GRS: Global Resolution Service for Mobility Support in the Internet

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***Abstract*—As it becomes a common need to support mobility in the Internet, there is a growing trend towards providing a general mobility management function in the protocol stack by resolving identifiers of mobile nodes to their locations. However, current mechanisms have drawbacks in both performance and functionality, especially when they are partially deployed. In this paper, we propose a Global Resolution Service (GRS) offered by Resolution Service Providers (RSP), which resolves identifiers in a flexible way according to diverse mobility scenarios. Simulation results show the advantages of our approach compared to existing solutions in terms of both flexibility and deployability.**

***Index Terms*—Mobility, identifier, resolution, handoff**

I. Introduction

A. Background

Mobility support in the current Internet is mainly provided by applications to send data to a mobile receiver with changing IP addresses. As the need for mobility support becomes more and more common, there is a growing trend towards providing a general mobility management function in the protocol stack. This trend arises from earlier IETF standards to recent publications and is also adopted by future Internet architectures. The proposals use diverse namespaces instead of IP addresses as identifiers of communication end-points. Usually identifiers keep unchanged while mobile nodes change their locations in the network topology [1]. Thus it can benefit applications by maintaining session survivability in an efficient way.

B. Existing Work

Such approaches call for a common mapping and resolution function in the protocol stack. A large number of proposals employ new infrastructure consists of distributed anchor points (e.g. Home Agents) to realize such a function [2]-[5]. The anchor points provide a two-step approach to reach a mobile node using its identifier. But it may take considerable time for the anchor points to get fully deployed, while partial deployment may lead to routing inefficiency and unreliability because of large path stretch [3][4]. In addition, considering the suggestions that mobility support should be decoupled from Internet access control [1], the anchors need to be deployed in an extremely large scale, which turns out to be quite difficult.

Other approaches propose to rely on DNS [6] which maps and resolves identifiers of mobile nodes directly to their addresses in a one-step manner. However, DNS is not designed for mobility scenarios, which shows up as its performance and scalability decrease when using low TTL value [7] for dynamic mappings and ineffectiveness in handling dual mobility (which means both communicating ends move simultaneously). Besides, DNS alone is not able to keep location privacy as it exposes mobile nodes' exact IP addresses.

Further, current proposals lack the flexibility to provide differentiated functions in different scenarios. As a common resolution function facing various mobility scenarios in the future Internet, it should consider diverse capacities of mobile devices, various requirements of mobile applications and different behaviors of mobile users to offer appropriate services. Moreover, since heterogeneous mobility protocols may co-exist in future Internet [1], it should also be taken into account to provide a universal mapping and resolution function to different mobility protocols.

C. Proposed Solution

To address the above problems, we proposed an idea called Global Resolution Service (GRS) [8] which provides mapping and resolution services to mobile users in global scope. In this paper, we further investigate detailed design and evaluation of the proposal. The key idea of GRS is to make associations between a mobile node's identifier and multiple IP addresses belong to both the mobile node and nearby RAs. Thus, GRS enables both possibilities to resolve a mobile node's identifier to its IP addresses directly and via RA indirection. To each requestor, GRS assigns different priorities to the candidate addresses associated with the requested identifier using a ranking algorithm which takes into account metrics including performance, cost, user preferences, etc., to ensure that the identifier is always resolved to the most appropriate address(es). In this way, GRS can offer a flexible resolution service in different mobility scenarios, which integrates the advantages of existing protocols.

In the rest of this paper, we first describe the protocol design and discuss on the deployment issues of GRS in Section II. Then we investigate the address ranking algorithm which serves as a key function of GRS in Section III. We make several simulations to show GRS's performance benefits in Section IV. Finally we conclude the paper and propose future work in Section V.

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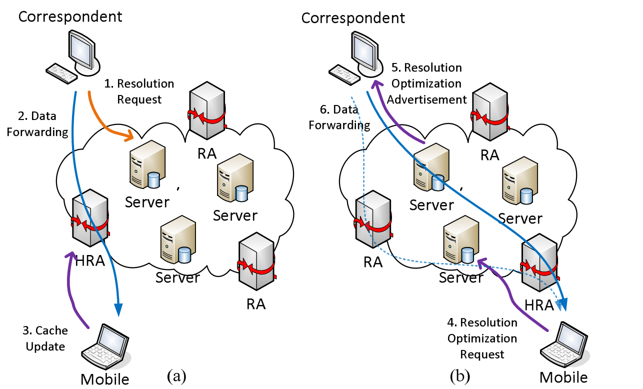

Figure 1. (a) location and handoff management; (b) resolution optimization

II. Protocol Design

A. Overview

GRS provides three main functions: location management, handoff management and resolution optimization. First, GRS provides identifier lookup service to achieve location management. Also, GRS deploys RAs which serve as anchor points and facilitate handoff management In addition, GRS offers *Resolution Optimization service* which tries to optimize the basic mobility management functions. To each mobile node that subscribes to the service, GRS associates several RAs to the node and regards addresses belong to both the mobile node and associated RAs as candidate addresses. When resolution optimization is triggered, GRS ranks all candidate addresses to get a list of prioritized addresses and sends the result to the nodes that require the service. Due to the page limit, we only present a simplified protocol design in this section; please refer to the technical report [11] for more details.

