# Network Mobility Management based on NEMO/MobileIPv6-MIB

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***Abstract*** - For conventional network management it is implicitly assumed that the managed object will not change its location. So only the static information is available, which is used for simple reporting. The scenario is quite different with mobile devices, as devices are inherently dynamic. It causes difficulties for monitoring processes of management information due to roaming of devices or wireless signal errors. So it has become imperative to review the current approach of network management. To overcome this problem, we propose a new network management technologies based on standard network management protocol. Our focus in this paper is mainly on two items: (i) location awareness, and (ii) intelligent monitoring scheme. Here, we explained about MobileIPv6/NEMO-MIB, which is aware of mobile device's dynamically changing location. We have also discussed the monitoring scheme of network management infomation in detail.

***Keywords***: MobileIP, NEMO, IPv6, SNMP

## 1 Introduction

Location of managed object is implicitly assumed as static for traditional network. The location related information, if available is static and its use is limited to reporting purposes. However, with mobile devices these attributes are inherently dynamic. So, it is important for network management to understand the dynamics of location of devices for planning, administering and controlling a network. When planing, distribution or managing configuration of parameters in mobility protocols, density, roaming frequency and visiting duration of devices in the network are the important piece of information. So it is essential to review the current approach of management and further reconsideration is required for configuration, operations, performance and security management.

The basic concept of *reachability* has changed due to the introduction of mobility of devices. An IP network can be connectionless and the routes may change dynamically. But in conventional thinking, under normal circumstances network devices are considered to be reachable. The same assumption is extended to the manager-agent management framework as well. In monitoring process, polling at a regular interval is conducted to collect management information. This interval is generally set larger than the response time, so that the time stamp of the polling request or the response can be considered as the time-stamp of the information.

There is a wide fluctuation of response time in mobility aware networks due to the instability of reachability and this can cause severe degradation of quality of collected information. Though there are certain conveniences of network mobility, considering NEMO environment, but optimized route can not always be used. In that case, the amount of polling traffic could be substantial. With available bandwidth for wireless network is usually narrow, it can cause severe network congestion on certain links. In this paper, we propose a network management framework, which takes into consideration the inherent dynamic nature of location and the instability. The rest of the paper is structured as follows. In Section 2 we describe the problem statement. In Section 3 we presents our proposal on MobileIPv6/NEMO-MIB and two monitoring schemes. Evaluation is discussed in Section 4 and in Section 5 we conclude our work.

## 2 Problem Statement

### 2.1 Network Model

MobileIPv6[1] and NEMO (Network Mobility Support)[2] realize node and network mobility in IPv6 Internet.

The MobileIPv6 architecture is described in terms of three types of entities: mobile node (MN), correspondent node (CN) and home agent (HA). When a MN roams from one network to another, the IP address changes. This address is called Care-of Address (CoA). Each MN has its own IP address authorized by its home network, and called Home Address (HoA). When CoA of MN changes, MN registers it to HA with HoA. HA maintains the registered CoA/HoA sets of MNs. It is called *binding cache*. When packets from CNs destined to HoA come, HA forwards them to the registered CoA.

NEMO is a simple extension of MobileIPv6, adding an entity called mobile router (MR). A MR is basically a router with the additional functionality of mobility support that normal routers does not have. A MR registers its network prefix to the binding cache. The prefix is called Mobile Network Prefix (MNP). Nodes connected to MNP can have mobility with MR.

In this paper, we call MN and MR as *mobile devices*. Both MobileIPv6 and NEMO enable global mobility of mobile devices with no restriction of area.

## 2.2 Needs of New Management Framework

Generally management of network devices is carried out by monitoring or setting the value of a "Managed object(MO)". MOs are accessed by SNMP. The traditional SNMP-based network management adopts *manager-agent management framework*. Agents that employ MIBs are monitored by a manager or managers using SNMP. Fig. 1-(a) shows the overview of this framework. Fig. 1-(b) describes two additionally needed extensions, to take into consideration the inherent dynamic nature of location and the instable nature of network reachability.

First, for all practical purposes, the scope of the concept of location in traditional network management has been limited to the "sysLocation" in the MIB-II [3] that is the MO provided static descriptive value. The traditional MIB-II is insufficient for managing dynamic nature of location because the location of a device changes dynamically in networks that support mobility. So the new MIB should be aware of inherent dynamic nature of location of devices. Thus *location-aware* MIBs will be needed. Main concern is the concept of location of the mobile device, and how to monitor and track the device locations monitored continuously especially in MobileIPv6/NEMO environment. In section 2.3 we consider about how to monitor the location of the mobile devices.

The second need is to overcome the instable nature of network reachability. Monitoring process is crucial for many types of management information, because the change in the values of the MOs with time is of key interest. Monitoring performance of mobility protocols, mobile devices and applications on the devices is an important aspect of network management. Location information also should be monitored. It is important to carry out periodical and continuous polling precisely. But the wide fluctuation of the response time between the manager and the agents caused by roaming of the device is unavoidable. The transient failure of wireless links will cause many packet losses. SNMP polling suffers from lots of polling timeout and they degrade the quality of collected management information. It is difficult to maintain a simplified monitoring process. Monitoring process should be more *intelligent* to overcome instability of the reachability. In section 2.4 we consider about this problem and propose a novel technology for continuous device monitoring over an instable network.

