Adaptive Path Selection for Improved Distributed Mobility Management

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Abstract— **Current mobility management schemes usually represent centralized or hierarchical architectures, which force data traffic to be processed by a centralized mobility anchor. This allows the mobile node (MN) to be reachable anywhere and provides an efficient method for seamless session continuity. However, all of the signal messages and data traffic converge on particular mobility anchor, which causes excessive signaling and traffic at the centralized mobility anchor and single point of failure issues as data traffic increases. To overcome these limitations and handle increasing data traffic, the distributed mobility management (DMM) scheme has emerged as an alternative solution. Although previous researches have been conducted on DMM support, because their schemes employ an unconditional way to make direct paths after handover, they have some drawbacks, such as several signaling and chain of tunneling problems. Therefore, this paper introduces a new DMM scheme which adaptively creates a direct path. To support it, we present the path selection algorithm, which selects the most efficient path between a direct path and no direct path based on routing hops and traffic load. Through the performance analysis and results, we confirm that the proposed scheme is superior in terms of signaling and packet delivery costs.**

Keywords: ***distributed mobility management; DMM; mobility anchor;***

1. Introduction

As the number of mobile nodes (MN) and mobile content services significantly increases, mobility management for this MN has become an important issue. Current mobility management has relied on centralized or hierarchical architectures in which a mobility anchor (MA) is located at the core side, as shown in Fig. 1. This allows the MN to be reachable and to support session continuity even though it is not connected to its home domain. While this is a benefit, there are also several drawbacks. First, as data traffic increases, traffic bottleneck and single point of failure issues easily occur at the MA. The further an MN becomes far away from the MA, the longer the data path becomes. Ultimately, a centralized mobility management essentially has various performance issues under evolved mobile environment [1] [2].

To resolve the overall issues which arise in centralized mobility management, a new mobility paradigm is being studied which is termed distributed mobility management [3] [4]. Conceptually, it distributes MA function from the core to the edge sides, so that the IP session of the MN is served at the level of the access router.

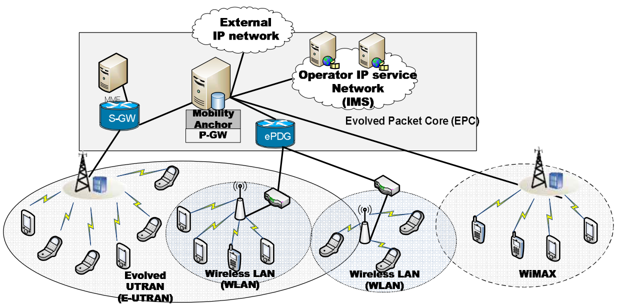

Fig. 1 The centralized mobility management reference model.

H. Chan proposed a DMM scheme in which the data routing function is handled in a distributed manner, while signaling control is maintained in a centralized manner [4]. This scheme notifies all of the

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corresponding nodes' (CNs) MAs about the MN's location in order to make a direct path between the MN and CN after handover. This scheme partially alleviates the burden of signal and data traffic which converges on a particular MA. However, when the MN communicating with several CNs frequently changes the attachment point of MA, this scheme sends the MN's location information to all MAs to which CNs are anchored in a lump, without considering the MN's condition. This is called the unconditional DMM approach (UDMM), in which several signaling and tunneling problems are encountered.

To address these problems, we propose a new DMM approach (NDMM) which adaptively creates a direct path between the MN and CNs, unlike UDMM, because using the direct path is not always efficient way. We present a path selection algorithm which selects an efficient path based on routing hops and load information between the direct path and the current path from the previous MA. To evaluate the efficiency of the proposed scheme, we compare the UDMM in terms of signaling cost and packet delivery cost.

The rest of this paper is organized as follows. In section II, we briefly explain the distributed mobility management scheme. In section III, we propose a new distributed mobility management approach. In section IV, we evaluate the performance of signaling cost and packet delivery cost based on an analytical model and present the numerical results. In section V, we offer our conclusions.

2. Related works

The conventional mobility management protocols--such as mobile IPv6 (MIPv6) or proxy mobile IPv6 (PMIPv6)--combine the control plane (i.e., allocating IP address, location management) and data plane (i.e., routing data traffic) into one MA, such as a home agent (HA) and a localized mobility anchor (LMA) [5] [6]. In such an architecture, all packets and signaling messages go through that MA, since one MA includes all mobility management functions. On the other hand, DMM distributes mobility management functions to the edge side. There are two kinds of approaches for DMM support: partial-based and full-based DMM. The partial-based DMM maintains a centralized control plane while distributing the data plane to multiple MAs, and the full-based DMM distributes both the control and data planes to other MAs [7].

