IEEE 802.11s Multihop MAC

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Introduction

- IEEE 802.11s is an amendment to IEEE 802.11 standard, that adds wireless mesh capabilities.
- IEEE 802.11s is still a draft.
- Notable feature of IEEE 802.11s is that mesh network is implemented at MAC layer, relying on MAC addresses rather than IP. It enables design and development of CPU-free network, with layer-2 multihop communication.

MANET and challenges

- MANET (Mobile ad-hoc network) is a self-configuring network with no fixed routers. Stations can move freely and topology of such network can change quickly and to any extent. Traffic can be carried by some subset of nodes.
- IEEE 802.11s was designed with MANET in mind.
- Challenges of dealing with MANET include:
    - changing characteristics of radio environment
    - complex medium access contention
    - rapidly changing topology
    - interferences
    - unreliable links

Routing and Metrics

- Two approaches to routing in MANETs:
  - Proactive – scheduled collection of route information. Overhead due to constant exchange of information. Forwarding tables calculated based on collected data.
  - Reactive – path discovery is activated when needed. Delay due to time needed to gather information. Need for path maintenance.
  - Hybrid protocols also exist, IEEE 802.11s presents example of such protocol.
- Metrics for routing decisions are varied.
  - Natural for dynamic topology would be hop count
  - Due to multirate capabilities, rate is a preffered determinant (airtime).
  - More advanced techniques include cost calculation (times, probability of failure, retransmission costs, usage of orthogonal channels).

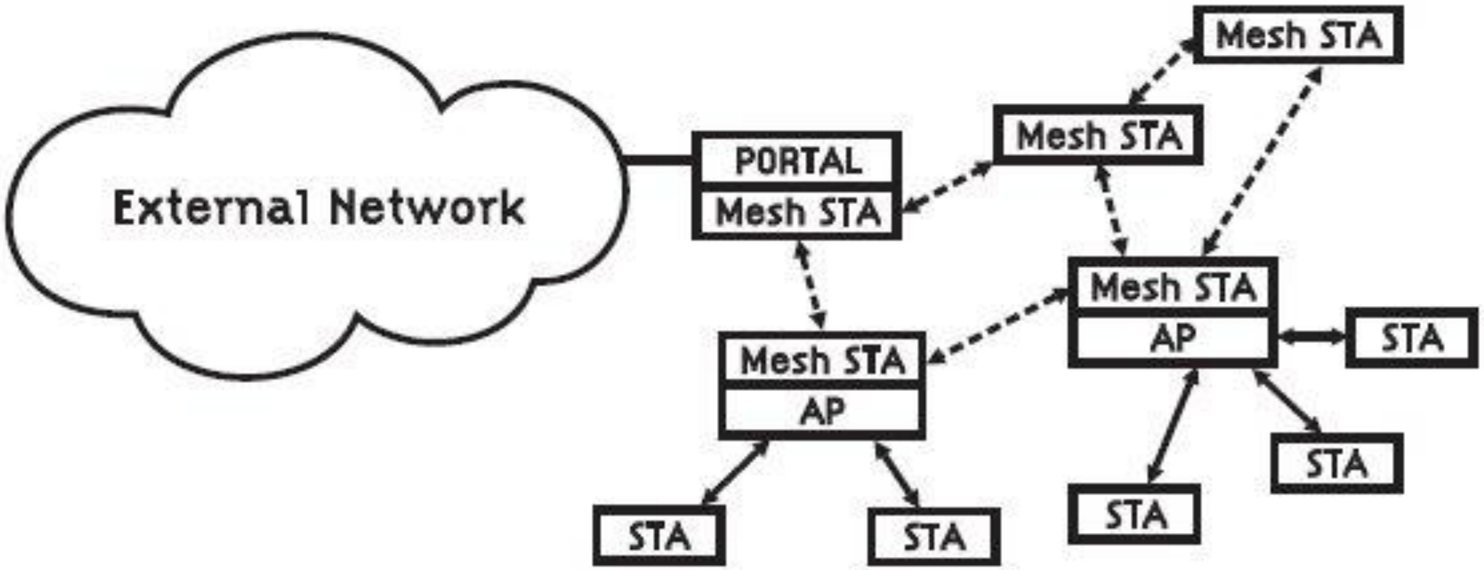
IEEE 802.11s group

- Group devoted to study of wireless mesh amendment for IEEE 802.11 began works in 2003. Many iterations over years.
- Emergence of handheld devices presented constraints on power, processing and memory demands for solution to problem.
- MAC layer solution is lightweight, hence it fits purpose nicely.

