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Approaches to Distributed mobility management using Mobile IPv6 and its extensions

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Abstract

Mobility solutions at the IP layer have been specified in the IETF for IPv4 and IPv6. These solutions include host and network based mobility. All of the mobility protocols enable IP session continuity by providing the mobile host with an IP address or prefix that remains constant even as the host moves and attaches to different access networks and points of attachment. Mobile hosts are anchored at a gateway via a tunnel and the address/prefix provided to the host via the gateway remains unchanged across mobility events. All IP sessions initiated or terminated at a mobile host are anchored via the gateway. A gateway centric approach such as Mobile IP, raises certain concerns in terms of cost and efficiency. A mobility model wherein the network entities enabling mobility are distributed is a way of alleviating the concerns of a gateway centric approach. This document considers ways to alleviate anchored mobility issues with approaches that could be considered in a deployment.

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1. Introduction

Mobility solutions at the IP layer have been specified in the IETF for IPv4 and IPv6. These solutions include host and network based mobility. All of the mobility protocols enable IP session continuity by providing the mobile host with an IP address or prefix that remains constant even as the host moves and attaches to different access networks and points of attachment. Mobile hosts are anchored at a gateway via a tunnel and the address/prefix provided to the host via the gateway remains unchanged across mobility events. All IP sessions initiated or terminated at a mobile host are anchored via the gateway. There are issues and concerns with such a mobility model which are discussed in this document. A mobility model wherein the mobility functions that reside in the network are distributed, is a way of alleviating the concerns of a gateway centric approach. This document also considers ways to alleviate anchored mobility issues with approaches that could be considered in a deployment.

Mobile IPv6 as specified in [RFC6275] [RFC3776] is a host based mobility protocol. It requires the MN to be anchored at a home agent. The home agent assigns the MN an IPv6 address or prefix that is static for the duration of the registration period. Similarly Proxy Mobile IPv6 [RFC5213] is a network based mobility protocol in which the mobility access gateway (MAG) assigns the MN a prefix provided by the local mobility anchor (LMA) for the duration of a valid registration. This prefix does not change across mobility events. The home agent and LMA entities can be viewed as centralized gateways. These gateways generally serve a large number of mobile hosts. All traffic to/from mobile hosts associated with an HA/LMA is routed through these gateways and as a result raises concerns such as :

1. single point of failure,

2. backhauling traffic to the gateway,

3. latency as a result of backhauling and additional processing,

4. cost and complexity, etc.

These issues are discussed in further detail in the document. It should also be noted that in addition to mobility for hosts, there is also specifications that deal with networks that are mobile. Network mobility is specified in [RFC3963]

The mobility working groups in the IETF have extended the basic protocols to address various issues and concerns. Hierarchical Mobile IP [RFC5380] and flow mobility [RFC6088], [RFC6089] are just a

few examples. Many of these extensions can be utilized in deployments to alleviate the issues that arise from an anchored mobility solution. A few approaches to how a distributed mobility model could be deployed using current protocols and extensions are also discussed in this document.

2. Terminology

Distributed Mobility

The term distributed mobility refers to an architecture in which the mobility function (entitie(s) in the network that are responsible for IP mobility) is distributed across multiple levels of hierarchy in a deployment. The mobility function(s) could be provided by an access point or base-station, or it could be a part of the access network. Distributed mobility would enable session continuity for hosts while not requiring that they be anchored at a single gateway (such as a home agent or Local Mobility Agent) all the time.

3. Problem statement

The lack of support for mobility at the IP layer has been addressed in IPv6 with the specification of Mobile IPv6 [RFC6275]. Various extensions to the protocol such as support for multiple care-of-addresses as well as the ability to operate while attached to an IPv4 network using Dual-stack Mobile IPv6 [RFC5555] have been specified. The protocol has not been widely implemented or deployed as of date for various reasons.

