



# To Mesh, or Not to Mesh

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**LigoWave Networks, Inc.**

# To Mesh, or Not to Mesh

## That is the Question

Whether 'tis nobler in the mind to suffer the slings and arrows of tangled Ethernet,

Or to take arms against a sea of RF, and by opposing end them, to die, to sleep, to transmit no more;

And by a sleep, to say we end the RF interference, and the thousands of dollars running cable is heir to?

***'Tis a communication devoutly to be wished!***

To die, to sleep. To sleep, perchance to dream of flowing wireless frames;

Aye, there's the rub, for in that omission of wires, what data traffic may come,

When Ethernet has shuffled off this mortal coil, mesh gives us pause.



# To Mesh, or Not to Mesh

## About The Bard

- Veteran in Mesh
  - Debugged my first mesh network after being at a WISP for only two weeks (spoiler: object lesson in self-interference)
  - Designed, deployed, and/or troubleshooted dozens of mesh deployments in the last 10 years, working for service providers and AP manufacturers
- Current Role
  - Prince (Director) of Business Development at LigoWave Networks, Inc., Canton, GA
  - All LigoWave Wi-Fi APs support mesh



CWNE #171

Blog: <http://emperorwifi.com>

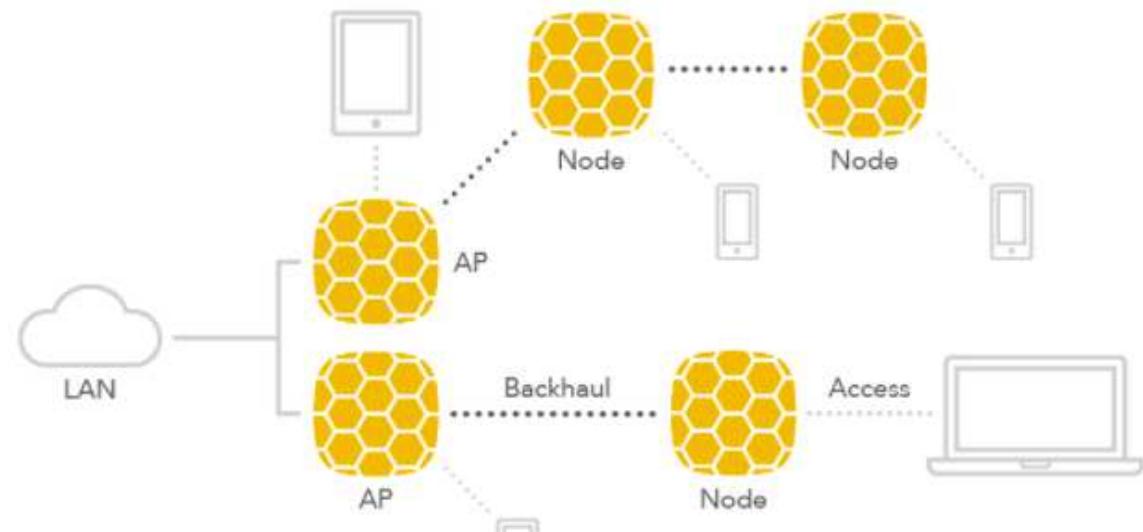
*“O God, I could be bound in a mesh network, and count myself @EmperorWiFi of infinite bandwidth – were it not that I have bad dreams.”*

# To Mesh, or Not to Mesh

## The Miracle of Mesh: Wi-Fi Without Wires



- Mesh provides both Wi-Fi service to clients and wireless backhaul to wired AP
- Automatically calculates the “optimal path” through the network, and can adapt to changes
- Designed for large scale networks where wiring is impossible or cost-prohibitive



