Management Framework for Network Mobilty Environment

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In the traditional network management architecture, based on the implicit assumption that a managed device will not change its location. This location related information is used for simple reporting purposes. However, due to the emergence of mobile devices, whose location attributes are inherently dynamic, previous assumption should be reconsidered. Monitoring processes of management information also encounters difficulties of network instability caused by roaming of devices or wireless signal errors. Therefore, current approach of network management needs to be reviewed. In this paper we propose a new network management technologies based on monitoring MobileIPv6/NEMO with SNMP. This paper focuses on the importance of two major aspects: (i) location awareness and (ii) intelligent monitoring process. We explain about the *MobileIPv6/NEMO-MIB* which is aware of mobile device's dynamically changing location. A thorough description of buffering monitoring scheme is also given in this paper.

1. Introduction

In the traditional network management architecture, location related information, where available, is static and is used for simple reporting purposes. Although attributes of mobile devices are inherently dynamic, it is important for network management to understand the dynamics of location of devices for planning, administering and controlling a network. For example, the density, roaming frequency and visiting duration of devices in the network are very useful information when planning distribution or managing configuration of parameters in mobility protocols. So the current approach of management needs to be reviewed and the implications on configuration, operations, performance and security management need to be reconsidered.

The concept of "reachability" has changed due to mobility. An IP network is connectionless and routes may change dynamically. Yet there is the implicit assumption that under normal circumstances network devices are reachable. The same assumption has been extended to the manager-agent management framework. In monitoring process, management information is collected by polling at regular intervals. The interval is generally larger than the response time, so the time-stamp of the polling request or the response is taken as the time-stamp of the information.

In mobility-aware networks, the instability in the reachability state causes the response time to fluctuate widely. This may cause a severe degradation of the quality of collected management information. In contrast with the convenience of network mobility, optimized route paths can not be always used. In that case, the amount of polling traffic is not negligible. A transfer of large amount of management information will cause a severe congestion.

In the paper, we propose a network management framework which take into consideration the inherent dynamic nature of location and its instability.

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 will be changed. The 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 the CoA of MN changed, the MN registers it to the HA with the HoA. The HA maintains the registered CoA/HoA sets of MNs. It is called *binding cache*. When packets from CNs destined to the HoA come, the HA forwards them to the registered CoA. NEMO is a simple extension of MobileIPv6, adding an entity called mobile router

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(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 as 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 problems in how to make device locations will be monitored and tracked 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 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 set up many packet losses. SNMP polling suffers from lots of polling timeout and they degrade the quality of collected management information. It is difficult to keep simplicity of the monitoring process. Monitoring process should become 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 process*, added to networking by mobility require extensions to the traditional network management framework.

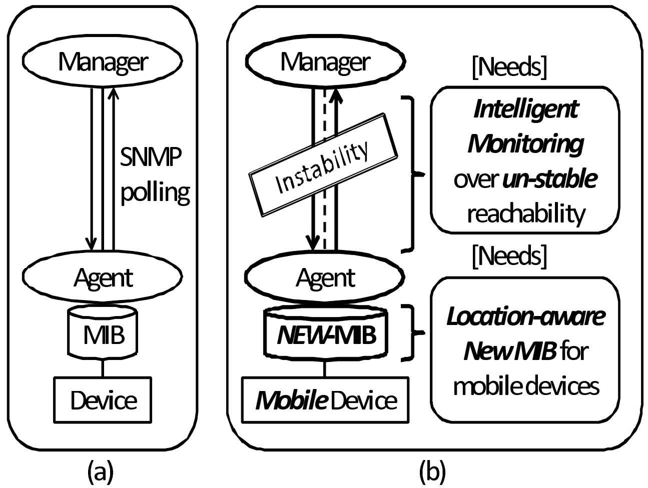


Fig. 1 Manager-Agent management framework using SNMP (a)Traditional management: Manager monitors device's MIB. (b) Extensions needed: 1) new location aware MIB of mobile device and 2)intelligent monitoring process that realize monitoring over instable reachability.

2.3 Location-awareness

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

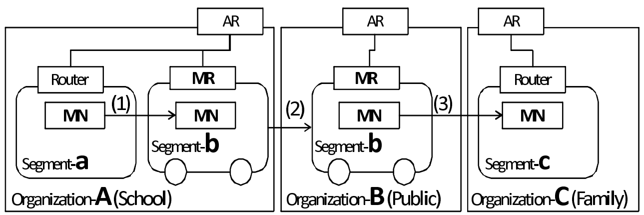
- Organizational Location: the administrative domain to which the mobile device belongs.

- Segment Location: the subnetwork to which the mobile device is attached.
- Geographical Location: the longitude, latitude, altitude information of the mobile device.

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.



