Supporting Mobility in a Publish Subscribe Internetwork Architecture

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***Abstract*—Information-Centric Networking (ICN) is constantly gaining momentum within the Future Internet research community. In the PURSUIT research project we are developing a clean-slate Pub/Sub Internetworking (PSI or Ψ) approach with integrated seamless mobility support. The novel ICN mechanisms supported in Ψ, along with smartly placed in-network caches, enable the architecture to handle both mobile and fixed devices in a uniform way. This paper presents a blueprint for optimizing mobility support in Ψ without modifications to the architecture or add-on solutions. We demonstrate a micro-mobility scenario that describes the functionality of Ψ's core components in supporting mobility and then sketch our plans for future work and a proper assessment of these designs.**

***Index Terms*—Future Internet, Information-Centric Networks, Mobility**

I. Introduction

The current Internet architecture is based on End-to-End point (E2E) communication, covering the needs of the time when it was designed. The former is widely considered as the root cause of many of its limitations and inefficiencies. Add-on solutions such as NATs, CDNs or Mobile IP were introduced in order to mitigate problems, even though they tend to violate aspects of the Internet architecture. Publish/Subscribe (Pub/Sub) continuously gains popularity within the research community as a clean slate *Future Internet* (FI) architecture due to its inherent information-centrism that manages to decouple information from its location. Research projects such as PURSUIT [1], PSIRP [2], and CCNx [3] investigate Pub/Sub as a FI architectural alternative. Unlike the current Internet, Pub/Sub fulfills the core need of users who are interested in the information itself rather than where the information resides.

The multicast nature, the provision of anonymity and the inherent asynchrony of Pub/Sub make it ideal for mobile environments [4]. First, anonymity and asynchrony enable the quick adaptation to the continuous attachment and detachment of *Mobile Nodes* or *Agents* (MNs or MAs) to *Access-Points* (APs) that reside at the edge of a mobile network. Note that APs are not necessarily wireless; they may refer to any kind of physical or software mobile layer, including wireless environments such as IEEE 802.11 or UMTS, or to a software MA that migrates to another physical host. Second, the multicast nature of Pub/Sub can handle large populations of MNs and their tendency to change locations continuously. Last, given the limited capabilities of MNs such as short battery life or bandwidth, multicast helps systems to better utilize their resources, e.g., by performing fewer (re)transmissions, which implies energy savings.

We present an on-going effort for enhancing the inherent mobility support of the Pub/Sub Intenetworking architecture (PSI or simply Ψ) [5]. Our work is within the context of PURSUIT, an EU-FP7 funded research project for a clean-slate, information-oriented FI architecture. There are several notable studies on mobility within the context of information-centric architectures which, due to lack of space, are discussed in the extended version of this paper [6]. We refer to i3 [7], DONA [8], ROFL [9] and CCNx [3]. We note that authors in [10] describe an idea that is closer to ours, using candidate brokers for caching subscription context. In the remainder of this paper, we present an overview of Ψ, our proposed enhancements for seamless mobility support in Ψ and conclude with our future plans.

II. Overview of Ψ and Mobility Support in Ψ

Ψ involves publishers, subscribers and an event notification service. Publishers advertise the availability of specific information items by issuing publication messages. Subscribers express their interest for consuming specific information items by issuing *subscription messages*. The event notification service locates the publishers who provide desired information items by matching the consumers' subscriptions; then it sets up the forwarding of information content from publishers to respective subscribers. Publications and subscriptions *do not* have to be issued in sync. Moreover, publishers and subscribers do not know the identities of each other (anonymity), nor do they need to be concurrently connected to the mobile network (asynchrony).

A *Rendezvous Network* (RENE) is an instantiation of the event notification service. It consists of several *rendezvous nodes* (RNs), each of which is responsible for a set of publications. The *Rendezvous Point* (RVP) of a specific publication is the RN that is responsible for the latter. As in [11], Ψ uses (statistically) unique *labels* for each discrete information item, composed by a pair of flat, semantically free identifiers: the *Rendezvous Id* (RId) and the *Scope Id* (SId). The RId derives from an application specific function applied to the advertised information item, while the SId corresponds to a scope. *Scoping mechanisms* in Ψ are used to control access to information and to enforce policies and strategies on information published within a certain scope. Scopes employ a hierarchical structure where sibling and parent-to-children relationships exist.

