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Abstract— Fast handoff in network mobility (NEMO) is very crucial for providing uninterrupted Internet services to the users in quickly moving vehicles. However, the NEMO basic support (NBS) protocol takes comparatively long time to complete the handoff process resulting in large number of packet drops. In this paper, we propose fast NEMO (FNEMO) to reduce the handoff latency and packet losses experienced in NBS protocol. FNEMO brings in the concept of IP pre-fetching and advanceregistration to acquire care-of-address for the anticipated future cells. Numerical analysis shows that FNEMO can support higher vehicle speed than that in fast MIPv6 (FMIPv6) and still has significantly low signaling overhead.

Keywords- Network Mobility, MIPv4, MIPv6, FMIPv6, fast handoff.

I. INTRODUCTION

In recent years, providing seamless Internet connectivity to the passengers of fast moving vehicles (e.g., trains, buses etc) has become an active research area [1]-[5]. A vehicle may contain a large number of mobile nodes (MN) forming a network. When the vehicle moves, all MNs in the network move as a single unit, which is referred to as network mobility (NEMO) [2]. The terminal mobility protoc aotoci

II. RELATED WORKS

A. Fast handoff for terminal mobility



Figure 3: Format of announcement packet

B.2 Deregistration

Once the MR has updated its HA, it then sends a deregistration packet to the PAR through CAR. The deregistration packet uses modified IPv6 type 2 routing header (Figure 4) [7]. The IP address of CAR is put in the options field so that the packet first visits the CAR and then goes to the PAR. The rest of the de-registration process follows normal deregistration procedure of the NBS protocol.



Figure 4: Modified type 2 routing header

B.3 IP pre-fetching and advance-registration

When the deregistration process is completed, the CAR derives the FAR using the algorithm shown in Figure 5. The input to the algorithm is the coordinate of neighboring ARs and the output is the coordinate of the FAR. So, the CAR can easily find out the IP address of FAR from table of binding (Assumption 4 in Section IIIA). Then, the CAR sends a packet to the FAR requesting for CoA allocation. The format of the packet is same as HI packet [9] and uses a new one-bit field M and a new option where necessary information for registration is included to perform advance registration (Figure 6). If M=0, it indicates that the packet is sent from the CAR on behalf of the MR. If M=1, it indicates that the packet is sent by the MR. The reply from the FAR contains the assigned CoA. The format of the reply follows the format of HAck [9] and uses a new one-bit field M (Figure 7). The value of M is copied from the CoA request packet (Figure 6). Then, the CAR forwards the allocated CoA to the MR (Figure 8), which sets it as FCoA². For this purpose, the format of FBack [9] is modified to include a one-bit field M. The value of M is copied from the reply packet (Figure 7). The sequence number is copied from the announcement packet of Figure 3. The mobility options contain the IP address of the FAR.



² If IP pre-fetching fails, then, on entering the new cell, the MR sends an announcement packet with A bit set to 0 which signifies that the MR is not assigned CoA in the current cell. The assignment of CoA then follows the normal procedure of NBS protocol.

Figure 5: Algorithm for finding FAR

Figure 6: Request for CoA

Figure 7: Reply from FAR

Figure 8: Reply from CAR to MR

IV. PERFORMANCE ANALYSIS OF FNEMO

To analyze the performance of FNEMO, we follow the approach presented in [11]. In particular, we provide analysis for finding maximum speed of a vehicle, V_{max} , signaling cost incurred by the protocol, handoff latency, and packet loss to perform fast handoff. The model used in our analysis is shown in Figure 9. In Figure 9, Q_P , Q_C , and Q_F denotes the past, current, and future cell, respectively. The Points A, B, and C are the position of the PAR, CAR and FAR respectively. The point E and I are the midpoint of the overlapping region between Q_P and

$$x \quad 2r^* \sin \cos^{-1} \frac{1.732^* c \quad 4r^2 \quad 3c^2}{4r} \tag{8}$$

 $c \quad \frac{2}{3}r \tag{9}$

and,

$$d_h = \frac{d}{2} * \frac{1 \cdot 10^{\frac{h}{k}}}{1 \cdot 10^{\frac{h}{k}}}$$
 (10)

where k is the environment specific attenuation characteristics [11].

