

Mesh Networking
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Introduction

- "A mesh network is a network that employs one of two connection arrangements, full mesh topology or partial mesh topology. In the full mesh topology, each node is connected directly to each of the others. In the partial mesh topology, nodes are connected to only some, not all, of the other nodes."
 - The term “mesh network” has become synonymous with Ad-Hoc and Mobile Networking.
 - The word “mesh” is used because if you draw the lines for all the connections, that's exactly what it looks like.
- There are three types of wireless mesh networks.
 1. Fixed
 - None of the devices can move around.
 - Commonly more useful for autonomous devices.
 2. Peer-to-Peer
 - *All* of the devices are mobile.
 - Are still pretty far from deployment, outside of a laboratory environment.
 3. Node-to-Node
 - Contains a mixture of fixed and mobile devices.
 - Is currently a more realistic solution than a Peer-to-Peer network.
- My presentation will focus on Peer-to-Peer. There's just too much information to talk about them all, and this is the most interesting one to me.

Characteristics of Wireless Peer-to-Peer Mesh Networks

- A Peer-to-Peer network can use either full or partial mesh topology.
- They are dynamic.
 - Data transmission routes change constantly, because as devices move around the quality or even the presence of previously established routes change.
 - In contrast, fixed mesh networks are not dynamic.
- They are fully mobile.
 - This means that there are no fixed points like in a Node-to-Node network. It also means that the network infrastructure is decentralized.
 - And this means that there is no need for a central server.
 - So they are essentially relieved of maintenance of servers.
 - So when OIT goes down, the entire campus will not.
 - And so essentially, a wireless peer-to-peer mesh network should require *no* maintenance!
- A device in a mesh network can be a “gateway” to other networks.
 - When an uplink of some kind is added via cell, satellite, or wire, the network becomes dynamically aware and can handle queued interactions. [Ref 3]
 - This means that if one device has a connection to the internet, it can be shared with the rest

of the network.

- This obviously has some limitations. If you have 43 laptops getting online through one other laptop, they won't have a very strong connection.
- **Organization and business models:** The decentralized nature of mesh networks lends itself well to a decentralized ownership model wherein each participant in the network owns and maintains their own hardware, which can greatly simplify the financial and community aspects of the system. [\[Ref\]](#)

Advantages

- Greater likeliness of being able to establish a connection.
 - In wireless systems with centralized servers, not every user can always achieve a connection to the server.
 - A common example of this is when one has no signal on their cell phone.
 - This usually happens when things like hills or buildings lie in the path you need to communicate along.
 - In a mesh network there is a greater likelihood that there *is* a path upon which a connection can be established.
 - Note, however, that this doesn't mean it's inevitable that it will always work.
- Enhanced reliability via route redundancy.
 - There usually are many routes to send transmissions through
 - So if one fails, there's another route to take.
- Easier network configuration.
 - Essentially, *no* network configuration other than telling the device to start looking for connections.

Difficulties With Mesh Networks

- In a busy network, there are a lot of devices accessing one frequency band.
 - This introduces capacity constraints.
 - The 802.15.5 standard currently being developed uses Bluetooth
 - Which should be able to handle increased connections because it divides the band into many sub-bands.
 - But it uses the 2.4GHz spectrum, which is already pretty busy.
- There are a lot of connections flying around in a mesh network.
 - So the infrastructure needs to be able to deal with this.
 - The AODV protocol takes steps to deal with this by using a routing method that minimizes network traffic associated with network control.
- In dynamic mesh networks, routing can get quite complicated.
 - This is the biggest challenge in implementing a mesh network protocol.
- A lot of demand is placed on the devices, draining their batteries.
 - As there are improvements in power consumption and battery life of wireless devices, mesh networks will be more viable.
- Latency
 - It takes time to send packets from point to point, and to establish routes.

Protocols

- Ad-Hoc On-Demand Distance Vector (AODV)
 - Primarily a routing protocol for mobile Ad-Hoc Networks.
 - It builds routes on request when they are needed by a device, rather than maintaining routes at all times.
 - Because there's no point in maintaining them, as optimal routes will constantly change.
 - The network remains silent until somebody needs a connection.
 - This leaves more airtime for data transmission.
 - Capable of multicast and unicast.
 - Routes are build using a route request / route reply query cycle:
 - When a connection is needed by a node, it broadcasts a request across the network. (RREQ.)
 - This request contains a sequence number for the device it wishes to connect to.
 - If a node has the route needed, it sends a unicast reply to the source. (RREP)
 - If it does not, then it rebroadcasts the RREQ.
 - The IP of the source is kept, so the devices can ignore the extra RREQ's it will inevitably get due to this method of rebroadcasting.
 - The nodes start to set up a route for the device requesting it as RREP's come in.
 - As better routes are determined, it can be dynamically changed.
- 802.15.5
 - The IEEE 802.15 Task group 5 is chartered to determine the necessary mechanisms that must be present in the PHY and MAC layers of WPANs to enable mesh networking.
 - The current draft is available at <http://www.ieee802.org/15/pub/TG5.html>
 - It is meant to be implemented in Bluetooth devices.
- Generations of wireless mesh products
 - First Generation
 - one radio provides both backhaul (packet relaying) and client services (access to a laptop).
 - Second Generation
 - one radio relayed packets over multiple hops while another provided client access. This significantly improved backhaul bandwidth and latency.
 - Third Generation (Current)
 - Use two or more radios for the backhaul for higher bandwidth and low latency. Third generation mesh products are replacing previous generation products as more demanding applications like voice and video need to be relayed wirelessly over many hops of the mesh network.

Applications

- Peer-to-peer mesh networks are still a ways off, so there are not yet any of the wide-scale community deployments we'd like to see.
- But the possible applications are limited only by your imagination
 - Environments in which many autonomous machines need to communicate with each other.

- A good example would be a wind farm. Each of the windmills on the wind farm need to talk to each other, and running lines to each of them would get expensive.
 - Environments where many devices won't have fixed backhauls
 - Third world countries, as well as domestic rural areas.
 - Cell phones
 - I would like to see a system where if your phone can't connect to a tower, it can connect through another cell phone nearby that *does* have a connection.
- A “hybrid” implementation could be very successful. This would be a system where there are fixed nodes in a location, and other devices come and go, using them as well as the other dynamic devices. They would have all the same capabilities of the other devices, but can guarantee more stability and flexibility.
 - But this goes against one of the fundamental reasons to desire a mesh network:
 - We want to avoid infrastructure!
 - This solution is viable however, and could be deployed soon.
 - This is a “Node-to-Node” wireless mesh network.
- The One-Laptop-Per-Child program
 - This is a program that was established by Nicholas Negroponte with the mission to provide laptops to children in third-world countries.
 - The idea is that it will help them in education.
 - The laptops being developed use mesh networking
 - Because in many third world countries, the infrastructure needed to set up a traditional network does not exist.
 - Mesh networks allow the children to communicate with nearby towns, and to access the internet if somebody out there does have an uplink.
 - <http://www.laptop.org/en/laptop/hardware/>
 - They use the 802.11b protocol for packet handling, and 802.11s to set up the mesh network.
 - 802.11s uses a combination of AODV and tree-based routing.

References

<http://www.oreillynet.com/pub/a/wireless/2004/01/22/wirelessmesh.html>

<http://moment.cs.ucsb.edu/AODV/>

http://www.moskaluk.com/Mesh/wireless_mesh_topology.htm

<http://www.ieee802.org/15/pub/TG5.html>

<http://www.laptop.org/>