EasyMesh™ illustration for LigoWave Infinity APs

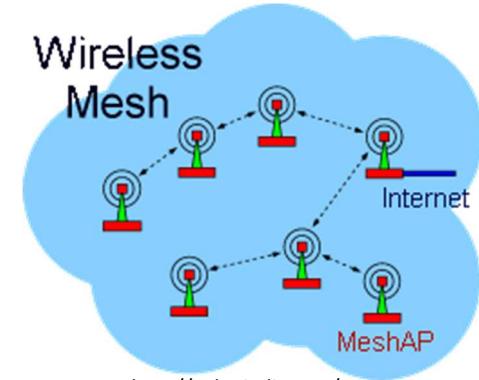
*“What a piece of work is mesh! How noble in reason, how infinite in faculties, in form and moving, how express and admirable in action, how like an angel in apprehension, how like a God! The beauty of no wire! The paragon of backhaul!”*

# To Mesh, or Not to Mesh

## Mesh Network Terminology

- **Root APs:** AP with a “wired” connection to the wired switch infrastructure network
  - Direct Ethernet or fiber-optic cable
  - Connected to dedicated wireless bridge point-to-(multi)point link on an independent channel
- **Node AP:** AP without a wired Ethernet connection. Wireless backhaul is established to a root AP or other node AP.
- Each wireless link is referred to as a *hop*
- Always use dual-band APs
  - Single-band APs: Simultaneous Wireless Backhaul and Client Access
  - Dual-band APs use 5 GHz for simultaneous Wireless Backhaul and Client Access. 2.4GHz radio is only for Client Access.

*“Neither a node AP nor a root AP be,  
For node oft loses both itself and friend,  
And root dulls the edge of client performance.”*

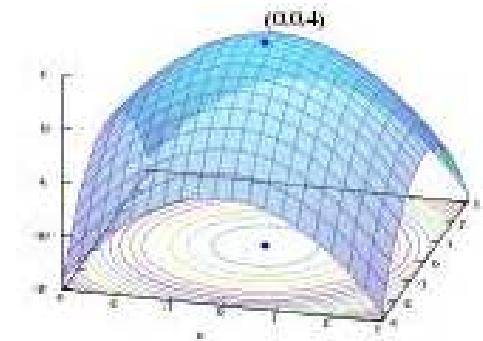


# To Mesh, or Not to Mesh

## Calculating the Path

- Remote APs calculate “best path” route through the network, adapt to changes in environment (e.g. APs going offline)
- Algorithm is proprietary to each vendor, but generally includes optimizing the following:
  - **Minimize hops:** Minimize latency by minimizing total number of hops to a root node
  - **Maximize signal:** Select links with the strongest RSSI to maximize data rates in the wireless link
  - **Balance load:** Account for number of clients and bandwidth consumption at each AP
- ***Note, these parameters can be conflicting, leading to counter-intuitive and sub-optimal solutions.***

*“There are more things in mesh optimization, Horatio, than are dreamt of in our philosophy.”*

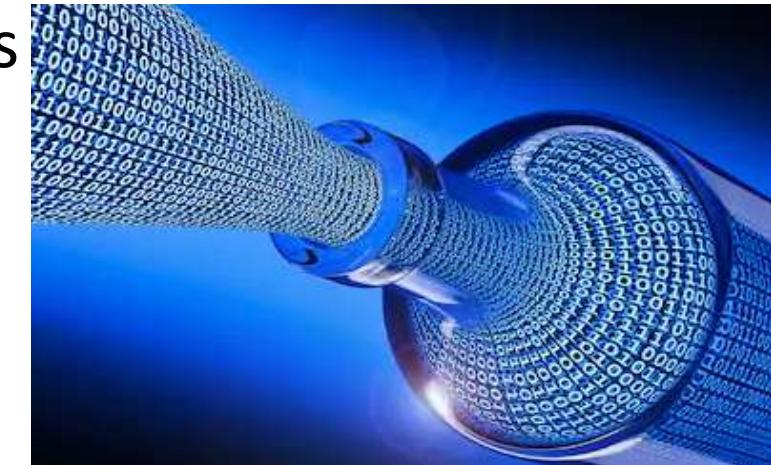


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# To Mesh, or Not to Mesh

## What's the Story with Mesh and Throughput

- Conventional “wired” Wi-Fi dedicates all wireless airtime to client access, as all backhaul is wired
- Mesh utilizes wireless airtime for both wireless backhaul and client access
- Mesh therefore results in reduced throughput and client capacity (50% per hop)
- ***Avoid mesh in performance-critical applications***
- Mesh should only be used in scenarios where running Ethernet cabling is unfeasible (physically impossible or cost-prohibitive)