The Internet has evolved to support real-time applications such as voice, multimedia streaming etc. These applications require low latency as well as no (or minimal) interruptions when switching interfaces or networks. Current IP mobility solutions based on Mobile IPv6 are well suited for non-real-time applications which are able to handle the delay which is caused by a mobile node doing a handover between networks or switching interfaces. Optimizations to support real time applications have also been specified such as FMIPv6 [RFC5568]. The centralized gateway approach of Mobile IPv6 has multiple issues and raises concerns that are captured in this document. One of the ideas is to move the mobility gateway closer to the actual point of attachment. This has benefits in terms of reduced latency but it also causes other issues such as the ability to support mobility when the MN moves to a different access network or the ability to do charging at a central node. Distributed mobility is an approach that has some merit and worth studying

further. At the same time the issues that are driving the mobility solutions towards a different model can be addressed by existing protocols with various extensions. The problems of a centralized gateway approach and reasons for considering distributed mobility need to be deeply analyzed and understood before beginning work on entirely new protocols for solving IP mobility.

4. Issues with current mobility models

Current mobility protocols have been designed with a stable topologically correct anchoring gateway in mind. They just do not tolerate mid-session anchor relocation. HMIP6, HA Switch, HA-reliability and LMA Redirect are attempts in that direction but fail or fall short.

In addition, one of the key deployment considerations of Mobile IPv6 is the location of each of the home agents or gateways, both initially and over time. Each operator has unique requirements; therefore, no single deployment model will suit all operators. The operator's own organizational structure could also influence the mobility architecture. Some operators have network OAM responsibilities that are assigned geographically, while others use a more centralized model. The deployment architecture that has been traditionally put forth is to have centralized gateway elements where all mobility control and data traffic is routed through them.

4.1. Backhauling all traffic to a centralized GW

A centralized home agent/gateway approach leads to backhauling all traffic to the node which has unfavorable operational consequences.

The sheer volume of the aggregated throughput traffic to backhaul all user data from a local aggregation anchor to centralized data centers with home gateways can be expensive in many scenarios. With high density deployments, the centralized architecture leads to heavy backhaul utilization, and the inability to distribute load quickly manifests unfavorably. In addition, local user traffic does not remain local. User traffic must travel all the way to the centralized gateway and back, even if the corresponding peer is topologically closer.

In addition, a centralized gateway model increases the cost of backhaul by preventing the off-loading of high-bandwidth services locally. Instead high-bandwidth services have their traffic backhauled to a centralized gateway in a data center. This will increase the distances and possibly the capacity associated with any backhaul.

4.2. Latency Considerations

While the support for Internet offload of user data can significantly reduce the core network backhaul, the mobility management element may be strategically positioned deeper in the network to efficiently set-up and process the signaling and control including optional policies. Such a hybrid architecture can provide for supporting a mix of real-time and non-real-time broadband services. Real-time applications can benefit from lower latencies by having data closer to the subscriber and peers and not backhauled. Non-real-time applications (such as e-mail) derive no such performance benefit and may have a more centralized traffic approach.

Current mobility models handle offload cases poorly. A consideration may be to clearly make a working toolbox for applications to select a prefix with anchored mobility and a prefix without anchoring.

4.3. Inefficient Routing and signaling overhead

Inefficient routing mechanism of a completely centralized mobility deployment approach causes QoS deterioration and may lead to heavy network congestion in the core.

In the centralized approach only the HA and the CNs manage a nodes mobility. Mobility signaling occurs each time a mobile node changes its point-of-attachment regardless of the locality and amplitude of its movement. As a consequence, the same level of signaling load is introduced independently of the user's mobility pattern. For example, if the HA and/or CNs are far from the MN, even if the MNs movement is small, the mobility signaling messages travel across several IP networks, the latencies of which reduce handover speed. Furthermore, route optimization which supports direct routing from CNs to the mobile node, generates excessive mobility messages and adds a significant extra load to the network.

4.4. Scalability and cost

In a completely centralized Mobile IPv6-based deployment approach, the home agent becomes a single point of failure. Also, a distributed deployment approach may provide better overall capacity and performance, but this must be weighed against the increase in capital costs for deployment of local distributed gateways. In addition, a completely centralized deployment model makes it difficult to scale with a large number of mobile nodes. Scalability costs are weighted from many perspectives such as the number of nodes in the overall system, the geographic distance of the traffic, the number of autonomous parties in the deployment approach and others.