B. Location and Handoff Management

Location and handoff management of GRS is shown in Figure 1(a). GRS employs a logically centralized server to store the mappings of all mobile nodes. Specifically, GRS maintains an *Association Table* for each mobile node which maps the identifier of the node to all its candidate addresses, as well as their priority, lifetime, etc. GRS also assigns each mobile node a *Home RA (HRA)* which keeps up-to-date *Mapping Cache* between the mobile node's identifier and its current address(es). Considering that the mobile node may roam in a large scope, its HRA is allowed to change.

Any node that wants to get the address(es) of a mobile node can send a *Resolution Request (RR)* message which contains the identifier of the mobile node to GRS. When receiving a RR message, GRS looks up the identifier within the message in the Association Tables and returns the address of the HRA to the requestor. After obtaining the response from GRS, the requestor is able to reach the mobile node by sending packets to the HRA which then redirects the packets towards the mobile node's current location.

When a mobile node changes its address(es) due to a roaming event, to maintain the session survivability, it should send a *Cache Update (CU)* message containing its identifier and the new address(es) to its HRA. After receiving and verifying the message, HRA updates the local mapping cache of the mobile node and then the data traffic relayed will be redirected to the correct location.

Though at the beginning of each session, the only way to reach the mobile node from its correspondents is to traverse the HRA, other ways (end-to-end or via alternative RAs) can be obtained from GRS later on during the communication, which means that other nodes (RAs or correspondents) may also have cached the identifier-to-address mapping of the mobile node. Thus besides the update in HRA, additional updates may be required according to how correspondent nodes communicate with the mobile node.

C. Resolution Optimization

The procedure of resolution optimization is shown in Figure 1(b), which is triggered by the mobile node by sending a request message to GRS. GRS first stores the association between the identifier of the mobile node and its current address(es) in the table. Then according to the mobile node's location, GRS also associates the identifier to the addresses of several nearby RAs. After applying to the ranking algorithm, GRS gets a list of addresses with different priorities and chooses the optimal address as the result of resolution optimization. Then GRS sends the result to the mobile node and the correspondent node. Besides, the specific RA, if any, whose address is in the result should also be informed and is then responsible for keeping the mapping cache and redirecting packets to the mobile node.

Resolution optimization may also trigger the changing of a mobile node's HRA in order to keep HRA as close to the mobile node as possible. If the HRA gets a low priority after the ranking, GRS will replace it with another RA that has a higher priority. Then the new HRA will serve as the mobile node's anchor point for incoming connections, but the previous HRA is still responsible for redirecting traffic that belong to existing connections and keeping mapping cache for the mobile node until it is expired.

D. Discussion on Deployment

When considering the deployer of GRS, we adopt the suggestion in that mobility should be treated as services separated from network access control provided by ISPs [1], and propose a third party called *Resolution Service Provider (RSP)* to offer such a service. Multiple RSPs may coexist in future Internet and provide universal but distinct resolution services, just as multiple ISPs providing IP "resolution" in today's Internet. Take Google as an example, imagine that Android apps are able to set up connections using Google Accounts based on the next Android version, and then Google becomes a RSP and is responsible for resolving Google Accounts to IP addresses. Along with the popularization of other mobility protocols, Google can add new functions to deployed RAs to support these protocols.

III. Address Ranking Algorithm

The key idea of the address ranking algorithm employed by GRS is to use a *cost function* to calculate the cost of each address associated with the mobile node, and address with a lower cost will be assigned a higher priority.

