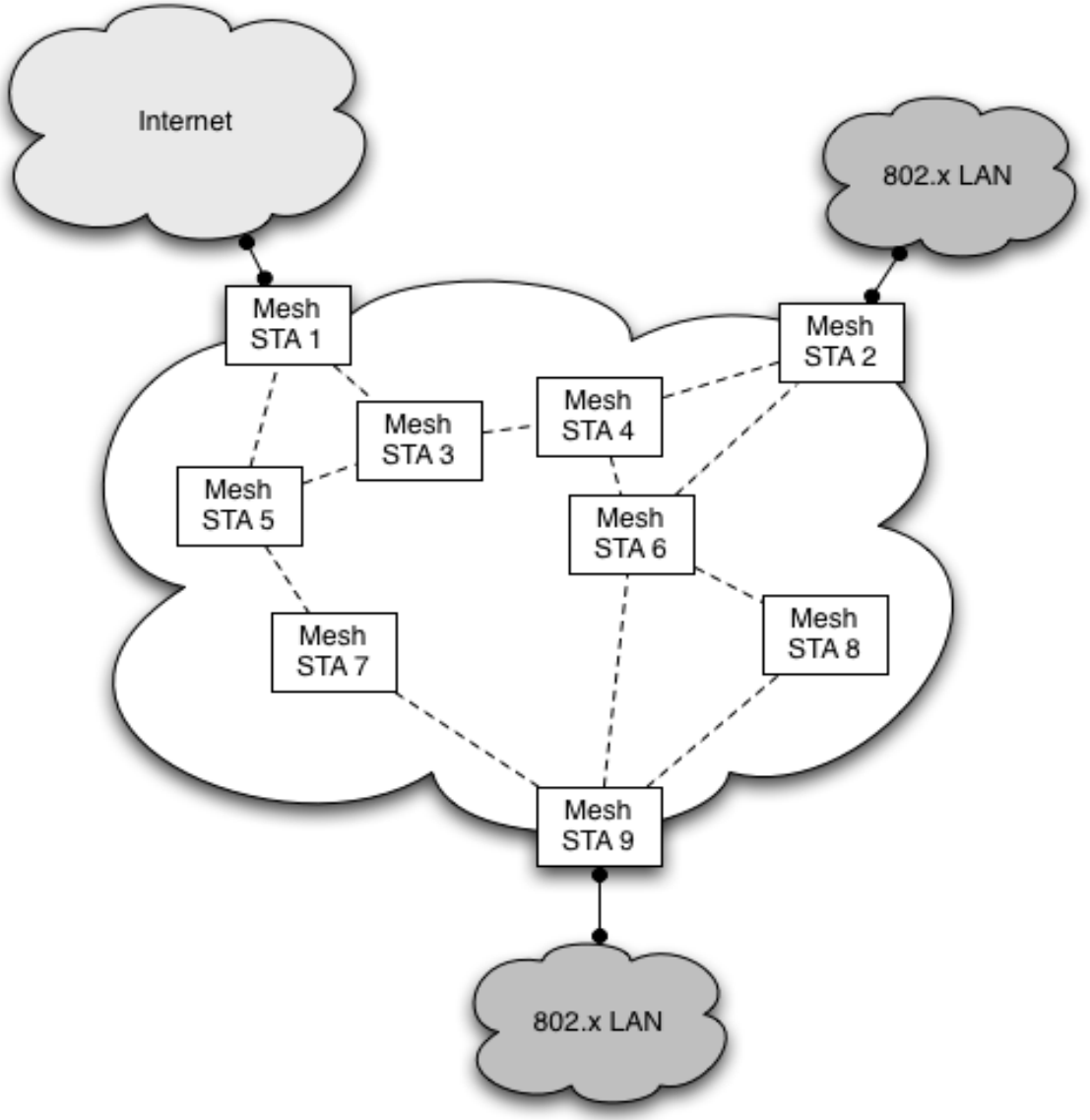
Wireless Mesh Networks under FreeBSD

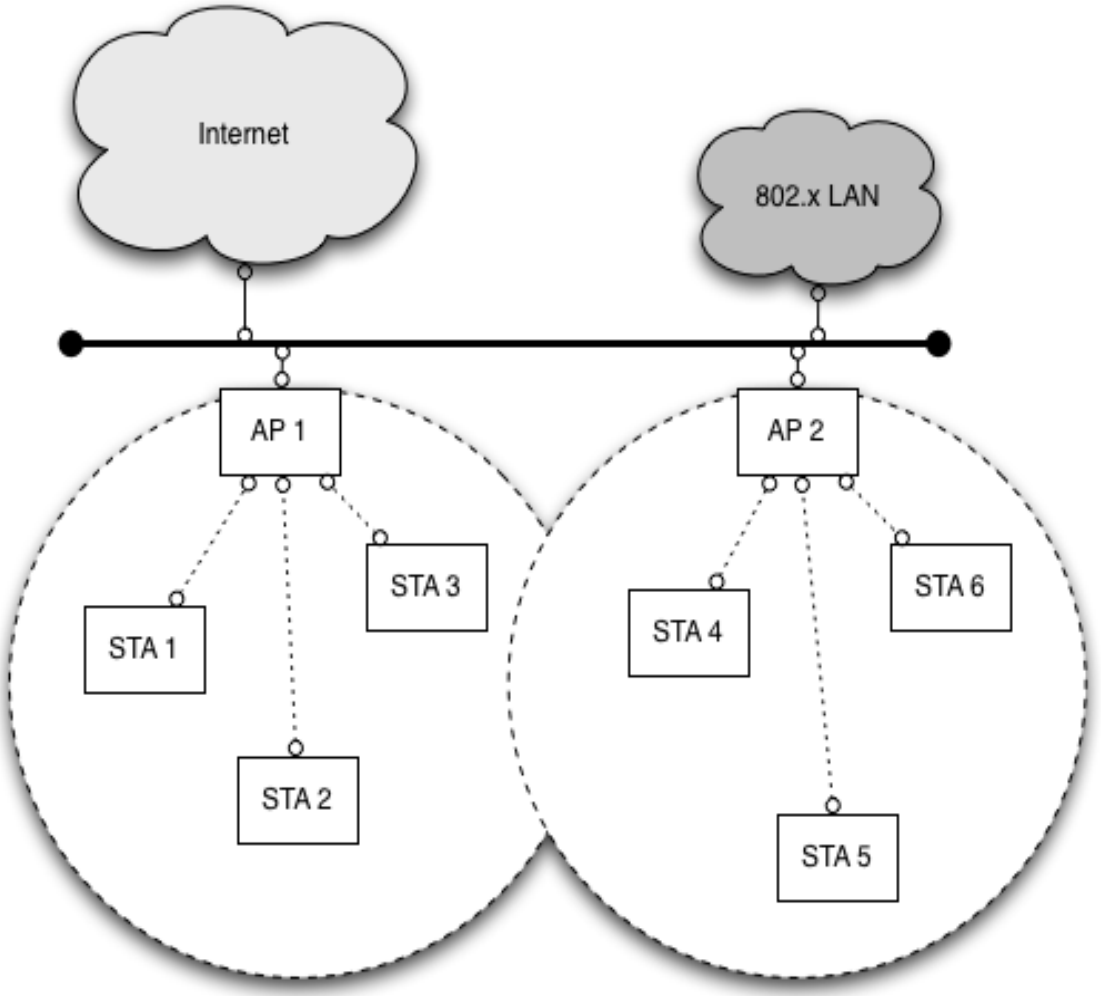


Rui Paulo – rpaulo@FreeBSD.org

EuroBSDCon 2009

Typical wireless network

- Relatively easy to setup
- Pricey if you want to cover a wide area
- Bandwidth shared by all wireless STAs on the same BSS



What's a wireless mesh network?

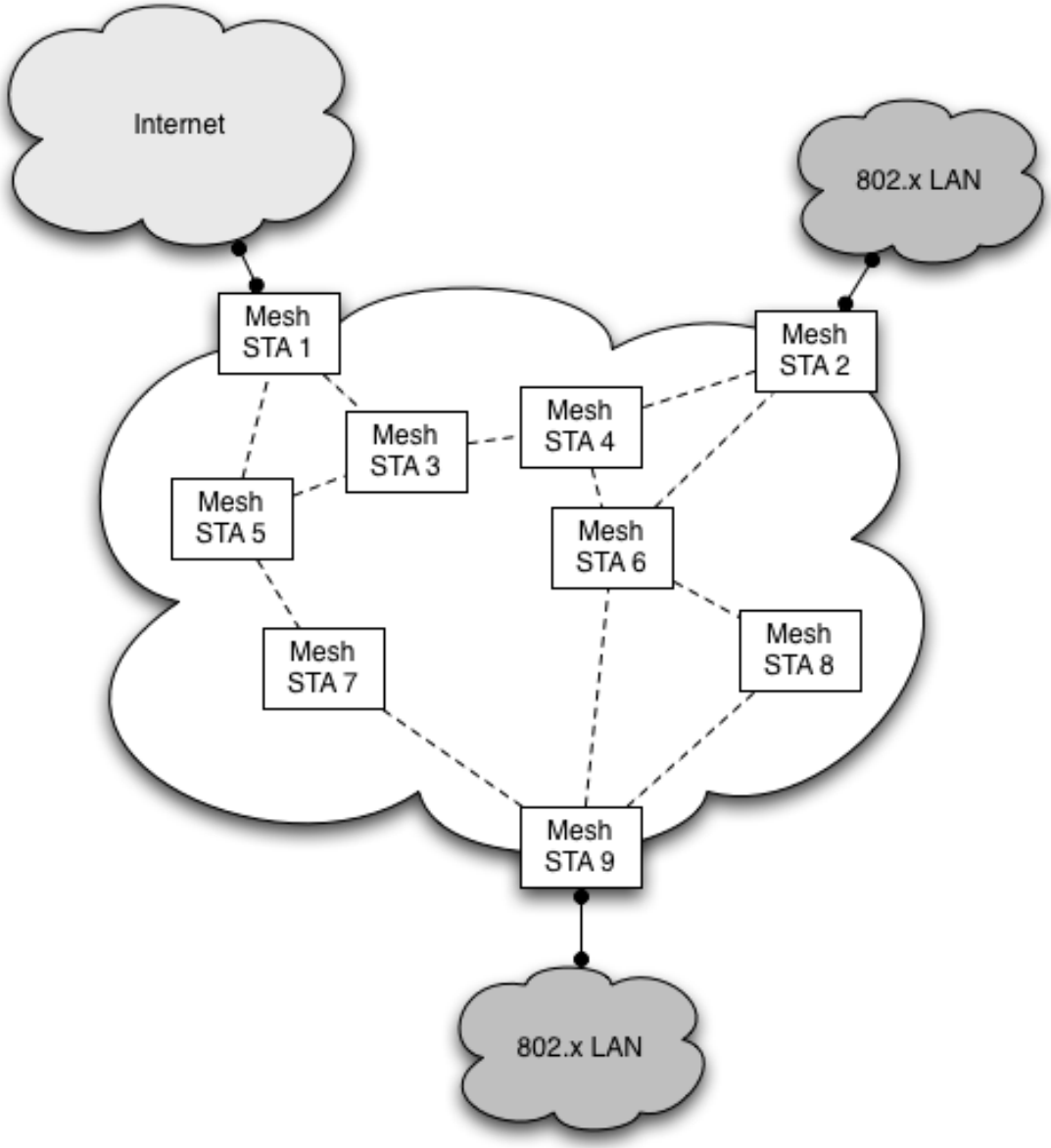
- Stations talk between each other (no central Access Point)
- Incorporates routing algorithms
- Local neighbors (peers) reachable with 0 hops
- Other nodes reachable with >= 1 hop(s)
- Several technologies available. We'll talk about 802.11s

