

Enmeshed in the Future

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About Me

Donald Eastlake 3rd is



- Chairman of the IEEE
 802.11 Mesh Networking
 Task Group (TGs)
- Co-Chair of the IETF TRILL
 Working Group and a member of the IETF Security
 Directorate



The Trend in Radio LANs

Radio Past

- Point-to-point, including client-server such as station to Access Point (AP)
- Broadcast, one-to-all
- Radio Future

– Mesh multi-hop

The Trend in Wired LANs

Wired LAN Past

- Multi-access, hubs
- Spanning Tree

Wired LAN Future

– RBridges – optimal pairwise paths in a general mesh.

The Trend in Wired LANs

 Spanning Tree restricts a network to a loop-free graph by turning off ports:



The Trend in Wired LANs

 TRILL / Rbridges uses optimal pairwise paths in the full mesh:



Mesh is the New Paradigm

- What's good about Radio Mesh?
 - Can give you:
 - Greater range due to relaying.
 - Higher bandwidth due to shorter hops.
 - Better battery life due to lower power.
 - Provides cheaper backhaul which, combined with "free" clients, can be leveraged to provide ultra low cost services.
 - Fewer wires yields greater mobility

Classic ESS

Wired Infrastructure



ESS Mesh Example

Wired Infrastructure



Home Mesh for Media

• Full home high bandwidth connectivity.

- May require meshed intermediate stations.



Utility Devices

 File servers, printers, projectors or the like may wish to have multiple simultaneous connections.



First Responder

• Fire, Police, EMS, ... radios. Need the improved range and connectivity of mesh.



All Local Radio is Going Mesh

- 802.11 (Wi-Fi)
 - Wireless Local Area Networks (WLAN, ≤ 100 meters)
 - 802.11s: Mesh Networking

• 802.15 (Bluetooth, Zigbee, and high rate)

- − Wireless Personal Area Networks (WPAN, ≤ 10 meters)
- More mesh-like from the start
- 802.15.5 Best Practices for mesh across 802.15.1, 802.15.3, and 802.15.4

• 802.16 (Wi-Max)

- Wireless Metropolitan Area Networks (WMAN)
- 802.16j: "multi-hop relay"

802.11 is the new Ethernet!

- "Everything" has 802.11 built in, clients are "free".
- Like Ethernet, 802.11 is way down the price and learning curve. >200,000,000 chipsets in 2006.
- Like Ethernet, 802.11 was a simple best-effort contention based protocol.
 - But, like Ethernet, it is being stretched to do what it shouldn't, wouldn't, couldn't do: QoS, Mesh, Security, Vehicular Mobility, Faster Rates, Fast Roaming, Etc.
- Bluetooth is profiling their protocols over 802.11.
 - In the future, Bluetooth devices will choose 802.11 if both are available, dual protocol devices will push 802.11 volume up even faster.
- Even before this Bluetooth effort, 802.11 volume was project as 1,000,000,000 a year in 2012. [ABI Research]

802.11 / Wi-Fi

- The largest Working Group in IEEE 802
 - About 250 voting members
 - More active task groups than any other IEEE 802 working group.
- The Wi-Fi Alliance is so successful that it has recently cut membership rates and has certified over 3,000 products.

Wi-Fi / 802.11

- Standard in laptops
- In PDAs, cellphones, cameras, cars, remote controls, ...
- In municipalities, coffee shops, book stores, hotels, restaurants (including McDonald's), gas stations, ...
 - 143,700 Wi-Fi hot spots at the end of 2006, up 47% from 2005;
 - 74% of Wi-Fi hot spots are currently in North America and Europe but by 2011, the Asia Pacific region will surpass them. [ABI Research]

Wi-Fi Speed

- 802.11 initially, 1 Mbps
- 802.11b High Speed in 2.4 GHz band, 11 Mbps
- 802.11a High Speed in 5 GHZ band
 54 Mbps, extended to 2.4 GHz band by 802.11g
- 802.11n High Throughput
 - Greater than 100 Mbps, Draft D2.0 passed Letter Ballot and is now available for purchase from the IEEE. Draft D3.0 in preparation.
- Very High Throughput (VHT) Study Group

 Greater than 1 Gbps, formed at the March 2007 802.11 meeting.

