Reliability Simulation of IP Micro Mobility Protocols Over Different Network Topologies

Sándor Imre
imre@hit.bme.hu

Máté Szalay
szalaym@hit.bme.hu

István Bagdi
bagira@impulzus.sch.bme.hu

Márk Székely
sm207@ural2.hszk.bme.hu

Department of Telecommunications
Budapest University of Technology and Economics
Magyar Tudósok krt. 2, Budapest, Hungary, H-1117

Abstract

Most of the micro mobility protocols are based upon a tree topology network. A new micro mobility topology, the hierarchy of rings was introduced earlier. This topology claims to have better reliability properties than the tree topology. We used simulations to have quantitative information about the enhancement in reliability. In this paper we present our simulation results.

Introduction

In the past years the number of Internet hosts has been growing rapidly. The number of handheld devices that can connect to the Internet has been growing too while the prices of such devices are falling. The Internet and telecommunications seem to converge, the resulting network will be based on IP. Not only a broadband IP backbone will be used in mobile systems, but also IP will appear in access networks providing full end-to-end IP connections. In the very near future IP networks will be even more widely used as they are today.

The growth of the Internet and the new services raise new demands. For example security and mobility have become crucial areas in IP networking.

The standard solution for mobility in IP networks is the MobileIP[1]. It provides large-scale mobility, but handovers may take a long time. In an always on scenario where the mobile nodes should change their access points to the network frequently (for example cellular phones) MobileIP is not able to solve the mobility problem. The solution to the problem mentioned above is the use of hierarchical mobility. MobileIP provides large-scale mobility with fast handovers, and another mobility solution provides small-scale mobility. Hence MobileIP is called "macro mobility" in this environment, the mobility solution that provides mobility in a well defined area with fast handovers is called "micro mobility". Macro mobility and micro mobility are used simultaneously. While the mobile node stays in the same access network, micro mobility is used, when is moves to a new access network a macro mobility handover takes place. With this solution slow macro mobility handovers are very infrequent.

There are already several micro mobility protocol recommendations for example CellularIP[2] and HAWAII[3].

Reliability means how the network tolerates failures that may occur in the network. It is not dealing with malicious attacks against the network. The protection against intentional damages is called security. The handling of node or link failures with as small performance degradation as possible is reliability.

This paper is structured as follows: first we give a short overview of the classical tree topology that is widely used in micro mobility networks and the new hierarchy of rings topology. Then the development and methods of our simulations are given in detail. After presenting the results of the simulation, the conclusions are drawn.

Examined Topologies

Classical Tree Topology

Most of the IP micro mobility protocols are based upon a tree topology network. The root node of the tree is the gateway to the IP backbone, the leaves of the tree are the base stations. The Cellular IP protocol [2] is based on a logical tree. In theory HAWAII [3] can be used over any kind of network topology, but in practice it is used over a tree topology, for other topologies would make handovers and routing unnecessarily complex. For this reason the details of HAWAII are always explained over a tree topology.

Tree topology is of course a good choice for micro mobility networks. It has good scalability and simple thus fast routing algorithms can be used. The tree topology suits the traffic requirements of a micro mobility network very well. In a micro mobility network most of the traffic flows between the base stations and the gateways. Figure 1 shows a tree topology micro mobility network

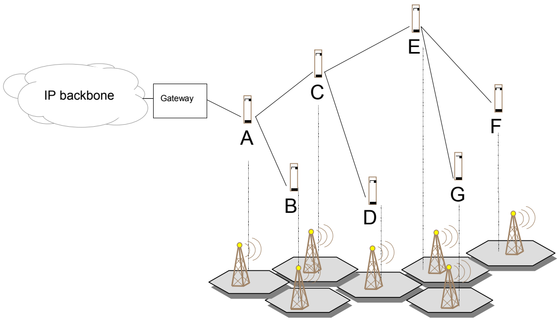

Figure 1. Tree topology micro mobility network

The major weakness of a tree topology network is poor reliability. If a node or link breaks down, a whole subtree is separated from the network. It is even more severe when the root node fails to function. If the gateway of the micro mobility network stops functioning, the whole network is separated from the IP backbone.