Why use a mesh network?

- Self configuring solution to expand existing wireless network
- Low cost
- Complicated topologies, including no line-of-sight
- Implement a WAN/MAN on wireless with low cost
- University campus, hotels, etc.
- Public safety services and military

What does it look like?

- Group of Mesh STAs: MBSS
- Mesh peers of Mesh STA 1 are Mesh STA 3 and Mesh STA 5
- Mesh Portals (bridges) connect the mesh to the rest of the world
- Mesh Portals are: Mesh STA 1, 2, 9



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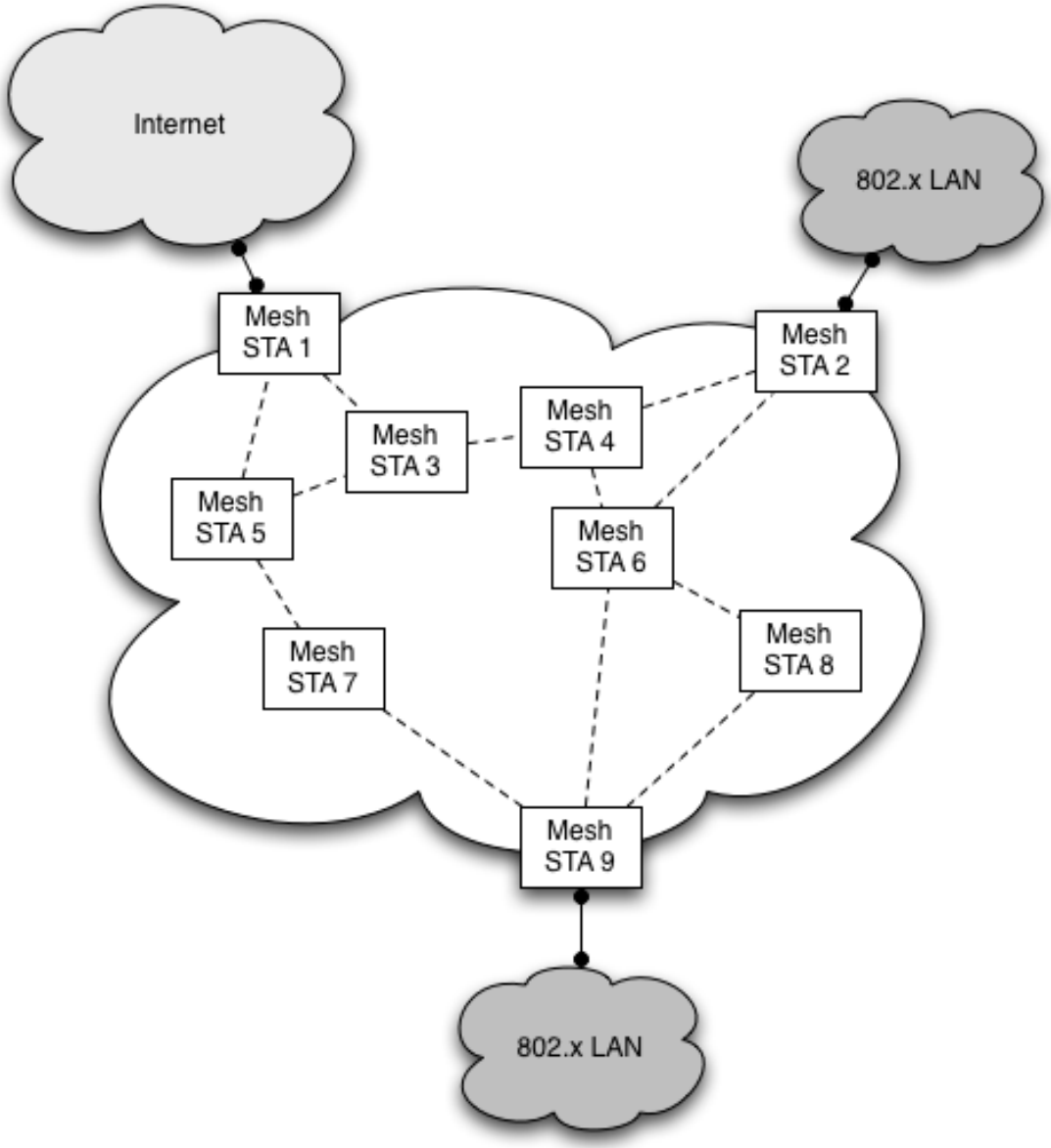
What does it look like?

- Note that 802.x LAN can be wired or wireless
- So we can combine Mesh + AP or Mesh + Wired
- The result is called ESS (Extended Service Set)



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Examples of mesh networks

- Meraki Mesh (special long range radio)
- Mesh Dynamics (multiple radios)
- OLPC XO-1 children's laptop
- Smesh (fast roaming)
- SolarMesh (mesh STA power comes from solar energy)
- SONOS multi-room music system

Introducing 802.11s

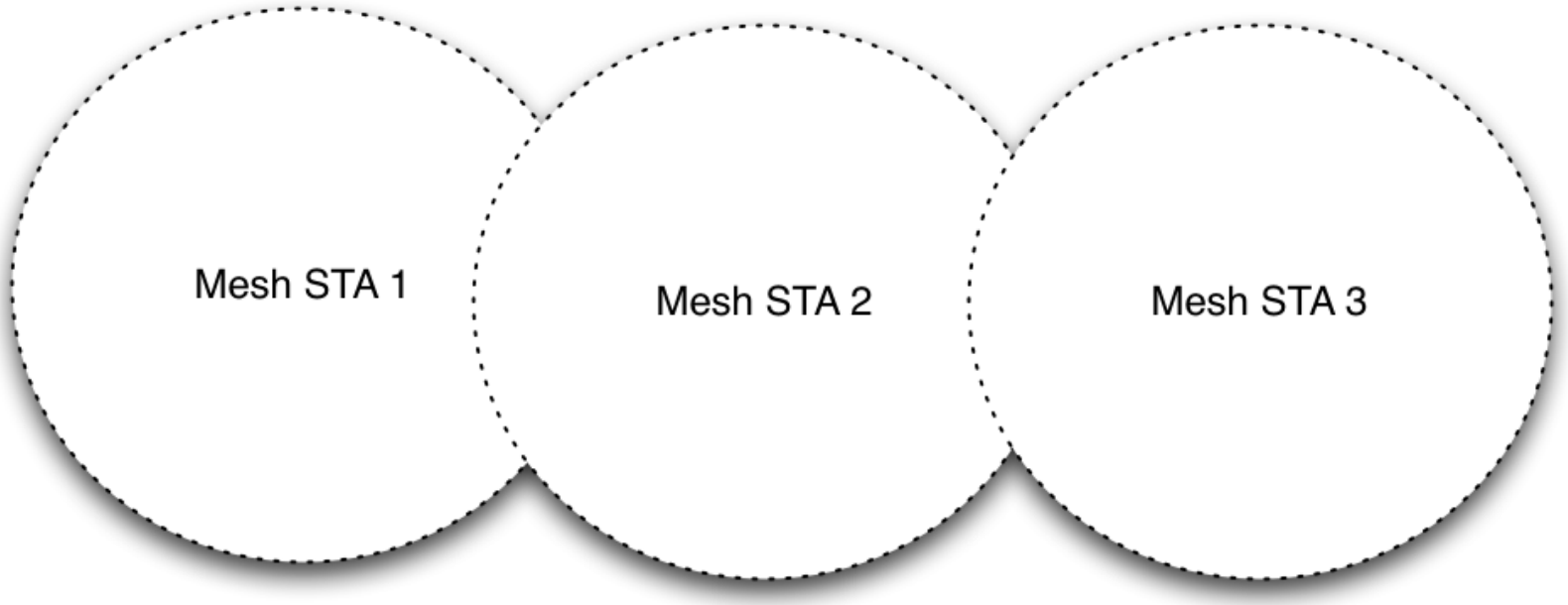
- IEEE implementation of wireless mesh networks
- Amendment of 802.11-2007
- No changes on the 802.11 MAC
- Currently under draft status – expected final version in 2010
- Most of the mesh configuration is optional – you can use your own routing algorithm
- Mandatory algorithms need to be implemented

Introducing 802.11s

- Works at OSI layer 2
- Mesh networks are identified by two parameters: Mesh ID and Mesh Configuration
- Mesh Configuration contains routing protocol ID, link metric protocol ID, and other protocol IDs
- These IEs are present on 802.11 beacon frames
- Peering with neighbor STAs happens when our parameters match with the ones in the beacon