Fig. 2 (a) shows the DMM scheme proposed by [4]. It only distributed the data plane into many locations, while keeping the control plane centralized in the home mobility anchor (H-MA). According to [4],

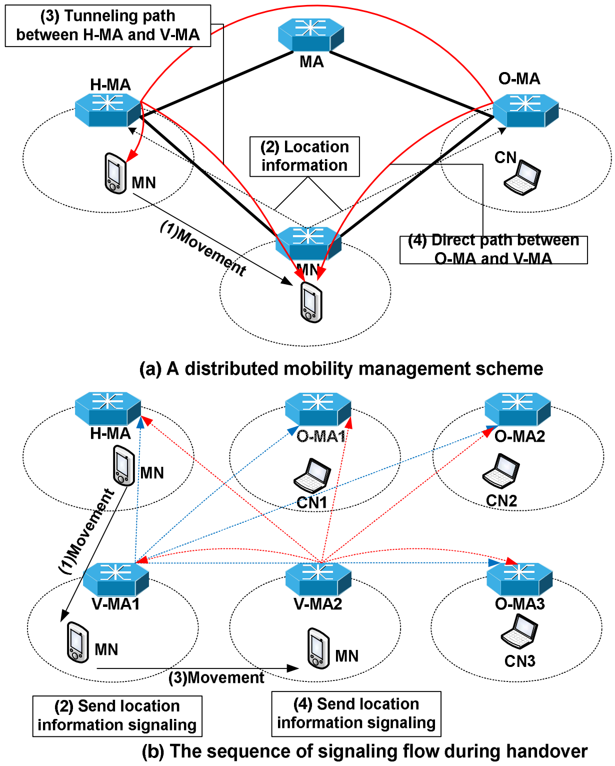

Fig. 2 The UDMM scheme and signaling flow during handover.

when MN moves to a visited network and is anchored to the visited MA (V-MA), the V-MA sends the location information of MN to both the H-MA and the originating MA (O-MA) as indicated (2) in Fig. 2 (a). If the H-MA receives location information, it forwards tunneled packets destined for the MN to the V-MA as indicated by (3) in Fig. 2 (a). On the other hand, if the O-MA receives location information, it will then update the cache table for the MN's location and forward packets to the V-MA directly without sending to the H-MA, as indicated by (4) in Fig. 2 (a).

Fig. 2 (b) shows the sequence of signaling message flow used in the handover procedure. It is assumed that the MN is initially anchored to the H-MA and communicates with three CNs which are anchored to different MAs, respectively. During the handover, severely inefficient signaling flows exist, and all MAs which receive signaling are required to handle the signaling packets where the MN frequently changes its MA. To counteract these drawbacks, a new DMM scheme is required.

3. Proposed scheme

Specifically, the proposed scheme compares the cost between the directly tunneled path (DTP) and currently tunneled path (CTP) from previous MAs, based on routing hops and traffic load information, and then selects the most efficient path. After that, it adaptively sends a location information request to the target MAs to create the DTP. We define the cnMA and mnMA to which the CN and MN are anchored, respectively.

3.1 Path selection algorithm

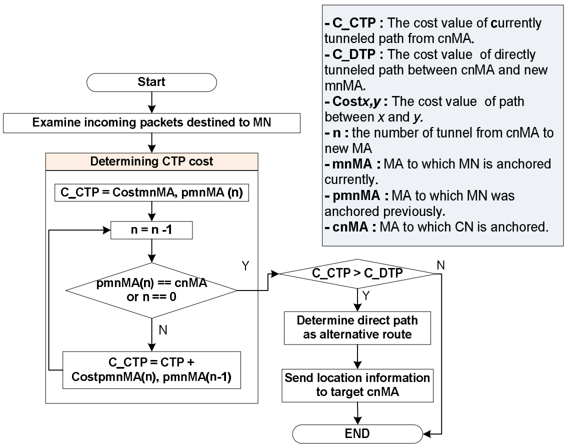

Fig. 3 Proposed algorithm to select the most efficient path.

We consider two costs: the DTP cost and the CTP (i.e., no direct path) cost between cnMA and mnMA. Our DMM scheme is activated by the proposed algorithm as shown in Fig. 3. To store the DTP cost, we extend a heartbeat signaling message [8], which is used to detect whether the other end is still reachable, as a reference [9]. For this reason, each MA periodically sends an extended heartbeat signaling message. The cost received by the MAs is stored in a cache table for serving as a reference for the next step. When the MN is away from the current mnMA and then anchors to a new mnMA, the new mnMA starts the algorithm as follows.