Scalable Hierarchy of Rings

As an alternative to the tree topology, the hierarchy of rings topology was introduced in [4]. This topology is basically a tree where the nodes are substituted by rings and the links are multiplied. The ring in the root of the tree is called the root ring, and this is the ring that contains the gateways of the network. Figure 2 shows a network of this topology.

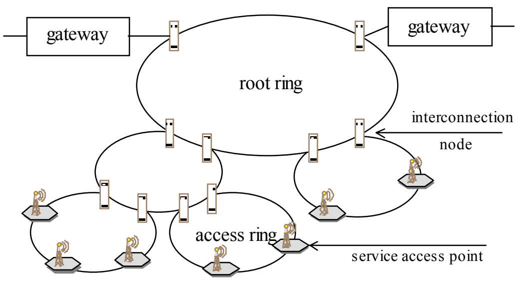

Figure 2. The hierarchy of rings topology

This network combines the good scalability of a tree topology with the good reliability of the ring topology. The micro mobility protocol over a hierarchy of rings topology is just a little bit more complex than over a tree topology, see [4,5].

This is not a way of making a tree topology network more reliable by using multiple links and rings, but a completely new topology. Consider a very simple tree topology micro mobility network: three base stations connected to a gateway. The equivalent hierarchy of rings topology has a root ring with about ten routers and three access rings. The three access rings can have more than a hundred base stations. Thus the cost of a hierarchy of rings topology network should not be compared to the cost of the equivalent tree topology network but rather to the cost of a tree topology network with the same number of base stations.

This increase in reliability is rather straightforward, but a simulation gives quantitative results.

Simulation

Simulation Environment

For our simulations the OMNeT++ discrete time event simulation tool [6,7] was used. It is an object oriented simulation environment; its development was an international project. The Technical University of Budapest, Technical University of Delft and Technical University of Karlsruhe were involved for example. It is a free software so our simulation can be easily reproduced anywhere. Despite of being free it is very powerful in functionality. Although only a few protocol packages are included in the distribution, as it becomes more widely used, the number of implemented protocols is rapidly increasing.

The network description language of OMNeT++ is called NED.

Extension of the Simulator

Then the various modules of the simulation and the connections between them were implemented in NED. The modules we developed can be used later in other simulations; some of them will be available as OMNeT++ packages.

As OMNeT++ does not support mobility by default, mobility had to be implemented too. We used a relatively simple mobility model in the first simulations, but if needed, a more complex model can be easily included in the future. For our reliability simulations this model was appropriate.

OMNeT++ has a graphical interface, so we decided to implement some animation features for our simulation. Using animation for the main simulation would have been much too resource consuming, the animation features were used only at a small simulation, its purpose was to detect possible errors in the simulation.

Simulation Scenarios

To examine reliability qualities, link and/or node faults had to be implemented. To keep our model simple we used only link failures. Two link failure models were used, links have two states in both models: working (up) state and broken (down) state. The first model was to make some (a fixed number) of the links broken. For example in the hierarchy of rings topology one link error should not cause any packet loss. In our second model each of the links is broken by a given (fairly low) probability.

The first failure model was used only to see how vulnerable the tree topology was. For our comparative simulations the second model was used.

The most important parameter examined in the simulations was the packet loss rate as a function of link error probability.

Two simulations were run with different network sizes. A smaller simulation was built (for both topologies) with animation for testing purposes, and another one with larger network sizes without animation for examining the packet loss rates.

The smaller hierarchy of ring topology network is shown in Figure 3.

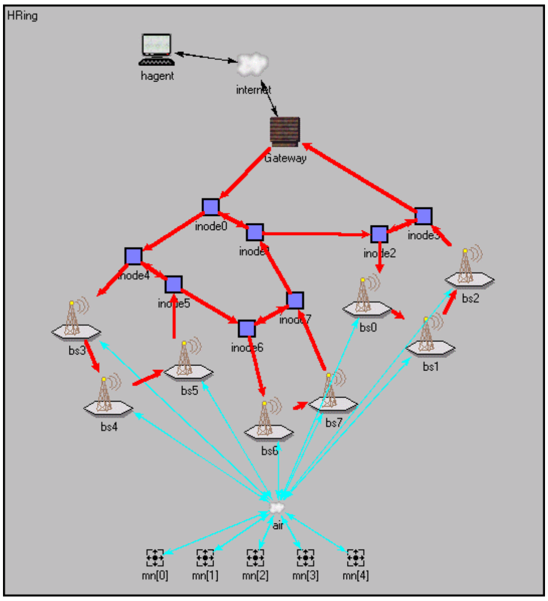

Figure 3. Small hierarchy of rings topology network

Examining the animations and the text outputs of the simulations we could find and correct the bugs of the simulations. When the simulation was working properly, and it had all the desired functionality, larger networks of both topologies were built.

