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ARARO: Aggregate Router-Assisted Route Optimization for Mobile Network Support

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ABSTRACT

Network Mobility basic support protocol (NEMO Basic) extends the operation of Mobile IPv6 to provide uninterrupted Internet connectivity to the communicating nodes of mobile networks. The protocol uses a mobile router (MR) in the mobile network to perform prefix scope binding updates with its home agent (HA) to establish a bi-directional tunnel between the HA and MR. This solution reduces location-update signaling by making network movements transparent to the mobile nodes (MNs) behind the MR. However, delays in data delivery and higher overheads are likely to occur because of sub-optimal routing and multiple encapsulation of data packets. To manage the mobility of the mobile network, it is important to minimize packet overhead, to optimize routing, and to reduce the volume of handoff signals over the nested mobile network. This paper proposes an aggregate router-assisted route optimization (ARARO) scheme for nested mobile networks support which introduces a local anchor router in order to localize handoff and to optimize routing. With ARARO, a mobile network node (MNN) behind a MR performs route optimization with a correspondent node (CN) as the MR sends a binding update message (BU) to aggregate router (AGR) via root-MR on behalf of all active MNNs when the mobile network moves. This paper describes the new architecture and mechanisms and provides simulation results which indicate that our proposal reduces transmission delay, handoff latency and signaling overhead. To evaluate the scheme, we present the results of simulation.

Keywords: handoff, nested mobile network, route optimization, ARARO, transmission delay

1. Introduction

The vast address space of IPv6 will enable mobile objects such as cars, buses, trains, airplanes, or ships to carry an IPv6 network, in which many kinds of information devices can act as an IPv6 host having the IPv6 address. If at least one of the routers in the IPv6 network connects to a router on the Internet, any host in the IPv6 network can communicate with any host on the Internet.

the Network Mobility (NEMO) working group [1] of the Internet Engineering Task Force (IETF) has developed a conceptual architecture of a mobile network and a NEMO basic support protocol (NEMO Basic) [2] by extending the operation of the Mobile IPv6 (MIPv6) protocol [3].

A mobile network, which is composed of one or more IP subnets, moves as a single unit in the Internet topology [4]. It uses a MR as a gateway to provide Internet connectivity via an access router (AR) to the mobile network nodes (MNNs). The MNNs are categorized into three groups: local fixed nodes (LFNs), local mobile nodes (LMNs), and visiting mobile nodes (VMNs). The home addresses (HoAs) of the LFNs and LMNs are associated with the mobile network' s IP subnet prefix, whereas the HoAs of the VMNs are associated with other networks. Therefore, a VMN arriving at a mobile network first configures a care-of address (CoA) from the mobile network' s IP prefix and then registers the CoA with its HA. A VMN may represent a single host or a network itself, such as a PAN (personal area network), resulting in nested mobility. In the case of nesting, MRs belonging to each mobile network form a hierarchy, with the (upper) parent-MR providing connectivity to (lower) sub-MRs.

In NEMO Basic, MRs associate their CoAs with their network prefix in the BUs sent to their HA This provides connectivity of the MR and consequently to each node in its embedded network. A major drawback of NEMO is that all communications to and from the mobile network must go through the MR-HA tunnel. This results in extra overhead and high delays. Moreover, with nested mobile networks, the problem increases with each nested level. Outbound packets must go through the HAs of all MRs of higher levels before reaching their destination. This is known as the "pinball problem" and causes high delay. Another major drawback of these IP-in-IP encapsulations is related to overhead. Indeed, each nested level introduces additional overhead which in turn increases the network load and the risk of congestion.

To deploy this mobile IP service widely, the Hierarchal Mobile IPv6 (HMIPv6) technology [5] is also being studied in IETF. By adding a mobility anchor point (MAP) in a visited network to manage local mobility there, we can limit HAs to providing only global or inter-MAP mobility management. This technology lets us to avoid frequent locational registration of MNs with HAs, which may be a long way from the MNs, and to reduce the time required for handovers.

