Network Mobility in MIPv6 Considering Arrival Time

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Abstract. Mobile IPv6 represents a global solution, providing mobility management for a wide variety of radio technologies, devices, and applications. In particular, Network Mobility basic support protocol is the one of fundamental solutions in MIPv6 which reduces the number of binding update messages issued from mobile network nodes except mobile routers. That is, it never reduces the number of binding update messages which mobile router issues. Significant research results relating to Network Mobility have been reported over last several years. However, practical and common issues exist within the technology; specification of Binding Update Lifetime has a substantial impact the system performance. The binding update message should be delivered periodically for the purpose of user location notification and binding authorization. If the lifetime is too short, the traffic load resulting from the messages may be significant. In addition, issues related to authorization can be problematic. In this paper, therefore, Network Mobility considering arrival time is devised to solve the binding update explosion of mobile routers without security problem in Network Mobility.

Keywords: network mobility, binding update, mobility type, kcredit, arrival time, mean resident time

1 Introduction

Mobile IP[1, 2] is recognized to be a promising solution for mobile communications including cellular backbone. In Mobile IP, *home agent (HA)* located in the home network manages mobile' s location and forwards packets destined to the mobile in the visited network. IETF has commissioned *NEMO (NEtwork MObility)* working group[3] to extend the existing protocols or develop new ones to support network mobility in an IPv6 network[4]. Among several kinds of issues in NEMO, we take an interest in a *binding update message (BU)* management which *Mobile Router (MR)* transmits to its HA and relevant *correspondent nodes (CNs)*. A MR sends BU message to its HA and CNs each time it changes its point-of-attachment. Figure 1 shows BU explosion of mobile network. *Local Fixed Node (LFN)* is permanently located in a mobile network and *mobile network node (MNN)* can be attached to mobile network [4, 5]. MR is a border router of a mobile network and CNs are all no-

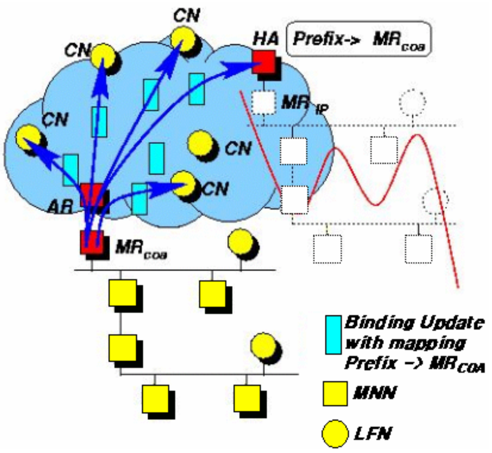

Fig. 1 Binding Update explosion

des communicating with MR, LFNs and MNNs. If the lifetime of BU is set too short , HA quickly detects that the MR is disconnected from the network. It, however, needs a lot of BU messages transmission over, which overburden processing overload on HA and deteriorates wireless bandwidth utilization. In addition, transmission of BUs from MR to a large number of CNs would cause a BU explosion. To suppress those BUs, only multicast delivery BUs has been proposed. Like this, multicast delivery of BUs for large mobile networks an innovative trend. However, MR should still send multicast delivery BU frequently to the number of CNs. Conversely, when BU message with long lifetime is received, HA and CNs keep it in a binding cache until the lifetime expires. Therefore, the number of BUs decreases and overhead for the messages is also reduced. However, issues relating to authorization can be problematic in terms of the current *return routability for network prefix* mechanism. The binding record will eventually occupy more space in both data structures-the *Binding Cache* and *Binding Update List*-of MRs [2]. As a result, a scheme is required to obtain the proper lifetime value, considering both the cases.

The authors in [6] propose a secure and lightweight extension of return routability in *Mobile IPv6 (MIPv6)*. The lifetime value can be long (upper bound is 8 hours). Thus, signaling can be reduced and the MN is not required to wake up as frequently. However, it is assumed that MN is a stable node, which may become an issue. If some information containing each MR's mobility pattern is known in advance in NEMO, an unreasonable assumption can be removed. Thus, we consider some kinds of vehicle (e.g. bus, train, airport etc.), which have uniform movement pattern for some networks. If the information related with each vehicle's past movements is maintained locally and is available, we can guess the current resident time considering arrival time and thus the proper MR's BU lifetime can be given whenever the vehicle enters a network. To do so, a MR records a kind of log whenever it leaves a network. It periodically computes the binding lifetime values for all its visited networks and maintains them in its profile. When the MR moves into any network after forming the profile, if there is any record for the network in it, an adaptive lifetime is applied to the BU lifetime.