Wi-Fi Spectrum

- 802.11 initial 2.4 GHz
- 802.11a 5 GHz
- 802.11j 4.9-5 GHz Japan
- 802.11-2007 Licensed 4.9 GHz US
- 802.11y 3.65-3.7 GHz US operation

Wi-Fi Security

- WEP a disaster
- Profiling of an early 802.11i Draft (WPA)
- 802.11i (WPAv2) Robust Data Security
- 802.11r includes security for rapid roaming
- 802.11w Protected Management Frames
- 802.11s includes mesh point security

Wi-Fi Mobility

- Wi-Fi has always supported "pedestrian" speed mobility
- 802.11r Rapid roaming, is designed to overcome the set-up overhead of QoS and Security for End Station – AP connections
- 802.11s Mesh, may need to do for MP MP connections what 802.11r did
- 802.11p Wireless Access in the Vehicular Environment, up to 200 kph relative velocity

Additional 802.11 Task Groups

- TGk Radio Resource Measurement
- TGT Wireless Performance
- TGu InterWorking with External Networks
- TGv Wireless Network Management
- TGz Direct Link Setup
- And Additional Study Groups
 - QSE Quality of Service Enhancement SG
 - VTS Video Transport Streams SG

Bumps in the Road for Wi-Fi Mesh

• Quality of Service:

- Congestion control is essential.

- Security:
 - Essential for integrity, authentication, and trust, as well as confidentiality.
 - Mesh makes security more complicated.
- Routing:
 - Not too hard for limited size meshes.

Some Details on 802.11s Wi-Fi Mesh Networking

- Chartered to produce an amendment to the 802.11 standard to create a Wireless
 Distribution System with automatic topology learning and dynamic path configuration.
 - Support unicast, multicast, and broadcast traffic.
 - Use 802.11i security or an extension thereof.
 - Target number of packet forwarding nodes: ~32
 - Extensible routing to allow for alternative forwarding path selection metrics and/or protocols.
 - Use the 802.11 four-address frame format or an extension.
 - Interface with higher layers and connect with other networks using higher layer protocols.

Mesh Points / Mesh APs



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802.11s Time Table

- Nov 2003: Mesh Study Group Formed
- Mar 2004: Charter (PAR) Approved
- Mar 2005: Joint Proposal Adopted
- Dec 2006: 1st Working Group Letter Ballot
- Nov 2007: 2nd Working Group Letter Ballot
- Sep 2008: 1st Sponsor Letter Ballot
- May 2009: Final 802.11 Approval
- Aug 2009: Final IEEE-SA Approval

Useful Websites

• IEEE 802.11:

- http://grouper.ieee.org/groups/802/11/
- <u>https://mentor.ieee.org/802.11/documents</u>
- The joint proposal on which 802.11s is being based: <u>ftp://ftp.802wirelessworld.com/11/06/11-06-0328-00-000s-joint-seemesh-wimesh-proposal-to-802-11-tgs.doc</u>
- The Wi-Fi Alliance: http://www.wi-fi.org
- Slides for tutorials on 802.11s, 802.15.5, 802.16j:

http://grouper.ieee.org/groups/802/802_tutorials/nov06/802.11s_Tutorial_r5.pdf http://grouper.ieee.org/groups/802/802_tutorials/nov06/15-06-0464-00-0005-802-15-5-mesh-tutorial.pdf

http://ieee802.org/16/sg/mmr/docs/80216mmr-06_006.zip

- IETF TRILL Working Group:
 - <u>http://www.ietf.org/html.charters/trill-charter.html</u>

Ubiquitous Mesh and Wi-Fi



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