MultiNet: Connecting to Multiple IEEE 802.11 Networks Using a Single Wireless Card

Ranveer Chandra
Department of Computer Science
Cornell University
Ithaca, NY 14853
Email: ranveer@cs.cornell.edu

Paramvir Bahl
Microsoft Research
One Microsoft Way
Redmond, WA 98052
Email: bahl@microsoft.com

Pradeep Bahl
Microsoft Corporation
One Microsoft Way
Redmond, WA 98052
Email: pradeepb@microsoft.com

IEEE INFOCOM 2004
Outline

- INTRODUCTION
- MOTIVATING SCENARIOS AND BACKGROUND
- THE MULTINET APPROACH
- IMPLEMENTATION AND SYSTEM EVALUATION
- DISCUSSION
- CONCLUSION
INTRODUCTION

- Propose MultiNet, a new virtualization architecture that abstracts a single wireless LAN (WLAN) card to appear as multiple virtual cards to the user.
INTRODUCTION

In this paper, make the following four research contributions:

- A new architecture for virtualizing WLAN cards.
- Algorithms for switching between disparate networks.
- A buffering protocol that ensures packet delivery to switching nodes, and
- A protocol for synchronizing nodes that switch between different networks.
MOTIVATING SCENARIOS

• Concurrent Connectivity
• Network Elasticity
• Gateway Node
• Increased Capacity
• Virtual Machines
BACKGROUND

- The limitations of IEEE 802.11 networks.
- Maintaining simultaneous connections to multiple wireless networks is a non-trivial problem.
Background

- Limitations in Existing Systems
  - The card cannot interact with nodes in another network if the nodes are operating on a different frequency channel.
  - IEEE 802.11 does not address the difficult issue of synchronization between different networks.
Next Generation of IEEE 802.11 WLAN cards

- As Native WiFi cards, implement just the basic time-critical MAC functions, while leaving their control and configuration to the operating system.
- These cards allow the operating system to maintain state and do not undergo a firmware reset on changing the mode of the wireless card.
THE MULTINET APPROACH

- MultiNet within the context of the following four questions:
  - What changes do we need to make in the networking stack to support MultiNet?
  - What buffering protocols should we use to ensure delivery of packets across the disjoint networks?
  - What switching algorithms should we use to get the best performance from MultiNet? and
  - How do we do synchronize multiple switching nodes in an ad hoc network?
THE MULTINET APPROACH

- The Virtualization Architecture
- Buffering Protocol
- Switching Algorithms
- Synchronization Protocol
THE MULTINET APPROACH

- The Virtualization Architecture
- Buffering Protocol
- Switching Algorithms
- Synchronization Protocol
THE MULTINET APPROACH

- The Virtualization Architecture

Fig. 1. Modified network stack
THE MULTINET APPROACH

- The Virtualization Architecture
- Buffering Protocol
- Switching Algorithms
- Synchronization Protocol
THE MULTINET APPROACH

- Buffering Protocol in the subsection below:
  1. Packets Sent from the MultiNet Card
  2. Packets Sent to the MultiNet Card
  3. Properties
  4. Buffering on IEEE 802.11 Access Points
THE MULTINET APPROACH

- Subsection
  - 1. Packets Sent from the MultiNet Card
    - If the adapter is active, the packet is sent to the card for transmission.
    - If the adapter is passive, the driver buffers the packet.
2. Packets Sent to the MultiNet Card

- Packets sent to a switching card over network $i$ will be lost if the card is in a different network $j$ at that instant.
THE MULTINET APPROACH

Fig. 2. Buffering in MultiNet
THE MULTINET APPROACH

3. Properties

- The buffering protocol is based on the assumption that nodes maintain their promises.
- A value larger than the actual switching time causes an extra delay in getting packets, while a smaller value results in packet loss.
THE MULTINET APPROACH

- 4. Buffering on IEEE 802.11 Access Points
  - MultiNet cards will fake PSM to the APs when they switch to another network.
  - When a card enters PSM, the AP automatically buffers packets for that card.
THE MULTINET APPROACH

- The Virtualization Architecture
- Buffering Protocol
- Switching Algorithms
- Synchronization Protocol
THE MULTINET APPROACH

- **Switching Algorithms**
  - *Strategies*: two strategies to determine the activity period of each network.
    - Fixed Priority
    - Adaptive Schemes
      - Adaptive Buffer
      - Adaptive Traffic
  - *Switching on IEEE 802.11 Network Cards*
    - If do not have any packets to send, it goes to sleep for the rest of its Activity Period.
THE MULTINET APPROACH

- **Synchronization Protocol**
  - *Effect on Infrastructure and Ad Hoc Networks*
  - *A Distributed Switching Algorithm*
    - It tries to achieve synchronized switching to and from the ad hoc network for all members of that network.
THE MULTINET APPROACH

- Algorithm Description
  - Define a leader of an ad hoc network to be a node with the largest MAC address in that ad hoc network.
  - Changes its $ATP$ and $SC$
    - $ATPi$: Activity (Time) Period in network $i$.
    - $SC$: Switching Cycle.
IMPLEMENTATION AND SYSTEM EVALUATION

Implemented on Windows XP. Windows provides a Network Driver Interface Specification (NDIS) as an intermediate layer between the network device drivers and IP.
IMPLEMENTATION AND SYSTEM EVALUATION

Fig. 3. The modified Windows network stack
The MPD exposes a virtual adapter for each network to which the wireless card is connected.