A subscriber expresses her interest for a specific publication by issuing a subscription message which the RENE delivers to a RVP. Upon receiving and matching a subscription, the RVP initiates the process of constructing a forwarding path from a publisher to the subscriber(s). A *Forwarding Identifier* (FId) is a Bloom filter based structure that includes all the links in the forwarding path that data need to traverse in order to be delivered to the subscriber(s) [12]. As a result, publishers can start sending data without knowing who the subscribers are or where they reside.

The Ψ architecture is ready to support MNs since its functionalities are location-independent and location-agnostic. We introduce the concept of *Smart Caches* (SC) to assist and enhance mobility management. Given a publication, SCs are smartly placed *in-network caches* designated by the RVP with respect to (1) the topology and (2) the current and expected future attachment positions of subscribers. A SC acts as an intermediate node that, apart from caching, mediates between the data exchanging parties. Therefore it is treated as both a publisher and a subscriber by the RENE.

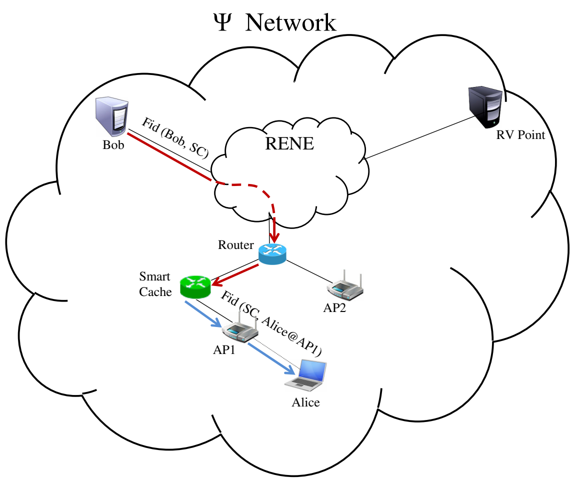

Fig. 1. Bob sends data to the SC; the SC resubmits data to Alice.

A. A Simple Scenario

We describe a micro-mobility scenario which involves the usage of SCs to explain the behavior of the basic network components of the architecture. Bob is a *fixed* node that issues a publication <*Bob_Sid, Bob_Rid, [metadata]*>. Alice is a MN[1] currently attached to AP1, who issues a subscription for <*Bob_Sid, Bob_Rid*>. Both the publication and the subscription find their way to the RVP through the RENE. The RVP designates a SC based on the topological knowledge of the topology management function [13]. The goal is to facilitate the delivery of data to Alice and any other prospective mobile subscribers in her network proximity. Upon matching a subscription, the RVP issues two forwarding paths: (1) *Fid(Bob, SC)* for the path from Bob to the SC; (2) *Fid(SC, Alice@AP1)* for the path from the SC to AP1, where Alice is currently attached to.

[1]Our solution treats MNs and software MAs in the same way, thus referring to MNs is equivalent to referring to MAs and vice versa.

As shown in Figure 1, Bob starts sending data to the SC, which in turn resubmits the data to Alice using *FId(SC, Alice@AP1)*. The SC gets data as a subscriber and caches them for at least the time required for Alice to move to a nearby AP such as AP2. In this micro-mobility scenario, the RVP can guess the APs that Alice might attach herself to next, estimate the required caching period and smartly place the SC to accommodate not only Alice, but also some future possible attachment points for Alice or other MNs.