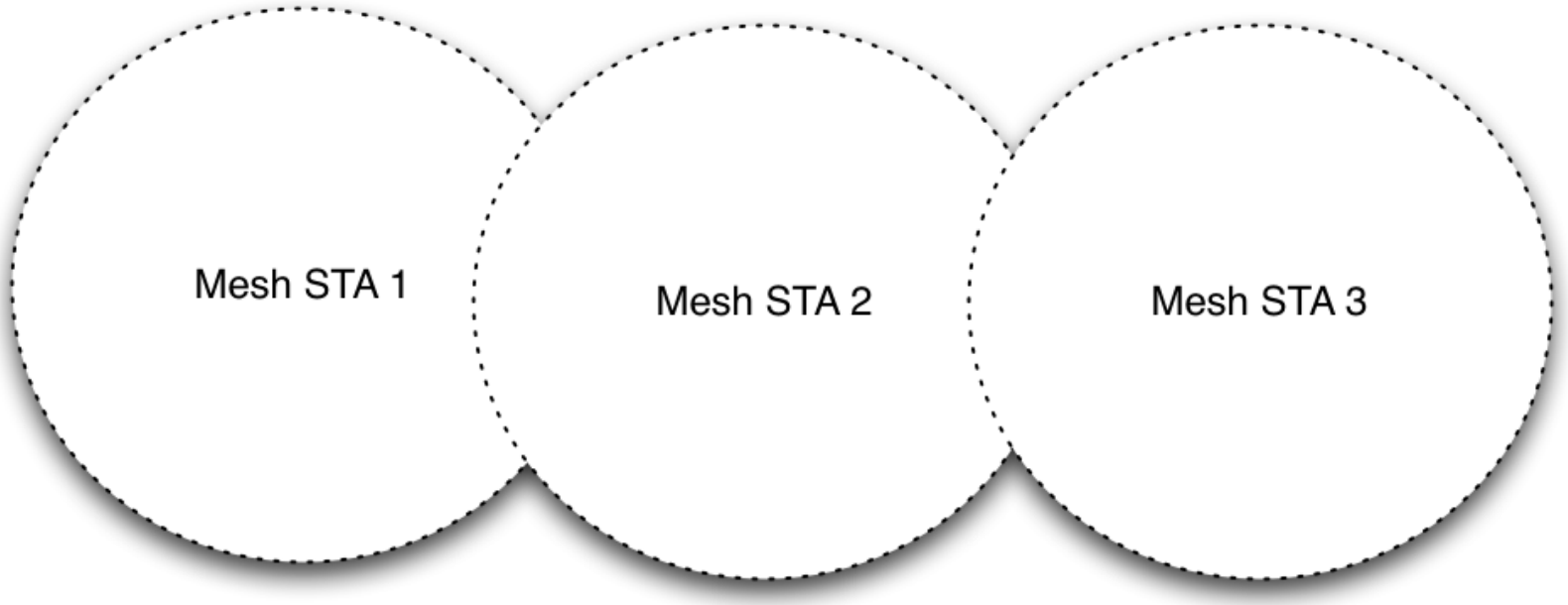
802.11s Peer discovery

- Mesh STA 1 peers with Mesh STA 2
- Mesh STA 3 peers with Mesh STA 2
- Mesh STA 2 peers with both

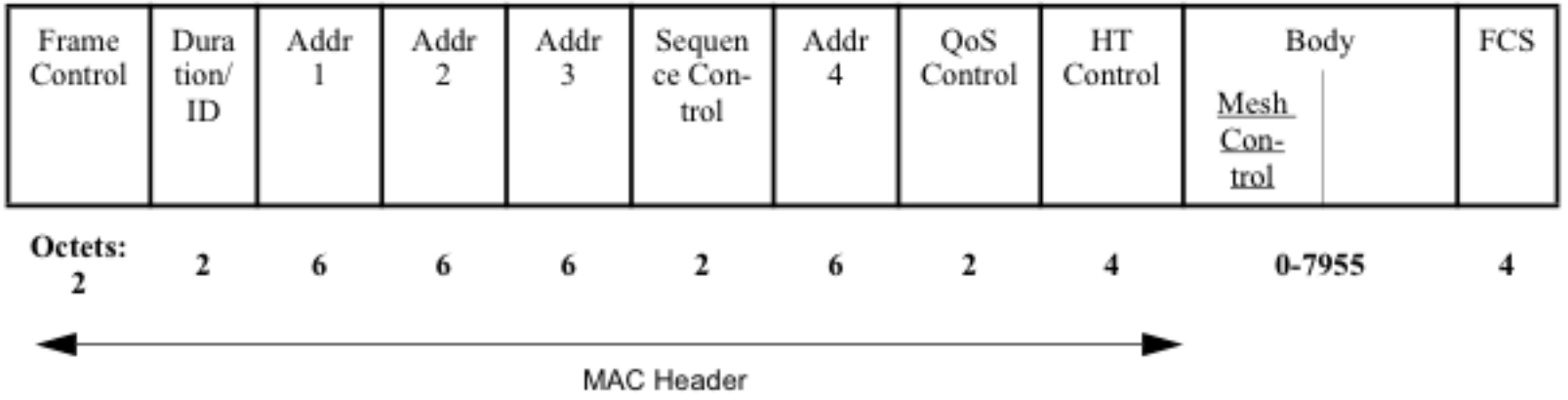


802.11s Peer discovery

- Mesh STA 1 and Mesh STA 3 can now talk to each other via Mesh STA 2
- You can use MAC ACLs to stop nodes from peering



802.11s Mesh Header



Mesh Flags	Mesh Time To Live (TTL)	Mesh Sequence Number	Mesh Address Extension (present in some configurations)
Octets: 1	**1**	**4**	**0, 6, 12, or 18**

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802.11s Algorithms

- Hybrid Wireless Mesh Protocol (HWMP) is the default routing algorithm (mandatory)
- Radio Aware Optmized Link State Routing (RA-OLSR) is the optional routing suggested by the spec
- FreeBSD implements HWMP for now – code is modular enough that it should be easy to support RA-OLSR

802.11s Algorithms

- Airtime is the default link metric algorithm (mandatory) – metric based on tx rate and error rate
- Authentication uses Simultaneous Authentication of Equals (SAE) (pre-shared secret)
- FreeBSD doesn't implement authentication, because we are waiting for the final standard

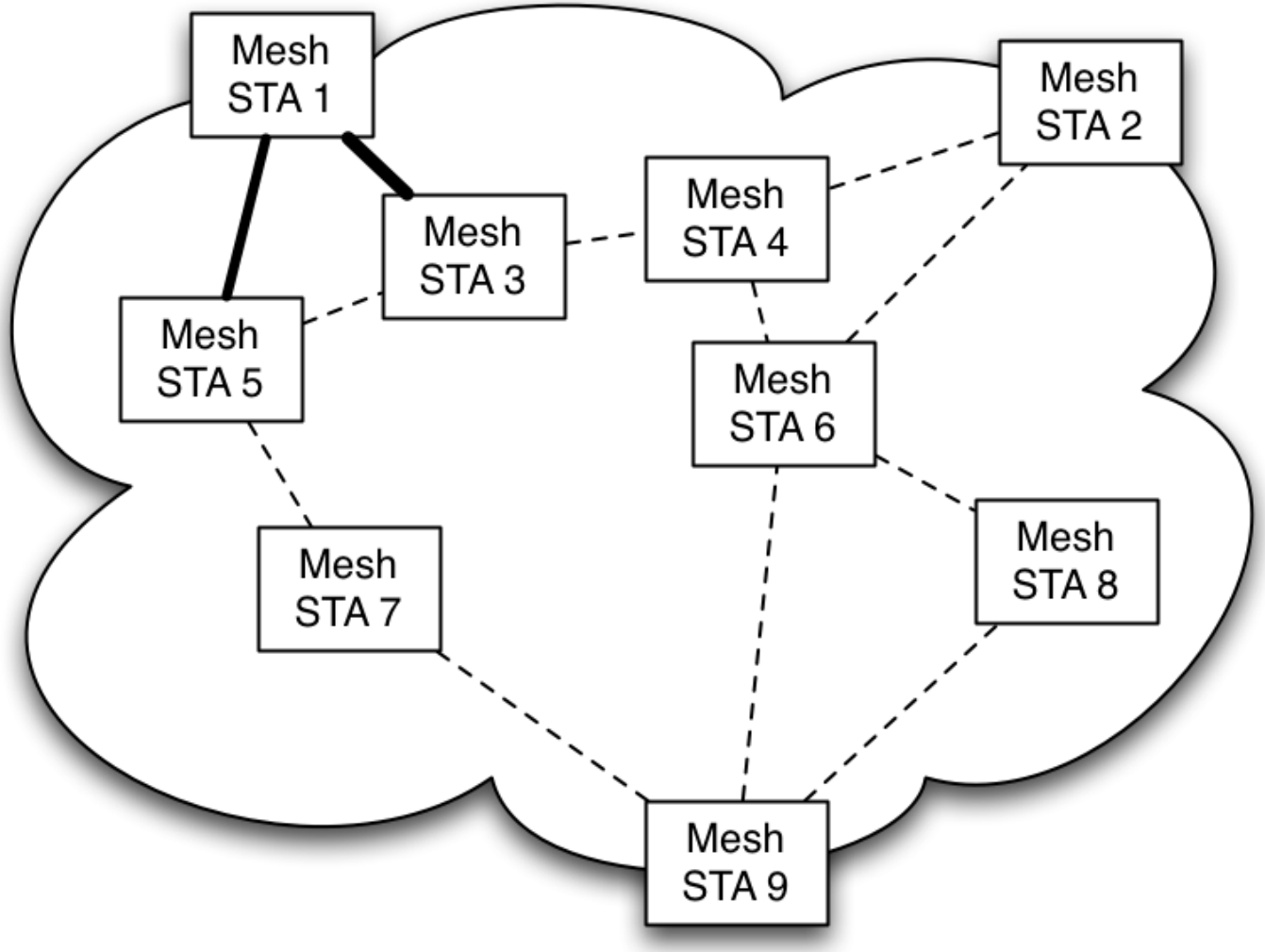
Hybrid Wireless Mesh Protocol

- Based on AODV (Ad-hoc On-Demand Distance Vector)
- On-Demand routing requires an exchange of path setup packets before actual data transmission
- Extended to enable proactive routing
- Proactive routing enables a root mesh STA to discover all nodes on the mesh