The new dimensions, *location-awareness*, and *intelligent monitoring scheme*, added to networking by mobility require extensions to the traditional network management framework.

## 2.3 Location-awareness

We classify the concept of location of a mobile device based on these three aspects:

Organizational Location: the administrative domain to which the mobile device belongs.

Segment Location: the subnetwork to which the mobile device is attached.

Geographical Location: the longitude, latitude, altitude information of the mobile device.

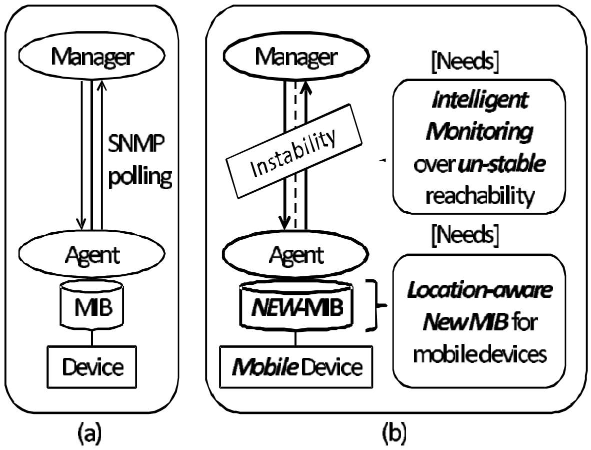
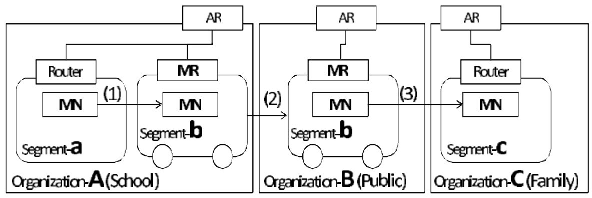



Figure 1: Manager-Agent management framework using SNMP (a)Traditional management: Manager monitors device's MIB. (b) Extensions needed: 1) new location aware MIB of mobile device and 2)intelligent monitoring scheme that realize monitoring over instable reachability.




| Location of Device | Organization | Segment | Geographic |
|---|---|---|---|
| Type-(1) | Unchange (A->A) | *Change(a->b)* | *change* |
| Type-(2) | *Change(A->B)* | Unchange(b->b) | *change* |
| Type-(3) | *Change(B->C)* | *Change(b->c)* | *change* |

Figure 2: Three types of location changes in a mobile node: Organization/Segment/Geographical location changes occur separately.

In the traditional network, all aspects of location of a device are fixed. Fig. 2 describes three separate scenarios of location changes for mobile devices in MobileIPv6/NEMO network environment. We can see that device and network mobility allows three different location aspects to change independently.

In scenario type-(1) the MN moves from a segment under a router (inside the school) to the other segment which is under the MR (mobile router deployed inside the school-bus) within the same organization (school network). In type-(2) the MN itself does not move, the MR leaves from one organization (school network) and connects to the other organization (public network). In type-(3) the MN moves from the segment (school-bus network that attaches to the public network) to another segment that belongs to the different organization (family network).

As described above, these location changes occur dynamically and independently, sometimes without user's intention. Looking current locations of mobile devices enables managers to get the current view of their managing devices, and the network.

### 2.4 Intelligent monitoring scheme

It is important to carry out periodical and continuous polling precisely in monitoring process. However, in general the concept of "time" in traditional monitoring does not have an exact definition.

As Fig. 3-(a) shows, in some cases it is the time when the request was sent by a manager. In others it is the time when the response is received. It is considered to be an unnecessary overhead to tag every observation with the actual time of the observation. In traditional networks the RTT between the manager and the monitored agent is generally of the order of 10ms. On WLANs it can goes upto the order of 100ms. The polling interval $t$ is of the order of several seconds. So, the inaccuracy introduced in the time-stamp may be considered to be negligible. But in a mobility-aware network, the RTT may vary widely. Typical latency of hand-over within same wireless access media is 300-500ms (L2 movement), and at least 3 seconds (L3 movement) [4] without any optimization. Thus information collection by polling at *regular intervals* in the traditional mode may cause an accuracy degradation of periodical information. Additionally, a traditional SNMP manager uses RTT information to fix the polling timeout. In the case of periodical polling, this approach results in a large number of timeouts and consequent data loss in data collection. This causes severe degradation in the quality of collected information.

To overcome these problems, we already proposed the *timestamped monitoring technique*. Fig. 3-(b) shows the brief structure of this technique. The *bulk retrieval technique* can be realized with *timestamped monitoring & buffering* proposed in [5] to solve the problem of data loss. Data buffering at the agent-side recovers data losses in polling.

In NEMO environment, where route optimization is not supported, all packets toward MN are forwarded through HA because packets from Manager to MN are encapsulated in bi-directional tunnel between HA and MR. Therefore transferring the excess of management information may causes performance degradation of HA network. So, if possible, it would be better to monitor MN without going through this tunnel, i.e connect directly. When MobileIPv6 supports route optimization, manager just monitor the MN.