Figure 9: Reference diagram used for analysis

We assume that the vehicle is in cell Q_c and the MR has completed the deregistration process. The CAR should request for new FCoA at point G and the MR should finish updating the HA by point K for successful handoff to cell Q_F . Let us denote by *T* to be the time taken by the MR to update the HA. Now, the distance between G and K is:

$$|\mathsf{GK}| = |\mathsf{GH}| + |\mathsf{HI}| + |\mathsf{IK}|$$
$$= 2r \quad 2x \quad \frac{x}{2} \quad d_h$$

Using Equation (10) we get:

 $t = \text{delay for FCoA request packet to reach FAR from CAR + delay for the packet containing FCoA to reach CAR from FAR + delay for forwarding FCoA to MR from CAR + time required for the MR to update its HA So, we have$

$$t \quad T \quad m \quad 4n$$
 (12)

Hence, we can write:

$$V_{\text{max}} = \frac{|GK|}{t}$$
 (13)

Putting the values of /GK/ and t from Equations (11) and (12) respectively, and simplifying we get,

$$V_{\text{max}} = \frac{2r}{2} \frac{3}{2} \frac{d}{2} \frac{1}{2} \frac{1}{1} \frac{10^{k}}{\frac{h}{2}} \frac{1}{1} \frac{10^{k}}{\frac{1}{10^{k}}}$$
(14)

Equation (14) describes the relation between maximum speed of a vehicle, minimum required cell size, and the size of the overlapping region.

For FMIPv6 in predictive mode, let us define W_{max} to be the maximum speed allowed. For handoff from cell Q_C to cell Q_F, the MR sends RtSoIPr packet at point K and receives FBack at point J. The distance covered during this interval, z, can be given as:

$$z \quad \frac{x}{2} \quad d_{h}$$

$$\frac{x}{2} \quad \frac{d}{2} * \frac{1 \quad 10^{k}}{\frac{h}{k}}$$
(15)

The time, *t*, needed to perform the handoff operation is:

t = m (for RtSolPr) + m (for PrRtAdv) + m (for FBU) + 2n (for HI) + 2n (for HAck) + m (for FBack) So, we have

$$t - 4m - 4n$$
 (16)

Thus, the maximum speed allowed in FMIPv6 is:

$$\max \frac{-}{t} = \frac{\frac{x}{2} + \frac{d}{2} + \frac{\frac{h}{2}}{\frac{h}{2} + \frac{1}{2} + \frac{h}{2}}}{\frac{1}{2} + \frac{h}{2}}$$



Figure 10: Variation of maximum speed with cell radius

Let us define T_{FMIPv6} and T_{FNEMO} as the time required for CoA assignment process of FMIPv6 and FNEMO respectively. T_{FMIPv6} is lowest when the speed of the vehicle is within the maximum allowable speed, W_{max} , so that the handoff process is successfully completed within the overlapping region. When the MR could not receive the FBack within the overlapping region, then it has to send a FBU again in the new cell and as a result, HI and HAck are exchanged again between the CAR and the FAR. This situation occurs when the speed of the vehicle is more than W_{max} but less than or equal to $\frac{2}{2m}$. In this case, T_{FMIPv6} includes the delay in link layer

handoff,

Let us denote the signaling cost for FMIPv6 and FNEMO by C_{FMIPv6} and C_{FNEMO} , respectively. The signaling costs include the cost for updating the HA. Let us assume that the cost for updating the HA is *T*. Also, in FMIPv6 there is a binding update procedure to update the CN. For the sake of simplicity, let us assume that the cost for updating the CN is also given by *T*. Thus, we have the following Equations for the signaling cost in FMIPv6 and FNEMO.

$$C_{FMIPv6} \quad T_{FMIPv6} \quad 2T \tag{20}$$

$$C_{FNEMO} \quad T_{FNEMO} \quad T \tag{21}$$

Figure 11 shows the signaling cost as the speed of a vehicle changes in a cell with radius r=60m. The FNEMO exhibits a constant signaling cost 114ms for vehicle speed 0 to 951.2 km/h. As the vehicle speed becomes more than 951.2 km/h, the signaling cost increases to 162ms. After that, increase in vehicle speed does not affect the signaling cost. For FMIPv6, however, the signaling cost increases as well as decreases with increase in speed of the vehicle. The first change (point a in Figure 11) occurs when the MR could not receive FBack resulting in exchange of FBU, HI, and HAck packets. The second change (point b) occurs when the MR could not send FBU. We note that, in this case, the signaling cost is decreased because no additional HI and HAck packets are exchanged. The third change (point c) occurs when the vehicle could not send the RtSoIPr from the overlapping region. After this change, the signaling cost no longer changes even if the speed of the vehicle increases.



will be same. However, if the speed increases beyond

For FMIPv6, no packet loss occurs when the speed of the vehicle is within W_{max} . When the vehicle speed is between W_{max}

and $\frac{z}{2m}$



Figure 13: Variation of packet losses with speed of vehicle

V. CONCLUSIONS

In this paper, we have proposed a modification of NBS protocol, called FNEMO, to improve the handoff performance. FNEMO utilizes the concept of IP pre-fetching and advance-registration to perform handoff operation with reduced delay and packet losses. The analysis presented in this paper clearly shows that the signaling overhead is very low for FNEMO compared to FMIPv6. Further, in comparison to FMIPv6, FNEMO can support higher vehicle speed, making it suitable for deployment in high speed vehicles.

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