In the large simulation both networks had 49 base stations and 150 mobile nodes. Figure 4 shows the structure of the large hierarchy of ring topology network. This network has 15 routers and 70 links while the tree topology network with the same number of base stations has 14 routers and 62 links. Exact cost analysis was not carried out but these numbers show that the hierarchy of rings topology does not require much more resources than the tree topology.

The positions of the base stations and the movement and traffic properties of the mobile nodes were exactly the same with the two different network topologies.

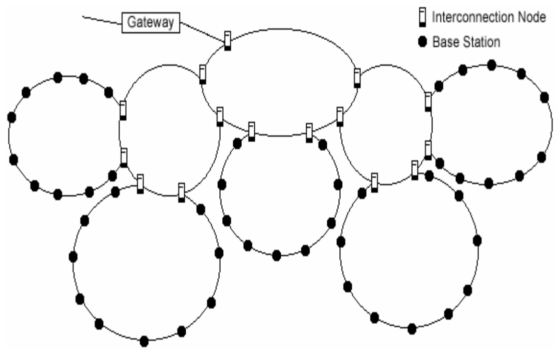

Figure 4. Large hierarchy of rings topology network

Simulation Results

The simulation was run several times with different link error probabilities up to 20%, which is really extreme. Packet loss rates were examined at the two different topologies. Figure 5 shows the results.

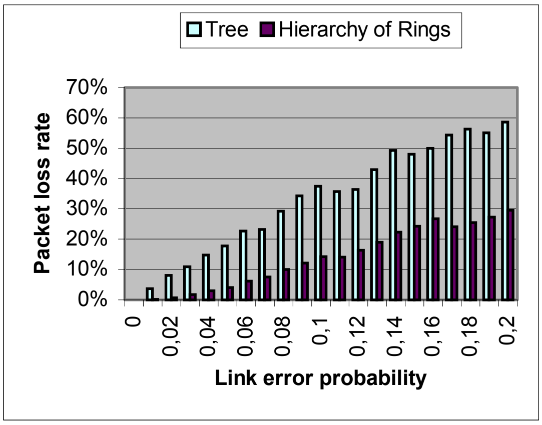

Figure 5. Plot of packet loss rate as a function of link error probability

The hierarchy of rings topology had smaller packet loss rates at every error probability. 20 percent link error probability is much more than what can be expected in real-life extreme situations. It just shows that the new topology produces two times less packet loss when the link error probability is very high. This is because the two-connectivity of the hierarchy of rings topology.

More interesting is the 0-2 percent range. That is close to real-life situations. In this domain the packet loss rate of the hierarchy of rings topology is about ten times less than that of the tree topology. The exact percentages of this range are given in Table 1. Thus if the link error probability is fairly low, the reliability of the hierarchy of rings topology is much better than the tree. As the link error probability increases, the difference decreases, but the hierarchy is still more reliable.

P	Tree	Hierar.of Rings
0	0%	0%
0.01	3.75%	0.19%
0.02	8.10%	0.76%
0.03	10.84%	1.71%
0.04	14.84%	3.03%
0.05	17.70%	4.11%
0.06	22.65%	6.11%
0.07	23.26%	7.56%
0.08	29.11%	10.03%

Table 1. Packet loss rates as a function of link error probability when the link error probability is low

Conclusions

We have designed and run a simulation of two micro mobility network topologies. Reliability was in the focus of our simulation. A tree topology network and a hierarchy of rings topology network were compared using the simulation tool OMNeT++. Some extensions were made to the simulation tool, then two networks of both topologies with different sizes were simulated. We examined the packet loss rates as a function of link error probability. Our results show that the hierarchy of rings network topology provides much better reliability especially in the low and normal link error probability domain.

Thus, the hierarchy of rings can be a true alternative IP micro mobility network.

Acknowledgments

The project is supported by OTKA F032268, (Hungarian Scientific Research Foundation)

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