Hybrid Wireless Mesh Protocol

- Mesh STAs use the root mesh STA as a way to reach other mesh nodes faster
- “Hybrid” comes from on-demand + proactive
- Let's look at some of the common scenarios with HWMP

HWMP Path Request (STA 1 to STA 8)



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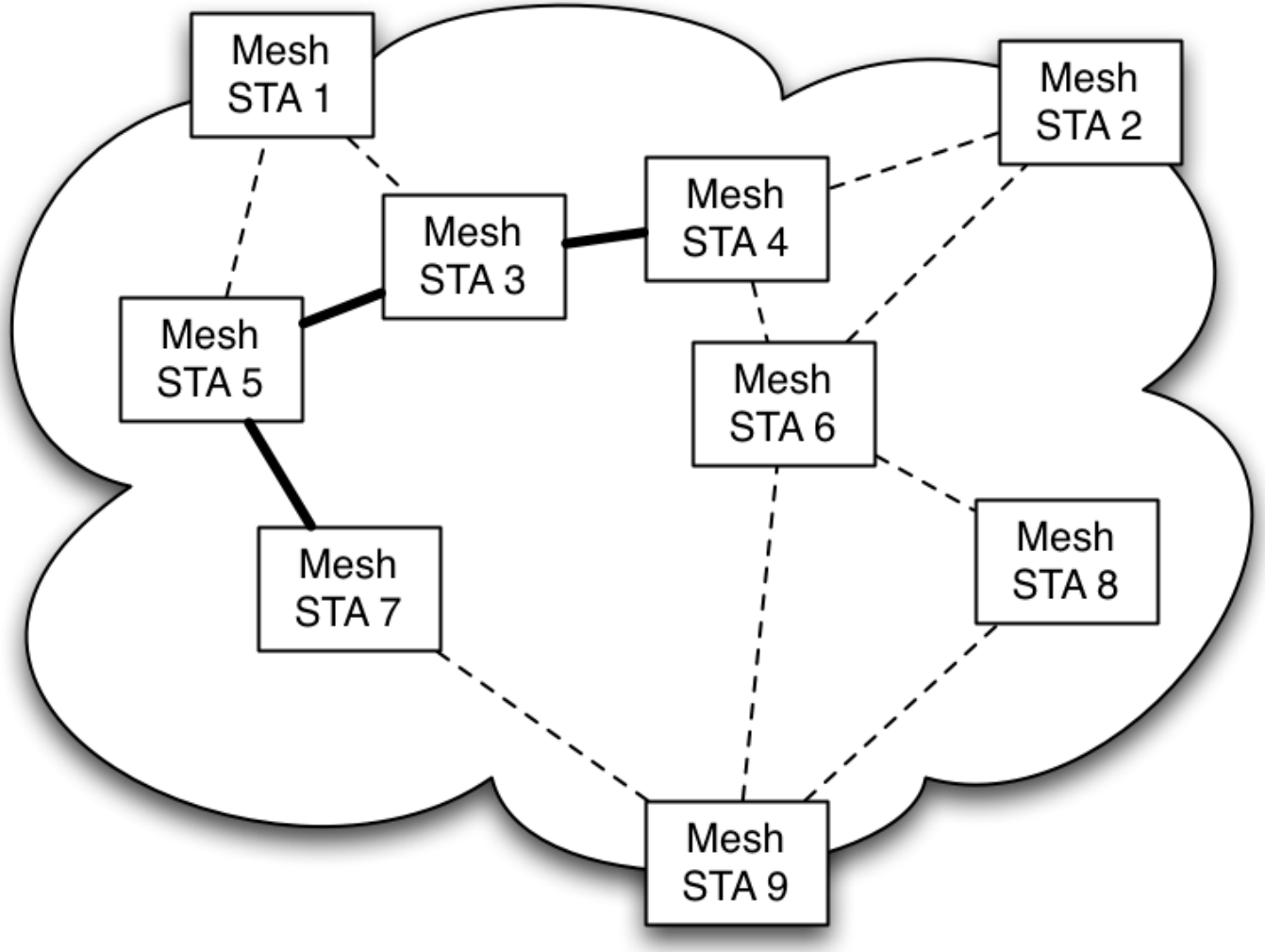
HWMP Path Request (STA 1 to STA 8)



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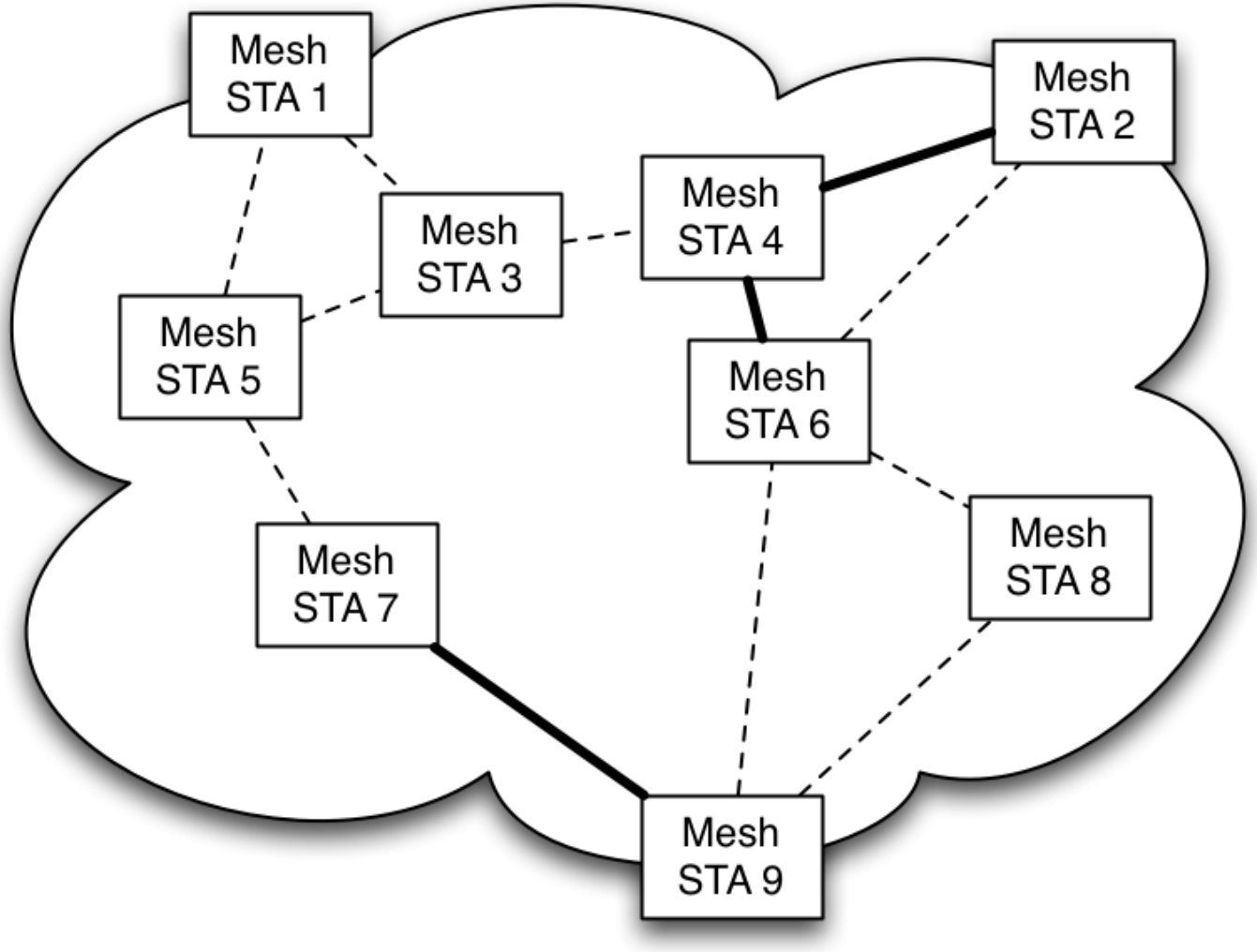
HWMP Path Request (STA 1 to STA 8)



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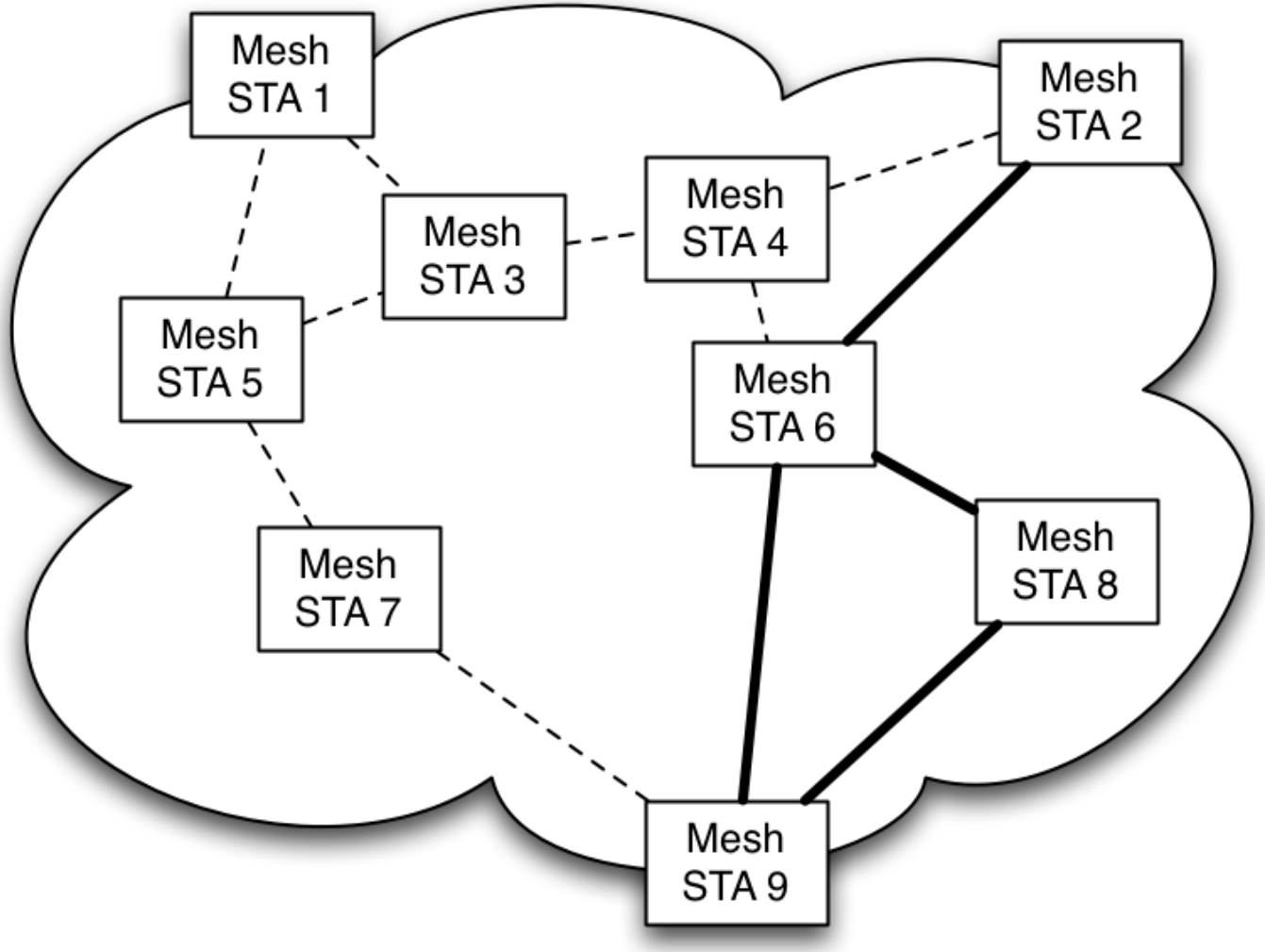
HWMP Path Request (STA 1 to STA 8)



