their peers directly (route optimization) by exploiting special IPv6 extension headers. However, the NEMO protocol (NEMOv4 [2] and NEMOv6 [32]), which provides mobility to networks instead of nodes, does not support route optimization, even in IPv6. That is why we believe that route optimization is an issue in the current Internet status (IPv4) and even in the future (IPv6). Note that a NEMO (NEtwork that MOves) can be seen as a *Mobile Community Network*. From the Internet infrastructure's point of view, a *Community Network* is a set of nodes located in the same geographical area. The nodes belonging to the *Community Network* are equipped with at least one wireless interface and can share information directly using an ad-hoc protocol. Regarding the connection with the Internet, the nodes belonging to the *Community Network* share a common point of attachment. This common point can be seen as the NEMO's mobile router. This router is equipped with two interfaces: an "external" long-range wireless interface intended to attach to the Internet and an "internal" interface intended to provide connectivity to the nodes belonging to the *Community Network*.

Solving the route optimization problem has attracted the attention of the research community and several solutions have been proposed [3–6]. The main idea behind these proposals is deploying multiple HAs in different Autonomous Systems (ASes). Then, a MN may pick the best HA according to its topological position thus, reducing the delay of the paths towards its peers. The main challenge of this approach is signalling the location of the different HAs throughout the Internet. Some of authors use the exterior Border Gateway Protocol (eBGP) protocol [3,5,6] while others [4] use Anycast routing. The main issue of these proposals is the scalability. On the one hand, using the exterior BGP protocol means increasing the load in the already oversized global routing table [7]. On the other hand, anycast's defiance of hierarchical aggregation makes the service hard to scale [8]. In addition, these solutions force the MNs to send the data packets through the HAs, increasing the load on these devices that may become the bottleneck of the whole system [1].

In this paper, we propose a scalable architecture, named fP2P–HN (flexible P2P Home agent Network) that solves the route optimization issue for Mobile IP and *Mobile Community Networks* (NEMO). We propose using an overlay Peer-to-Peer (P2P) network to signal the location of the different HAs [17]. When a MN detects that its current HA is too distant it queries its *Original HA* (the one serving the MN's Home Network) that belongs to the fP2P–HN network for a closer HA. Then, the fP2P–HN network uses BGP information to locate a HA that reduces the delay of the paths between the MN and its peers, for instance by choosing a HA located in the same AS as the MN. Since security is one of the main concerns in mobility, we also present an architecture that provides trustworthiness to the HAs belonging to the P2P network and that allows that the MNs can be authenticated by the HAs (and vice versa).

Our solution allows deploying multiple HAs at different ASes without impacting the exterior BGP global routing table or requiring anycast routing; however, the HAs are still responsible of forwarding all the MN's data packets. In order to alleviate their load, we propose to deploy flexible HAs (fHA) [18]. The main idea behind the fHAs is that a registration from a MN to a HA can be viewed as an internal route from the network's point of view. That is, when a MN registers a new location into its HA, it is actually installing a new route (Home Address → Care-of Address). We believe that this route can be announced throughout the network using the interior BGP (IBGP [31]) protocol to each of the AS' Border Routers. Then, the Border Routers are aware of the current location of the MN and will decapsulate and forward any packets addressed to/from the MN directly, just as regular packets. Thus, MN's data packets are not forwarded by the HAs but by the Border Routers. It is worth to note that HAs are not necessarily devices designed for routing purpose whereas routers are routing-dedicated devices.

Our solution fP2P–HN is simple, scalable and secure. Moreover it does not require deploying any new entities on the Internet. At the Inter-domain level, we signal the location of the HA using a P2P network instead of using eBGP or anycast. At the Intra-domain level we signal the location of the MN using IBGP, in this way the Border Routers are aware of the location of the MN and the load of the HA is significantly reduced. As we will see later, we evaluate the performance of our proposal through simulation. Our results show that the fP2P–HN is scalable since the amount of signalling messages per HA does not increase, even if the number of deployed HA increases. This amount of signalling, in the worst case, is around 20 kbps per HA. We also show that the average reduction of the communication's delay compared to Mobile IP/NEMO grows from 23% (with a minimum deployment) up to 80% (with large deployments). Whereas the reduction of the load at the HA varies between 54% (in the worst case) and nearly 100% (in the best case).

In our previous work, we presented a P2P Home Agent network that signals the location of different HAs throughout the Internet [17]. In [18], we presented the flexible HAs, that reduce significantly the traffic load. The main contributions of this paper are three: the first contribution is the novel architecture fP2P–HN (Section 2) which is based on both solutions. The second contribution is the evaluation of the solution (Section 3). Finally, the third contribution, is a security architecture (Section 2.7) that provides authentication to the nodes belonging to the network.

2. Flexible P2P home agent network

In this section, we detail the fP2P–HN architecture. Please note that an fHA (flexible HA) is a Home Agent that