HomeMesh: A Low-Cost Indoor Wireless Mesh for Home Networking

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This article from:
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Outlines

- Introduction.
- HomeMesh System Architecture.
- HomeMesh Channel Assignment Algorithm.
- Access Path determination.
- Evaluation.
- Conclusion.
Introduction

- Wi-Fi (Wireless Fidelity) has become popular.
- Users gain wireless access to Internet via Wi-Fi.
- Wi-Fi deployment is limited to areas where wired LAN is available.
- Due to the short transmission range in indoor environment.
- Wireless Mesh Network (WMN) is a practical and efficient solution to extend the wireless coverage.
Introduction

- WMN consists of Mesh Router (MR) and Mesh Client (MC) nodes.

- MR:
  1. is the WMN Backbone.
  2. Provides wireless access to MC.
  3. Maintain connectivity for MC (routing) and WMN (security and load balancing).
Introduction

- WMN existing solutions are mainly industrial-based with complex algorithms and expensive hardware.

- HomeMesh proposes a simple and low-cost WMN solution for indoor home environment.

- HomeMesh achieves Wi-Fi extension by using nonproprietary off the shell technology.
HomeMesh System Architecture
HomeMesh System Architecture

- HMR has a traditional gateway/repeater functions in addition to routing functions.

- HMRs are built on general purpose computer systems and no extra hardware is required.
Strengths

- Wi-Fi coverage extension.
- Low deployment cost.
- Load balancing and fault tolerance.
- Compatible with existing Wi-Fi devices.
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>Hyacinth</th>
<th>Meraki</th>
<th>HomeMesh</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware requirement</strong></td>
<td>Existing PC/notebook</td>
<td>Need new mesh routers</td>
<td>Existing PC/notebook</td>
</tr>
<tr>
<td><strong>Deployment cost</strong></td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td><strong>MAC layer modification</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Radio channel</strong></td>
<td>Multiple</td>
<td>Single</td>
<td>Multiple</td>
</tr>
<tr>
<td><strong>Channel assignment</strong></td>
<td>Complicated</td>
<td>Simple</td>
<td>Simple</td>
</tr>
<tr>
<td><strong>Routing overhead</strong></td>
<td>Relatively High</td>
<td>Relatively low</td>
<td>Relatively low</td>
</tr>
<tr>
<td><strong>System management</strong></td>
<td>Centralized</td>
<td>Distributed</td>
<td>Distributed</td>
</tr>
</tbody>
</table>
HomeMesh CA Algorithm

- Each HMR has two radios (wireless interfaces).
- Each HMR operates on two orthogonal channels.
- No channel can be used by two consequence links.
- Simple, efficient and practical CA.
- Wireless connectivity! (not discussed).
HomeMesh CA Algorithm

(a)

(b)
Access Path Determination

Path selection:

- The access path of each HMR to the Internet is formed dynamically based on ETX hop metric.

- ETX: Expected Transmission Count.

- ETX calculates number of transmissions including retransmissions.

- HomeMesh may use ETT, WCETT, or others.
Access Path Determination

Mesh Routing Table:

- Exchange messages to update data.
- Broadcast interval can be defined by users.
- HMR maintains a soft-state table contains list of HMRs within its transmission range.
- When two paths have same ETX, hop count is used.
Access Path Determination

(a) Wi-Fi access point → Default path
HM mesh router → Wireless connectivity

(b) ID | Sum of ETX | Hops to gateway | Valid
MR2  | 5          | 2               | True
MR1  | 6          | 2               | True
MR4  | 8          | 3               | True

(c) ID | Sum of ETX | Hops to gateway | Valid
MR0  | 5          | 1               | True
MR2  | 5          | 2               | True
MR4  | 6          | 3               | True
Evaluation

- MadWi-Fi is used to manipulate the master mode radio.

- Linux for configuration.

- PC → HMR: run HomeMesh script in the user space → initialize the HMR table.

- Wireless card is the only hardware required.
Evaluation

Path-1
Path-2

(a)

Path 1 = 3
Path 2 = 4.5
Path 1 = 6
Path 2 = 6
Path 1 = 7
Path 2 = 8

(b)

Client FTP goodput (Kb/s)

0 1000 2000 3000 4000 5000 6000 7000
Conclusion

- Wireless mesh networks can effectively extend Wi-Fi coverage.

- Most of the proposed and implemented solutions are industry-oriented, with high power consumption, and require expensive hardware.

- HomeMesh, a practical and cost-effective implementation of a WMN that extends Wi-Fi coverage in the home environment.

- The router protocol is simple and lightweight, and may be installed on any desktop PC or notebook.

- The HMRs are compatible with the existing Wi-Fi products, and therefore are transparent to APs and mobile clients.

- HMRs dynamically select the access path to the Internet.
Thank you.
ETX Routing Metric (MIT03)

- Present High throughput routing metric on Multi-hop wireless networks
- Expected Transmission Count (ETX)
- Useful with long paths and scalable network.
- ETX is Implemented as a metric for DSDV and DSR.
- Single radio Nodes.
ETX Routing Metric (MIT03)

- ETX = the expected number of transmissions, including retransmissions, needed to send a packet across a link.
- Let
  - $p_f =$ Probability of packet loss in the forward direction.
  - $p_r =$ Probability of packet loss in the reverse direction.
  - $p =$ Probability of packet transmission from x to y NOT successful.

  $$p = 1 - (1 - p_f)(1 - p_r)$$

- Let $S(k) = \Pr\{ \text{the packet will be successfully delivered from x to y after k attempts} \} = p^{k-1}(1-p)$

$$ETX = \sum_{k=0}^{\infty} k \times S(k) = \frac{1}{1 - p}$$
ETX Routing Metric (MIT03)

- The **path metric** is defined as the sum of the ETX values of each length.

- **Assumptions made for ETX:**
  1. Prob. A given packet transmission is independent of its size and it is iid.
  2. ETX is bidirectional
  3. ETX based on the loss rate but not link BW.

- ETX does well in **homogenous single-radio** case.

- ETX **DOES NOT** perform well in an environment with different rates and multiple radios.