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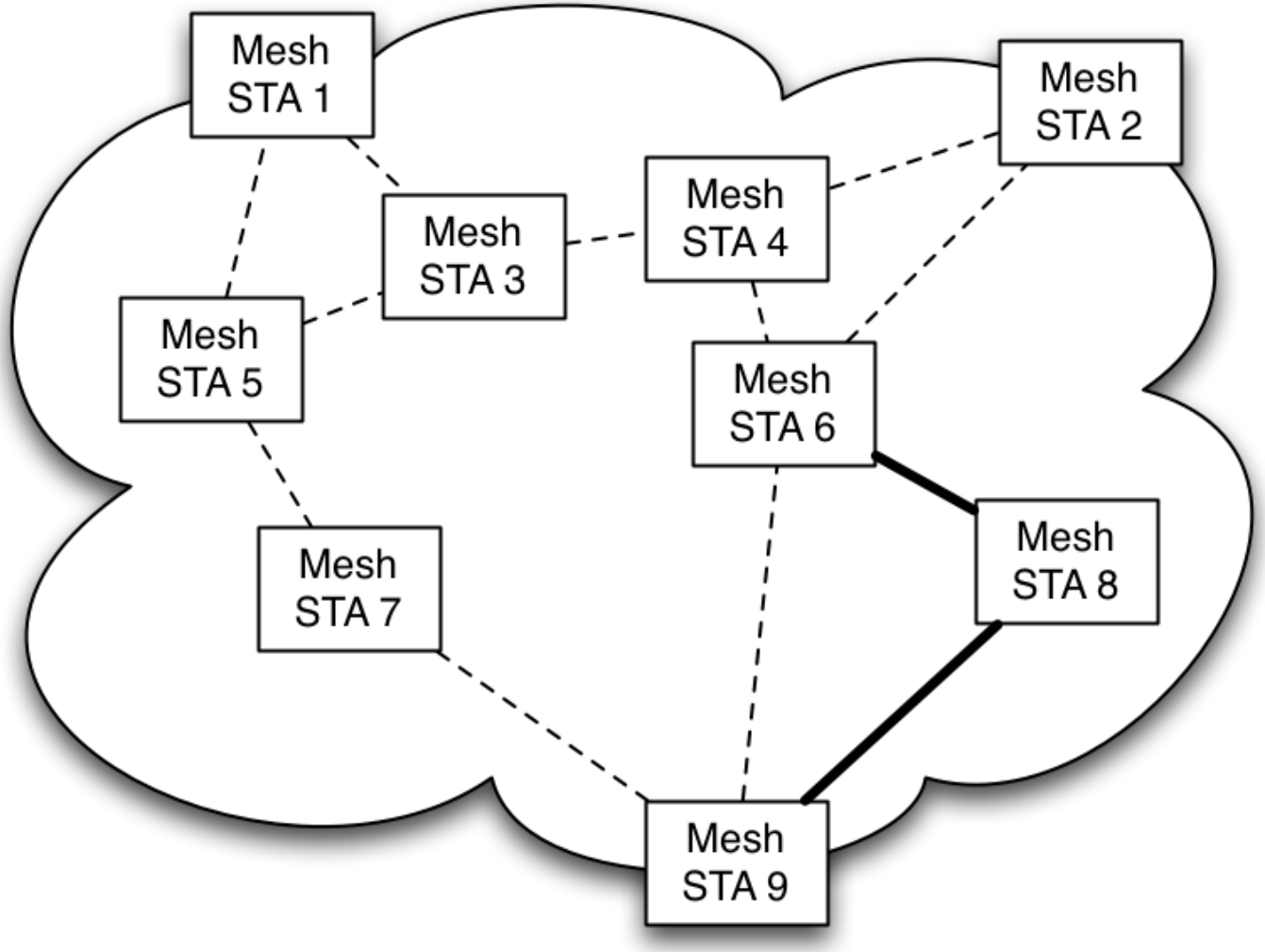
HWMP Path Reply (STA 8 to STA 1)



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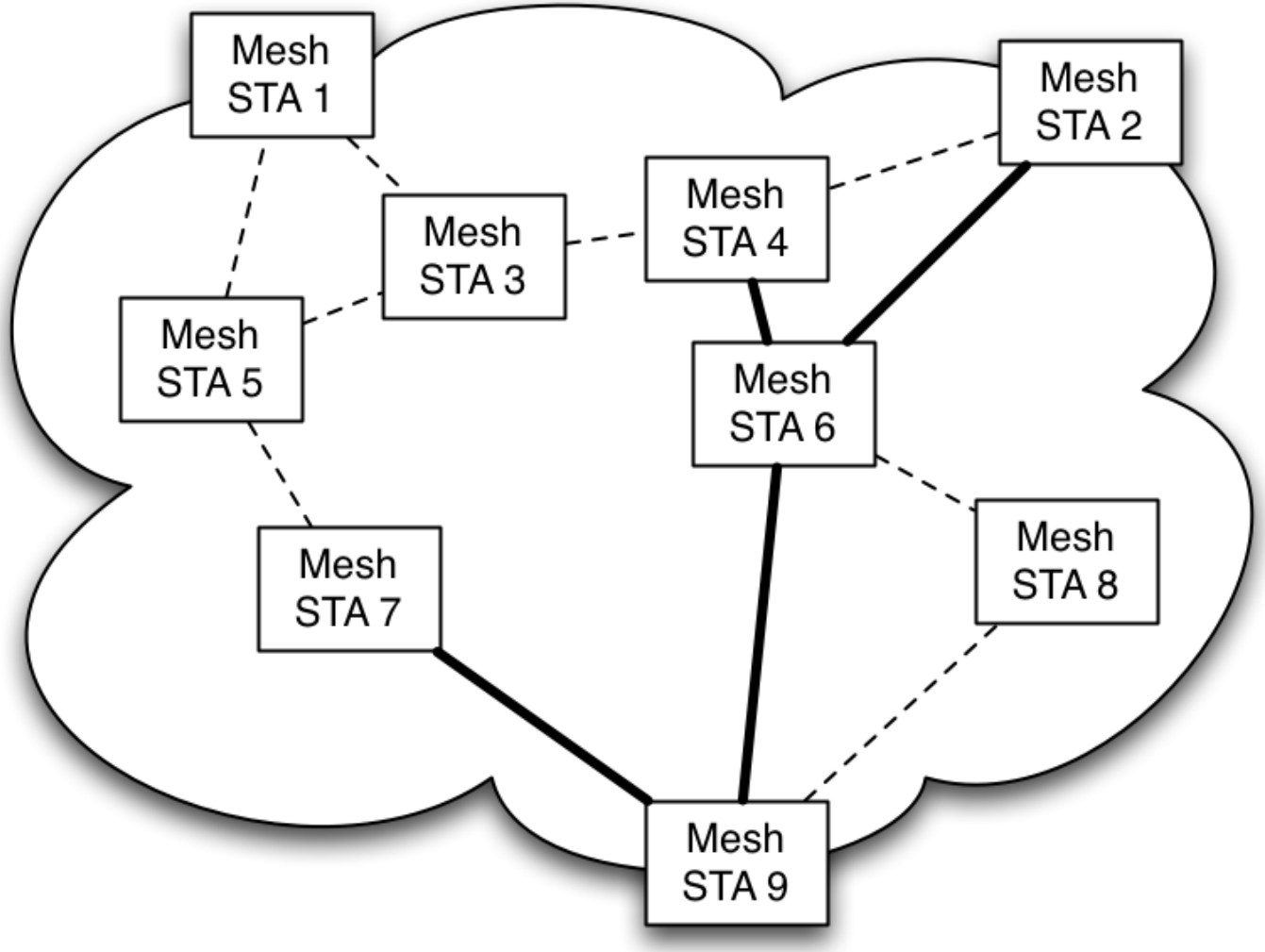
HWMP Path Reply (STA 8 to STA 1)