<https://image.shutterstock.com/image-photo/3d-illustration-bottleneck-260nw-722637007.jpg>

*“You cannot, sir, take from me any thing that I will more willingly part withal: except my throughput, except my throughput, except my throughput.”*

# To Mesh, or Not to Mesh

## The Ghost of Mesh: Self-Interference

- All mesh radios in a mesh group need to be on the same channel.
- Every time an AP intercommunicates with client devices, that consumes airtime for neighboring APs
- This self-interference further lowers airtime capacity, by causing more retries.
- ***Devote the 5 GHz radio to backhaul only.***

*"I am the ghost frame, doomed for a certain period of time to propagate the earth at night, while during the day I'm trapped in the fires of purgatory until I've interfered with neighboring APs. If I weren't forbidden to tell you the secrets of RF physics, I could show you RF interference that would slice through your soul, freeze your blood, make your eyes jump out of their sockets, and your hair stand on end like dipole antennas. But mortals like you aren't allowed to see RF waves in the air."*

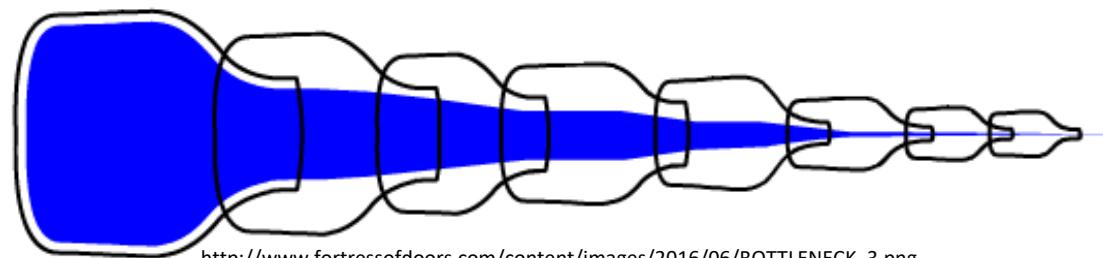


HAMLET IN THE PRESENCE OF HIS FATHER'S GHOST.  
Lie, Hamlet, it is but  
To thine alack over thy dear father thus.  
[https://theweviewfromsarlisworld.files.wordpress.com/2016/10/john\\_gilbert\\_-hamlet\\_in\\_the\\_presence\\_of\\_his\\_fathers\\_ghost.jpg?w=840](https://theweviewfromsarlisworld.files.wordpress.com/2016/10/john_gilbert_-hamlet_in_the_presence_of_his_fathers_ghost.jpg?w=840)

# To Mesh, or Not to Mesh

## Why Mesh Failed in the 2000's

- Original mesh APs
  - Most were single-band 802.11g
  - Later and more expensive dual-band models were 802.11a / 802.11g
- Remember how mesh works:
  - A mesh AP spends  $\frac{1}{2}$  of its time talking to client devices, and  $\frac{1}{2}$  of its time talking to the next mesh hop
  - Lose 50% throughput on first hop, 75% on 2<sup>nd</sup> hop, 87.5% on 3<sup>rd</sup> hop, etc.
- With a maximum 54 Mbps half duplex data rate ( $\sim$ 20 Mbps maximum data throughput), it didn't take a lot of hops for "the rest to be silence".