Fig. 4 explains another problem intuitively. During MR's long term disconnection, there will be large amount of data buffered at agents. Just after reconnection, agents may send them all together and there will be a sudden surge in monitoring traffic. It causes congestion of MR's upstream link and may seriously affect to other communications of MNs. If MR moves into a narrow bandwidth environment, the affect of this problem become severe. We need to control the timing or the amount of monitoring traffic to avoid this.

## 3 Proposal

### 3.1 MobileIPv6/NEMO-MIB

To manage location, we proposed *MobileIPv6-MIB* [6] and *NEMO-MIB* [7] objects in the MobileIPv6/NEMO-MIB as shown in Table 1.

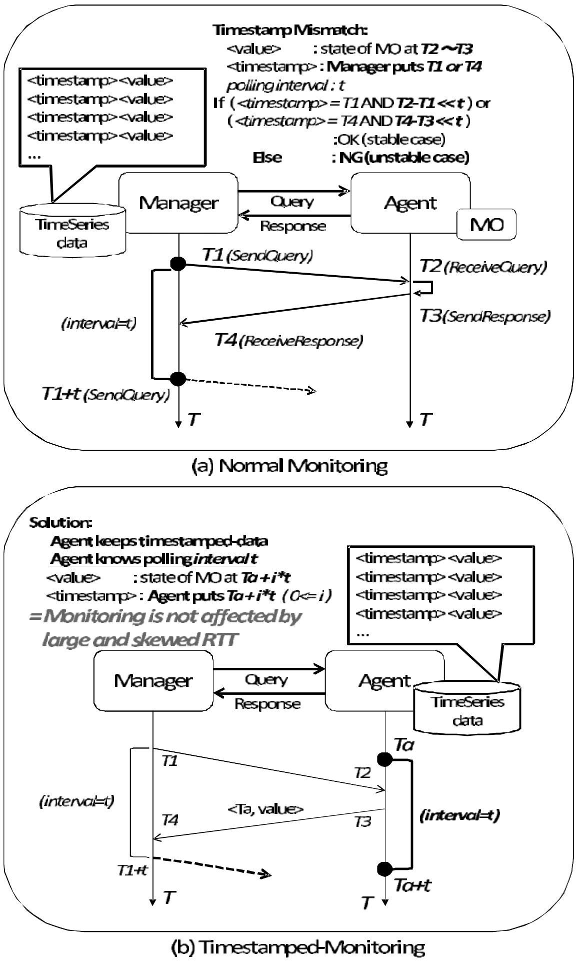



Figure 3: Timestamped monitoring - (a) Normal periodical monitoring contains risk of time-stamp mismatch (b) Agent itself puts time-stamp

A mobile device's global address (CoA) potentially reveals address of the network to which the device is attached. Thereby the location of the mobile device (the organization and/or the segment that the device exists in) can be traced. Location information can be collected from *binding information* available at the HA that is communicating with the mobile device (MR/MN).

The MobileIPv6/NEMO-MIB can provide location information of mobile devices, by using MNPs of MRs and MR/MN's CoAs.

MobileIPv6-MIB is the MIB module for MobileIPv6 entities. *mip6BindingCacheTable* reveals the binding cache information of MNs that is maintained in the HA (or in the CN). This reveals the segment that the MN is connecting. If the prefix of the CoA is from static network, the organization where the MN is connecting is also revealed. *mip6BindingHistoryTable* has the expired binding cache information. We can track the movement of mobile devices from the history. *mip6MnBLTable* is the list of binding update that is maintained by the mobile device itself. It shows the attempts of binding update by the MN. It is possible by using this table to get information of CoAs even after some binding updates had been failed.

*NEMO-MIB* is the MIB module for NEMO entities. *nemoBind-*

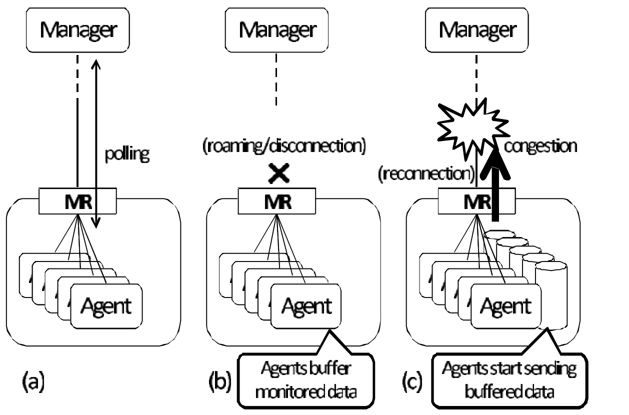



Figure 4: (a) Normal polling (b) Agents buffer data during MR's disconnection (c) Data sending after reconnection causes a congestion of MR's upstream

