Report: the Simulation for Network Mobility based on NS2

Kong Ruoshan
Adv. Research Center for Sci. & Tech., Wuhan University, China
krs1024@126.com

1. Basic Topology

- NS2 provides the command “make-lan” for users to create a LAN. A mobile network is essentially a LAN, so our extension program provides a similar command for users to create a mobile network: create-mobile-network.
- In a mobile network, an MR and some LFNs are included, and a local Base Station is also necessary so that the other mobile networks and the VMNs can attach to this mobile network.
- Multi-homing and LMN will not be supported in our extensions because they are too complex.

Thus, the basic topology of a mobile network in NS2 is designed as follows. The “Local BS in LAN” is abbreviated as “LBS”.

![Figure 1. Basic topology of a mobile network in NS2](image)

2. Configuration of the Hierarchical Address

- In NS2, a hierarchical address is definitely divided into 3 parts: Domain number (high level 10 bits), Site number (middle 11 bits), and Node number (low level 11 bits).
- For NEMO, each BS is responsible for a site, and as a part of a site, a mobile network must have its mobile network prefix (MNP), so the address hierarchy must be further divided inside a site: one part is allocated for the mobile networks, and the remaining is reserved by the BS for the dynamically attached MR or MN to configure their CoA.
- Also, the MNP must be divided into two parts: one part for MR and LFNs, and the rest reserved by LBS.
- In Mobiwan, when a BS broadcast a Router Advertisement (RA) message, the prefix length is not specified, and the MNs always assume the length is 21. After we further divide the address hierarchy, the prefix length must be taken into consideration.

The address hierarchy is designed as follows: as in Mobiwan, a BS is responsible for a site that has a prefix of 21 bit, and the suffix of a BS is always 0. If a BS acts as the HA for some mobile network, the low level 11 bits inside this site should be further divided into 2 parts:

- Part 1 is an m-bit prefix (21<m<32) that can cover the BS’s address, and is reserved by the BS for dynamically attached MR or MN to configure their CoA.
- The rest part in the site is allocated to mobile networks.

The MNP is further divided:

- The LBS occupies a prefix of n bits (m<n<32) for dynamically attached MR or MN to configure the CoA.
- The rest part is reserved for the MR and the LFNs. The prefix occupied by the LBS must be located at the highest end of the MNP. Also, the LBS’s address must be covered by its prefix, and the suffix of the LBS must be set to 0.

For example, the BS’s address is 1.1.0, and m is set to 24, then the MRs or MNs who dynamically attaches to this BS will get a CoA in the range of 1.1.0 to 1.1.255, and the rest part (1.1.256 to 1.1.2047) will be allocated to the mobile networks who take this BS as HA.
The length of MNP should be set to \( m \) according to the BS. Thus, the address coverage of each mobile network should be 1.1.256 - 1.1.511, or 1.1.512 - 1.1.767, or 1.1.768 - 1.1.1023…

If the mobile network covers 1.1.256 to 1.1.511, and \( n \) is set to 26, then the LBS should cover 1.1.448 to 1.1.511; if the mobile network covers 1.1.512 to 1.1.767, and \( n \) is set to 26, then the LBS should cover 1.1.704 to 1.1.767.

3. Mobility

If the LBS moves with the MR, it may cause two problems:

- The RA messages from LBS will always be received by the MR and may cause the “self-attach” loop routing problem. Besides, it is hard to avoid “loop-attach” for nested NEMO.

- The wireless signal of LBS will be overlapped with the signal from the common BSs, and the interference will decrease the wireless communication efficiency.

Our solution:

- Make the MR mobile and make all the other nodes (including LBS) in the mobile network still.
- The coordinates of the LBS should be set when creating a mobile network in the simulation script, and the users must make sure the LBS’s wireless coverage is not overlapped with any other BS’s wireless coverage.
- The users should design the MR’s moving path carefully so as to make sure the MR will not enter the wireless coverage of the sub-NEMO’s LBS.

Such solution will lead to a strange scene: the MR is connected to the LAN by wired link, and the LAN keeps still, but the MR is moving here and there. But this will not change the delay and the rate of the packets, so it has no influence on the simulation results.

4. Static Route Computation in NS2

In NS2, every simulation test starts with “\$ns run”. This command will startup the event scheduler and compute the static route for the whole network topology.

- In NS2, the domain number, site number and the node number in the address must be as small as possible. That is to say, if there isn’t a domain that has the number 2 in the topology, there must not be a domain whose number is
larger than 2; if the site 1.1.xxx has 3 nodes, the addresses of the 3 nodes must be 1.1.0, 1.1.1, 1.1.2.

- When NS2 computes the static routes, it always assumes this rule is obeyed.
- In NEMO, the address hierarchy must be further divided inside a site, and each part has its own prefix, so it’s impossible to keep the address continuity inside a site. This will cause illegal access to the memory.