1) Upon receiving the packets destined to MN at the new mnMA, it checks the packets and then determines the CTP cost. The new mnMA knows this cost by receiving a location information response from the previous mnMA. The previous mnMA carries its cache table to the new mnMA. As shown in Fig. 4 and reflecting Fig. 5, for example, if packets sent from the cnMA3 arrive at the mnMA2, the mnMA2 can know the CTP cost by looking at the cache table; it then determines the cost using the sum of the cost between cnMA3 and mnMA1 and between mnMA1 and mnMA2.

2) The new mnMA compares the cost between CTP and DTP by looking at the cache table.

Cache Entry at mnMA2

Start MA-ID	End MA-ID	cost	Direct/indirect
cnMA3	mnMA2	40	direct
cnMA2	mnMA2	40	direct
cnMA1	mnMA2	10	direct
mnMA1	mnMA2	15	direct

Start MA-ID	End MA-ID	cost	Direct/indirect
cnMA3	mnMA1	15	indirect
cnMA2	mnMA1	20	indirect
cnMA1	mnMA1	15	indirect

Fig. 4 Example of cache entry for MA.

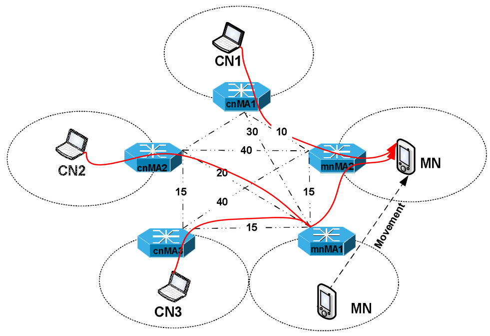

Fig. 5 Packet flows of proposed scheme during the handover.

3) If the cost of CTP is lower than the cost for DTP between a specific cnMA and mnMA, the mnMA does no signaling, and the current tunneled path is retained. Otherwise, the mnMA notifies the target cnMA of the MN's current location by sending a location signaling message.

3.2 Handover procedure

Fig. 5 shows the packet flows of the proposed scheme during the handover. We suppose that the MN is initially anchored to the mnMA1 and the IP address is then allocated. When the MN moves to the mnMA2, the mnMA2 sends the location information of the MN to the mnMA1 for a seamless handover.

Upon receiving packets destined for the MN at the mnMA2, the mnMA2 determines the CTP cost of packets by utilizing the proposed algorithm. Assuming that the cost of each path is denoted as indicated in Fig. 5, the mnMA2 only sends a location information request to the mnMA1 and then cannot perform any signaling for other cnMAs, because only the DTP cost between the cnMA1 and the mnMA2 is lower than for CTP.

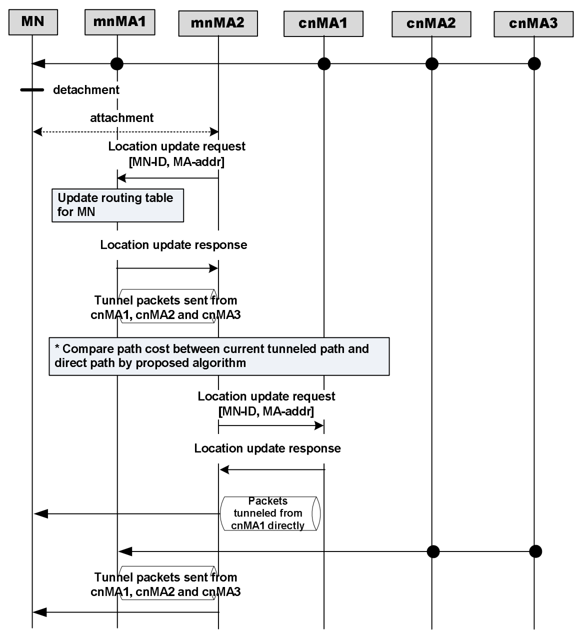

Fig. 6 Protocol procedure of proposed scheme during handover.

Fig. 6 shows the protocol procedure during the handover, assuming that only the DTP cost between the cnMA1 and the mnMA2 is lower than the CTP cost. Thus, the number of signaling messages and the chain of tunneling can be reduced by considering CTP and DTP costs.

4. Performance analysis and numerical results

This section presents a performance analysis of the UDMM and the NDMM scheme. For ease of analytical modeling, we assume that an MN is communicating with three CNs which are anchored to different MAs, and the MN is about to move to another MA. Under these assumptions, we analyze the signaling cost and packet delivery cost of two schemes and offer the numerical results by comparing their performances.