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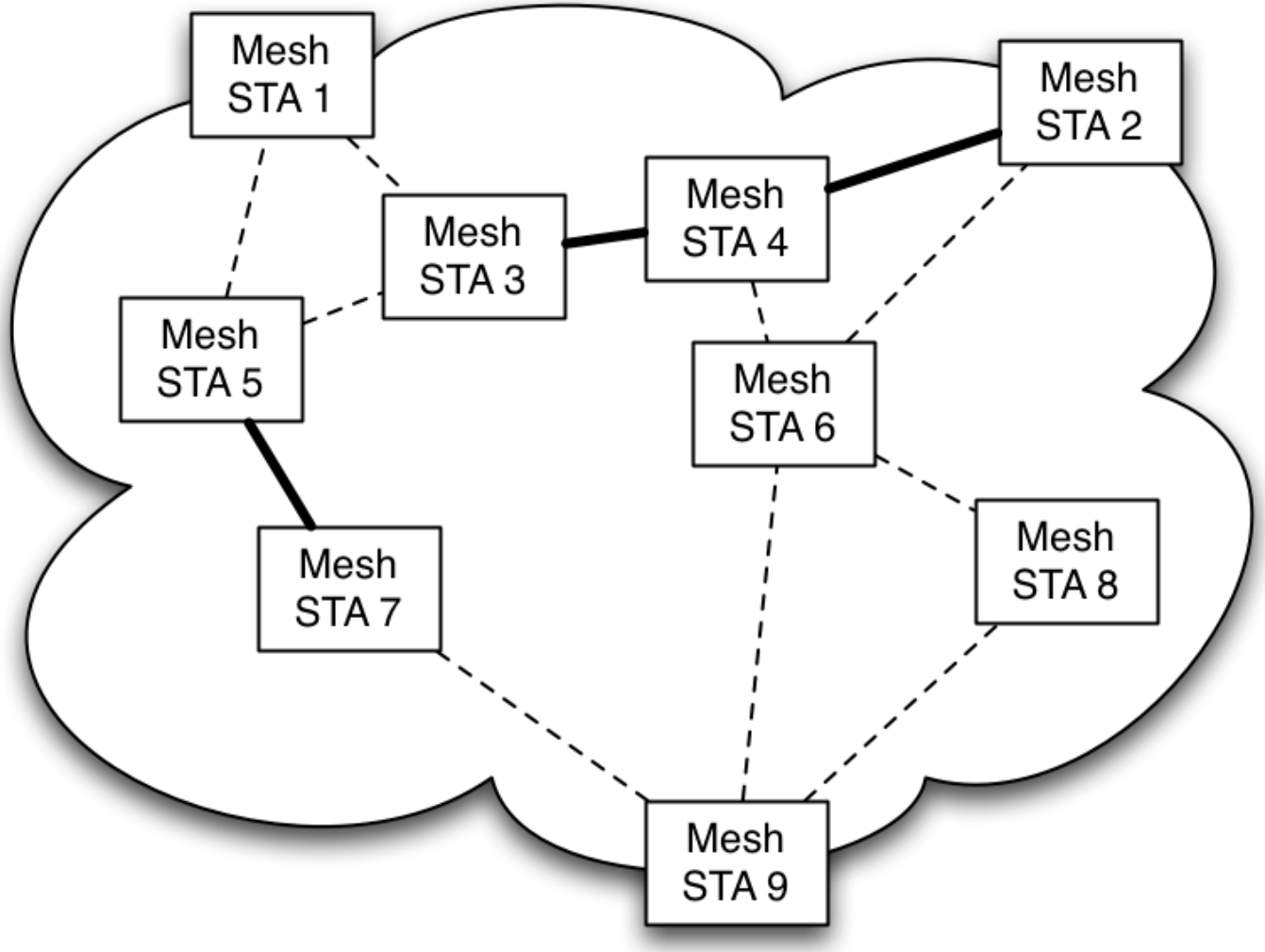

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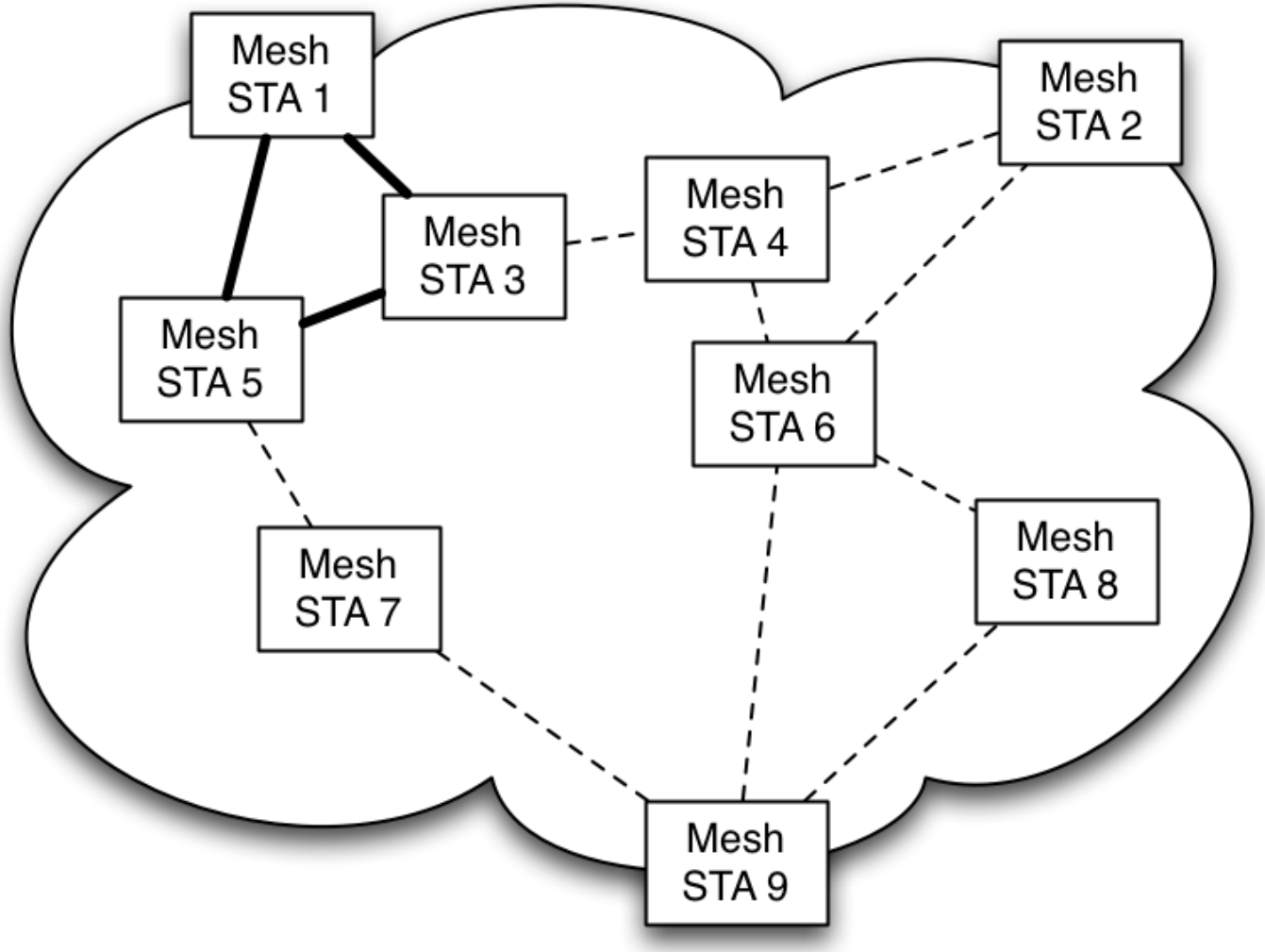
HWMP Path Reply (STA 8 to STA 1)



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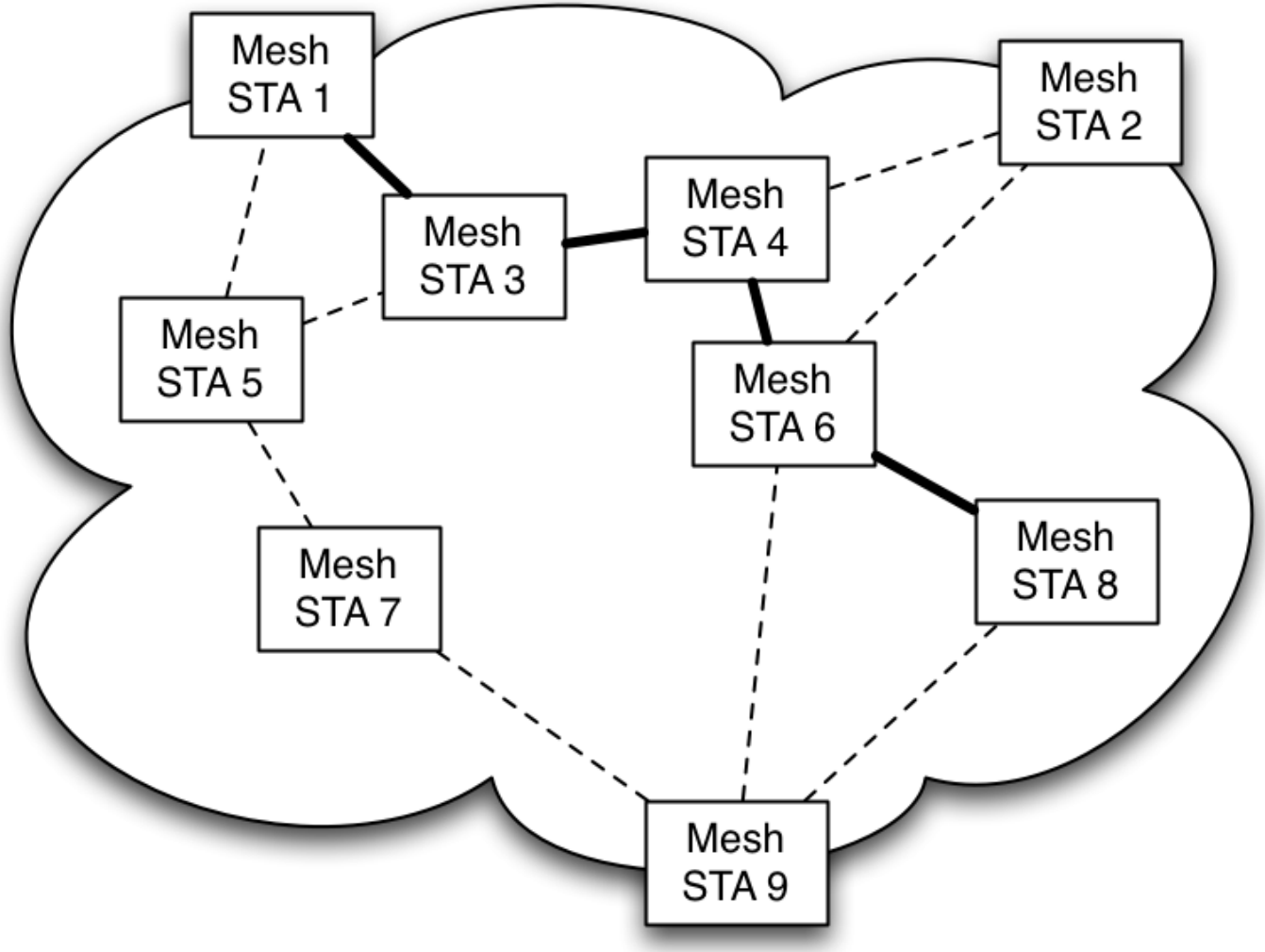
HWMP Path: STA 1 to STA 8