Figure 4. A common work flow of NS2

Our solution: separate the creation of mobile network from the first step in the above figure and put it behind the static route computation. So we design a special mode for writing a script of NEMO simulation:

```
proc create-my-topo {} {
    ......
    creating backbone network (including routers, BSs, CNs, and other wired nodes)
    creating MNs
    setting MNs’ moving paths
    $ns at 0 "add-nemo-to-topo"
    $ns at 0.0001 "configuring sessions related to NEMO"
    ......
}
proc add-nemo-to-topo {} {
    creating LFN nodes
    creating MR nodes
    creating mobile networks using the above MRs and LFNs
    setting MRs’ moving paths
}
```

Thus the work flow is changed as follows:

Figure 5. The creation of mobile networks is performed by the event scheduler

The simulation script MUST be written in this mode so that the static route computation problem can be avoided.
5. HA/BS
A prefix_classifier_ module is added to BS node structure so that the BS can bind a prefix to a CoA. This module can judge whether a packet’s destination address is covered by certain prefix. The node structure of BS is as follows:

![BS's node structure for NEMO](image)

Figure 7. BS’s node structure for NEMO

6. MR
An MR node also needs a module similar to prefix_classifier_ to judge whether a packet should be sent to the LAN, but the prefix_classifier_ cannot be used here because the MR has some special requirement. So we add a new module – prefix_classifier_mr_ – to the MR, and the MR’s node structure is as follows:

![MR's node structure](image)

Figure 8. MR’s node structure

The prefix_classifier_mr_ module should deal with the following special cases:
- The packets whose source address is the MR’s CoA should not be encapsulated, such as the BU message.
- The packets destined to the CoA of the MR should be received and processed directly but not encapsulated.
- The packets destined to the HoA of the MR should be received and processed directly but not sent to the LAN interface although the HoA is covered by the MNP.
- The broadcast packets should be received and processed directly but not encapsulated.

The above four kinds of packets should be sent to the address classifier directly, otherwise, the prefix_classifier_mr_module should send the packet to the LAN interface or the encap_module according to the prefix of the packets’ destination addresses.

7. LBS

An LBS is a simplified BS that never acts as an HA. An LBS has the same modules as a BS, but the pointers between the modules are different.

![Figure 9. LBS’s node structure](image)

8. Other Important Technologies

Following the NS2 command “make-lan”, we write the OTCL procedure “make-mobile-network”, which needs the following parameters:

- MR node
- LBS node
- node list of LFNs
- length of MNP
- length of the LBS prefix
- some other parameters for LAN (delay, MAC protocol, and so on)

However, this procedure is not simple enough because the LBS node is the inner detail of a mobile network and should be transparent to users. So we write another procedure “create-mobile-network”, which needs the following parameters:
This procedure will calculate LBS’s address according to the parameters and create the LBS node, and then it will invoke the “make-mobile-network” procedure to create the LAN.

It should be noted that a LanNode object will be created when creating a LAN, and this object also needs an address, and the MR’s next address is allocated to it, so this address must not be used in the simulation script. For example, if the MR’s address is 1.1.256, then 1.1.257 must be reserved and cannot be used by an LFN.

9. Further Extensions for Route Optimization Schemes

Based on the previous extensions for RFC 3963, three route optimization schemes for NEMO are realized. In these schemes, the node structure of MR and BS/LBS are not changed, but the function of some modules may be modified.

9.1 Optimized Route Cache Protocol (ORC)
The key of ORC scheme is the Correspondent Router (CR). The CR’s node structure is as follows:

![Figure 10. CR’s node structure](image)

Two new modules are added: anycast_detector_ is used to detect the anycast addresses, and prefix_classifier_cr is used to calculate the packets’ source addresses.

9.2 IPv6 Reverse Routing Header and its application to Mobile Networks (RRH)
RRH scheme has no requirement for the infrastructure, and the key of RRH scheme is the process of the RRH header. A chain should be created in BS’s regagent_ module to record each MR’s nesting situation. The encap_ and decap_ modules of the MR and the BS should be changed.

9.3 Route Optimization for Mobile Network by Using Bi-directional Between Home Agent and Top Level Mobile Router (TLMR)
This scheme is somewhat similar to the RRH scheme. A chain is created in BS’s regagent_ module to record each MR’s Top Level MR (TLMR). Every MR may act as a TLMR and receive the registration from the other MRs, so a chain is created in MR’s regagent_ module to record each sub-MR’s parent MR. The encap_ and decap_ modules of the MR and the BS should also be changed.
10. Conclusion

The extensions for RFC 3693 is firstly realized, and based on that, three route optimization schemes are supported. Our extension programs have some limitations:

- The users have to design the coordinates of the wireless node and the moving paths of the MRs carefully.
- The simulation script must be written in a special mode.