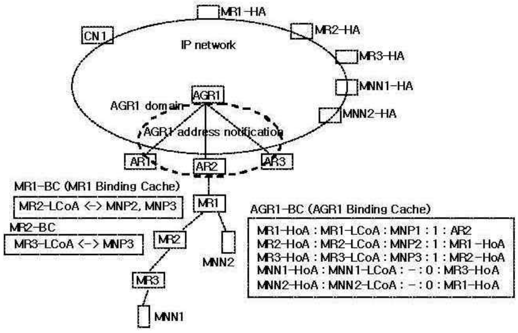
In response to overcome some of aforementioned drawbacks, Our proposed scheme reduces the number of control messages and the handoff latency as it enables a aggregate router (AGR) to just update the binding information for a MR, using a BU from the MR instead of the MNNs behind the MR when the MR moves locally within the AGR domain. This scheme also enables packets to be optimally routed to MNNs in the mobile network via AGR. The remainder of this paper is organized as follows: Section 2 summarizes the related literature. Section 3 describes our proposed scheme on supporting network mobility. A performance evaluation of the proposed architecture and mechanisms is described in Section 4. Finally, in Section 5, we present some concluding remarks.

2. Related Work

Route optimization is a mechanism that not only shortens the data delivery path between a MN and CN, but also reduces the potential level of encapsulation. Nevertheless, route optimization requires some route update signaling and/or additional information in the IP headers of data packets to enable packets to follow the optimal path and reach their destination intact. The generic consideration in designing a route optimization scheme is to use a minimum of signaling and/or additional information in the packet header. Some solutions to the problems of route optimization in NEMO have been published [6] [7]. Thubert et al. proposed the use of a new routing header, routing header (RH) type 4, also called a reverse routing header (RRH), for MNN-originated outbound packets, and a modified RH type 2 for inbound packets destined for MNN [6]. The RH type 4 collects the CoAs of all nested MRs, which are later included in the modified RH type 2 to reduce the number of nested encapsulations for inbound packets. This scheme, however, optimizes the path between the HA and the MR serving the MNN, not between the CN and MR. Moreover, it requires MRs to modify packet headers, which would increase computational overheads. Perera et al. [7] proposed assigning the MR a prefix pertaining to the visited network and advertising the prefix in a router advertisement to the MNNs. MIPv6-enabled MNNs first configure their CoAs from the prefix using a stateless address auto-configuration, and then perform route optimization by sending BUs to their HAs and CNs. As this scheme requires MNNs to configure their CoAs every time the network moves, it could possibly cause a binding implosion problem [8].

3. Proposed Route Optimization Scheme

We describe the operations of the ARARO scheme to provide the route optimization for a nested mobile network which has multiple levels of MRs as shown in Fig. 1. In this scheme, all MRs keep a binding cache, which we call MR-binding cache (MR-BC) for all the nested mobile routers behind them. Additionally, the AGR keeps another binding cache (AGR-BC) for all active MNNs that have ongoing communication sessions with CNs.



MR2-LCoA <-> MNP2, MNP3

MR3-LCoA <-> MNP3

MR1-HoA : MR1-LCoA : MNP1 : 1 : AR2
MR2-HoA : MR2-LCoA : MNP2 : 1 : MR1-HoA
MR3-HoA : MR3-LCoA : MNP3 : 1 : MR2-HoA
MNN1-HoA : MNN1-LCoA : - : 0 : MR3-HoA
MNN2-HoA : MNN2-LCoA : - : 0 : MR1-HoA

Fig.1 Nested Mobile Network Architecture for proposed routing method

The MR-BC is used to store binding between the local CoAs (LCoAs) of nested MRs and their mobile network prefixes (MNPs). As shown in Fig.1, when the sub-MR (MR3) attached to a parent-MR (MR2), MR3 sends a routing update message (RU) to MR2 to register the MR3's LCoA (MR3-LCoA) and the