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*

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

2.4 Intelligent monitoring process

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 can be considered as 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 have 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 discon-

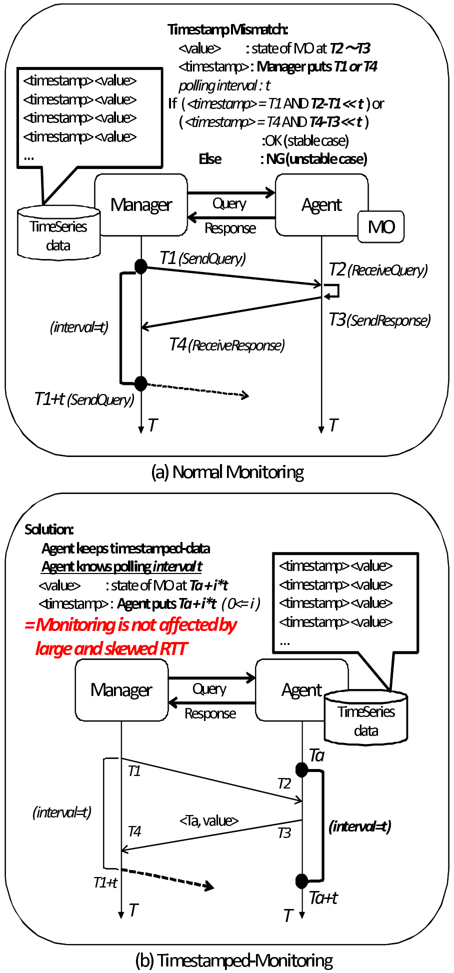


Fig. 3 Timestamped monitoring - (a) Normal periodical monitoring contains risk of time-stamp mismatch (b) Agent itself puts time-stamp

nection, large amount of data will be buffered at agents. Just after reconnection, agents may send them all together and thus monitoring traffic become large. It causes congestion at MR's upstream link and may seriously affect other communications of MNs. If MR moves into a narrow bandwidth environment, the affect of this problem become severe. So there is an urgent need to control the timing or the amount of monitoring traffic to avoid this.

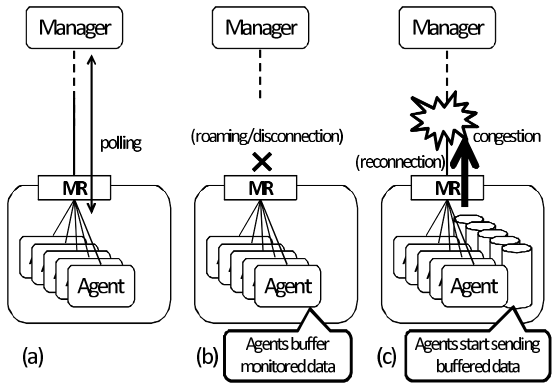


Fig. 4 (a) Normal polling (b) Agents buffer data during MR's disconnection (c) Data sending after reconnection causes a congestion of MR's upstream

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.

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 that 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. *nemoBindingCacheTable* 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 reason of faults, performance degradations, and so forth. Managers have to find and monitor changes in these locations all of the time.

3.2 Direct Monitoring Method

To collect management information effectively, a direct monitoring method which store the managed information on MR for MNs is proposed. 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 describes the overview of the direct monitoring method. At MR we use buffering scheme like mobisnmp[5)], which is different from[5)]. Its managed values are buffered with not only time-stamp but also identifications of each MNs. Here MR periodically monitors the managed value from MN and store it in the buffer. When manager requests 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 continued 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.

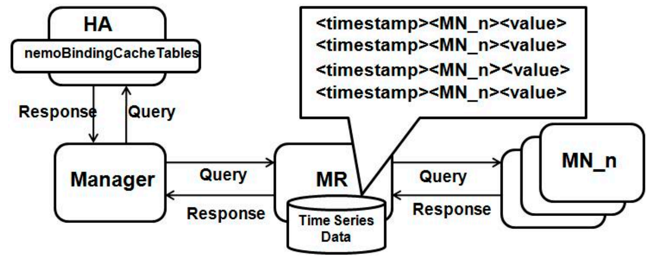


Fig. 5 Overview of direct monitor method

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 in 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 to buffered managed information. If the MR's upstream link is disconnected, it counts the duration of 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 how much monitoring traffic should be requested after the upstream is reconnected.

If t_{ex} is the time at which the amount of monitoring traffic M exceeds the limitation $U * L$ as a result of estimation, according to each NM, MR calculates the parameter D. D is the *maximum delay*. Then Manager chooses delay time between 0 and D. D is calculated to make M lower than the limitation $U * L$. If MR moves into a narrow bandwidth environment, our method is expected to

	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

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

work more effectively.

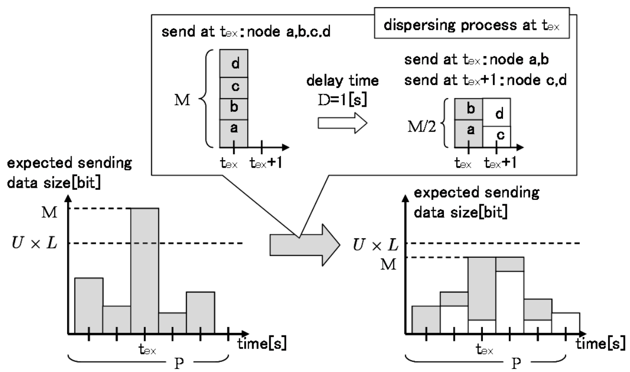


Fig. 6 Delayed data sending method

4. Conclusion

For MobileIPv6/NEMO network environment, we described a new network management technologies of location-awareness and an intelligent monitoring process. We proposed the *MobileIPv6/NEMO-MIB* to trace mobile device's inherent dynamic nature of location, and introduced an intelligent monitoring methods to transfer management information effectively.

This is one of the first application for monitoring mobile devices and networks that are entirely based on Internet Standard network management protocols of MobileIPv6/NEMO. This expands the scope of network monitoring to mobile devices and networks, and new areas of management, such as *location management*, in which network monitoring can be applied.

Acknowledgments

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