2 Binding Management Scheme

Return Routability for Network Prefix (RRNP) procedure: NEMO requires periodic RRNP procedure and the reestablishment of the binding at the CN [7]. This authorization should be performed every 7 minutes. It can represent a burden for MRs, which have the binding ready for a possible packet but are not currently communicating. This can be problematic for a MR in standby mode. To solve the problem, we include the Lifetime Credit Authorization option [6] in the BU and *Binding Acknowledgement (BA)* of which the content is based on the binding management key (*Kbm*) [2].

Instead of a fixed limit (7 minutes), the MR can continue to use an existing address test longer than the time already been reachable at this address. To authorize this, a keyed hash using the next key credit (*Kcredit*), must be provided and calculated as follows:

$$Kcredit = hash(Kbm_N \mid hash(Kbm_{N-1} \mid hash(Kbm_{N-2} \mid \ldots Kbm_1)))$$

here | denotes concatenation and Kbm_1 through Kbm_N are used to calculate the Binding Authorization Data option in the BU and all subsequent BUs. The next *Kcredit* is calculated based on the previous *Kcredit* and the latest *Kbm*. The MR and CNs should both hold some state in the binding cache entries, related to the credit authorization. The following conceptual information must be kept: The total time of binding for MR's home address, the current *Kcredit* value and the number of *Kbm* values is included in the *Kcredit* value.

Binding Update Messages: A binding for a MR is all fours that contain the home address, CoA, network prefixes and the binding lifetime. In this paper, three kinds of BU messages are used according to the lifetime.

(1) BU_α has a default lifetime (LT_α) of BU, which is the same value as one used in existing MIPv6 [2]. After switching to new domain, a MR should send BU_α to its HA and CNs, asking it to direct all incoming packets to new CoA.

(2) BU_β has an adaptive lifetime (LT_β) and *Kcredit* value of BU, which is computed based on local profile. A MR has to transmit it to its CNs. This value is the total time which will keep the current binding for MR's home address. The number of *Kbm* is the result that this value is divided by 3.5 minutes [2]. *Kcredit* value is calculated by using these values.

(3) BU_0 contains zero lifetime value (LT_0) of BU. When a MR migrates to a network in another domain before BU_β has expired, it will be used to notify CNs that the cached data about BU_β has become stale and thus they have to remove the data.

That is, BU_α and BU_0 are originally used in MIPv6 but BU_β is newly devised in this paper. BU_β will be used only where the guessed resident time is longer than a threshold value.

Proposed Scheme: Vehicles (train, bus and airport, etc) have uniform movement path in some networks. When a MR in them leaves a network, information (*moving log*) regarding the visit, is recorded. The log contains an ordered pair (*l, AT, DT*), which means network identifier, arrival time and departure time, respectively.

```
// Whenever a MR moves out a network.
// $Count_b$:Threshold of Count
If(MN have visited network m){t=$DT_n$-$AT_n$
If(t >$\rho$*$LT_\alpha$){Record moving log
            $Count_m$ = $Count_m$ + 1
            $Sum_m$ = $Sum_m$ + $t_n$   }   }
```

```
//Periodic calculation
//LT:lifetime
Mean=Sum/$Count_m$
For(all moving logs to network m){Calculate $Var_m$}
                                          //equation (1)
If($Count_m$<$Count_b$)LT=$LT_\alpha$
Else{If($Mean_m$<=$\rho$*$LT_\alpha$ or'mobility type I')LT=$LT_\alpha$
      Else{$LT_\beta$=$Mean_m$*V
           LT = $LT_\beta$      }      }
```