The MMD maintains the state for each virtual adapter.

The advantage of this architecture is that there is a different IP address for each network.
The MPD manages the state of the virtual adapters.

- Switches the association of the underlying card across different networks, and
- Buffers packets if the SSID of the associated network is different from the SSID of the sending virtual adapter.
IMPLEMENTATION AND SYSTEM EVALUATION

- The MMD maintains the state for each virtual adapter.
  - Includes the SSID and operational mode of the wireless network.
  - It is also responsible for handling query and set operations meant for the underlying wireless adapter.
IMPLEMENTATION AND SYSTEM EVALUATION

- **MultiNet Service**
  - At the user level.
  - It interacts with other MultiNet nodes, and
  - Passes signaling messages to the MultiNet Driver to either start or stop a switching and buffering action.
  - Responsible for signaling the switching time to the MPD. This signal indicates the time to switch the card, and activate another network.
IMPLEMENTATION AND SYSTEM EVALUATION-1

- **Switching Delay**

<table>
<thead>
<tr>
<th>Switching From</th>
<th>Unoptimized Legacy</th>
<th>Optimized Legacy</th>
<th>Optimized Native WiFi</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS to AH</td>
<td>3.9 s</td>
<td>170 ms</td>
<td>25 ms</td>
</tr>
<tr>
<td>AH to IS</td>
<td>2.8 s</td>
<td>300 ms</td>
<td>30 ms</td>
</tr>
</tbody>
</table>

TABLE I

The delays on switching between IS and AH networks for IEEE 802.11 cards with and without the optimization of trapping media connect and disconnect messages.
IMPLEMENTATION AND SYSTEM EVALUATION-1

- **Switching Strategies**

Fig. 4. Amount of time taken to complete the FTP transfer of a file on an ad hoc and infrastructure network for different switching strategies.
Adaptive Switching

Fig. 5. Variation of the activity period for two networks with time. The activity period of a network is directly proportional to the relative traffic on it.
IMPLEMENTATION AND SYSTEM EVALUATION-1

- *MultiNet versus Multiple Radios*

Fig. 6. Packet trace for the web browsing application over the infrastructure network
Fig. 7. Packet trace for the presentation and chat workloads over the ad hoc network.
IMPLEMENTATION AND SYSTEM EVALUATION-1

TABLE II

<table>
<thead>
<tr>
<th>Network</th>
<th>Two Radio</th>
<th>MultiNet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ad Hoc</td>
<td>4.4 Mbps</td>
<td>1.1 Mbps</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>5.8 Mbps</td>
<td>4.35 Mbps</td>
</tr>
</tbody>
</table>

Fig. 8. Comparison of total energy usage when using MultiNet versus two radios
TABLE III

THE AVERAGE PACKET DELAY IN INFRASTRUCTURE MODE FOR THE VARIOUS STRATEGIES

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Avg Delay (in Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Radio</td>
<td>0.001</td>
</tr>
<tr>
<td>MultiNet</td>
<td>0.157</td>
</tr>
<tr>
<td>Two Radio PS</td>
<td>0.156</td>
</tr>
<tr>
<td>MultiNet PS</td>
<td>0.167</td>
</tr>
</tbody>
</table>

Fig. 9. Energy usage when using MultiNet and two radios with IEEE 802.11 Power Saving
### IMPLEMENTATION AND SYSTEM EVALUATION-1

<table>
<thead>
<tr>
<th>Num Networks</th>
<th>Avg Delay (in Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.191</td>
</tr>
<tr>
<td>3</td>
<td>0.261</td>
</tr>
<tr>
<td>4</td>
<td>0.332</td>
</tr>
<tr>
<td>5</td>
<td>0.410</td>
</tr>
<tr>
<td>6</td>
<td>0.485</td>
</tr>
</tbody>
</table>

**TABLE IV**

The average packet delay in infrastructure mode on varying the number of MultiNet connected networks.
DISCUSSION

- Discuss various ways in which the performance of MultiNet can be improved further.
  - Reducing the Switching Overhead
  - Network Port Based Authentication
  - Can MultiNet be done in the Firmware?
  - Impact of Virtualization
CONCLUSION

- The affect of switching on TCP performance and scaling in multihop networks. These problems need to be explored in greater detail and we are working on them actively.