A. Cost Function

We introduce $V_{d,a}$ and $V_{l,a}$ to represent predicted E2E delay and handoff latency respectively when resolving to address a. For addresses of RA, $V_{d,a}$ can be approximated by adding up RA-Mobile distance D_{RM} and RA-Correspondent distance D_{RC}. While $V_{l,a}$ can be obtained using D_{RM} since handoff takes at least one-way time from the mobile to RA to transmit location update. For addresses of the mobile node, both $V_{d,a}$ and $V_{l,a}$ can be obtained by Mobile-Correspondent distance D_{CM} since both data packets and location updates travels directly between both end nodes. Using the distances and approximation method above, we get the formula to calculate the cost of address a.

$$C_a = \alpha V_{d,a} + \beta V_{l,a} = \begin{cases} \alpha \dfrac{(D_{RC} + D_{RM})}{\max(V_{d,a})} + \beta \dfrac{D_{RM}}{\max(V_{l,a})} & (1) \\ \alpha \dfrac{D_{CM}}{\max(V_{d,a})} + \beta \dfrac{D_{CM}}{\max(V_{l,a})} & (2) \end{cases}$$

where Formula (1) and (2) apply to the cost calculation of RA's addresses and mobile node's addresses respectively. The maximum values in the formula are used for normalizing $V_{d,a}$ and $V_{l,a}$, while α and β are weights of the two metrics. In practice, α and β can be assigned flexibly to satisfy different requirements from hosts or applications.

B. Distance Measurement

GRS needs to measure D_{RM},D_{RC} and D_{CM}. D_{RM} and D_{RC} can be measured proactively by interactions between RA and end nodes that subscribed to the service. For example, GRS may collect and store *Ping* results periodically to approximate the distance while end nodes only need to passively answer the probing packets. To measure D_{CM}, we propose two solutions:

1) Direct Measurement

This solution requires active participation of end nodes by sending and replying each other probing packets to get the exact value of D_{CM} and report it to GRS. However, performing end-to-end measurement may bring heavy overheads to end nodes, especially when the devices are energy-constrained.

2) Distance Prediction

We employ an algorithm called Triangulated Heuristic to approach D_{CM}. Suppose we have a series of RA-Mobile and RA-Correspondent distances as $D_{R_1M}, D_{R_2M}, \dots, D_{R_NM}$ and $D_{R_1C}, D_{R_2C}, \dots, D_{R_NC}$. Then as suggested in existing research on network coordinates [9], D_{CM} can be predicted by

$$D_{CM} = \max(|D_{R_iM} - D_{R_iC}|) \quad i\epsilon\{1,2,\dots,N\} \qquad (3)$$

Though the value inaccuracy may be unavoidable, as we can see in the simulation section, when comparing with direct measurement, the prediction algorithm is able to preserve the priority of addresses quite well.

IV. SIMULATION

A. Methodology

We use MHA [4] and ILNP [6] as references when simulating the performance of GRS. We implemented several common mobility management functions based on NS-3 simulator (version 3.13), and due to the page limit, we put the details in the technical report [11].

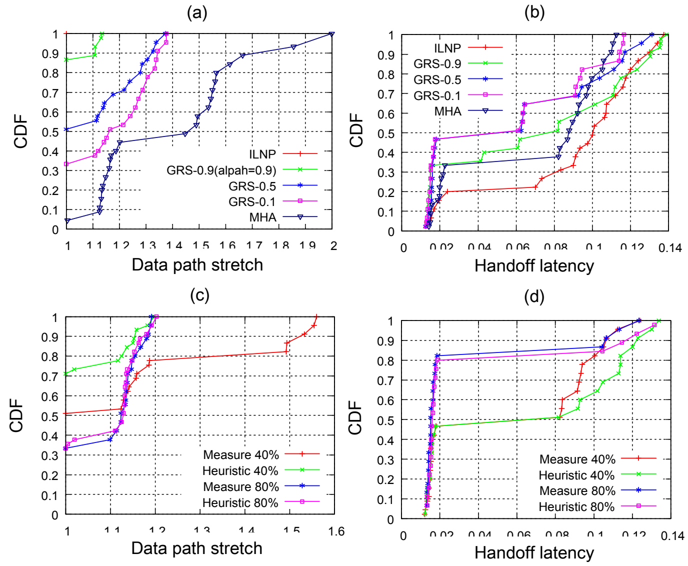

Figure 2. Cumulative Distributed Function (CDF) of data path stretch and handoff latency of (a, b): MHA, ILNP and GRS with different α and β values; (c, d): direct measurement and distance prediction

The simulation topology is built according to the distance data measured in real Internet environment from RIDGE Project [10]. This data set contains all-pair pings results of more than 200 nodes. We choose a subset of them and construct 10 domains by gathering geographically nearby nodes (latency less than 30ms) and select one node in each domain as the candidate location for RA deployment while others are candidate locations to deploy mobile nodes and their correspondents. GRS server is an additional node that stays relatively close (50ms latency) to all other nodes.