4.1 System model

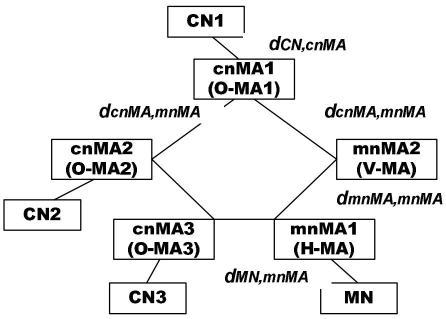

Fig. 7 System model.

Fig. 7 illustrates the network model for the performance analysis. The $d_{x\text{-}y}$ denotes the hop distance between two network entities, x and y. We assume that mobility domain consists of N cells and that all cells have a circular shape with size S. In addition, each MN moves at an average velocity of v; the session arrival process to the MN follows a Poisson distribution; and the residence time that the residence time that the MN stays are follows and exponential distribution. It is also assumed that the path cost between the MAs is used as shown in Fig. 5. Thus, we define μ_s and λ_s as the cell-crossing rates for which the MN keeps its residence in the same domain and at the same session arrival rate. From these, we obtain the average number of movement, $E(N_s)$, and express it as follows [10]:

$$E(N_s) = \mu_s / \lambda_s . \qquad (1)$$

$$\mu_s = 2 \cdot v / \sqrt{\pi \cdot S} \cdot (\sqrt{N} - 1) / \sqrt{N}. \qquad (2)$$

4.2 Signaling cost

We define the signaling cost as the signaling operation required after the MN's handover. As shown in equations (3) and (4), the C_z denotes the signaling cost to conduct the handover operation of the z scheme. It can be calculated as the sum of the location information request and response messages cost, considering the MN's movement. Each scheme's signaling cost is expressed by

$$\begin{aligned} C_{UDMM} = {} & E(N_s) \cdot (\tau \cdot (d_{H-MA,V-MA} \cdot L_{LI}) + P_R \cdot (d_{H-MA,V-MA} - 1) \\ & + P_{H-MA} + \tau \cdot (d_{O-MA1,V-MA} \cdot L_{LI}) + P_R \cdot (d_{O-MA1,V-MA} - 1) \\ & + P_{O-MA1} + \tau \cdot (d_{O-MA2,V-MA} \cdot L_{LI}) + P_R \cdot (d_{O-MA2,V-MA} - 1) \\ & + P_{O-MA2} + \tau \cdot (d_{O-MA3,V-MA} \cdot L_{LI}) + P_R \cdot (d_{O-MA3,V-MA} - 1) \\ & + P_{O-MA3}), \end{aligned} \qquad (3)$$

$$\begin{aligned} C_{NDMM} = {} & E(N_s) \cdot (\tau \cdot (d_{mnMA1,mnMA2} \cdot L_{LI}) + P_R \cdot (d_{mnMA1,mnMA2} - 1) \\ & + P_{mnMA1} + n \cdot (\tau \cdot (d_{mnMA2,cnMA1} \cdot L_{LI}) + P_R \cdot (d_{mnMA2,cnMA1} - 1) \\ & + P_{cnMA1})), \end{aligned} \qquad (4)$$

where τ is the unit transmission cost over a wired link, and L_m is the amount of the signaling message, respectively. The w_q is the routing processing cost between routers, while P_{MA} is the processing cost required in each MA.

4.3 Packet delivery cost

The packet delivery cost is defined as the cost of bandwidth consumption incurred by data packets between the MN and its CNs. The PC_z denotes the packet delivery cost of the z scheme. It can be calculated as the sum of the processing cost issued by the MAs and the data packet costs over a wired/ wireless network:

$$\begin{aligned} C_{UDMM} = {} & 3 \cdot \kappa \cdot (E(S) \cdot L_{data}) \cdot d_{CN-MA} + P_{MA}) \\ & + \tau \cdot (E(S) \cdot L_{data}) \cdot (d_{O-MA1,H-MA} + d_{O-MA2,H-MA} \\ & + d_{O-MA3,H-MA}) + 3 \cdot \tau \cdot (E(S) \cdot (t + L_{data})) \cdot d_{H-MA,V-MA} \\ & + 3 \cdot (\tau \cdot (E(S) \cdot (t + L_{data})) \cdot (d_{O-MA1,H-MA} + d_{O-MA2,H-MA} \\ & + d_{O-MA3,H-MA}), \end{aligned} \qquad (5)$$