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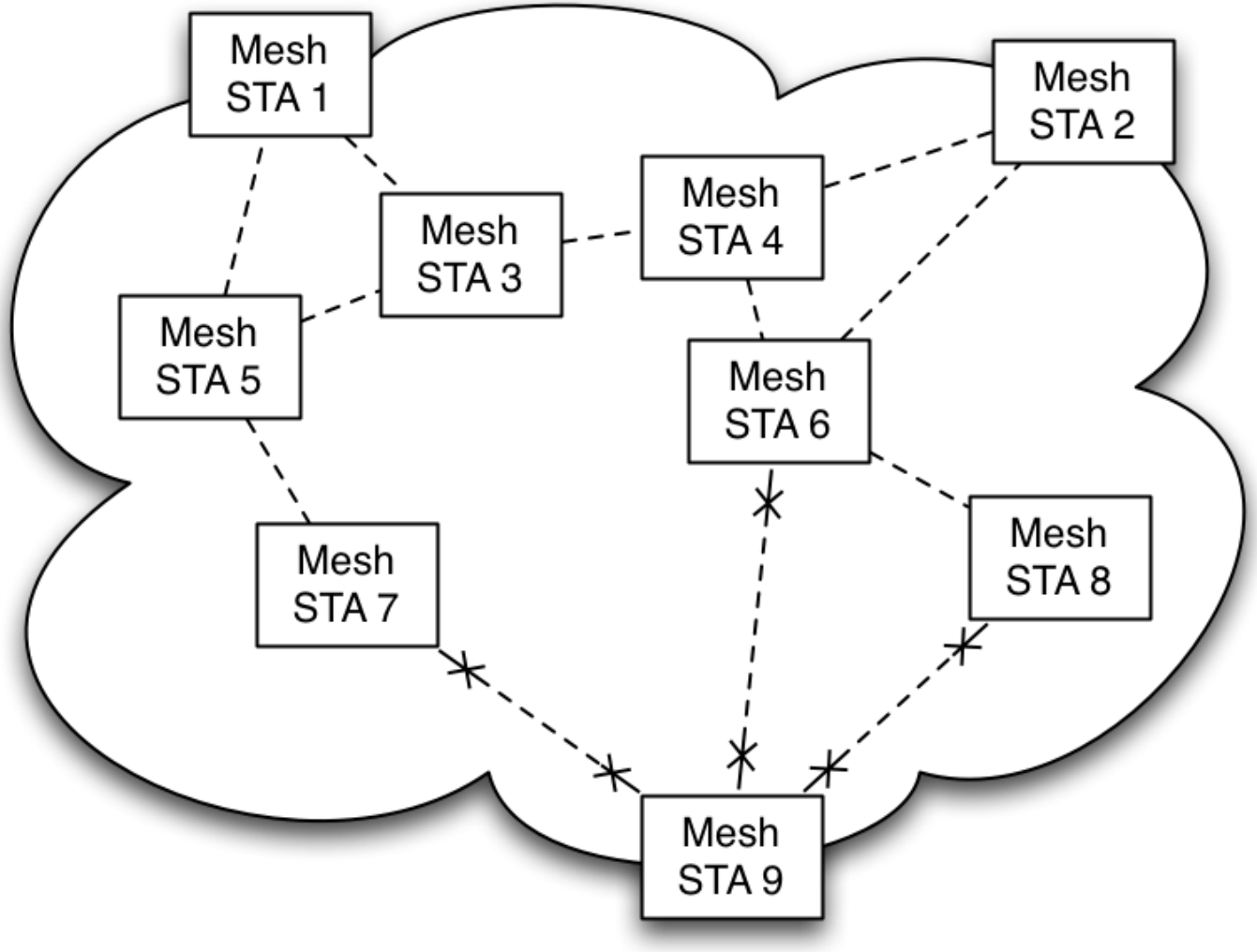
HWMP Topology Change