MR3's MNP (MNP3). MR2 use this information to forward a packet addressed to the MNN1-LCoA. Similarly, MR2 registers its LCoA and all mobile network prefixes (MNP2, MNP3) with MR1 by sending RU (MR2-LCoA, MNP2, MNP3). In other words, if a MR (MR3) detects the movement of its mobile network, it sends a RU to the parent-MR (MR2), containing the MR3's LCoA and MR3's MNP. Then, the parent-MR (MR2) updates its binding cache entry and resends the RU to its parent-MR (MR1) recursively. At this time, the RU from the parent-MR (MR2) contains MR2-LCoA and MR2-MNP (MNP2), and sub-MR's MNP (MR3-MNP), with MR2-LCoA being used as next hop address for MR1 to send packets destined to MR2 or MR3. In conclusion, if a RU reaches the root-MR, the routing update procedure is completed.

To localize handoff signals, reduce handoff latency time and support route optimization in this scheme, the AGR maintains binding information for all MNNs and MRs in its domain in its binding cache (AGR-BC). AGR-BC is composed of HoA, LCoA, MNP, MR/MNN, and parent-MR field as shown in Fig. 1. Our proposed scheme applies the hierarchical location management method to a mobile network and manages the location of the mobile network and MNNs within it hierarchically. AGR1 periodically sends its address to ARs, which are connected as subordinates of AGR1. When root-MR (MR1) connects to AR2, MR1 sends a router solicitation message (RS) containing a request for AGR address and MNP. Next, AR2 sends a router advertisement message (RA) to MR1, containing AGR1 address and AR2-prefix. Then, MR1 creates its LCoA using AR2-prefix, sets AGR1 address as its regional CoA (RCoA). MR1 then sends a BU containing MR1-HoA, MR1-LCoA, MR1-MNP (MNP1), 1 (meaning a MR) and its parent MR (AR2) to AGR. AGR1 register the information to bind the MR1-LCoA and MR1-HoA, MR1-MNP, 1, and AR2. After this, MR1 sends a BU to its HA (MR1-HA) to register AGR1 address as its RCoA. Next, MR1 sends a RA to MNNs in its mobile network, containing AGR1 address and its MNP (MNP1).

Each MNN behind MR1 also detects new AGR address in the case where MR1 is already connected to AR2. The MNN (MNN2) creates MNN2-LCoA and its RCoA (AGR1 address) from the RA received from MR1. MNN2 sends a BU with MNN2-HoA, MNN2-LCoA, 0 (Not a MR) and its parent MR (MR1-HoA) to AGR1, and a BU containing the AGR1 address and MNN2-HoA to its HA (MNN2-HA). At this time, AGR1 caches the relation information to bind MNN2-HoA, MNN2-LCoA, 0 (Not a MR), and MR1-HoA. Other sub MRs and other MNNs in Fig. 1 could be applied the same procedures as above-mentioned method.

Fig. 2 shows the sequence of route optimization from CN1 to MNN1. MNN1 sends a BU to CN1 to register binding information that MNN1-RCoA is AGR1 address. On arrival of the BU, the CN1 creates a binding between the MNN1-HoA and AGR1 address mentioned in the alternate CoA option field. In this situation, CN1 can send packets destined to MNN1 via AGR1 using RH type2. RH type 2 is an extension header defined in MIPv6. AGR1 checks the home address option (HAO) field of the RH type 2 header of an inbound packet to get the HoA of the MNN1 that the packet is addressed to. The MNN1's HoA

(MNN1-HoA) is used to search for the corresponding LCoA (MNN1-LCoA) in the AGR1-BC. AGR1 encapsulates this packet with MNN1-LCoA after searching for it in its binding cache and transmits the packet to MNN1.