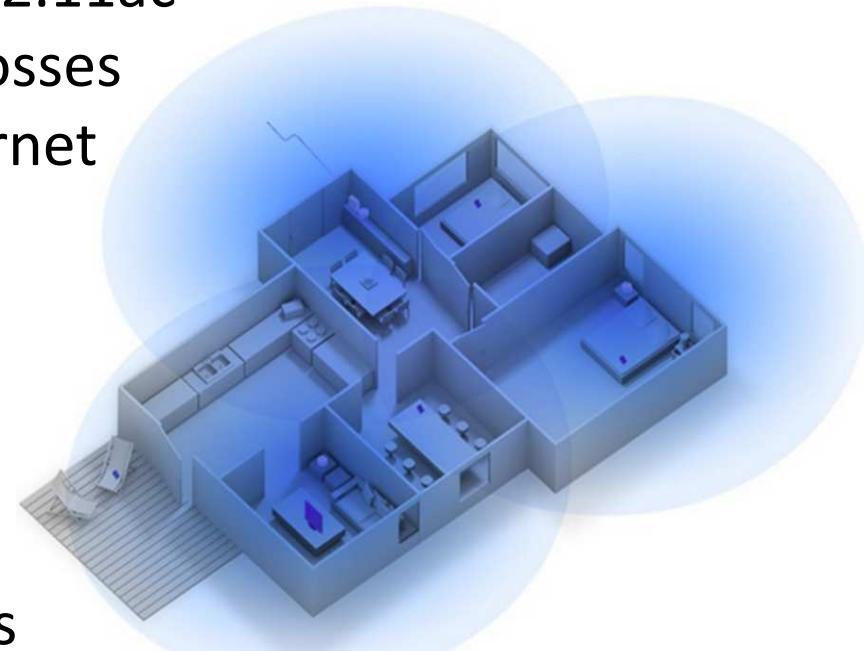
[http://www.fortressofdoors.com/content/images/2016/06/BOTTLENECK\\_3.png](http://www.fortressofdoors.com/content/images/2016/06/BOTTLENECK_3.png)

*"There must've been a moment, at the beginning, where our backhaul could have been wired. Somehow we missed it. Well, we'll know better next time."* - Rosencrantz and Guildenstern are Dead

# To Mesh, or Not to Mesh

## Why Mesh Is a Hot Product Now, in Home Wi-Fi

- The technology meets the needs
  - Current mesh APs are dual-band 802.11ac
  - More tolerant of 50% throughput losses
  - 802.11ac throughput >> home internet bandwidth
- Easy for home user to install
  - No need to run cabling
  - Most configure via phone apps
- Typically sold in a three pack
  - One root node and two mesh nodes
  - One or two hops maximum
  - Small coverage areas: scalability not a requirement



<https://blog.google/products/google-wifi/making-mesh-your-wi-fi/>

*“Though home mesh be madness, there is method in it.”*

# To Mesh, or Not to Mesh

## The Fundamentals are Still Fundamental



- Still sacrifice user capacity / data throughput
- 5 GHz attenuates fast through walls: data rates between nodes may not be at MCS 09 (867 Mbps)
- Typical data throughput performance of about 25 Mbps in home environment
  - Not taking advantage of available bandwidth
  - May prove inadequate for demanding households (e.g. multiple streaming Netflix)
- Mesh will break down faster as more IoT devices flood the home network



<http://www.basiccivilengineering.com/wp-content/uploads/2016/05/solid-foundations.jpg>

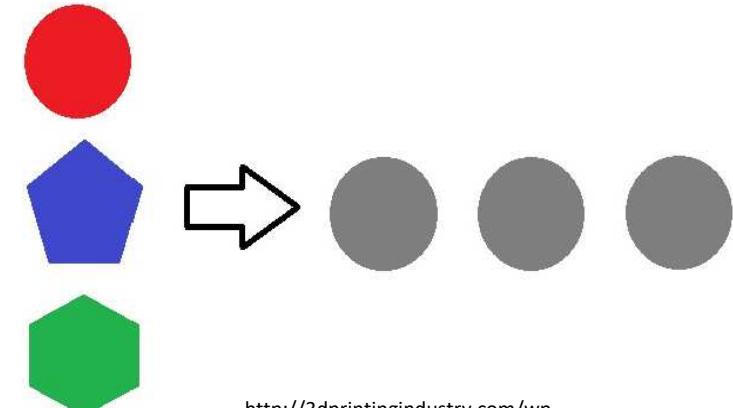
*“A little more than ‘meh’, a little less than ‘mesh’.”*