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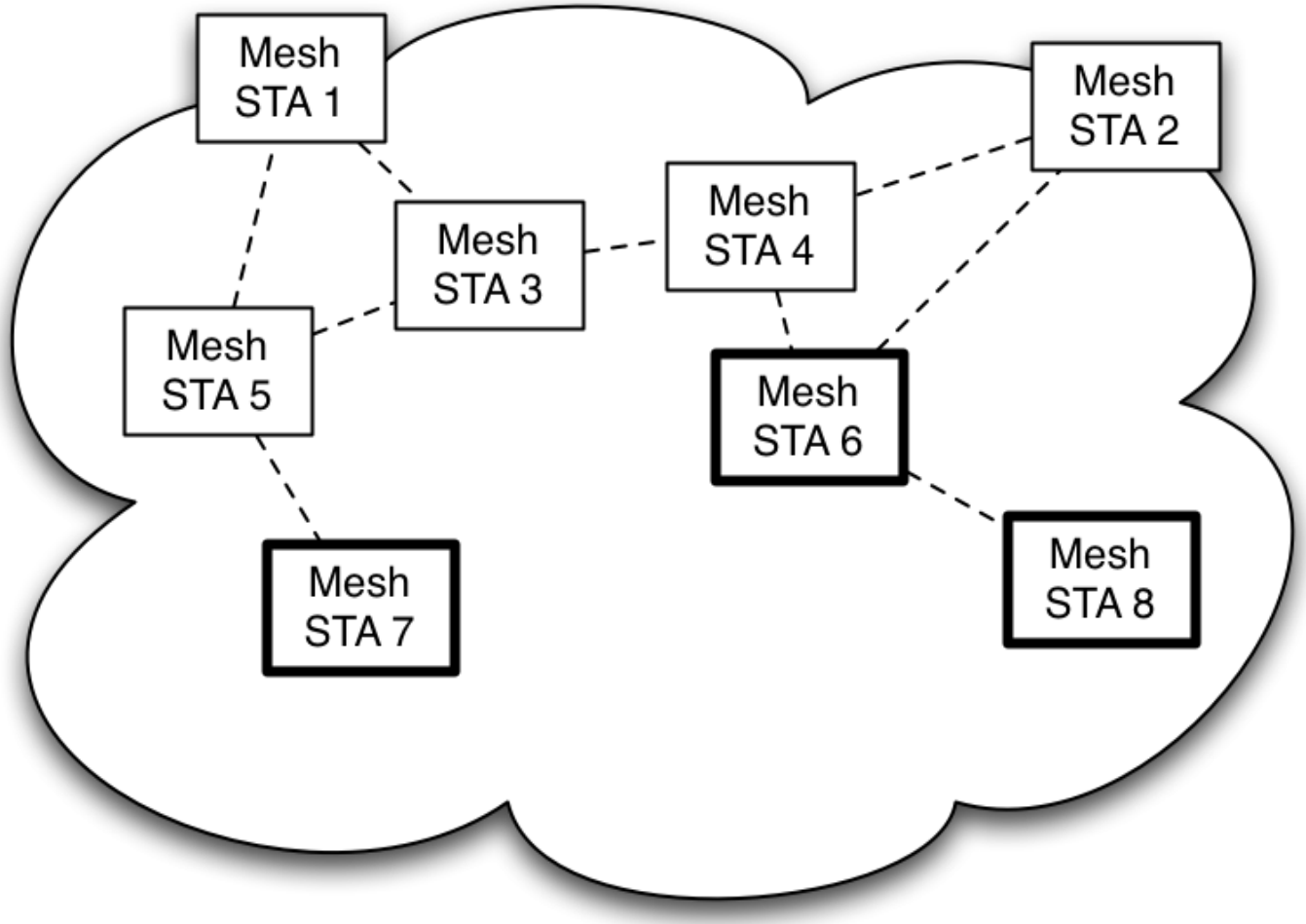
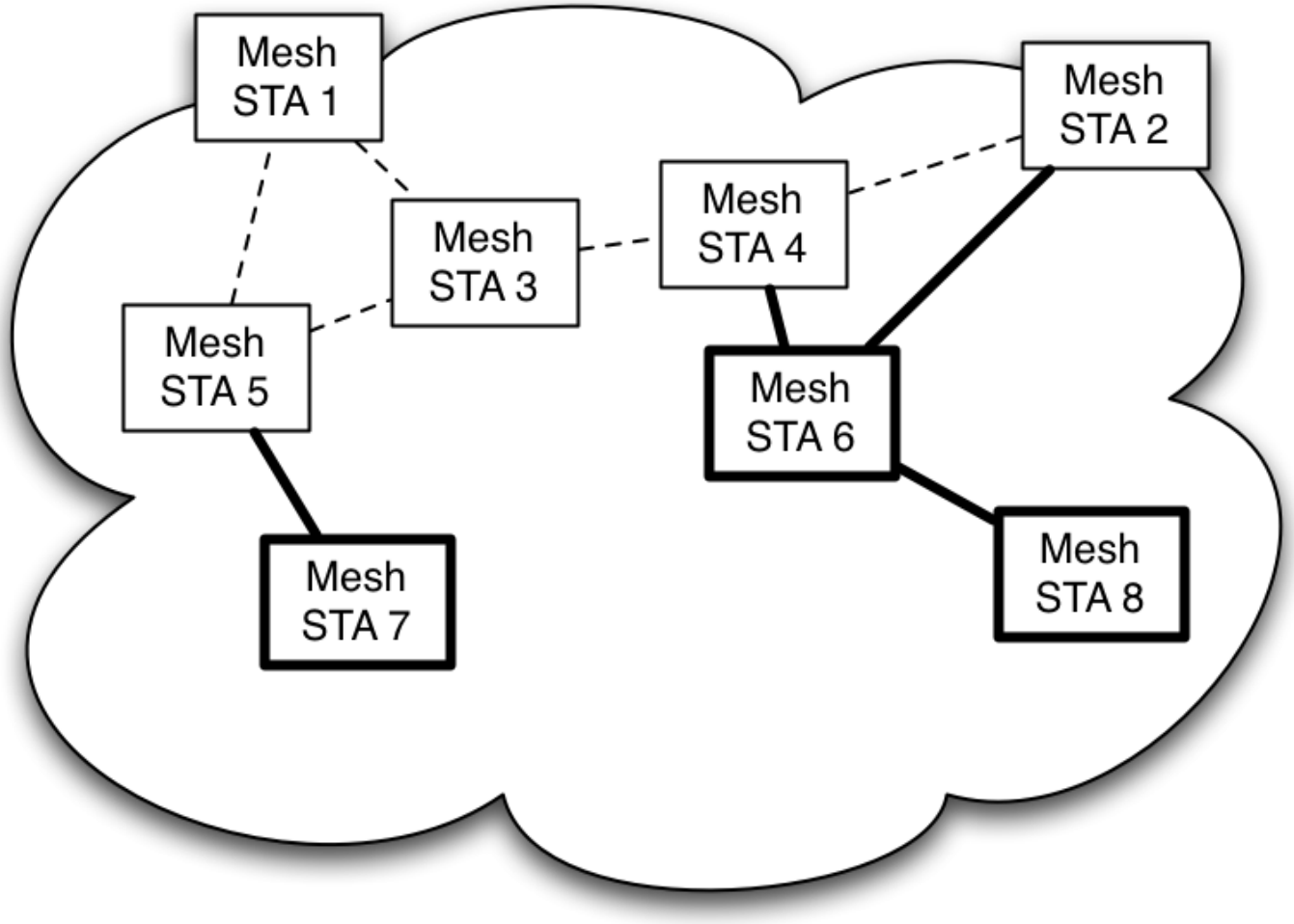
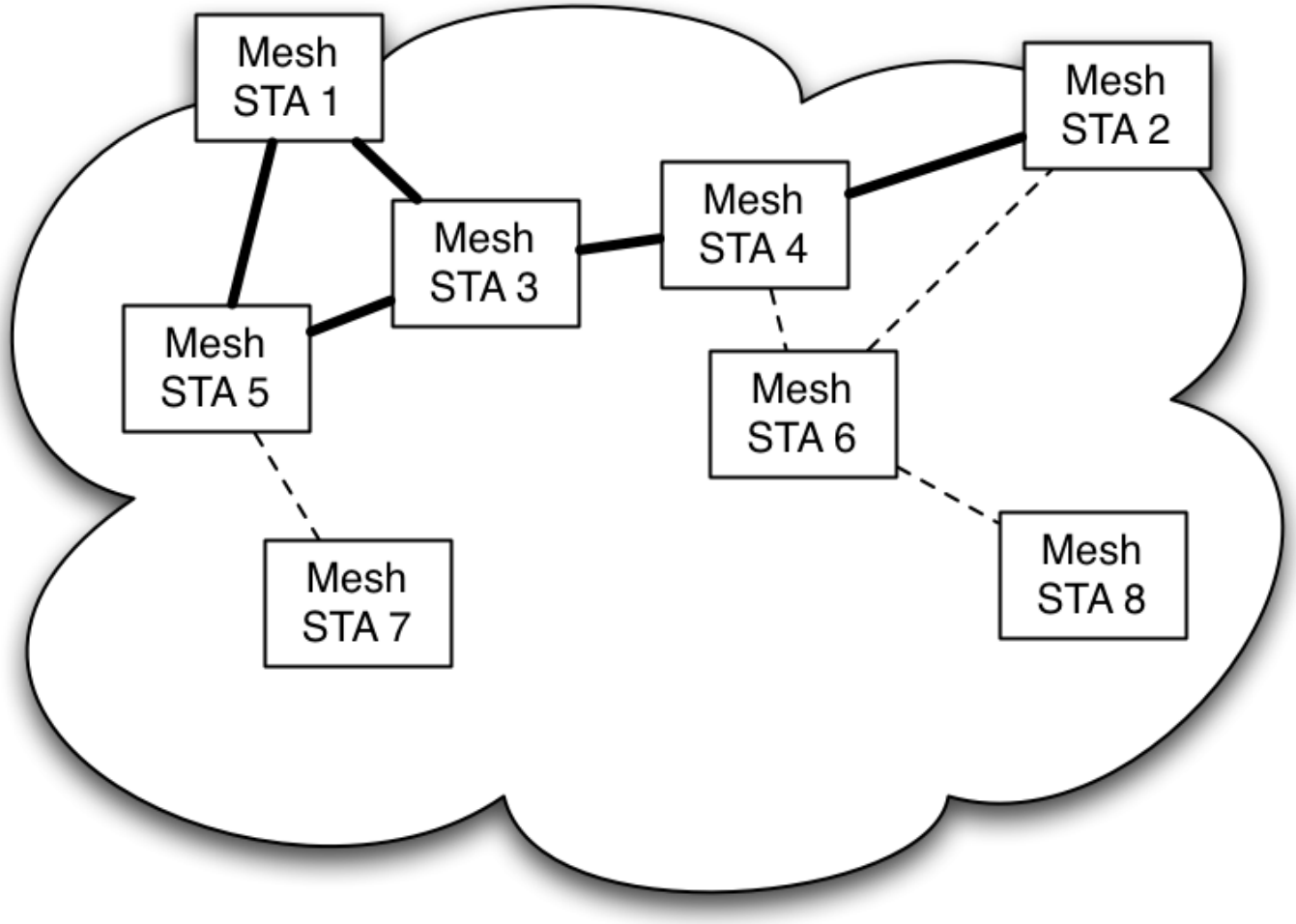
HWMP Topology Change



HWMP Topology Change



HWMP Topology Change



Notes on HWMP

- Sequence numbers are used to drop old packets & to avoid loops
- Each station tracks the last seq. number seen from the other stations
- Path setup may take a while (seconds) if the number of hops is high
- Packets must be queued while node discovery happens

802.11s on net80211

- Second public implementation of 802.11s
- Experimental status
- First release in FreeBSD 8.0
- Sponsored by The FreeBSD Foundation
- Started on late April. Working implementation on late July.
- Linux compatibility is coming

802.11s on net80211

- Each wlan driver needs to be changed for mesh support
- Drivers working already: ath(4), ral(4) and mwl(4)
- Firmware-based drivers (like ipw, iwi, wpi, etc.) won't work
- Drivers that do hostap, can be changed to work with mesh mode easily
- Next step is to play with USB wlan drivers

802.11s on net80211 – user side

- `ifconfig wlan0 create wlanmode mesh channel <chan> meshid freebsd-mesh`

```
wlan0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> metric 0 mtu 1500
        ether 00:0b:6b:2d:dc:d8
        media: IEEE 802.11 Wireless Ethernet autoselect mode 11a <mesh>
        status: running
        meshid freebsd-mesh channel 36 (5180 Mhz 11a) bssid 00:0b:6b:2d:dc:d8
        regdomain ETSI country PT ecm authmode OPEN privacy OFF txpower 17
        mcastrate 6 mgmtrate 6 scanvalid 60 wme burst bintval 1000 meshttl 31
        meshpeering meshforward meshmetric AIRTIME meshpath HWMP
        hwmprootmode DISABLED hwmpmaxhops 31
```

802.11s on net80211 – user side

- `ifconfig wlan0 list sta`

```
ADDR               CHAN LOCAL  PEER   STATE RATE RSSI IDLE  TXSEQ  RXSEQ
00:0b:6b:2d:dc:d8    36     0     0    IDLE   0M 18.5   15      1    192
00:0b:6b:2d:db:ac    36  9827  a5b3   ESTAB  54M 14.0    0      2  28752
00:0b:6b:2d:dd:17    36  afdb  ab30   ESTAB  54M 19.0    0      5  25024
00:0b:6b:87:1c:f0    36  1904  825c   ESTAB  54M  6.0    0     30    192
```

- `ifconfig wlan0 list mesh`

```
DEST               NEXT HOP          HOPS METRIC LIFETIME   MSEQ FLAGS
00:0b:6b:2d:dd:17 00:0b:6b:2d:dc:d8    1   2842     5000      9    V
00:0b:6b:2d:dc:d8 00:0b:6b:2d:dc:d8    0      0     5000      0    V
00:0b:6b:2d:db:ac 00:0b:6b:2d:dc:d8    1    347     5000      4    V
```

802.11s on net80211 – user side

- `ifconfig wlan0 hwmprootmode NORMAL`
  Root mesh station discovers nodes using PREQ packets.
- `ifconfig wlan0 hwmprootmode PROACTIVE`
  Root mesh station discovers nodes and asks for proactive PREPs. This means that the mesh STA will always send a PREP even if it already has a path to the root mesh STA.
- `ifconfig wlan0 hwmprootmode RANN`
  Root mesh station discovers nodes using RANN packets.

Performance measurements

- For 0 hops performance is the same as adhoc mode
- As hops increase, performance decreases about 50%
- E.g.:
  - 0 hop: ~28Mbps / 1 hop: ~14Mbps / 2 hops: ~7Mbps / 3 hops: ~3.5Mbps / etc.
- You can also use a 802.11n card which makes the mesh significantly faster

Performance measurements

- Performance can be increased by use of Mesh Coordinated Channel Access (MCCA)
- MCCA works a bit like TDMA
- Mesh STA reserves a time slot and coordinates that time slot with all the neighbors
- Currently looking at how it works – we'll try to implement it in the future

Acknowledgments

- **The FreeBSD Foundation** for sponsoring this project - www.freebsdfoundation.org
- **Sam Leffler** for his patience, time and help
- **Gateworks Corp.** for a GW2358 ARM board www.gateworks.com
- **Cozybit** for the Wireshark patches enabling mesh sniffing - www.cozybit.com
- **Your** donations to the FreeBSD Foundation made this project possible!

References + Q&A

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- http://www.ieee802.org/11/Reports/tgs_update.htm
- http://en.wikipedia.org/wiki/IEEE_802.11s
- http://o11s.org/ - Linux implementation