Message Delivery in Heterogeneous Disruption-Prone Networks

Demonstration Abstract

Marc Mendonca
UC Santa Cruz
msm@soe.ucsc.edu

Rao Naveed Bin Rais
INRIA
nbrais@sophia.inria.fr

Thierry Turletti
INRIA
turletti@sophia.inria.fr

Katia Obraczka
UC Santa Cruz
katia@soe.ucsc.edu

1. INTRODUCTION

The vision of a world where users can be connected "anytime, anywhere", considered futuristic only a decade ago, is now becoming reality. One critical enabling technology for "universal connectivity" is the ability to interconnect different types of networks, ranging from wired, infrastructure-based wireless (e.g., cellular-based networks, wireless mesh networks) to infrastructure-less wireless networks (e.g., mobile ad hoc networks, or MANETs, vehicular networks, or VANETs). Interconnecting such different networks presents several challenges including seamless message delivery. Additionally, a number of emerging applications such as environmental monitoring, emergency response, and vehicular communications, to name a few, require that future internetworks be tolerant to frequent, long-lived connectivity disruptions.

Most current approaches, such as EDIFY [1] or CCN [2], only provide partial solutions to the heterogeneity problem faced by future internets. One of our research goals is to provide a flexible mechanism to bridge together infrastructure-based and infrastructure-less networks even under intermittent connectivity. For this purpose, we have developed MeDeHa (Message Delivery in Heterogeneous, Disruption-prone Networks [3])[1], a framework to allow message delivery across an internet consisting of different types of networks. Unlike previous proposals, one of MeDeHa's features is that it does not require any modification to existing MANET routing protocols.

For this demonstration, we have implemented the MeDeHa framework on both a Linux-based testbed as well as the ns-3 simulator. This approach allows us to create a "hybrid" network that is composed of both real– and simulated nodes.

Creating a hybrid network has several benefits over simulated or testbed-only networks. Testbed scenarios are limited by many factors, including size, cost, and limited mobility. While simulated scenarios do not have these constraints, it can be difficult to duplicate "real" network traffic and guarantee that the simulated results are a representation of what would have happened on real hardware. By combining the two approaches, we are able to create more interesting scenarios to showcase the functionality and scalability of the MeDeHa framework.

2. MEDEHA OVERVIEW

MeDeHa incorporates node and network heterogeneity and tries to make use of it whenever possible. To facilitate message delivery, MeDeHa nodes (MDH) have several responsibilities, including finding paths (or a suitable relay) to a destination across all connected networks, acting as a relay for other nodes to forward or buffer messages, and exchanging topological and routing information to aid in relay selection.

MeDeHa's notification protocol [3] plays a key role in seamless message delivery across multiple heterogeneous interconnected networks. It collects information about a node and its neighborhood and shares that information with other nodes by exchanging *notification messages*. Neighborhood information is then used by MDH nodes to construct their routing/contact tables. We can describe MeDeHa's protocol both in terms of functionality and network operation. With respect to functionality, MeDeHa's notification protocol has two main components, named *neighborhood sensing* and *neighborhood information exchange*. Neighbor sensing is used to detect immediate neighbors, which is done using broadcast of periodic *HELLO* messages (e.g., in ad hoc or MANET networks), or using underlying network information (e.g., association information in infrastructure-based networks). Neighborhood information exchange is performed using the information collected via neighbor sensing.

[1]A preliminary version of MeDeHa is described in [4]

With respect to network operation, the notification protocol can also be divided into two components, *infrastructure network operation* and *infrastructure-less network operation*.

Infrastructure-based network operation involves collecting nodes' connectivity information (association / disassociation). This information is exchanged between APs, which are also able to act as relays to store messages for unavailable destinations.

Infrastructure-less operation is based on gathering network information from neighboring nodes (using protocol messages [3]), also passing this information to an infrastructure-based network through gateway (GW) nodes, if possible. A key benefit of infrastructure-less networks (e.g., MANETs) is the ability to extend the coverage area or act as a "transit" network to link two disjoint infrastructure network segments. MeDeHa also incorporates MANET routing protocols without requiring any modification to these routing protocols.