Fig. 2 Lifetime calculation algorithm

The average resident time and the frequency of logs in network are considered when the adaptive lifetime (LT_β) is calculated. When the MR moves from network *m* to another, it adds current information to a moving log. The average resident time for all visited networks is periodically calculated and the algorithm is described in Fig. 2. At first, the resident time (t_n) for n^{th} visit to network *m* is computed by just subtracting the AT from the DT. The comparison of t_n and $\rho * LT_\alpha$ is used to exclude the moving log where the resident time is small (that is, the case where a MR recently passed by the network for a moment while migrating to a specific destination). It is assumed that t_n is compared with ρ (≥ 1) times as long as LT_α. Sum_m and $Count_m$ mean total resident time and total visit number to network *m* respectively. During the calculation, if the number of visits to network *m* is less than a constant value ($Count_b$), BU_α will be used since poor (or no) regularity is found in network *m*. The variance as well as the average resident time in this case is considered. To begin with, the movement patterns for all networks in the profile are divided into ***mobility type R*** and ***I*** to present the degree of accuracy the profile. To quantify the difference, the variance is calculated for all networks as Eq. (1):

$$Var_m = \frac{1}{n}\sum_{i=1}^{n}(t_i - Mean_m)^2 \qquad \textbf{(1)}$$

If Var_m is smaller than constant δ, network *m* is classified as *mobility type R* (the reliable network). Otherwise, the network belongs to ***mobility type I*** where the profile cannot give reliable information. The lifetime value for the next BU is calculated by multiplying the mean resident time by the constant *V*. The calculated value, LT_β, will be used as the lifetime for BU_β when the MR visits network *m* after creating the profile.

The resident time for some networks often depends on the arrival time. In this way, we devise a scheme which considers the time region of the arrival time to enhance the accuracy of the profile.

During periodic calculations, the mean resident time per (*network ID, arrival time region*) pair must be considered, not simply the network. To do so, a scheme to determine the arrival time regions from moving logs is required. Five different cases are considered as shown in Fig. 3. The following information is also maintained in the profile per arrival time region:

- AT_{mn}^{high}: the highest (or latest) arrival time
- DT_{mn}^{low}: the lowest (or earliest) departure time
- $Count_{mn}$: the number of visits included in the n^{th} arrival time region
- $TotalCount_{mn}$: the total number of visits considered in the n^{th} arrival time region

where subscriptions n and m represent n^{th} arrival time region to network m. Since the arrival time region is considered as well as the visiting network, each arrival time region maintains its visiting number ($TotalCount_{mn}$, $Count_{mn}$) separately.

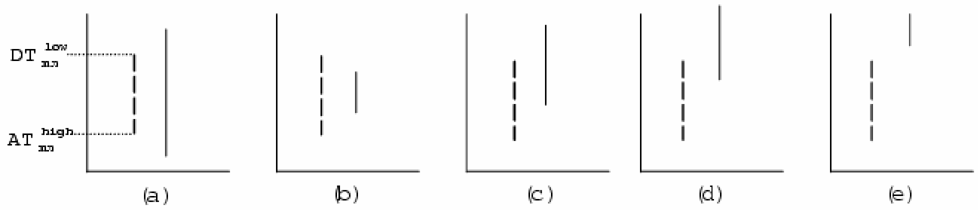

Fig. 3. Various Cases of Visiting Time

In the figure, the vertical dotted line represents the time interval ($Interval_{mn}=DT_{mn}^{low}-AT_{mn}^{high}$) that one arrival time region calculated. The solid line presents the current visiting time. In the case of Fig. 3-(e), it is natural to exclude a new visit from the arrival time region. Visit in Fig. 3-(a) or (b) requires to verification of the MR resides too long or too short in the network. If the resident time is longer than $3/2\times Interval_{mn}$ or shorter than $1/2\times Interval_{mn}$, the difference between both grows too long and thus, the current visiting log cannot provide reliable information. That is, the log is completely excluded; the log is not too long, the log is also used in periodic calculations. Not only the length of resident time but also the time that a MR has arrived must be considered. Figure 3-(c) and (d) initially appear to be similar cases. However, if both are considered, the arrival time region does not provide useful information. Thus, the following process is required for an accurate determination.

```
middle = $Interval_{mn}$ /2
if (middle ≥ arrival time of current visit)
the current log includes the $n^{th}$ arrival time region
else the current log is excluded
```

Then, if the current log is included into n^{th} arrival time region of network m, $Count_{mn}$ and $TotalCount_{mn}$ both increase by 1. Otherwise, only $TotalCount_{mn}$ increases by 1 (Fig. 3-(a) and (b)) since this variable will be used to determine the accuracy of the profile. If the arrival time in the current visit is earlier than AT_{mn}^{high}, it is enough to be considered contrary to the cases shown in Fig. 3-(c), (d), and (e). The moving log excluded from the above algorithm will be used to form another arrival time region, except the regions described in Fig. 3-(a) and (b). After arrival time regions are determined using this method, both comparisons between ratio $Count_{mn}$ and $TotalCount_{mn}$ and Var_m are required to evaluate the usefulness of the information regarding the arrival time region. That is, if Var_m is smaller than δ and $Count_{mn}/TotalCount_{mn}$ is larger than γ, the arrival time region to network m is regarded as ***regular mobility type***. In the other cases, it is considered that without regularity (***irregular mobility type***).