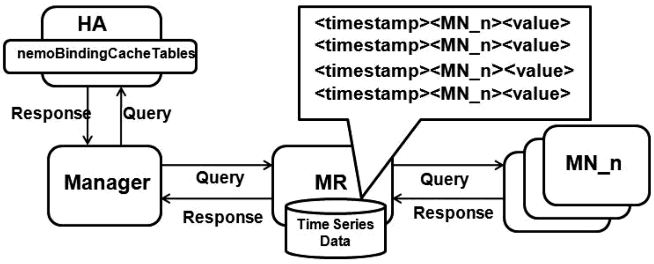



Figure 5: Overview of direct monitor method

*ingCacheTable* is extended with *mip6BindingCacheTable*. It will serve the segment/organization information of MRs. NEMO-MIB also defines the *nemoHaMobileNetworkPrefixTable* that contains information of the registered MNP in the MR's network. If the mobile device has the CoA from the MNP, it can be revealed that the mobile device is connecting to the MR's segment.

These give rise to a new area of management - *location management*, wherein the location of a mobile device is monitored, analyzed, utilized and controlled, as new applications are emerging in this area. It helps to diagnose the cause of the faults, performance degradations, and so forth. Managers have to find and monitor changes in these locations all the time.

## 3.2 Direct Monitoring

To collect management information effectively, we propose a direct monitoring method which store the managed information on MR for MNs.

In NEMO environment which does not support route optimization, packets from Manager to MN are encapsulated in bi-directional tunnel between HA and MR. As all the packets toward MN are forwarded through HA, manager can not connect MN directly. As manager can connect CoA of MR directly, in our proposed method we are considering about fetching the management information from MN through MR.

Fig. 5 illustrates the overview of the direct monitoring method. At MR we use buffering scheme like mobisnmp[5]. Its managed values are buffered not only time-stamp but also identifications of each MNs. Here MR periodically monitors the managed value from MN and store it in its buffer. When manager tries to request the buffered managed information, first, the manager picks up a MR's CoA in the nemoBindingCacheTables of HA's NEMO-MIB. Then it collects managed information buffered in MR. Since MR's CoA may change frequently, manager always makes continuous efforts to pick it up. This method can omit wasted managed traffic, and thus can lead to higher performance, especially when bandwidth of HA is narrow.

## 3.3 Delayed Data Sending Method

We propose a novel method to prevent congestion on MR's upstream link caused by SNMP agents that buffered large amount of management information and send them at a burst. We call this method as *delayed data sending method*. The idea is illustrated in Fig. 6. This method is based on direct monitoring method.

The MR monitors the polling interval that managers requests for managed information. When the MR's upstream link is disconnected, it also monitors the duration of its disconnection. The MR has the configured value of $L$. $L$ is the permitted ratio of MR's upstream bandwidth $U$ for monitoring. Monitoring traffic can consume at most $U*L$. This value is configured to avoid congestion of the upstream link. The MR estimates the amount of monitoring traffics to be transmitted after the upstream is reconnected. If monitoring traffic $M$ assumes to exceed the limitation $U \times L$ during next transmission, proposed method decides how much transmission should be delayed and how many times information data should be divided so that monitoring traffic would not exceed the limit.

Considering the interval of monitoring traffic, amount of its traffic, and disconnection duration, MR estimates the amount of monitoring traffic traveling through MR at each time. If total amount of monitoring traffic $M$ assumes to exceed the limitation $U \times L$, MR delays and divides the transmission into blocks with following procedure. In our scheme, we take an approach so that each traffic will be distributed fairly.

If monitoring traffic exceeds the limitation $U \times L$, MR firstly divides the information data into $\lceil M/U \times L \rceil$ blocks, for example, $B_1$, $B_2$, $B_3$. Then transmission time of divided blocks are arranged so that $B_2$, $B_3$ will be transmitted at $t+u$, $t+2u$, where $t$ is the transmission time of $B_1$ and $u$ is the unit of time. If maximum amount of arranged monitoring traffic $M$ still exceeds the limitation $U \times L$, then each block of transmission is divided into two. Then transmission time of divided blocks are re-arranged again. In spite of the adjustment, if it exceeds the limitation, MR plans to divide block of transmission into three. In this way, re-arrangement of the delay and division of the transmission will be done repeatedly until maximum amount of monitoring traffic $M$ is less than the limitation $U \times L$.

Fig. 6 shows a very simple case to explain it. There are 4 nodes, a, b, c and d. In this case, for node c and d, MR

Table 1: Managed Objects in MobileIPv6/NEMO-MIB related to location management

| | *Name of the object* | *Entities to maintain* | *Description* |
|---|---|---|---|
| MobileIPv6-MIB | mip6BindingCacheTable | HA/CN | Models the Binding Cache |
| | mip6BindingHistoryTable | HA/CN | Tracks the history of the Binding Cache |
| | mip6MnHomeAddressTable | MN(MR) | List of Home Addresses pertaining to the MN(MR) |
| | mip6MnBLTable | MN(MR) | Models the Binding Update List |
| NEMO-MIB | nemoBindingCacheTable | HA | Extended Binding Cache in NEMO |
| | nemoMrBLTable | MR | Extended Binding Update List in NEMO |
| | nemoHaMobileNetworkPrefixTable | HA | List of Mobile Network Prefix registered by HA |