# To Mesh, or Not to Mesh

## The Dream vs. The Reality of Standardization

- The Dream: Enable inter-vendor mesh communication
  - IEEE: 802.11s (2006)
  - WFA: EasyMesh Certification (2018)
- Open-source algorithms (examples):
  - Better Approach To Mobile Adhoc Networking (B.A.T.M.A.N)
  - Hybrid Wireless Mesh Prococol (HWMP) [802.11s]
- Reality: Every vendor does mesh differently
  - Algorithm tuning is considered a trade secret by AP vendors
  - Each vendor uses a different set of parameters to optimize

*“This above all: to thine own nodes be true, and it must follow, as the night the day, thou canst not then be false to any client.”*

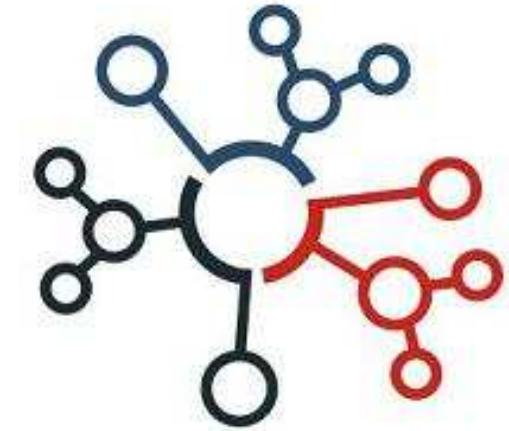


<http://3dprintingindustry.com/wp-content/uploads/2012/12/Standardization.jpg>

# To Mesh, or Not to Mesh

## When You Have to Mesh, Deploy It Right

- Cluster the mesh APs
  - Space root APs roughly evenly throughout the property
  - Ensure up to four remote nodes APs are nominally one hop away from a root AP  
*i.e. at least 20% of AP are root APs*
  - Use dedicated wiring or separate wireless bridge backhaul links to create the additional root APs
- Backhaul channelization
  - Set each root AP and each wireless bridge link to a static & non-overlapping channel  
*Each mesh cluster is on a separate channel*
  - Set all node APs to auto channel  
*Allows for self-healing if a root node goes offline*



[https://www.kom.tu-darmstadt.de/fileadmin/\\_migrated/pics/SW\\_Cluster\\_Logo\\_01.jpg](https://www.kom.tu-darmstadt.de/fileadmin/_migrated/pics/SW_Cluster_Logo_01.jpg)

*“Mesh, the undiscovered country, from whose bourn no Wi-Fi engineer returns.”*

# To Mesh, or Not to Mesh

# Design Example: Mesh in an RV Park



- RV Park: 437 spaces plus pool and clubhouse
  - 2.4 GHz: Wi-Fi client access
  - 5 GHz: Wireless bridges & mesh
    - Red lines: Dedicated wireless backhaul links via *LigoDLB 5-20ac*
    - Other lines: Nominal mesh links between *NFT 2ac Outdoor* APs in dedicated clusters