3. IMPLEMENTATION

We implement the MeDeHa framework on both real nodes and the ns-3 network simulator. This approach along with the emulation and real-time scheduling available in ns-3 allows us to create hybrid scenarios that involve both real– and simulated nodes simultaneously.

3.1 Testbed Implementation

Figure 1 shows the development approach that we take to implement the MeDeHa framework on the Linux kernel. To achieve high portability and compatibility with the existing infrastructure, the notification protocol is implemented at the network layer as a user-space daemon. All required MeDeHa information is included as part of the IP header (as IP option) and no transport or application data is modified. The IP header option for MeDeHa is shown in Figure 2. This allows MeDeHa nodes to function over existing networks with existing protocols.

The Linux implementation uses Netfilter [5] to hook into the Linux protocol stack and passes network packets to the user-space daemon for further processing. As shown in Figure 1, all incoming and outgoing packets are intercepted before passing through the kernel routing algorithm. The daemon determines whether a packet should be buffered or forwarded based on whether a connected next hop destination or relay exists.

Neighborhood connectivity is determined through a combination of MeDeHa control messages and 802.11 management frames as described in the MeDeHa specification [3], [4]. The daemon must also use this information to manage the kernel routing table and continue to accept packets from user applications even if it appears that connections are disrupted.

In MANET networks, only nodes that will be acting as a gateway (GW) are required to run the MeDeHa framework. This allows existing MANET nodes to benefit from MeDeHa without modification, while also aiding MeDeHa nodes by extending the coverage area. The GW communicates and builds information about the MANET network using an existing routing protocol (such as OLSR). Additionally, it must gather and share information about other networks by exchanging control messages with other MANET or infrastructure GWs. This information is then used to relay messages between nodes in different networks.

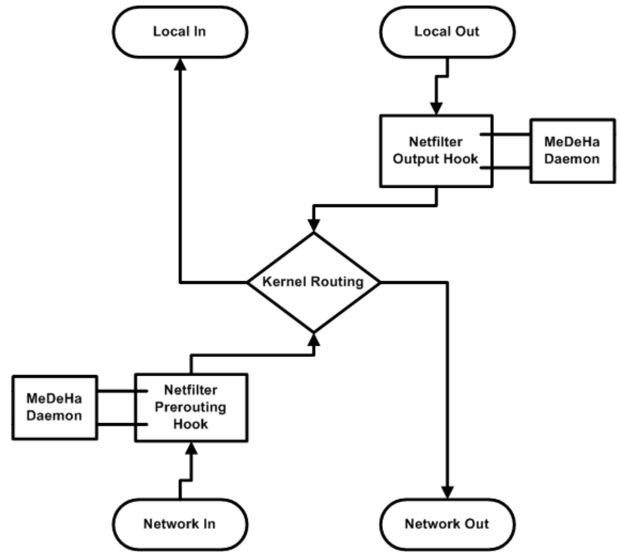

Figure 1: MeDeHa's implementation on the Linux 2.4 kernel. Both Incoming and Outgoing packets are intercepted for processing before being passed to Linux kernel routing

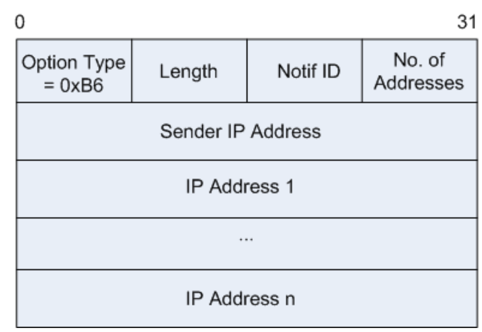

Figure 2: MeDeHa notification header implemented as IP header option

3.2 Simulator Integration

We integrate the ns-3 MeDeHa implementation with the testbed through the ns-3 emulation and real-time scheduling capabilities, as shown in Figure 3. Specifi-

