Distributed Mobility Management: Status and Challenges

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Outline

• Problem Statement and Requirements for DMM

• Some of Candidate Schemes in the IETF DMM WG

• Research Activities on DMM in Korea
  – Mobile Oriented Future Internet (MOFI)

• Conclusions
Problem Statement and Requirements for DMM
Centralized MM

- Current cellular networks
  - Hierarchical architecture
- Centralized mobility anchor
  - HA, LMA
Distributed MM

• Future mobile networks
  – Flat architecture
• Mobility management
  – Distributed Control
  – Distributed anchors: HA/LMA => AR/MAG
• Advantages
  – Optimal routes
  – Low control overhead
  – Handling a single point of failure and attack
Centralized vs. Distributed MM

Centralized MM

Distributed MM
Problem Statements (1)

• Lack of Route Optimization
  – Routing via a centralized anchor results in a longer route
    • (e. g.) MIP-RO, PMIP-LR
    • Reactive mode: after initial data delivery via HA/LMA
Problem Statements (2)

- **Scalability**
  - Data traffic explosion
  - Control traffic (signaling) overhead
Problem Statements (3)

• Single point of failure and attack
  – Centralized anchoring architecture
    • Vulnerable to a single point of failure or attack
    • requires duplication and backups of the support functions
  – Distributed MM architecture
    • Mitigated the problem to a local network (a smaller scope)
Problem Statements (4)

- Network Evolution to Flat Architecture
  - Mobile networks become less hierarchical
    - UFA (Ultra Flat Architecture) in 4G mobile networks
    - Each edge router performs most of functionality necessary
  - Centralized MM can become more non-optimal
    - Content servers in a content delivery network (CDN) are moving closer to access networks
    - Peer-to-peer communication within a same domain
  - Distributed MM shall support both hierarchical networks and flat networks
DMM Requirements (1)

• DMM should be designed to consider
  – Distribution of the mobility anchors (e.g. HA)
    • In order to achieve a more flat design
    • This would improve scalability and robustness of the mobility infrastructure
  – Placing the MM closer to the edge of network (e.g. AR)
    • In order to achieve routing optimality and lower delays
    • Offloading near the edge of the network
    • Benefit of the core network load
DMM Requirements (2)

• DMM should be designed to consider
  – Separating control and data planes by splitting location and routing anchors
    • This could minimize the signaling overhead between the mobility anchors
    • We may keep the control plane centralized, with the data plane distributed
  – Reusing existing protocols while minimizing changes,
    • in order to allow faster adoption of the technology
Approach 1: Partially DMM

- Only data plane is distributed
  - With centralized control plane
Approach 2: Fully MM

• Both data and control planes are distributed
  – Search-driven
Candidate Schemes
in IETF DMM WG
Internet Drafts (1/3)

① PMIPv6-based distributed anchoring
   ➢ draft-bernardos-dmm-distributed-anchoring-00

② A PMIPv6-based solution for Distributed Mobility Management
   ➢ draft-bernardos-dmm-pmip-01

③ A architecture of distributed mobility management using mip and pmip
   ➢ draft-chan-dmm-architecture-00

④ Requirements of distributed mobility management
   ➢ draft-chan-dmm-requirements-00

⑤ Dimensioning considerations for distributed mobility architecture
   ➢ draft-demaria-dmm-dimensioning-considerations-00

⑥ PMIPv6-based Distributed Mobility Management
   ➢ draft-jaehwoon-dmm-pmipv6-00

⑦ Use of Proxy Mobile IPv6 for Distributed Mobility Management
   ➢ draft-jikim-dmm-pmip-00
Internet Drafts (2/3)

1. Local Prefix Lifetime Management for Proxy Mobile IPv6
   - draft-korhonen-dmm-local-prefix-00
2. IPv6 Prefix Mobility Management Properties
   - draft-korhonen-dmm-prefix-properties-01
3. Address Selection for DMM
   - draft-liu-dmm-address-selection-01
4. DMM Dynamic Anchor Discussion
   - draft-liu-dmm-dynamic-anchor-discussion-00
5. Mobility API Extension for DMM
   - draft-liu-dmm-mobility-api-00
6. PMIP Based DMM Approaches
   - draft-liu-dmm-pmip-based-approach-02
7. PMIP Based DMM Approaches
   - draft-luo-dmm-pmip-based-dmm-approach-01
Internet Drafts (3/3)