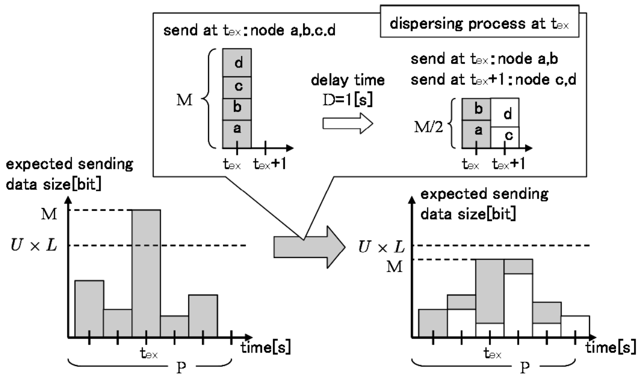



Figure 6: Delayed data sending method

waits for 1 sec to send the data. As a result, $M$ has been successfully controlled not to exceed the limit ($U * L$). Delayed data sending method controls transmission for large amount of buffered management data. If MR moves into a narrow bandwidth environment, our method becomes more effective. A more detail description of our method can be found in [8].

# 4 Evaluation

## 4.1 Experimental Environment

We build an experimental MobileIPv6/NEMO network in our laboratory, using SHISA [9], one of most widely-used MobileIPv6/NEMO implementations. Fig. 7 shows the structure of the network. IPv6 is deployed in the entire network. One single MR is attached with a few MNs. It can moves from one network to another. Each network has an Access Router (AR).

There are 3 rooms, each room has different types of access network. In Room-1 the AR connects to the home network, that is, where the HA of MR exists. Its structure is almost same as a simple LAN. The IPv6 upstream of our laboratory is *JGN2-IPv6*. In Room-2, it is a foreign network, and the upstream is via cellular network. Here IPv6 connection is non-native, that is, the IPv6 connection is provided by tunnel technology. Also Room-3 is a foreign network but here it natively connects to IPv6. It connects to the *SINET-IPv6*. In Room-1 and Room-3, ARs are wire-connected. But in Room-2, the AR has a cellular network interface and is connected with the wireless link.

These networks can be divided according to its performance. In Room-1 RTT and packet loss rate between HA and MR is low. In Room-2 the RTT between HA and MR is big and there can be high packet loss. In Room-3 packet loss rate between HA and MR is low, but RTT is medium.

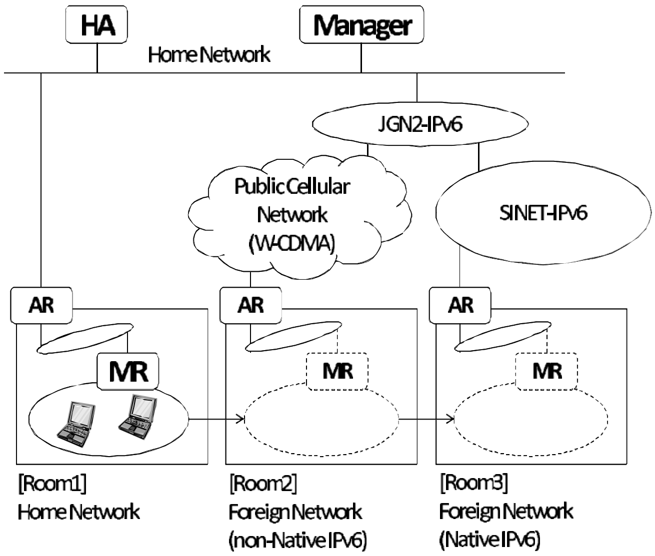



Figure 7: Topology of the experimental network: It includes 2 foreign networks: the native-IPv6 network and the cellular network which is non-native-IPv6 network.

## 4.2 Binding related data collection using prototype system

Fig. 8 shows the result of polling by the prototype SNMP manager from the prototype MobileIPv6/NEMO-MIB module implemented in SNMP agents running on HA and MR. Fig. 8-(a) shows *mip6BindingCacheTable* (binding cache table) from the HA. Fig. 8-(b) reveals *mip6MnBLTable* (binding update list table) collected from the MR that corresponds to (a).

We confirmed that the manager can get correct information about bindings from MIB modules in every case that the MR/MN connects to one of the 3 rooms in our experimental network. This result reveals that our MIB implementation can provide correct binding related information to managers without serious trouble, in a reasonable MobileIPv6/NEMO environment. To our knowledge, this is one of the pioneering work on implementation of MobileIPv6/NEMO-MIB. It demonstrates the feasibility of monitoring mobile devices using the Internet standard network management protocol, SNMP. Apart from the traditional traffic or configuration information, the MobileIPv6/NEMO-MIB does contain information

