OMNI: an Overlay Mobile ad-hoc Network at the edge of the Internet

Sho Fujita
Graduate School of Information Science and Technology
The University of Tokyo
7-3-1, Bunkyo, Tokyo, Japan 113–8656
fujisho@hongo.wide.ad.jp

Hiroshi Esaki
Graduate School of Information Science and Technology
The University of Tokyo
7-3-1, Bunkyo, Tokyo, Japan 113–8656
hiroshi@wide.ad.jp

1 Introduction

When a system consists mainly of mobile nodes, the IP addresses and the network layer topology among them change dynamically. In order to maintain communications in such a situation, the applications must implement mechanisms to discover the new IP addresses of the affected nodes and/or the path to them.

To allow unmodified applications to work in such situations, an overlay network through which IP datagrams are transparently routed has been studied in previous works [1][2][3]. However, as far as we know, previous works need one or multiple *core nodes* which must be reachable from all the nodes. Some nodes become unreachable, when they lose reachability to the core nodes. As a result, even if applications running do not have single points of failure, the overall systems have them.

In this paper, we present a middleware named Overlay Mobile ad-hoc Network at the edge of the Internet (OMNI), which provides a consistent view of a network to distributed applications running on mobile nodes. OMNI forms and maintains an overlay network among the mobile nodes without depending on core nodes that are reachable from all the nodes. Moreover, OMNI can be extended by implementing routing algorithms that are suited to specific environments.

2 OMNI Design

OMNI provides mechanisms to form an overlay network, and implement routing algorithms on the overlay network. The architecture of OMNI consists of two layers:

- The *logical link layer*, which hides the complexities of the underlying network.
- The *logical network layer*, which routes and forwards IP datagrams through the logical links.

Both of layers allow us to define a consistent network which is independent of lower IP network topology changes.

2.1 Logical Link Layer

The logical link layer forms and maintains an overlay network. The overlay network consists of *channels*, which are logical connections between two nodes. There are two types of channels;

- A *shared channel* is shared among multiple nodes: e.g., an IP subnetwork. A multicast message on a shared channel is delivered to multiple nodes whose IP addresses are unknown in advance.
- A *point-to-point channel* is made between two nodes: e.g., a UDP tunnel. In order to make a point-to-point channel, a node must know the IP address of the peering node in advance. The IP address is configured by an administrator or assigned by a directory service such as DNS and DHT. A multicast message on a point-to-point channel is delivered only to the peering node.

A node that passively establishes a channel learns the IP address of the peering nodes. The configured and learned IP addresses are distributed and shared among nodes by the logical link layer. Therefore, the administrator does not need to manually configure all the channels by himself.

A node with OMNI has one or multiple channels. OMNI provides three primitive interfaces of the channels to the upper layer protocols. In other words, the logical network layer, which will be described later, is implemented by using these interfaces.

- *handleMessage(message, neighbor)* is a callback function called by OMNI when it receives a message through an overlay network. *message* is a received byte array and *neighbor* is a socket address of the node which transmitted the message.
- *multicastMessage(message)* is a function which transmits a *message* to all neighboring nodes; it multicasts the *message* from all the channels.
- *unicastMessage(message, neighbor)* is a function which transmits a *message* to the neighboring node specified by *neighbor*.

Note that the logical link layer hides most of the characteristics of the underlying network.

2.2 Logical Network Layer

The logical network layer is located above the logical link layer and shows interfaces which resemble those of the underlying network layer. It provides a *virtual network device* for an overlay network. The virtual network device has a *logical IP address* on it. The logical IP address is the identifier of the nodes in the overlay network. Since a logical IP address does not identify a location but a node itself, it does not change even when the node moves to different locations. The virtual network device is the entry point of IP datagrams to the overlay network. When the logical IP address is chosen as a source address of an IP datagram, it is delivered to the overlay network through the virtual network device. OMNI encapsulates the IP datagram and forwards it through the overlay network by the destination address. When the datagram is forwarded to the target, it is decapsulated and brought back to the physical IP network through the virtual network interface.

As a whole, the logical network layer allows the higher layers to operate as is, even when the underlying network is changing.

2.3 OMNI Implementation

We have implemented a prototype system of OMNI as a proof-of-concept of our design. The virtual network device is based on a TUN/TAP device which is available on most of platforms.

Our target is a mobile environment where we have observed MANET characteristics[5](Fig.1). That is, links are not necessarily bidirectional, transitive and stable. Since it is difficult for traditional routing protocols to operate in such a dynamic environment, we implemented a reactive routing protocol which derives from DYMO[4].

Initially Node 2 and 3 are manually configured to have a logical link to Node 1 (Fig. 1-a). Node 1 learns the IP addresses of Node 2 and 3, then distribute them to Node 2 and 3. Now Node 2 and 3 know each other (Fig. 1-b). Since the IP address of Node 2 is cached, Node 3 can reconnect to Node 2 even when Node 1 is disconnected (Fig. 1-c).

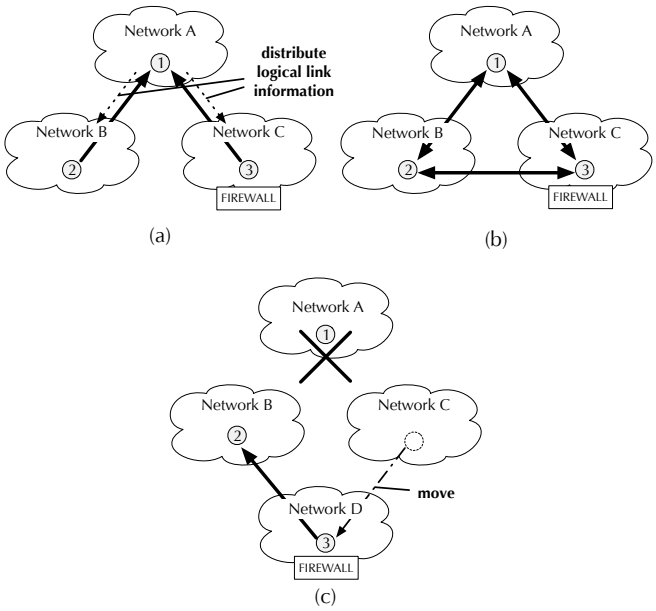

Figure 1. maintenance of an overlay network

3 Conclusion

We have presented a middleware named OMNI that provides mechanisms for forming an overlay network, and routing IP datagrams through the overlay network. OMNI allows an unmodified application to run in mobile environments. Moreover, OMNI does not depend on global reachability. For future work, we will evaluate distributed applications such as BitTorrent over mobile nodes with OMNI.

References

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