3 Performance Analysis

Simulation Model: The simulation model for the scheme is depicted in Fig. 4. Each MR collects log data that contain (l, AT_n, DT_n) whenever it leaves a visited network. It is assumed that the resident time at any network follows Gamma distribution [8] with shape parameter α. As it is generally known, Gamma distribution is selected because it can be shaped to represent various distributions as well as measured data that cannot be characterized by a particular distribution.

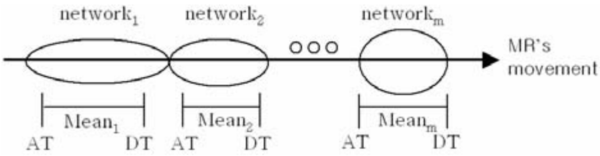

Fig. 4. Simulation Model

Equations (2), (3), and (4) describe the density function for resident time, the mean resident time at a visited network and the variance for the resident time distribution, respectively, where t is the resident time at each visited network.

$$f(t) = \frac{\lambda^\alpha}{\Gamma(\alpha)}(\lambda t)^{\alpha-1}e^{-\lambda t}, t \geq 0 \tag{2}$$

$$E(t) = \frac{\alpha}{\lambda} \tag{3}$$

$$V(t) = \frac{\alpha}{\lambda^2} \tag{4}$$

It is important to note, however, that the resident time follows an exponential distribution where parameter $\alpha=1$, $\lambda=1/E(t)$ in Gamma distribution. The results are shown as the amount of bandwidth allocated by those messages.

All parameters of our experiments are presented in table 1. The constant parameters defined in previous section are first described in the table where ρ and $Count_b$ are used to check whether to consider the current movement log or not, and δ and γ to defermine mobility type of the network. The values are selected from various experiment settings however they will not affect the overall performance since both scheme and NEMO treat diconnection in the same manner. *V* mean the weight value for the calculated lifetime of *regualr mobility type*.

Table 1. Parameter Settings.

Parameter	Value	Meaning
ρ	2	
$Count_b$	10	Threshold of Count
δ	10	Constant value to determine regular type
γ	0.8	Constant value of $Count_{mn}/TotalCount_{mn}$ for regular mobility type
V	1.0	V value for regular type
κ	0.3	Intra-domain moving rate

The Results: In Eq. (5) and (6), BW_{NEMO} and BW_{PRO} mean the amounts of the allocated bandwidth for BUs in NEMO and the proposed scheme, respectively. $Size_{BU}$ is defined as the size of a BU (88bytes = IPv6 header (40bytes) + Binding Update Extension Header (28bytes) + Mobile Network Prefix Option (20bytes)) [7, 4]. f_{HA} is denoted as the BU emission frequency from the MR to its HA and f_{CN} is the average BU emission frequency from the MR to its CNs. When a MR migrates, κ represents the intra-domain moving rate. The domain-crossing rate is 1-κ, meaning the number of crossing domains divided by the total number of crossing subnets. The MR transmits *M* consecutive BUs to its external CNs, and transmits another BU to its HA, receiving a BA from HA.

In Eq. (5), *#CN* is the number of the current CNs which are not on the MR's home network. When a MR migrates along networks, it transmits a BU to each CN and to its HA equal to f_{CN} and f_{HA}. In Eq. (6), if the profile information proposed in this paper can be used, the refreshment frequency may be reduced to f_{PRO}.

$$BW_{NEMO} = Size_{BU} \times \{\kappa \times (f_{CN} \times (\#CN+1)+f_{HA})+(1-\kappa) \times (M \times \#CN+2)\} \tag{5}$$

$$BW_{PRO} = Size_{BU} \times \{\kappa \times (f_{PRO} \times (\#CN+1)+f_{HA})+(1-\kappa) \times (M \times \#CN+2)\} \tag{6}$$

$$BW_{NEMO\_multi} = Size_{BU} \times f_{NEMO\_multi} \tag{7}$$

$$BW_{PRO\_multi} = Size_{BU} \times f_{PRO\_multi} \tag{8}$$

In Eq. (7) and (8), BW_{NEMO_multi} and BW_{PRO_multi} show the amounts of the allocated bandwidth for multicast delivery BUs in NEMO and the proposed scheme, respectively. $Size_{BU}$ is the same as one described above. f_{NEMO_multi} and f_{PRO_multi} are the multicast refreshment frequency in NEMO and the proposed scheme, respectively.