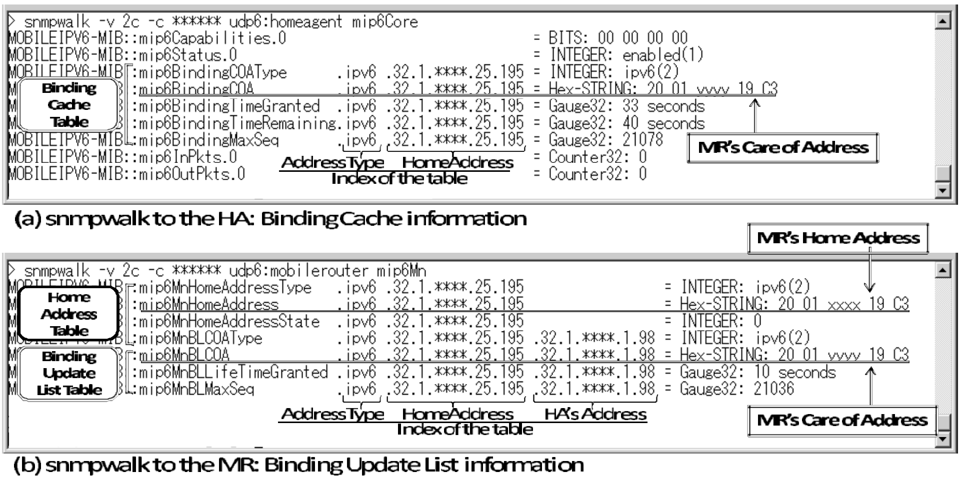



Figure 8: Screenshot of SNMP polling of the implemented prototypes

that provides location information in one form or the other for monitoring mobility. Information that can be collected from MobileIPv6/NEMO-MIB is mandatory in developing new management applications for location-aware network management in MobileIPv6/NEMO network. The example of application is explained in section 4.4.

### 4.3 Delayed data sending method

To verify the effectiveness of our proposed *delayed data sending method*, we compared the performance by using ns-2 [10].

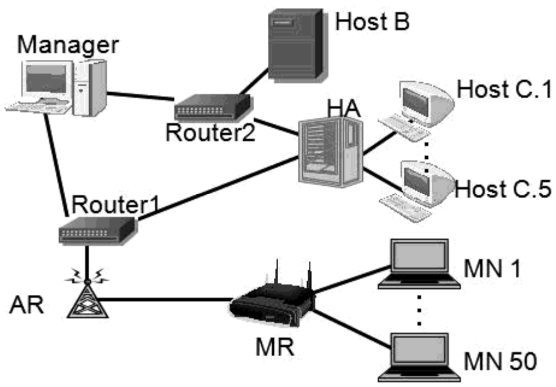



Figure 9: Simulation environment

Simulation environment is shown in Fig. 9. There are 50 MNs connected under the MR. We configured that, 1) manager polls MOs in 30 sec interval, 2) each MN collects 10 MO per 5 sec, 3) the size of each MO is 100 bytes, 4) five hosts (C1, C2, C3, C4 and C5) are connected at HA to produce background traffic toward host B, 5) MR's bandwidth between AR and MR is configured as 11 Mbps, and others are set at 50 Mbps. Simulations time is 600 seconds. To increase the amount of monitoring traffic bursty, link between MR and AR goes down from 90 to 210 sec.

In the above described environment, two kinds of simulation scenarios are examined. In scenario (1), VoIP traffic is transmitted from one of the MN to Host B at 1Mbps. In scenario (2), five hosts (C1, C2, C3, C4 and C5), which are connected under HA, transmit traffic to B at 10Mbps respectively. The limiting value $L$, the permitted ratio of MR's upstream bandwidth $U$ for monitoring, is configured as $0.1(= 10\%)$.

By scenario (1), we confirm that proposed method can keep the monitoring traffic to a constant level and lead to the reduction of interference on VoIP traffic in terms of throughput and jitter.

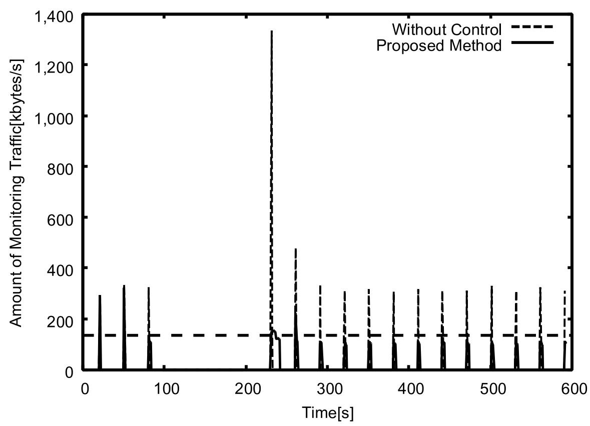



Figure 10: Monitoring traffic from 0 to 600 sec

Fig. 10 shows monitoring traffic during simulation. Traffic details just after the re-connection is shown in Fig. 11. These graphs show that, without controlling, the amount of traffic violates the limitation. On the other hand, our proposed method hardly exceeds the limit. Therefore our proposed method can effectively distribute bursty management data transmission for avoiding congestion on upstream link of MRs.

To confirm that proposed method can reduce the interference on VoIP between MN and host B, throughput and jitter of VoIP are measured as shown in Fig. 12 and 13. These results show, that by suppressing the amount of monitoring traffic to a lower level, proposed method can enable VoIP not only to achieve higher throughput but also can keep jitter low.

