PHY Aided MAC: A New Paradigm

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Outline

1. Introduction
2. Demonstrating Implementation Feasibility
   - Encoding the Signals
   - Detecting the Signals
   - Hardware Implementation
3. Efficient MAC Protocol Using PHY Signaling
   - Medium Access Control
4. Result And Analysis Of Simulation Study
   - Comparing with DCF
5. Future Work and Conclusion
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Why is the Internet so slow?

I need wired connection - wireless is too slow!!!
**OFDM Basics**

- Multicarrier modulation technique
- Non-interfering subcarriers
- Each subcarrier can be retrieved by FFT

\[
f_1 = f_c + 10 \times f_\delta
\]

\[
f_2 = f_c - 10 \times f_\delta
\]

Composite Waveform in time domain:
\[
f = f_1 + f_2
\]

FFT of \( f \)
Utilizing OFDM for Simultaneous Communication

- AP assigns unique subcarrier frequencies to each client.
- AP queries using the whole spectrum.
- Clients respond back in each subcarrier.

**Figure:** Infrastructure-based network

**Figure:** Schematic Illustration of OFDM Wave properties

**Figure:** Waterfall Plot in VSA

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Variation of Tone Duration with Queue Size

Table: Signaling Scheme for AP

<table>
<thead>
<tr>
<th>State</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; &amp; 2&lt;sup&gt;nd&lt;/sup&gt; symbol</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; &amp; 4&lt;sup&gt;th&lt;/sup&gt; symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO packets to send</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>YES, LOW Priority, Queue &lt; 33%</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>YES, MEDIUM Priority, 33% ≥ Queue ≤ 66%</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>YES, HIGH Priority, Queue &gt; 66%</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Tone Detection

Near Far Effect

Figure: Signal Timing Diagram
Energy Detection
8 Clients transmitting tone with variable delays

Figure: Composite Waveform

Figure: FFT of Composite Waveform
Demonstrating Implementation Feasibility

Hardware Implementation

Hardware Implementation with 3 Nodes

Figure: Nallatech XtremeDSP Development Kit with Xilinx Virtex-IV FPGA

Based on previous work:
Transmitter $^a$, Receiver $^b$

$a$ Fifield et. al., Experiences With a Platform for Frequency-Agile Techniques, DySPAN’07

$b$ Dutta et. al., An Intelligent Physical Layer for Cognitive Radio Networks, WICON’08

(a) Broadcast

(b) ACKs
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Parallel Polling

- **DCF Contention Based Period**
- **Schedule Based Period**
  - Multiple Uplink Frames
  - Single Downlink Frame
  - Uplink Frames are flexible width
What do we gain?

**Figure**: Comparing SMACK with PCF/DCF
Result And Analysis Of Simulation Study

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## Simulation in QualNet Network Simulator

**Table: General Simulation Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds</td>
<td>10</td>
</tr>
<tr>
<td>Packet Size (VoIP)</td>
<td>120\textit{bytes} (G7.11 codec)</td>
</tr>
<tr>
<td>Packet Arrival Interval</td>
<td>15\textit{ms} (G7.11 codec)</td>
</tr>
<tr>
<td>Physical Layer Data Rate</td>
<td>36\textit{Mbps}</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>120\textit{secs}</td>
</tr>
<tr>
<td>Pathloss Model</td>
<td>Two-Ray</td>
</tr>
<tr>
<td>Application Layer</td>
<td>CBR</td>
</tr>
<tr>
<td>Transport Layer</td>
<td>UDP</td>
</tr>
<tr>
<td>Mobility</td>
<td>None</td>
</tr>
</tbody>
</table>
Simulation Results - Comparing with 802.11a DCF

(a) Throughput

(b) Delay

(c) Jitter
Result And Analysis Of Simulation Study
Comparing with DCF

Bandwidth Utilization with Time

**PAMAC**

![Graph showing bandwidth utilization for PAMAC with time (msec) on the x-axis and node ID on the y-axis.]

**802.11**

![Graph showing bandwidth utilization for 802.11 with time (msec) on the x-axis and node ID on the y-axis.]

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Future Work and Conclusion

**Future Work**
- Compare with PCF and TDMA
- Extend the current protocol for multi-AP network
- Extend the signalling mechanism in decentralized network
- Utilizing the tones for reliable broadcast or multicast
- Increase the size of testbed

**Conclusion**
- Simultaneous tone transmission is feasible
- Lower layer signalling can be utilized in higher layers
- Implemented prototype in a reconfigurable hardware
Questions?