Journal of Network and Computer Applications (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

DLM: Delayed location management in network mobility (NEMO)-based public transportation systems☆,☆☆

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A R T I C L E I N F O

Keywords:
Network mobility (NEMO)
Mobility management
Location management
Public transportation

A B S T R A C T

Network mobility basic support (NEMO-BS) supports efficient group mobility. However, when NEMO-BS is applied to public transportation systems where mobile nodes (MNs) frequently get in/off the public transportation, significant signaling overhead owing to frequent and unnecessary binding updates can occur. To address this problem, we propose a delayed location management (DLM) scheme where an MN postpones its binding update for a pre-defined timer to mitigate the binding update overhead. To evaluate the performance of DLM, we develop an analytical model for the binding update cost and the packet delivery cost during the boarding time. Also, a timer selection algorithm is proposed to optimize the performance of DLM. Evaluation results demonstrate that DLM can reduce the binding update cost and packet delivery cost in a balanced manner by choosing an appropriate timer.

1. Introduction

Network mobility basic support (NEMO-BS) is a mobility support protocol where a collective mobility of multiple mobile nodes (MNs) is handled as a single unit (Devarapalli et al., 2005; Lee et al., 2012). When MNs are connected to a mobile network (MONET), a mobile router (MR) broadcasts a router advertisement (RA) message with its mobile network prefix (MNP) and then MNs configure their care of addresses (CoAs) based on the MR's MNP. After that, MNs conduct binding updates to their home agents (HAs). Then, when the MONET moves to a new access router (AR), only MR conducts the binding update to its HA while MNs in the MONET do not need to execute any binding updates.

However, when NEMO-BS is applied to a public transportation, unnecessary signaling overhead due to binding updates can occur since MNs frequently get in/off the public transportation. Specifically, when an MN gets off before the public transportation moves to another AR (i.e., an MN has a short boarding time), the binding update for MN's CoA based on the MR's MNP can be unnecessary. Fig. 1 shows an example of the unnecessary binding update. When an MN gets in a public transportation (Step 1 in Fig. 1), the MN configures its CoA based on the MR's MNP and conducts a binding update to its HA (Steps 2–3 in Fig. 1). Then, when the public transportation moves to another bus station (Step 4 in Fig. 1), the MN gets off the public transportation (Step 5 in Fig. 1). In this case, the binding update in Step 3 for supporting collective mobility is useless. Note that the distance between two bus stops in local bus service is typically $300 \sim 400$ m (Washington Metropolitan Area Transit Authority) and the maximum diameter for one macro-cell is 3 km in urban areas (3GPPBS 3GPP). In such environments, there is non-negligible probability that an MN gets off before the public transportation moves to another AR.

Intuitively, if an MN with short boarding time does not conduct instantly the binding update when the MN gets in the public transportation, such unnecessary binding update can be reduced. Based on this idea, we propose a delayed location management (DLM) scheme where an MN postpones its binding update until a pre-defined timer T expires. In DLM, the mobility of the MN is managed by mobile IPv6 (MIPv6) before the timer expiration. On the other hand, after the timer expiration, the mobility of the MN is handled by the MR. Therefore, the packets to the MN are forwarded through MN's HA, MR's HA, and MR. Also, the MN does not need to conduct any binding update when the

☆☆ This work was supported by the R & D program of MOTIE/KEIT [10051306, Development of Vehicular Cloud-based Dynamic Security Framework for Internet of Vehicles (IoV) Services] and National Research Foundation of Korea Grant funded by the Korean Government (NRF-2014R1A2A1A12066986).

☆ A preliminary version of this paper was presented at the 12th EAI International Conference on Heterogeneous Networking for Quality, Reliability, Security and Robustness (QShine) 2016, July 2016 (Ko et al., 2016).

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http://dx.doi.org/10.1016/j.jnca.2016.12.010
Received 27 August 2016; Received in revised form 16 November 2016; Accepted 2 December 2016
1084-8045/

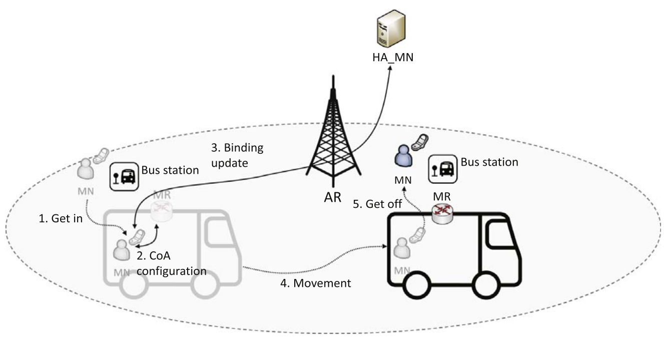

Fig. 1. Example of the wasting binding update.

public transportation handovers to another AR. Note that we only consider the scenario where the MN resides in the public transportation. That is, the procedure after the MN gets off the public transportation is beyond scope of this paper. To evaluate the performance of DLM, we develop an analytical model for the binding update cost and the packet delivery cost during the MN attachment time.[1] By delaying the binding update, inefficient packet routing caused by the NEMO-BS can be diminished[2] (i.e., the packet delivery cost can be reduced). However, if the binding update is excessively delayed, all MNs conduct their binding updates individually whenever the public transportation moves across another AR, and therefore the binding update cost increases significantly. To balance the reduced packet delivery cost and the increased binding update cost, we propose a timer selection algorithm based on the developed analytical model. Evaluation results demonstrate that DLM can reduce the binding update cost and packet delivery cost in a balanced manner by choosing an appropriate timer.