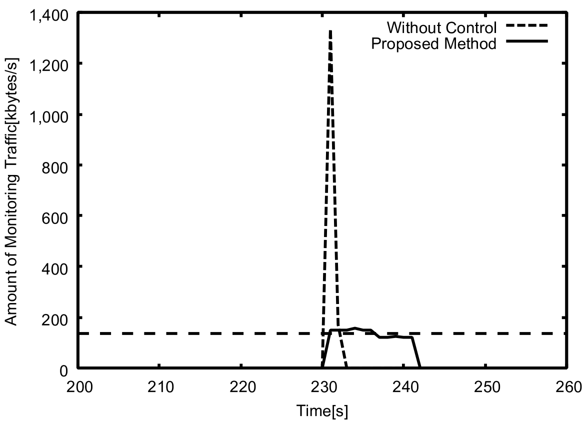



Figure 11: Detail of monitoring traffic right after link between MR and AR has recovered

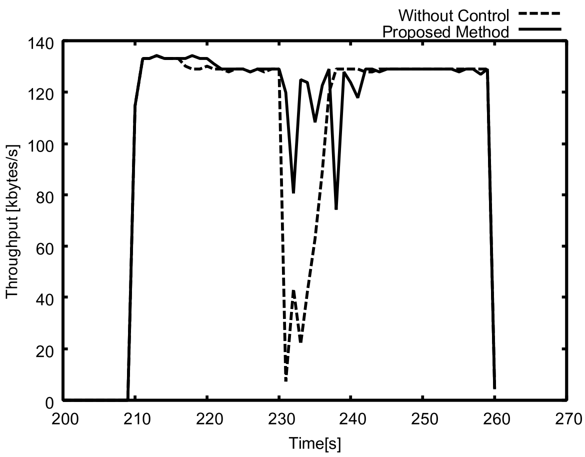



Figure 12: Comparison of throughput when the transmission is between MN to host B

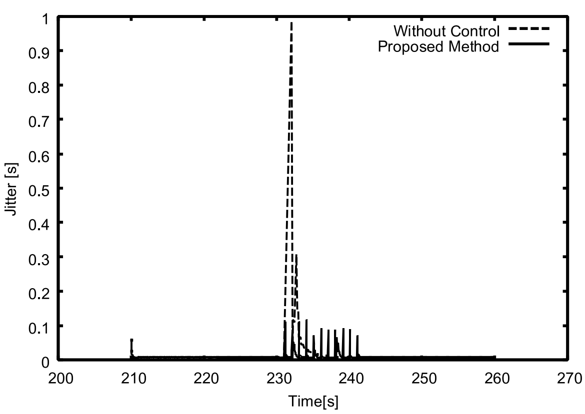



Figure 13: Comparison of jitter when the transmission is between MN to host B

Therefore, the proposed method can reduce the interference on other traffic under MR during monitoring.

Finally, to show the effect of direct monitoring, we measure the traffic from one host connected under HA to host B. Traffic on host C3 and host C4 is shown in Fig. 14 and 15 respectively. Both results show that proposed method is free from interference of monitoring traffic, and thus achieved higher throughput. This means proposed scheme is capable of reducing the interference on HA traffic effectively.

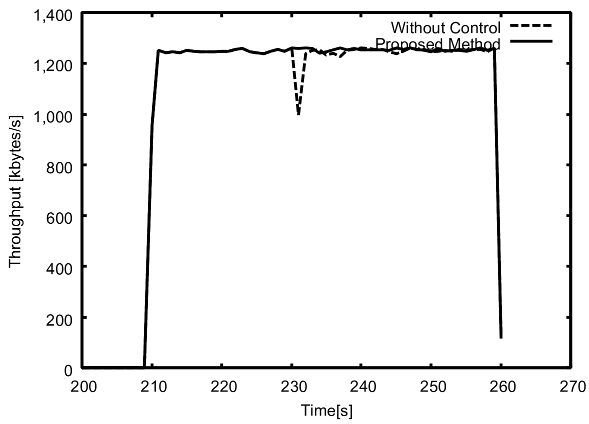



Figure 14: Comparison of throughput when transmission is between C3 to host B

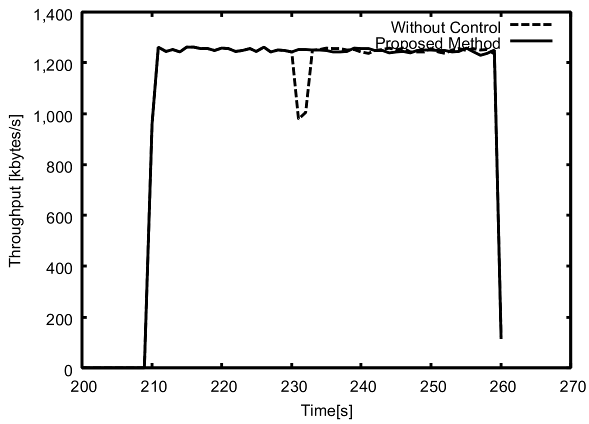



Figure 15: Comparison of throughput when transmission is between C4 to host B

## 4.4 Effective management application using location

As explained in this paper, the location-awareness and the intelligent monitoring scheme are novel and important axes of network management technologies.