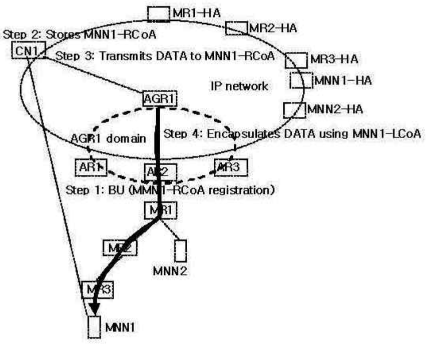


Fig.2 Procedures – Optimization of the route from a CN in proposed ARARO scheme

Similarly, MNN-oriented outbound packets have the AGR address and the address of the CN in the source and destination address fields, respectively. These packets are tunneled to the AGR using the AGR address as the destination address and the MNN-LCoA as the source address in the outer IP header. The AGR decapsulates and forwards the packet normally to the CN.

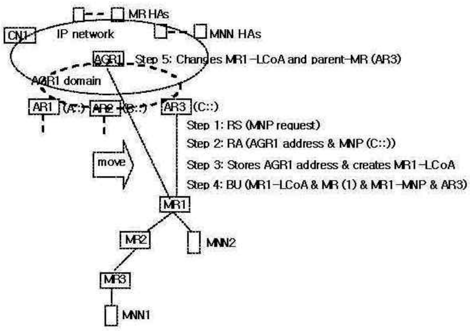


Fig. 3 Procedures – Mobile Networks Handoff

Fig. 3 shows the procedure of mobile networks handoff within the same AGR1 domain where MR1 performs the handoff to a new link and configures a new LCoA. MR1 then sends a BU just to AGR1 containing its new LCoA and parent MR's address which is AR3. Then, AGR1 updates the LCoA and parent MR's address for MR1. The need to send BUs from each MNN within mobile networks managed by MR1 to AGR1 is eliminated like NEMO Basic. That means our scheme avoids increasing signaling volume due to handoff management. However, if the AGR address is changed, it is necessary to updates the AGR addresses of MNNs and sub-MRs within MR1's nested mobile network.

4. Performance Evaluation

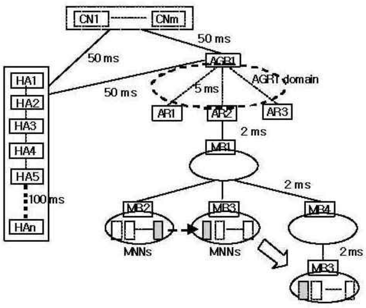


Fig. 4 Network Model for Simulation

In this section, we present some comparative performance results with the NEMO Basic. We consider a three-level nested mobile network as depicted in Fig. 4. HA1 to HA4 are respectively HAs of MR1 to MR4. The remaining HAs is the HAs of MNNs. We set up the CN as a traffic source at a Constant Bit Rate (CBR) over a User Datagram Protocol (UDP), producing fixed length packets of 1500 bytes every 10 ms. Then the MNN acts as a sink node receiving packets from CN. The setup link topology consists of wired link and wireless link. The wired link is fixed and used at the connection of CN to AGR, CN to HA, HA to AGR, and AGR to the AR. The wired link bandwidth is set to 100 Mbps. The wireless link bandwidth is set to 11 Mbps with the wireless link latency set to 2 ms. The packet service rate was 100 packets/second corresponding to data rates of 1.2 Mbps. The handoff interval was set to 2 seconds. We evaluated each scheme assuming 5, 10, 100 MNNs in the mobile network. The simulation assumes that delay between HA and HA is 100 ms, delays between CN and HA, CN and AGR and HA and AGR are the same, 50ms and delay between MMR and AR is 5ms. Furthermore, packet header size, BU size and binding acknowledgement message (BACK) size are also predefined: 40 bytes, 112 bytes and 96 bytes respectively.