Handoff is simulated by changing locations of the mobile nodes. When new addresses are obtained (50ms after losing previous address), the mobile nodes update the mapping cache that are stored on GRS server, anchor points or correspondents. Each correspondent node sends *Ping Request* continuously (one per 10ms) to the mobile node which will then reply to it. The correspondent node gets the statistics of RTT value and packet loss which contributes to the overall simulation result.

B. Cost Function

In each turn of the simulation, we deploy 10 correspondent-mobile pairs randomly among 10 domains. Each correspondent node sends 3000 *Ping Requests* to the mobile node while the mobile node performs 10 handoffs by switching to another location inside the domain. We do not simulate the resolution optimization procedure but assume that each pair of nodes has got the optimal resolution result (based on direct measurement) before communication. Anchor points are also randomly located in the domains with 40% deployment rate. We select different α and β values to evaluate the cost function.

Figure 3 shows the Cumulative Distribution Function (CDF) of data path stretch and handoff latency collected using MHA, ILNP and GRS with α set to 0.1, 0.5 and 0.9 (β equals to $1-\alpha$).

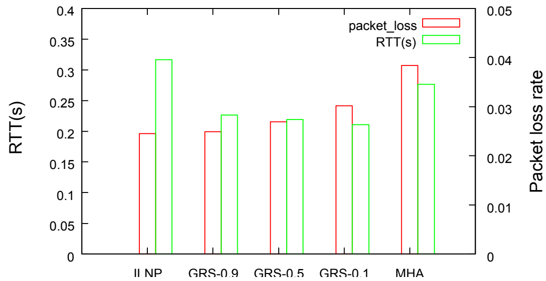

Figure 3. RTT and packet loss rate of MHA, ILNP and GRS with different α and β values

As we can see from the figures, GRS has lower data path stretch than MHA as well as a larger amount of low handoff latency values than all other protocols. We can also find that larger α results in shorter data path stretch but larger handoff latency. Figure 4 further illustrates the measured RTT and packet loss rate of all the protocols, which both demonstrates GRS's performance benefits and implies a tradeoff in assigning different weights to the two metrics in the cost function. This tradeoff also shows the flexibility of GRS in satisfying different requirements from mobile applications.

C. Distance Prediction Algorithm

We evaluate the distance prediction algorithm using the same scenario as the previous one except that we fix α value to 0.5 but varies anchor deployment rate. Figure 5 shows the CDF of collected data path stretch and handoff latency using direct measurement (*GRS-measurement*) and Triangulated Heuristic (*GRS-heuristic*) with 40% and 80% deployment respectively. Results show that prediction results are more accurate when deployment rate is higher. However when deployment rate is low, *GRS-heuristic* still outperforms other protocols as it preserves both low path stretch and handoff latency.

D. Deployment

Another feature of GRS we show in this section is its advantage in incremental deployment. We also use the same mobility scenario as previous two simulations with α set to 0.5 and anchor point deployment rate varies from 10% to 100%. Direct measurement is applied in this simulation.

Figure 6 shows both measured RTT and packet loss rate of MHA, ILNP and GRS with different deployment rate. As we can learn, both RTT and packet loss rate of GRS are approximate to the optimal one of MHA and ILNP due to its flexibility in choosing an optimal resolution method, which proves that GRS is able to keep its performance as good as possible in different deployment status.

V. Conclusion and Future Work

Resolution from identifiers to IP addresses plays an important role in mapping-based mobility protocols, and we consider it necessary to enhance the resolution service towards better flexibility and deployability by proposing a Global Resolution Service offered by third parties in the Internet. We show that GRS is able to provide differentiated resolutions in different scenarios and keep its performance as good as possible in each stage towards global deployment.

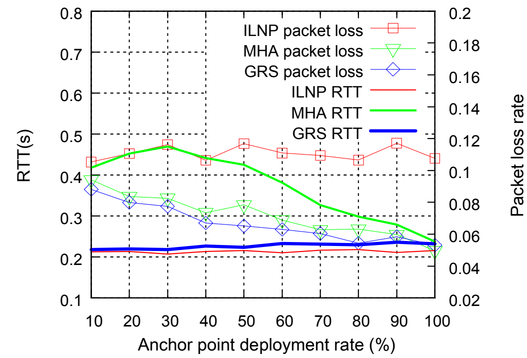

Figure 4. RTT and packet loss rate of MHA, ILNP and GRS with different anchor point deployment rate

In the future work, we will further research into GRS including investigating the deployment strategy of RA and consider the movement of nodes as a metric in the ranking algorithm, etc. Besides further studies, future work of GRS also includes improved simulations, prototype implementation as well as experiments in real Internet environment.

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