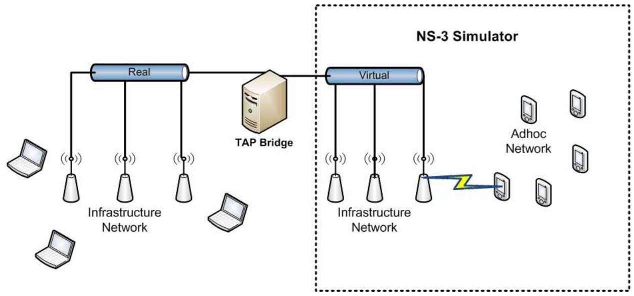

Figure 3: A sample hybrid experimentation setup involving real nodes acting as APs and stations, and virtual nodes running in the NS-3 simulator

cally, we use ns-3 TAP [7] to bridge part of the simulated network to the testbed network. This works by creating a "ghost" node on the ns-3 network that passes all Ethernet frames between a Linux TAP device on the real node and the simulated links to which the ghost node is connected. Packets can then be routed between the simulated network and the networks to which the real node is connected. To our knowledge, we are the first ones to perform this kind of hybrid experiments.

4. DEMONSTRATION

The demonstration will showcase our implementation of MeDeHa and its abillity to perform message delivery over heterogenous networks. Additionally, we plan to demonstrate hybrid scenarios where part of the network will run in a simulation platform (ns-3) and the other part will run on real nodes.

4.1 Scenario

Our demonstration testbed will initially consist of 5 Linux laptops with 802.11g wireless cards: 4 of the laptops will be configured as wireless stations or access points and the remaining laptop will be set up to run a network of virtual ns-3 nodes. To demonstrate message delivery in a disruption-prone environment, links between network segments will be intermittently disconnected and wireless stations will move between regions of access point connectivity. Some of the stations will act as gateways for a MANET in which the demo session attendees will be able to participate. In addition, if Internet access is available we plan to communicate with external nodes of our testbed located at UCSC and at INRIA.

The simulated portion of the hybrid network will consist of 30 stations along with 5 access points that will be connected to each other over Ethernet. Several stations in the simulator will be mobile and will move between access points and MANETs.

To demonstrate message delivery, nodes will run file transfer and chat applications. The real nodes will have the potential to communicate with each other as well as with the virtual nodes.

4.2 Setup and Miscellaneous Information

- Equipment: 5 Linux laptops
- Facilities: Power and Internet access
- Setup Time: 1 hour
- Demo Competition: Eligible
  Marc Mendonca - PhD Student
  University of California - Santa Cruz
  Rao Naveed Bin Rais - PhD Student
  University of Nice - INRIA

5. CONCLUSION

Providing seamless message delivery in heterogeneous internets comprising infrastructure and ad hoc networks is becoming a critical enabling technology for future internets.
The contribution we hope to demonstrate is two-fold: (1) we introduce and implement a flexible mechanism to bridge together infrastructure-based and infrastructure-less networks while supporting episodic connectivity; (2) we conduct "hybrid" experiments, showcasing the ability of MeDeHa to deliver real network traffic over a variety of scenarios on both real and simulated networks.

6. REFERENCES

[1] M. Chuah, L. Cheng, and B. Davison, *Enhanced Disruption and Fault Tolerant Network Architecture for Bundle Delivery*, in Proceedings of IEEE Globecom, 2005.
[2] Van Jacobson, D. K. Smetters, J. D. Thornton, M. Plass, N. Briggs, and R. L. Braynard, *Networking Named Content*, in Proceedings of ACM CoNext, 2009.
[3] Rao Naveed Bin Rais, Thierry Turletti, and Katia Obraczka, *MeDeHa - Efficient Message Delivery in Heterogeneous Networks with Intermittent Connectivity*, INRIA Research Report No. 7227, 2010.
[4] Rao Naveed Bin Rais, Thierry Turletti, and Katia Obraczka, *Coping with Episodic Connectivity in Heterogeneous Networks*, in Proceedings of 11th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM), Vancouver, BC, Canada, 2008.
[5] *Netfilter*, http://www.netfilter.org/.
[6] *Hostapd*, hostapdhttp://hostap.epitest.fi/hostapd/.
[7] *NS-3 Tap Bridge*, http://www.nsnam.org/doxygen-release/group___tap_bridge_model.html.