On Seamless Connectivity over Multi-Radio and Multi-Channel Wireless Mesh Networks

Sho Fujita
The University of Tokyo
fujisho@hongo.wide.ad.jp

Tadashi Yasumoto
The University of Tokyo
tadashi@hongo.wide.ad.jp

Hiroshi Esaki
The University of Tokyo
hiroshi@wide.ad.jp

1. INTRODUCTION

In IEEE802.11 wireless mesh networks (WMN), we had suffered from performance degradation caused by contention and interference. To avoid the issue with a reasonable cost, we have been working on the configuration where nodes are equipped with multiple commodity IEEE802.11 interfaces and antennas. Although the WMNs of the configuration were segmented by multi-channelized links, traditional applications needed it to be a single-tier and easy-to-use network. In this paper, we present a scheme introducing a virtual link layer that allows mobile nodes to move around without changing its identifier and losing its connectivity to such kind of WMNs. We have implemented a prototype system of our scheme using the click modular router framework [2]. We have confirmed that existing applications, such as DHCP and mDNS, run on the multi-radio and multi-channel WMN without any modification.

2. AD-HOC WIRELESS MESH NETWORK

Some IEEE802.11 based large-scale WMNs have been deployed so far. These WMNs were carefully planned along with the population distribution, and were composed of specialized hardware, such as high-gain and/or directional antennas. It needs still large investment while it might be paid off for a long time. Hence, it is difficult to apply them to the situations where the network is needed only for a short time. For example, meetings or conferences held where network infrastructure does not exist and disaster-stricken areas where existing network infrastructure become unavailable.

Therefore, we have been studying on *ad-hoc WMN*, which is deployed and withdrawn on demand. So as
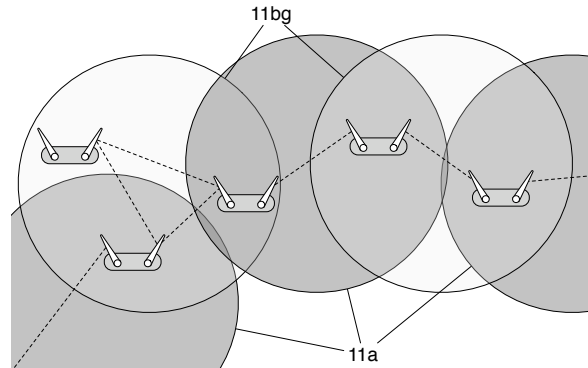
Figure 1: An example configuration of our multi-radio and multi-channel WMNs

to make it perform well with a reasonable cost, we have developed a node equipped with multiple commodity IEEE 802.11 WLAN interfaces and omni-directional dipole antennas. These WLAN interfaces use IBSS mode. Figure 1 depicts an example configuration of the WMN consisting of the nodes. Each node assigns different channels to two interfaces. Note that we assigned channels from different frequency bands to two interfaces of a node, as Draves et al. pointed out in [1]. Otherwise, we observed interference between common IEEE802.11 devices even if we assigned the most distant channels of the same frequency band. In this configuration of WMNs, we can achieve high throughput since we can reduce interference among channels. On the other hand, it is difficult for mobile nodes to maintain connectivity because they have relatively small cells with different channels and do not have any shared channel like cellular networks.

3. SEAMLESS CONNECTIVITY

We consider host-based routing on a set of stationary nodes configured like the example in the last section and a set of mobile nodes. However, we can not simply apply ad-hoc routing protocols to them since most

of ad-hoc routing protocols assume on operation under the single-channel environment. We have to assign the same channel as the neighboring nodes before getting connectivity to them. Consequently, routes, which mobile nodes search for, largely depends on channel assignments. We introduce a virtual link layer to decouple the handover and routing process and then utilize existing ad-hoc routing protocols so as to provide seamless connectivity to mobile nodes.

3.1 Routing over Virtual Link

First, we introduce a virtual network interface that is independent of physical network interfaces. It is always active no matter if physical ones are active or not. Its configuration is invariant even if physical ones are replaced. Hence, if we use the MAC address of the virtual network interface as routing identification, we can conduct the routing process independently of the handover process.

At this stage, assuming that access points have a simple tree topology, we use the simple forwarding scheme, which is bridging with loop prevention based on a duplicated packet detection. Each node maintains a sequence number for the duplicated packet detection. The frames transmitted from the virtual network interfaces are encapsulated by a header that includes this sequence number. This mechanism, which is similar to that of Simplified Multicast Flooding [3], confirms uniqueness of packet. While packets are forwarded to all the physical network interfaces in the initial state, each node learns the connectivity to other nodes then forwards packets with the specific destination MAC address only to the specific physical network interface.

3.2 Interaction with Handover

We have to select the channel and BSSID to handover in IEEE802.11 IBSS mode. As Velayos et al. analyzed handover time in [4], detection phase, where decrease in link quality is detected, and scan phase, where new access points are scanned, are also dominant in the IBSS mode. As an example configuration of handover process, we explain a handover technique using two physical network interfaces at the same time. Figure 2 depicts the interaction between the routing and the handover daemon in this configuration. In this technique, the *switch* maintains which network interface is communicating. The interface in use, which is called *working interface*, is connected to the virtual network interface without doing any process that might degrade the link quality, such as scanning. On the other hand, the interface not in use, which is called *backup interface*, proactively searches for neighboring nodes and evaluates the qualities of them. The handover process compares the qualities of the working and backup interfaces and then swaps their roles if the backup interface is superior. We
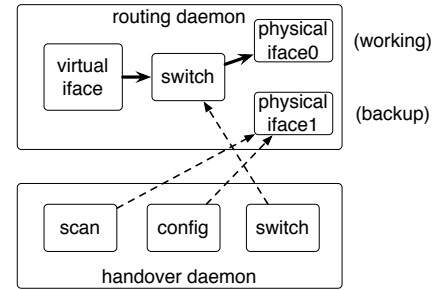

Figure 2: Interaction between the handover and routing

can achieve seamless handover that does not include the detect and scan phases since at least one network interface is connected to the APs.

4. EARLY RESULTS AND CONCLUSION

We have constructed a commodity-based IEEE802.11 WLAN multi-radio and multi-channel WMN and addressed its practical configuration. In order to achieve seamless connectivity over the WMN in the configuration, we introduced a scheme that introduces a virtual link layer decoupling the routing and handover processes. We have implemented a prototype system of the scheme on the click modular router framework [2]. We combined the simplified routing process, which is bridging with loop prevention, with the handover process, which uses two physical network interfaces at the same time. Although we have to modify the system software of the mobile nodes, the virtual network interface hides the configuration changes of the physical network interfaces. We have confirmed that existing applications, such as DHCP and mDNS, can run on the WMN without any modification.

5. REFERENCES

[1] R. Draves, J. Padhye, and B. Zill. Routing in Multi-Radio, Multi-Hop Wireless Mesh Networks. In *Mobicom*, 2004.

[2] E. Kohler, R. Morris, B. Chen, J. Jannotti, and M. F. Kaashoek. The Click Modular Router. In *ACM Transactions on Computer Systems*, 2000.

[3] J. Macker and S. D. Team. Simplified Multicast Forwarding for MANET. *Work in Progress*, Feburary 2008.

[4] H. Velayos and G. Karlsson. Techniques to Reduce IEEE 802.11b MAC Layer Handover Time. Technical report, KTH, Royal Institute of Technology, 2003.