*“The @EmperorWiFi doth protest too much, methinks.”*

# To Mesh, or Not to Mesh

## Takeaway Messages



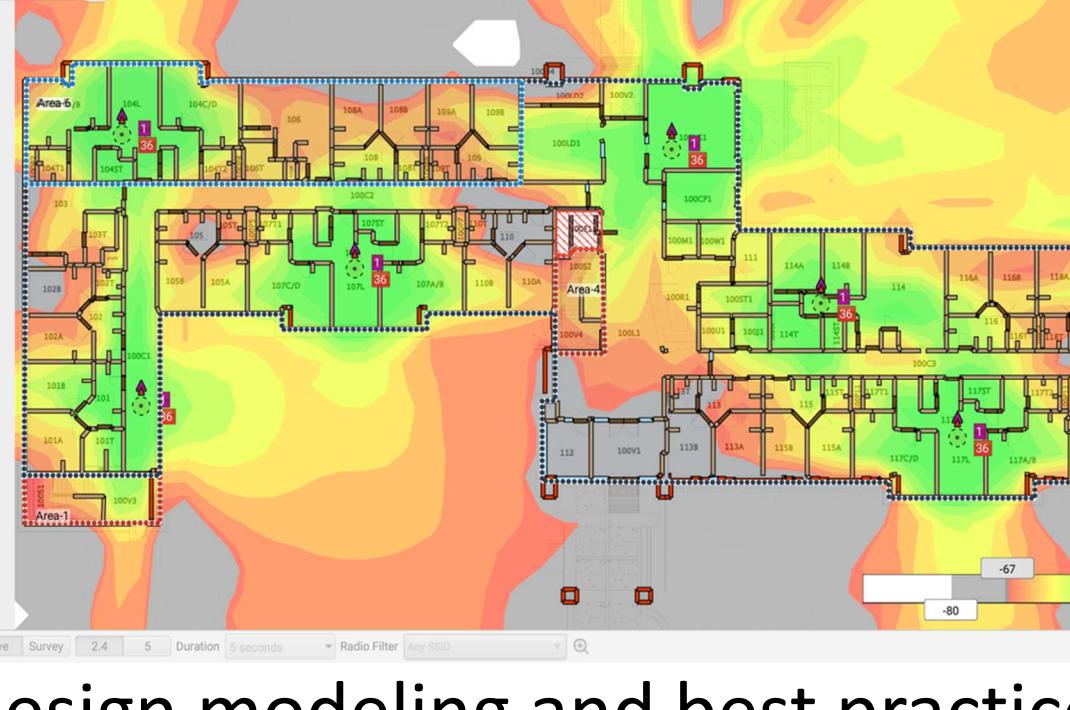
- Mesh is appropriate only in particular circumstances
  - Absolutely cannot run wires
  - Performance of network is not critical
- Mesh involves compromises on performance
  - User capacity
  - Throughput
- Designing for mesh is tricky
  - Group your nodes and roots into small clusters
  - Carefully channelize your clusters
  - Dedicate one band solely to backhaul

*"The mesh network is the thing, to capture the conscience of Wi-Fi Kings."*

# To Mesh, or Not to Mesh

## Designing for Mesh With Ekahau & LigoWave



- Have a project that requires mesh?
  - Talk to either @LigoWave or @Ekahau
  - We will help you plan your network with predictive design modeling and best practices for deploying mesh in your environment.The image shows a screenshot of the Ekahau Site Survey software interface. The main window displays a floor plan of a building with various rooms and hallways. A color-coded heatmap overlay indicates signal strength levels, ranging from green (strong signal) to red (poor signal). Numerous access points are marked with small icons and labeled with identifiers such as 104L, 104C/D, 106, 108A, 108B, 109A, 109B, 100LD1, 100V2, 100I/B, 100U2, 100C/D, 100V1, 100I, 100ST1, 100U1, 100Q1, 111, 114A, 114B, 114C, 114D, 114E, 114F, 114G, 114H, 114I, 114J, 114K, 114L, 114M, 114N, 114O, 114P, 114Q, 114R, 114S, 114T, 114U, 114V, 114W, 114X, 114Y, 114Z, 115A, 115B, 115C, 115D, 115E, 115F, 115G, 115H, 115I, 115J, 115K, 115L, 115M, 115N, 115O, 115P, 115Q, 115R, 115S, 115T, 115U, 115V, 115W, 115X, 115Y, 115Z, 116A, 116B, 116C, 116D, 116E, 116F, 116G, 116H, 116I, 116J, 116K, 116L, 116M, 116N, 116O, 116P, 116Q, 116R, 116S, 116T, 116U, 116V, 116W, 116X, 116Y, 116Z, 117A, 117B, 117C, 117D, 117E, 117F, 117G, 117H, 117I, 117J, 117K, 117L, 117M, 117N, 117O, 117P, 117Q, 117R, 117S, 117T, 117U, 117V, 117W, 117X, 117Y, 117Z, 118A, 118B, 118C, 118D, 118E, 118F, 118G, 118H, 118I, 118J, 118K, 118L, 118M, 118N, 118O, 118P, 118Q, 118R, 118S, 118T, 118U, 118V, 118W, 118X, 118Y, 118Z, 119A, 119B, 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