$$\begin{aligned} C_{NDMM} = {} & 3 \cdot \kappa \cdot (E(S) \cdot L_{data}) \cdot d_{CN-MA} + P_{MA}) \\ & + \tau \cdot (E(S) \cdot L_{data}) \cdot (d_{O-MA1,H-MA} + d_{O-MA2,H-MA} \\ & + d_{O-MA3,H-MA}) + 3 \cdot \tau \cdot (E(S) \cdot (t + L_{data})) \cdot d_{H-MA,V-MA} \\ & + (\tau \cdot (E(S) \cdot (t + L_{data})) \cdot (d_{O-MA1,H-MA} + d_{O-MA2,H-MA} \\ & + d_{O-MA3,H-MA}), \end{aligned} \qquad (6)$$

where $E(S)$ is session length in packets, and κ and t denote unit transmission cost for the wireless link and the tunnel header size, respectively.

4.4 Numerical results

We employ some of parameter values used in the literature [10] [11], as shown in Table I**.**

Fig. 8 shows the signaling cost according to the velocity of the MN during handover, in which the

MN's velocity varies from 0 to 80. In the case of UDMM, since the MA to which the MN is newly anchored sends a location information request to all MAs to which CNs are anchored and the previous MN's MA, the signaling cost is higher than for NDMM. On the other hand, NDMM selectively sends a location information request to target MAs based upon the proposed algorithm; the result is superior to UDMM, and it is largely dependent on the number of DTPs.

Fig. 9 shows the packet delivery cost as the session arrival rate to the MN during handover. The result indicates that the UDMM is higher than the proposed scheme, because all packets consume bandwidth--not only the tunneled path but also the directly tunneled path. In the case of NDMM, it also consumes the bandwidth of the tunneled path from the previous MN's MA, but it consumes the DTP if the DTP cost is lower than the CTP cost.

Table 1 Parameters used for numerical results

Parameters	Values	Parameters	Values
τ, k	10, 20	w_q P_{MA}	8, 24
λ_s, t	10, 46	L_{LI}, L_{data}	76, 100
S, N	31400 ,30	$d_{CN,cnMA}$, $d_{MN,mnMA}$	1
$E(S)$	46	$d_{cnMA,mnMA}$, $d_{mnMA,mnMA}$,	15

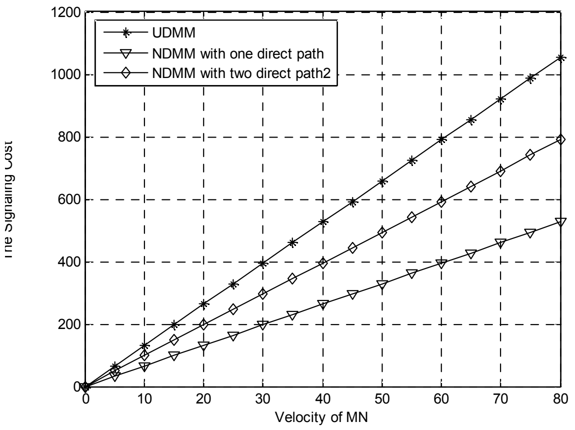

Fig. 8 Signaling cost as velocity of MN after handover.

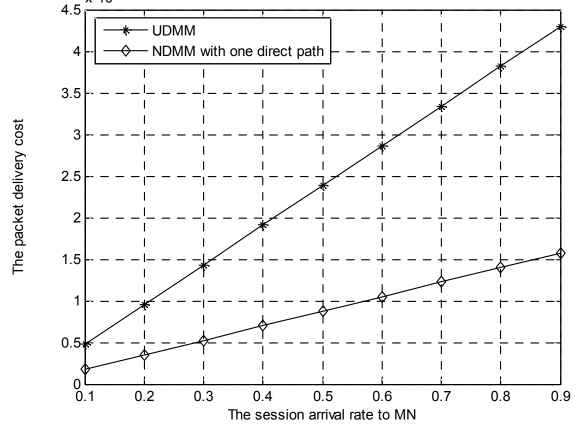

Fig. 9 Packet delivery cost as the session arrival rate after handover.

5. Conclusion

Distributed mobility management is an important issue, because current centralized mobility management leads to bottlenecks and single point of failure when data traffic increases significantly.

This paper proposed a new DMM scheme which can minimize signaling and a chain of tunneling problem by adaptively creating a direct path. In order to support our scheme, we presented a path selection algorithm which selects the most efficient path by comparing the path costs based on routing hops and traffic load between the DTP and the CTP. Through the performance analysis, we confirm that the proposed scheme is superior to UDMM in terms of signaling overhead and packet delivery cost. For future work, we will evaluate additional performance factors using a simulator.

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