In this section we explain about the example application now we are constructing.

The application will be apart from the traditional simple demonstration of network traffic and configuration information. The application uses location information to track the path of a mobile device. The MobileIPv6/NEMO-MIB modules can provide information of the network that the mobile

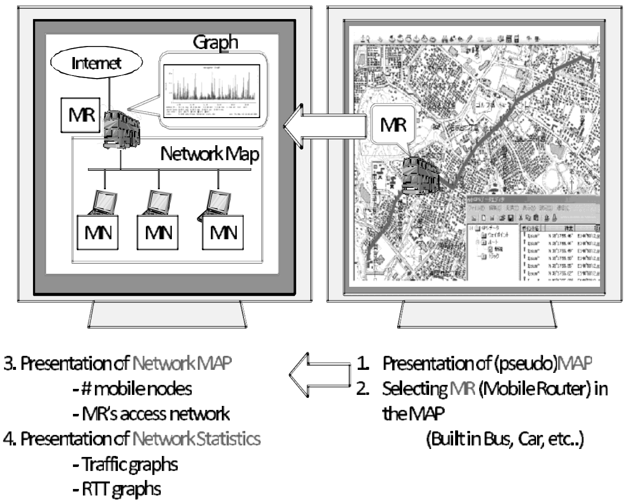



Figure 16: The screenshot of the application that realizes location-aware network management

device is currently connecting. It also provides the list of networks that the mobile device had been connected in the past. Three types of location of the mobile device can be determined with reasonable accuracy using other MIBs that service geographical location information like GPS-MIB. This opens up a new vista of tracking mobile devices for management. The application also shows how the path of a mobile device can be tracked even when it is out of network reach. It demonstrates that mobility-aware networks can be managed by using already standardized and widely utilized management protocol same as any other device and network. The mobility related status, parameters and metrics can be evaluated. The traffic can be monitored and the network configuration can be discovered.

We envisage the application that supports dynamic network topology visualization. Fig. 16 is a screenshot of the application. In this image, a MR is deployed on a public transport, like bus. GPS equipment is connected to the MR and it makes possible to locate the bus on the geographical map. This works only as an interface to point out for human managers that manages MRs. When a human manager points the bus, the application shows the information of the MR and its network. By using the information from MobileIPv6/NEMO-MIB, it is possible to show the network the MR is attached now. The information of MNP shows prefixes that is reachable under the MR. It is also possible to show the number of MNs connected to the MR. These functions reveal the network topology of MR's network. Traffic information of MR's network is also possible to provide.

## 5 Conclusion

For a new network management technologies of MobileIPv6/ NEMO network environment, we propose a *location aware* and intelligent monitoring scheme. We explained about the *MobileIPv6/NEMO-MIB* which is aware of mobile device's inherent dynamic nature of location, and we introduce an intelligent monitoring scheme. This is one of the first applications for monitoring mobile devices and networks that are completely based on Internet Standard network management protocols of MobileIPv6/NEMO. It expands the scope of network monitoring to mobile devices and networks, and also demonstrates new areas of management e.g. *location management*, in which network monitoring can be applied.

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## REFERENCES

[1] D. Johnson, C. Perkins, and J. Arkko, "Mobility support in IPv6," Jun. 2004, RFC 3775.

[2] V.Devarapalli, R.Wakikawa, A.Petrescu, and P.Thubert, "Network mobility (NEMO) basic support protocol," Jan 2005, RFC 3963.

[3] K. McCloghrie and M. Rose, "Management information base for network management of tcp/ip-based internets: MIB-II," Mar. 1991, RFC 1213.

[4] C.T.Chou and K.G.Shin, "Smooth handoff with enhanced packet buffering-and-forwarding in wireless/mobile networks," *Wireless Networks*, vol. 13, no. 3, pp. 285–297, 2007.

[5] K.Koide, G.Kitagata, H.Kamiyama, D.Chakraborty, G.M.Keeni, and N.Shiratori, "MobiSNMP - a model for remote information collection from moving entities using SNMP over MobileIPv6," *IEICE Transactions on Communications*, vol. E88-B, no. 12, pp. 4481–4489, 2005.

[6] G.M.Keeni, K.Koide, K.Nagami, and S.Gundavelli, "Mobile IPv6 management information base," Apr. 2006, RFC 4295.

[7] S.Gundavelli, G. M.Keeni, K.Koide, and K.Nagami, "Network mobility (NEMO) management information base," Apr. 2009, RFC 5488.

[8] T.Maruyama, K.Koide, G.M.Keeni, and N.Shiratori, "An efficient method of information collection for management in NEMO environment (in Japanese)," in *IEICE Technical Report MoMuc2008-43(2008-9)*, Sep. 2008, pp. 1–6.

[9] "SHISA," http://www.mobileip.jp/.

[10] "The network simulator 2 (ns-2)," http://www.isi.edu/nsnam/ns/.