5. Enhancements to improve mobility

Enhancements to the Mobile IPv6 protocol have been done to improve mobile communications in certain scenarios so that mobility operations are efficient and optimized.. A key area of enhancements is in reducing the delays in the data path redirection operation that is defined in Mobile IPv6 operations. Mobile IPv6 has adopted route optimization and HMIPv6 to reduce the traversal of data traffic to the mobile nodes new location changes in its point of attachment. Delays in data traffic redirection will depend upon the location of the anchor agent that performs the redirection. As such enhancements focus on moving these anchor agents closer to the mobile node.

5.1. HMIPv6

Using Mobile IPv6, a mobile node sends location updates to any node it corresponds with each time it changes its location, and at intermittent intervals otherwise. This involves a lot of signaling and processing, and requires a lot of resources. Furthermore, although it is not necessary for external hosts to be updated when a mobile nodes moves locally, these updates occur for both local and global moves. Hierarchical Mobile IPv6 (HMIPv6)is designed to enhance mobility support in MIPv6 and micro-mobility management. The benefit of the HMIPv6 enhancement is to reduce the amount of signaling required and to improve handoff speed.

The key concept behind HMIPv6 is to locally handle handovers by the usage of an entity called the Mobility Anchor Point (MAP) located at any level in a hierarchical network of routers. The major issue on HMIPv6 is designing the MAP selection scheme that can reduce frequent handover mobility signaling and improve handover performance.

5.2. Dynamic assignment of HA

Dynamic assignment of HA is an enhancement to reduce both the signaling traffic and the data traffic to the home network. The dynamic HA assignment may take into account the geographical proximity of the HA to the mobile node. It may also consider performance factors such as HA load-balancing or other criteria.

5.3. Route Optimization

Mobile IPv6 Route optimization is an enhancement to optimize the data path between two communicating nodes despite changes in the IP connectivity on the mobile node side. The data path reduction between the communicating nodes helps to reduce one way packet delay when both nodes are under the same localized domain and the mobility gateway is far away. The process of reducing data path is referred

to as route optimization. Route optimization helps reduce the delay and thus important for real-time applications. An enhanced version of route optimization may also enable continued communications during periods of temporary home-agent unavailability.

6. Distributed mobility - What does it imply

Mobility is a service that provides significant value to a network operator. The ability to offer connectivity and services that work seamlessly across mobility events such as the switching of an access network type etc. creates a much superior end-user experience and thereby a demand for such service. Cellular networks have offered mobility for voice and messaging (short message service) since the late 80s and early 90s. These networks have been evolving and are now offering broadband data services and Internet connectivity. The network architectures are also using Internet protocols and technologies to a significant extent. Traditionally the architectures of these networks has been hierarchical in nature. While such an architecture served operators well in the past, it has limitations when it comes to offering data services and Internet connectivity. There is an effort to distribute functionality that generally has resided in centralized gateways much more closer to the edge of the network. The line between the access and core network is fading and hence a need to rethink how mobility service is affected in such an evolving architecture.

Distributed mobility is a way to deploy existing mobility solutions that do not require a mobile host to be anchored at a gateway all the time but instead be attached to different mobility agents/gateways in the network depending on the access, location and other factors. Session continuity via distributed mobility is expected to be on par with that provided by an anchored mobility solution.

Does it require an entirely new approach to mobility architectures that would be based on the goal of distributing mobility related functions? It is an easy option to consider redesigning on a clean sheet of paper. However this is not a pragmatic approach. It is much more optimal to consider what are the issues that are created as a result of a centralized gateway architecture and then develop extensions to the protocols and, deployment models, that can address those issues. The implications of distributed mobility architectures on access and core networks needs to be also considered in any design.