The main contribution of this paper is two-fold: 1) DLM can be implemented with different mobility management schemes (i.e., NEMO-BS and MIPv6) by adjusting the timer value. Accordingly, DLM can achieve adaptive performance optimization in network mobility environment; and 2) extensive evaluation results are presented and analyzed under various environments to assess the performance of DLM.

The remainder of this paper is organized as follows. The related works are summarized in Section 2. The detailed operations of NEMO-BS and DLM are described in Sections 3 and 4, respectively. The performance analysis model and a timer selection algorithm for finding the optimal timer are illustrated in Section 5. Evaluation results and concluding remarks are given in Sections 6 and 7, respectively.

2. Related works

To improve the performance of NEMO-BS, a number of schemes have been proposed in the literature (Qiang et al., 2014; Kim et al., 2005; Cho et al., 2006; Calderon et al., 2006; Chuang and Lee, 2011; Barman et al., 2015; Kabir et al., 2013; Ernest et al., 2016; Nguyen and Bonnet, 2015; Pack et al., 2009). Qiang et al. (2014) suggested an adaptive route optimization scheme which consists of the mobility transparency sub-scheme and the time saving sub-scheme, and a threshold is introduced to determine which sub-scheme is used in the current situation. In Kim et al. (2005), Kim et al. proposed a simple route optimization (*s*-RO) scheme where a correspondent node (CN) maintains binding information of MRs to obtain the optimal path to the MN. Cho et al. (2006) introduced a routing optimization scheme using a tree information option (ROTIO). In this scheme, each MR sends two binding update messages to the top-level MR (TLMR) and its HA, respectively. Then, the packets to the MN in the public transportation are transmitted only through the HA of the MR and the TLMR. Calderon et al. (2006) introduced a mobile IPv6 route optimization for NEMO (MIRON) scheme based on the carrying authentication for network access (PANA) and the dynamic host configuration protocol (DHCPv6) by modifying the software in the MR. Chuang and Lee (2011) proposed a domain-based route optimization (DRO) scheme which incorporates ad-hoc routing techniques and uses a double buffer mechanism to achieve route optimization. Barman et al. (2015) suggested a route optimization method by introducing two new IPv6 extension headers named as anchor point request (APR) and anchor point grant (AGR). Kabir et al. (2013) suggested another route optimization technique by using two CoAs for each MR and two types of entries in the routing table in each MR. To mitigate the sub-optimal routing problem in NEMO-BS, Ernest et al. (2016) developed network-based distributed mobility management (DMM) scheme which decomposes logical functions of the local mobility anchor in proxy MIPv6 (PMIPv6) and distributes the routing management function to the gateway of the different networks. However, the binding update cost for the CoA derived from the MR's MNP is not considered in these works (Qiang et al., 2014; Kim et al., 2005; Cho et al., 2006; Calderon et al., 2006; Chuang and Lee, 2011; Barman et al., 2015; Kabir et al., 2013; Ernest et al., 2016).

On the other hand, Nguyen and Bonnet (2015) introduced a hybrid centralized and distributed mobility management architecture in NEMO which inherits the advantage of DMM while mitigating its drawback in the situation when an MN has a long-lived flow and/or high mobility. However, no optimization method is investigated in this work (Nguyen and Bonnet, 2015). Pack et al. (2009) proposed an adaptive NEMO support protocol where the adaptive binding update is conducted depending on the session to mobility ratio (SMR) in hierarchical MIPv6 (HMIPv6) networks. Also, the optimal SMR threshold is derived to obtain the optimal performance. In so doing, the adaptive NEMO support protocol achieves a better performance than NEMO-BS particularly when the mobility of the public transportation is high. However, the case where MNs get off before the public transportation moves to another AR is not considered in Pack et al. (2009).

3. Background

In this section, binding update and packet delivery procedures of NEMO-BS are introduced.

3.1. Binding update procedure of NEMO-BS

Fig. 2(a) and (b) show the binding update procedures of MN and MR in NEMO-BS, respectively. When an MN gets in a public transportation such as bus, subway, etc. (Step 1 in Fig. 2(a)), the MR advertises its MNP and the MN configures its CoA based on the MNP (Step 2 in Fig. 2(a)). After completing the address configuration, the MN sends a binding update message to its HA (i.e., HA_MN) (Step 3 in Fig. 2(a)). Then, for upcoming movements, the MN needs not to update its location to HA_MN when the MN remains in the same public transportation. On the other hand, when the MR moves to another AR (Step 1 in Fig. 2(b)), the MR configures a new CoA based on the network prefix sent from AR 2 (Step 2 in Fig. 2(b)). After that, the MR sends another binding update message to MR's HA (i.e., HA_MR) for registering the new CoA (Step 3 in Fig. 2(b)).

3.2. Packet delivery procedure of NEMO-BS

Fig. 3 shows the packet delivery procedure of NEMO-BS. When a CN sends packets to the MN, the packets are first transmitted to HA_MN (Step 1 in Fig. 3) and forwarded to the MN's CoA. Since the

[1] To focus on the tradeoff between the binding update cost and the packet delivery cost, we assume that the internal WiFi connection from the MR and the external cellular connection from the AR provide comparable bandwidth and/or connectivity.

[2] If the binding update for CoA based on the MR's MNP is conducted, the packets for MNs in the public transportation are forwarded through the MN's HA, the MR's HA, and the MR. Otherwise, the packets are forwarded only through the HA of the MN.