4.1 End-to-End Packet Delay

One of the main advantages of using route optimization techniques lie in delay reduction. Packet transmission delay measurements from a CN to a MN in the mobile network are depicted in Fig. 5. This is related to the reduction of the number of nested tunnels. Indeed, the proposed solution requires only a unique tunnel from AGR to MN regardless of the number of nested levels in the mobile network. The packets, in NEMO Basic, must pass through multiple tunnels from the MN to MN-HA. The packet transmission delay saving time between ARARO and RRH method is 56.33 ms at level 0 and 56.58 ms at level 3. RRH method is superior to NEMO Basic but is inferior to ARARO.

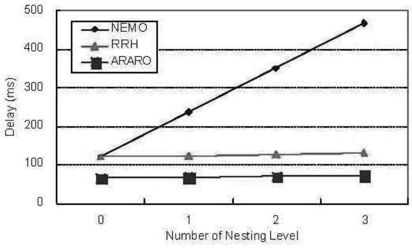


Fig. 5 Packet Delivery Delay

4.2 Handoff Latency

Handoff latency is the mean time from handoff initiation to completion. Fig. 6 shows the handoff latency for each scheme when a mobile network is assumed to move locally at nesting level 2 within AGR domain. NEMO Basic requires that MR only performs a registration operation to its HA/CNs instead of MNNs connected to the MR. However, ARARO requires that MR also performs a registration operation to AGR instead of MNNs behind the MR.

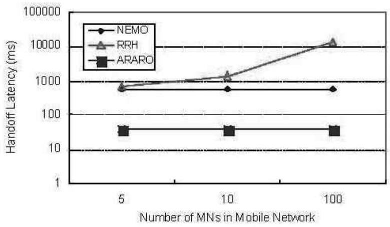


Fig. 6 Handoff Latency

As we can see, the handoff delay with the proposed approach is decreased to 551 ms regardless of the number of MNNs in the mobile network, compared to NEMO Basic. On the other hand, the difference of ARARO and RRH depends on the number of MNNs, e.g., 659 ms with 5 MNNs, 13903 ms with 100 MNNs since RRH require each MNN in the mobile network to send BUs to its CNs/HA when handoff occurs. As the number of MNNs in the mobile network is increased, the handoff latency of RRH increases enormously. Therefore, when compared to other schemes, ARARO is the most efficient.

4.3 Handoff Signals

The handoff signals are - RS, RA, BU and BACK [3]. Fig. 7 shows the number of handoff signals required in each scheme whenever handoff occurs. With regard to signaling overheads, both NEMO Basic and ARARO offer low and constant values. On the other hand, in RRH, increasing the numbers of MNNs increases the number of handoff signals. If the number of MNNs is 100, ARARO provides about the same level of performance as NEMO Basic, while it requires about 500 fewer handoff signals than RRH.

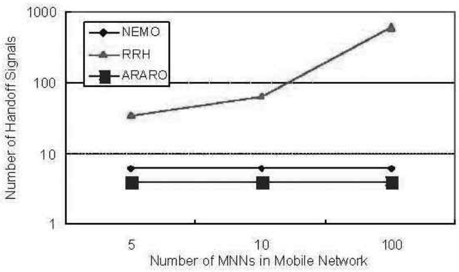


Fig. 7 Number of Handoff Signal

5. Conclusions

The NEMO Basic provides advantages by reducing location update overheads. However, it has the side effect of increasing packet delivery overheads due to pinball routing and multi-layer encapsulation of data packets. To solve this problem, this paper has a new mobility management mechanism for optimizing the end-to-end route for MNNs/MRs within a nested mobile network environment. By developing AGR to provide a mobility anchor point (MAP) function in HMIPv6 and slightly changing in the implementation of the NEMO Basic in the local components of a mobile network such as MRs and MNNs, the proposed approach could provide more effective route optimization that would reduce the burden of location registration for handoffs. The ARARO enables a CN to forward packets directly to the mobile network without any tunneling, which reduces packet delays and encapsulation overhead in the core network. It also reduces handoff latency and the volume of handoff signals. Our future subjects of study include investigating security issues between MRs and distributing the processing load by locating multiple MRs in a mobile network while retaining most of the predicted benefits.

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