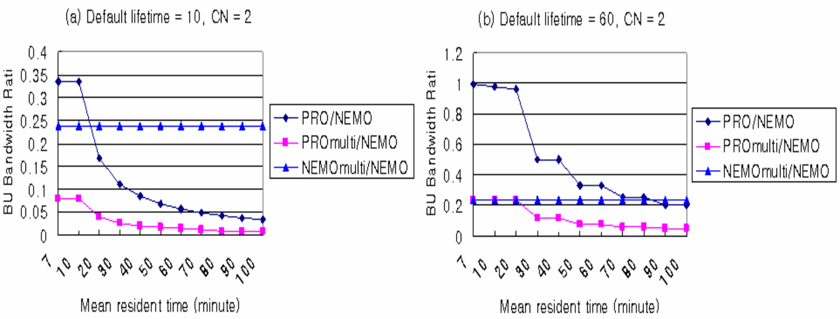

Fig. 5. The comparison of BU bandwidth in Gamma distribution in case of CN=2.

Figure 5, 6, 7 and 8 represent the comparison between the proposed schemes(*PRO, PROmulti*) and NEMO(*NEMO, NEMOmulti*) in Gamma and an exponential where the mean resident time varies from 7 to 100 minutes and variance is set to 0.01. When It is assumed that a MR migrates as *regular mobility type* in 30% of the all networks recorded in the profile, *irregular mobility type* in the remaining 70%. As mentioned in Section 2, the networks recorded as *regular mobility type* provide reliable information for their subsequent visits than those with *irregular mobility type.* BU bandwidth depends on *#CN*, f_{HA}, f_{CN}, $f_{PRO,}$ f_{NEMO_multi} and f_{PRO_multi}. The behaviors of the BU bandwidth are almost identical, when variance is 0.01 and 0.1. Figure 5 and 6 represent only results where variance is 0.01. In the figure, the Y-axis value is a relative value comparing the schemes. That is, if the value is smaller than 1.0, the proposed schemes save more bandwidth than the other schemes. At first, it is known that variance has little influence on overall performance. The reason is as follows: Vehicles have irregular movement patterns and variance is one of the factors that affect irregularity. Thus, the profile is used to capture reliable information unaffected by the factors, i.e., variance.

From Fig. 5-(a), ratio of PRO to NEMO decreases as mean resident time increases. In case where mean resident time=50, only 10% of messages are required with PRO compared with NEMO. Ratio NEMOmulti to NEMO shows a fixed value as the mean resident time increases since both are never benefited from the profile. However, ratio PROmulti to NEMO decreases near to 0 as mean resident time increases.

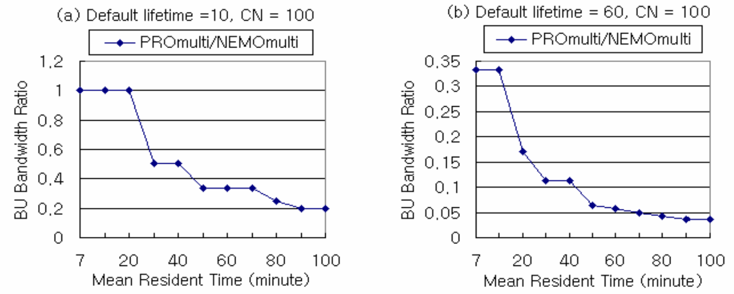

Fig. 6. The comparison of BU bandwidth in Gamma distribution in case of CN=100.

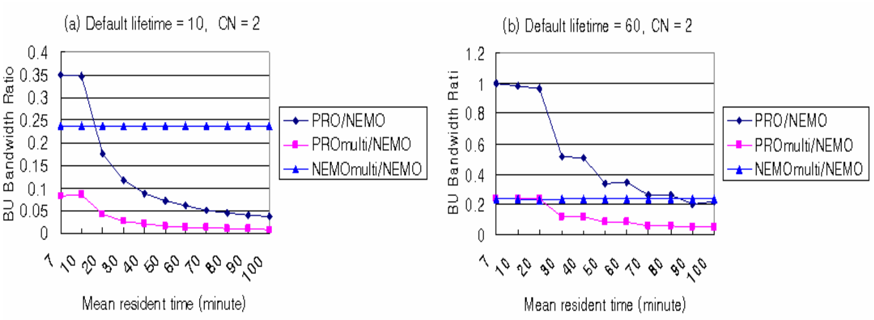

Fig. 7. The comparison of BU bandwidth in an exponential distribution in case of CN=2.