7. Approaches using current protocols for distributed mobility

We believe that most of the needed basic protocol functionality for distributed mobility management is already there. What is missing seem to be related to general system level design and lack of mobility aware APIs for application developers. One of the simple approaches for distributed mobility management is to avoid traditional "anchored mobility" like Mobile IPv6 when possible and rather use local (care-of) addresses for the communication. Use of local addressing also implies less mobility related signaling load in the network. For example [RFC5014] already provides means for an application to explicitly request for a prefix that has mobility characteristics (IPV6_PREFER_SRC_HOME) or a prefix that is local to the current access network (IPV6_PREFER_SRC_COA). It is not guaranteed that the IP stack in the MN would always respect the suggestion received from the application. In general it is also important that possible solutions in distributed mobility management space requires minimal changes in mobile hosts.

Another aspect that is in interest of distributed mobility management concentrates on allocating mobility anchors that are topologically close to the MN. Existing protocols such as HMIPv6 [RFC5380] provide a solution that is close what is needed. What might be needed in addition is a mechanism to "chain" multiple MAP-domain to extend the micro-mobility area, or provide another RFC5014 like prefix type (IPV6_PREFER_SRC_MAP). We could also consider Mobile IPv6 + Proxy Mobile IPv6 interactions Scenario A.1 in [I-D.ietf-netlmm-mip-interactions] a similar solution. Finally, yet another approach for exploiting locality are Proxy Mobile IPv6 localized routing solutions [I-D.ietf-netext-pmip6-lr-ps] which allows bypassing the remote central Local Mobility Anchor when ever possible and have a direct communication via closer to MNs Mobile Access Gateways.

Home Agent Switch [RFC5142] extension to Mobile IPv6, Runtime LMA assignment [I-D.ietf-netext-redirect] extension to Proxy Mobile IPv6 and Mobile IPv4 Dynamic HA Assignment [RFC4433] all provide solutions to dynamically assign a mobility anchor to the MN. What is missing from these solutions, is a protocol or rather a system level solution for a "seamless mobility anchor relocation" during an existing mobility session. However, that would be rather challenging due the fact that a mobility anchor relocation usually implies topological location chance in the network, which would also mean different prefixes/subnetworks for home addresses from the IP routing point of view. Within a reasonably small autonomous system or otherwise restricted area maybe some kind of interior routing solution could be used to assist mobility anchor relocation.

8. Potential future work

As the MEXT working group evolves and transitions to one that is focused on dealing with distributed mobility, there is a need to clearly understand the drivers for such an approach and whether these could be dealt with via a framework that uses existing mobility protocols and extensions and can be applied in a manner that deals with those concerns.

One of the key efforts could be in understanding the key concerns driving the need for a distributed mobility solution and identifying various approaches using existing protocols and extensions to overcome them.

1. Work on the generic solution for anchor relocation. This might be a architecture describing work, rather than protocol work. I believe we have most protocols already in place but not glued together.

2. Work on address selection beyond RFC 5014 (with coloring i.e. the end host stack knows properties of the prefix it got) and rapid deprecation/renumbering of prefixes (needed when CoAs change and applications try to use CoA for something local). This could potentially be new protocol work an containers for coloring prefixes (RA and DHCPv6) and how to handle local prefix deprecation during handovers.

3. Work on localized mobility that does not involve signaling with gateways or "mobility signaling". This could lead to work below the IP layer, e.g. intra-AS mobility is handled using some interior routing protocol enhancement.

9. IANA Considerations

This document has no requests to IANA.

10. Security Considerations

This document is a discussion of distributed mobility solutions. Some of the approaches that are considered for deployment do have security implications. However since the approaches being discussed are based on existing mobility specifications developed within the IETF, they have already been reviewed for security. This document does not raise any new security concerns.

11. Summary and Conclusion

Distributed mobility is a way of deploying mobility protocols that minimise the issues that arise from a centralized gateway centric approach that comes from a hierarchical model. As the amount of traffic in a network grows, operators are less willing to transport all the traffic to a centralized gateway just for the sake of enabling mobility. The mobility models have to evolve to meet the changing environment of mobile networks and traffic patterns.

Using many of the extensions and protocols that have been defined for Mobile IPv6 it is possible to deploy a mobility solution that meets the criteria of distributed mobility architecture. The concerns fo a centralized gateway approach can be addressed using deployment techniques effectively.

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