1. An AR-level solution support for Distributed Mobility Management
   - draft-ma-dmm-armip-00
2. A Route Optimization solution support for Distributed Mobility Management
   - draft-ma-dmm-romip-00
3. Authentication and Mobility Management in a Flat Architecture
   - draft-mccann-dmm-flatarch-00
4. Approaches to DMM using MIPv6 and its extensions
   - draft-patil-dmm-issues-and-approaches2dmm-00
5. DMM Comparison Matrix
   - draft-perkins-dmm-matrix-03
6. Distributed Mobile IPv6
   - draft-sarikaya-dmm-dmipv6-00.txt
7. Distributed Mobility Anchoring
   - draft-seite-dmm-dma-00.txt
• Dynamic Mobility Anchoring (DMA)
  – Based on PMIP: HA/LMA => MAG(AR)
  – Mobility-enabled Access Routers (MARs): MAG(AR)
    • Data traffic anchoring and binding update to MNs
    • MAR allocates HNP (HoA) to MN in its region

• Operations
  – A new MAR acts as a Home MAR (H-MAR)
    • for the new flows using the HNP allocated by itself
  – The new MAR also acts as a Visited MAR (V-MAR)
    • for flows using the HNP allocated by a previous MAR
  – As a result, any MAR can act as both an H-MAR and a V-MAR for flows belonging to the same MN
Packet routing when MN moves from MAR1 (AN1) to MAR2 (AN2)
  - On-going flow with CN1 during the movement
  - After the movement, MN initiates flow with CN2
• Analysis
  – DMA can be applied to the flow mobility with multiple interfaces
  – How to specify whether the MN will be associated with a permanent address for an external CN?
  – DMA requires that each MAR advertises different per-MN prefixes set (two different HNPs for MN)
• Distributed Anchoring Function (DAF)
  – Distributed Routing Function (DRF)
    • Optimize routing between MN-CN
  – Distributed Mobility Function (DMF)
    • Relocation of MN’s distributed anchor
• Location Management Function (LMF)
  – Maintain mappings between MN’s HoA and its location (CoA)
• Location Query and Tunneling
• Anchor Relocation
Focus on the partially distributed model

Mobility Access Anchor Router (MAAR) can act as MAG&LMA (for data forwarding)
  - Traffic can be locally routed or tunneled to MN by using MAARs

Tunneling establishment between MAARs is performed via standard PMIP signaling
  - The extended LMA plays the role of Central Mobility Database (CMD)
    - Three operational modes are proposed (relay, proxy, locator)
• Example
Activities on DMM in Korea: Mobile Oriented Future Internet (MOFI)
MOFI (www.mofi.re.kr)

MOBILE ORIENTED FUTURE INTERNET (MOFI)

Introduction

It is expected that the future Internet would be evolved toward 'mobile-oriented' environment, whereas the architecture of current Internet was historically designed for 'fixed-oriented' environment and thus it is inevitably subject to some architectural limitations in the viewpoint of 'mobile-oriented' future networks. This leads us to re-design of Internet architecture to effectively support the mobile-oriented future network environments.

The Mobile Oriented Future Internet (MOFI) is a new architecture of future Internet to support the mobile environment, which is designed based on the following building blocks: Host Identifier and Local Locator (HILL), Query-First Data Delivery (QFDD), and Dynamic and Distributed Mapping System (DDMS). In HILL, each host has a globally unique Host ID (HID) which is used for end-to-end communication, whereas an IP address of the network router is used as a Locator (LOC) by which the packet routing is performed 'locally' within a network. In QFDD, the signalling operation for LOC query is performed before data transmissions so as to obtain an optimal path. In DDMS, the HID-LOC mapping for hosts is managed in the dynamic and distributed way.

In MOFI, it is assumed that the network consists of a lot of domains. Each domain, which is identified by an Autonomous System (AS) number, has a lot of Access Routers (ARs). A domain will be interconnected to the other domains via Gateway (GW) over global Internet. For packet delivery, Access Delivery Protocol (ADP) is used between hosts and AR, and Backbone Delivery Protocol (BDP) between AR and GW, with the help of HILL. In MOFI, the...
### Problem Statements and Design Principles

<table>
<thead>
<tr>
<th>Problems of Current Internet</th>
<th>MOFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP address as both ID and LOC</td>
<td>Separation of Host ID and LOC (IP address)</td>
</tr>
<tr>
<td>Address-based communication and global routing</td>
<td>HID-based communication and LOC-based local routing</td>
</tr>
<tr>
<td>Data-driven packet delivery with non-optimal routes</td>
<td>LOC query before data delivery for optimal routes</td>
</tr>
<tr>
<td>Static and centralized ID-LOC mapping system</td>
<td>Dynamic and distributed HID-LOC mapping management</td>
</tr>
<tr>
<td></td>
<td>Host ID and Local LOC (HILL)</td>
</tr>
<tr>
<td></td>
<td>Query-First Data Delivery (QFDD)</td>
</tr>
<tr>
<td></td>
<td>Dynamic and Distributed Mapping System (DDMS)</td>
</tr>
</tbody>
</table>
Three Functional Blocks