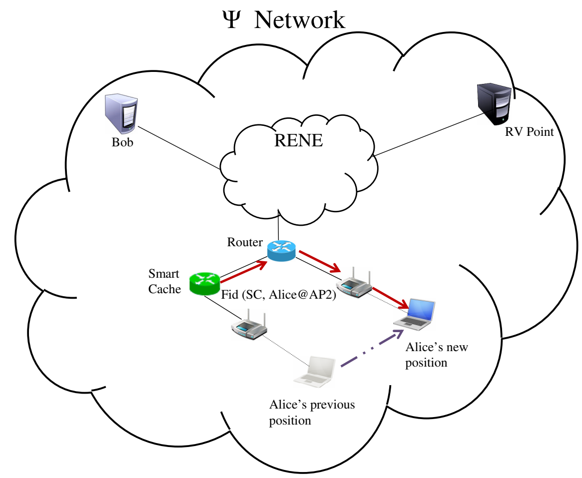

Fig. 2. Alice moves while data are in transit. Data are sent to both AP1 and AP2 via a multicast tree

At some point Alice decides to move to AP2 while data are still in transit to AP1 (Figure 2). Upon performing the handoff to AP2, Alice re-subscribes to <*Bob_Sid, Bob_RId*>. Note that the RVP has currently recorded two different publishers whose publications match this subscription; the one is Bob and the other one is the SC. The RVP makes an anycast choice between the two and thus reaches the *best suited publisher* with respect to the current location of Alice. SC will most likely be the chosen data source, as it was originally designated in order to accommodate future possible attachment points for Alice. Note that (1) data are still sent to AP1 via a multicast tree until all past or future subscriptions submitted from AP1 expire and that (2) data that were sent to AP1 during the handoff phase to AP2 are not lost; they are cached at the SC and later forwarded to AP2. Alice is now attached to AP2 and the RVP can either select a new SC for Alice or instruct Bob to directly send the data to Alice in AP2. The fact that no data in transit are lost while Alice moves is particularly important for streaming and real-time applications where SCs can be used to redirect such data to the current position of Alice.

The SCs are neither a new type of component nor an add-on to the Ψ architecture which has integrated support for mobility [4]. SCs are more likely to be existing ordinary caches for frequently requested content; we simply "promote" a simple cache to operate as another publisher. If there are no caches in the network, the RVP can delegate other nodes as SCs, e.g., routers with caching capabilities. As a side effect of their operation, SCs also enhance anonymity by mediating between publishers and subscribers.

B. Smart Cache Selection Mechanisms

We consider two different selection mechanisms for delegating the role of the SC: *RVP forecasting (RVPf)* and *AP based (APb)*. In both cases, the RVP treats the SC as another publisher and subscriber for information. The two mechanisms differ with respect to who initiates this procedure and when this action is performed. RVPf assumes that the RVP has an up-to-date knowledge of the current topological organization of the network via a topology-manager function [13]. Consequently, RVPs can forecast the candidate future position of MNs in micro-mobility handoffs, therefore it is possible to designate SCs before the subscribed MNs move.

In contrast, the underlying idea in APb is that APs in wireless environments can detect a reduction of the signal strength when an MN moves away from them. Hence, the current AP as well as a prospective AP may infer the tendency of the MN to move. The current AP sends a control message to the RVP, requesting the reconsideration of the current SCs and perhaps the designation of new SCs. Once the RVP receives this control message, the procedure followed is identical to that in the previous sections (add a new SC as a publisher to the RVP, create the suitable FIds to send data via new SCs, etc.).

The APb selection mechanism adds some extra control messaging for every hand-over, which represents a small overhead, compensated by taking load off the RVP. This is quite important, since the RVP performs the matching of subscriptions to publications; overloading it could cause delays to rendezvous and consequently to data delivery. Moreover, APb allows the RVP to take action *only when the MN actually moves* to another AP, without the need to execute the topology function for every MN in order to see its possible next positions and delegate the corresponding SCs. Unfortunately, APb is not suitable for non-wireless mobile networks, while AVPf is.

III. Conclusions and Future Work

This paper presented an enhancement concept for mobility in Ψ, based on the smart placement of caching elements. Such SCs guarantee a seamless delivery of data to mobile subscribers. Our work is part of on-going research towards a uniform Pub/Sub Internetworking architecture for both mobile and fixed environments. We plan to investigate the correctness and effectiveness of our proposed solution, and to study any further possible uses of SCs, e.g., as transport protocol mediators enhancing the anonymity of principals and facilitating transport mechanisms. We will also proceed to evaluate the performance of our ideas via simulations of a Ψ architecture incorporating SCs. This will help us verify the suitability of our suggestion and further study scenarios that involve mobile publishers.

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