Figure 5-(b) shows the results when LT_α is set to 60 seconds. In the figure, ratio of *PRO* to *NEMO* decreases less than that in Fig. 5-(a). This indicates that the BU bandwidth ratio is affected by the longer LT_α. Namely, the amount of BU for all schemes generated much less than that in Fig.5-(a). Thus, we come to know that bandwidth usage in the *PRO* is the more efficient than the NEMO from Fig. 5. In addition, the *PROmulti* is also the more efficient than the *NEMOmulti*.

In Fig. 6, it is described ratio of *PROmulti* to *NEMOmulti* when #CN =100. As the number of CN increases, multicast BU frequency in *PROmulti* and *NEMOmulti* is not affected by the number of CN. However, both are affected by the lifetime. Where mean resident time is 40 minutes, *PROmulti* requires 50% of messages in Fig 6-(a) and only 12% of messages in Fig 6-(b), compared with *NEMOmulti*.

The reason is that *NEMOmulti* BUs are transmitted to its HA and CNs when the MR is roaming but the *PRO* only transmits the BUs to refresh time is also lengthened if a long resident time is computed for the current location from the profile. There may be differences between the computed lifetime and real resident time. In spite of this, the level of reduced bandwidth is substantial, in networks where MRs are determined as consisting mainly of *regular mobility type*. In particular, when a MR does not migrate across domains frequently, most of the signaling load is generated by the refreshing BUs. The central improvements proposed in this paper, are achieved by decreasing

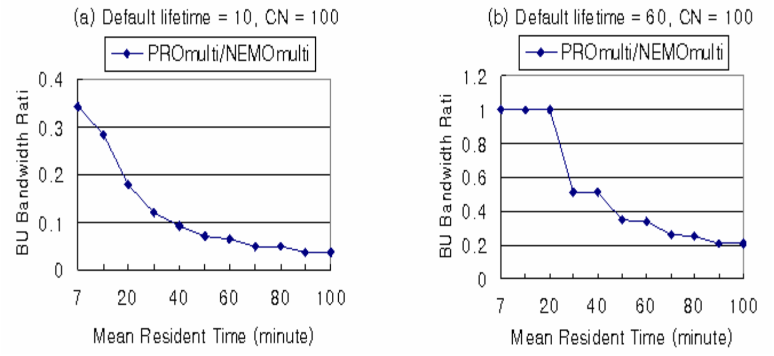

Fig. 8. The comparison of BU bandwidth in Exponential distribution in case of CN=100.

the number of periodic refreshing BUs. Figure 7 and 8 represent the comparison between the proposed schemes(*PRO, PROmulti*) and NEMO(*NEMO, NEMOmulti*) in an exponential distribution where the mean resident time varies from 7 to 100 minutes. The behaviors of BU bandwidth ratio in Fig. 7 and 8 are almost identical with those in Fig. 5 and 6. That is, the function of the resident time distribution rarely has an influence on the overall performance.

As a result, in case of the MR has a *regular mobility type*, it is important to note he re that the mean resident time can be much longer than LT_α in reality. The MRs, therefore, will only transmit a small number of messages. Although the MR migrates regular, the default mechanism in NEMO will be used and thus there is little additional overhead. Thus, the efficiency of the proposed schemes can improve over the results presented in this paper.

4 Conclusion

In this paper, network mobility considering arrival time is proposed in MIPv6. The overhead incurred by frequent BUs is reduced, by capturing some regularity in movement patterns of each MR. That is, from the MR's arrival time as well as average resident time in visited networks, the adaptive lifetime is computed and applied dynamically. The main contributions in this paper, are allowing limited wireless bandwidth to be utilized effectively, and greatly improving the efficiency in the MR, by reducing the amount of BU messages. However, the correctness of the profile is required for more in depth analysis, to ascertain the effects of each parameter through data mining algorithms since the proposed schemes are based on local profiles.

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