- Query-First Data Delivery (QFDD)
- Dynamic and Distributed HID-LOC Mapping System (DDMS)
- Host ID and Local LOC (HILL)
HILL: Host ID & Local Locator  
(HID-based global comm. & LOC-based local routing)
QFDD: Query First Data Delivery

(a) Data-driven Packet Delivery with Non-optimal Route
(b) Query-First Data Delivery with Optimal Route
Data Plane: Protocol Stack

<table>
<thead>
<tr>
<th>Application/Transport</th>
<th>Network (IP address): End-to-end communication &amp; global data routing</th>
<th>Application/Transport</th>
<th>Communication (HID): End-to-end communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC/PHY</td>
<td>elivery (LOC): Local data routing</td>
<td>MAC/PHY</td>
<td></td>
</tr>
</tbody>
</table>

(a) Current TCP/IP

(b) MOFI
Data Delivery Model
DDMS: Overall Architecture
Intra-domain DDMS: DHT-based Mapping System
Inter-domain DDMS: Domain-based Mapping System
HID-LOC Binding (Non-roaming)

* In the figure, DFC(X:Y) represents DFC(HID:LOC)
HID-LOC Binding (Roaming)

* In the figure, DFC(X:Y:Z) represents DFC(HID:LOC:status)
LOC Query (Non-roaming RH)

*In the figure, DFC(X:Y) represents DFC(HID:LOC)*
LOC Query (Roaming RH)

* In the figure, DFC(X,Y) represents DFC(HID:LOC)
DDMS Messages

<table>
<thead>
<tr>
<th>Message</th>
<th>Full Name</th>
<th>Encoding</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBR</td>
<td>HID Binding Request</td>
<td>0000 0000</td>
<td>Host or LMC</td>
<td>LMC or GMC</td>
</tr>
<tr>
<td>HBA</td>
<td>HID Binding ACK</td>
<td>0000 0001</td>
<td>LMC or GMC</td>
<td>Host or LMC</td>
</tr>
<tr>
<td>LQR</td>
<td>LOC Query Request</td>
<td>0000 0010</td>
<td>LMC or GMC</td>
<td>LMC or GMC</td>
</tr>
<tr>
<td>LQA</td>
<td>LOC Query ACK</td>
<td>0000 0011</td>
<td>LMC or GMC</td>
<td>LMC or GMC</td>
</tr>
<tr>
<td>LUR</td>
<td>LOC Update Request</td>
<td>0000 0100</td>
<td>LMC</td>
<td>LMC or GMC</td>
</tr>
<tr>
<td>LUA</td>
<td>LOC Update ACK</td>
<td>0000 0101</td>
<td>LMC or GMC</td>
<td>LMC</td>
</tr>
</tbody>
</table>
Implementations: Linux-based Implementation

- **Network Configuration**
  - Control
  - Data

- **Host**
  - OS: Ubuntu Linux Ver. 9.04
  - Kernel: Linux kernel 2.6.28.11
  - Use 6 to 4 tunneling & netfilter

- **Data Delivery Network**
  - ADP: Private IPv4
  - BDP: Public IPv4

- **Access Router & Local Mobility Controller**
  - OS: Ubuntu Linux Ver. 10.04
  - Kernel: Linux kernel 2.6.32.16
  - Use iptables & netfilter

- **Service Applications**
  - Web Camera Streaming service
  - Web server (MOFI homepage)
  - SDMC Visualizer
  - Real-time Packet Capture (Wireshark)
Implementations:
Click-based Implementation

- Internetworking legacy IPv4 & MOFI host
  - STARCRAFT game between legacy IPX host & MOFI IPX host
Implementations: NS-3 Simulator

- Performance Comparison with Proxy Mobile IPv6
  - Simulation topology and scenario
Conclusions

• Motivations
  – Traffic (control/data) overhead at central anchor (HA/LMA)
  – (intrinsic) Router Optimization (from initial data transmission)
  – A single point of failure (central anchor)
  – Evolution to Flat Network Architecture

• DMM WG is just activated (March 2012)
  – First, Gap Analysis & DMM Requirements
  – Next, Solutions (probably based on MIP/PMIP)
  – Most of proposals are based on “partially DMM” (fully DMM ?)

• Further Issues
  – HoA (address) allocation (in the viewpoint of external CN)
  – Many works are needed for comparison of candidate schemes