- To support multihop forwarding at MAC layer, changes to frame formats are done, along with optional medium access method and few other optimizations to performance and security.

Network architecture

- Nodes in IEEE 802.11s fall into four categories:
  - Station (STA) – node that requires services, but does not forward frames, nor participate in path discovery mechanisms.
  - Mesh STA – node that participates in formation and operation of mesh cloud.
  - Mesh AP – Mesh STA, that has an attached AP to provide services for client STAs.
  - Portal – Mesh STA with additional functionality of a bridge or gateway between mesh cloud and external network.



Mesh creation

- 802.11s uses Mesh ID as equivalent of SSID in infrastructure networks.
- Mesh ID, path selection protocol and path selection metric characterize mesh network and define a Profile. Mesh STA may support various profiles, but all nodes in shingle mesh cloud must share profile.
- 802.11s mandatory profile includes Hybrid Wireless Mesh Protocol (HWMP) for path discovery and Airtime Link metric for path selection.
- Mesh network is formed as Mesh STA finds neighbors that share profile (beacon frames and probing). Frames include mesh related fields. Once neighbor is found Mesh Peer Link Management protocol is used. This includes Peer Link Open/Confirm/Close frames. Links are identified by MAC addresses and link identifiers.

Internetworking

- Portal stations are responsible for internetworking with other LAN networks, and serving as gateways to layer-3 subnets.
- Portal STA has to announce that it is connected to other networks. Special Portal Announcement (PANN) frame is used for that.
- Stations keep MAC addresses of available Portals.

Path Selection

- Hybrid Wireless Mesh Protocol uses beacon frames to convey configuration parameters. Hybrid properties allow it to operate in reactive and tree-based proactive modes simultaneously. When tree-based path is not optimal, on-demand path discovery mechanism may be used to find better path.
- Airtime Link metric accounts for time consumed to transmit test frame, it takes into account bit rate, overhead from physical layer, probability of retransmission

$$c = \left[O + \frac{B_t}{r} \right] \cdot \frac{1}{1 - e_f}$$

O - constant overhead latency

r - data rate

B_t - test frame size

e_f – test frame error rate

Frames in 802.11s

- To allow multihop functions at MAC layer, 802.11s extends frame formats to support four or six MAC addresses and introduces new frame subtypes (for example mesh beacon frame is subtype of management frame).
- Mesh header is included in frame body.
- Four adresses include:
    - SA (Source Address) – of node the generated frame
    - DA (Destination Address) – of node that is the final destination of the frame
    - TA (Transmitter Address) – of node transmitting the frame
    - RA (Receiver Address) – of node receiving the frame.

If two non-mesh STAs are communicating through mesh, two additional addresses are used: Mesh SA and Mesh DA.

Conclusions

- Layer 2 approach presents opportunities for low power consumption, forwarding traffic without full TCP/IP stack, without CPU. Whole operation is performed by Network Interface Card (NIC). This allows for “standalone antennae” – inexpensive, low power devices with only wireless NIC, acting as mesh point (Mesh AP or Portal).
- However burdening layer 2 may require higher processing power and memory in NIC.
- IEEE 802.11 is designed for small groups of nodes, sufficiently close to each other to permit connectivity. If distance grows and the mesh becomes too sparse there will be no connectivity whatsoever. And if mesh is too dense, it is arguably better to switch to infrastructure mode, without considerable overhead of path discovery mechanism.
- Therefore 802.11s may be attractive for limited set of scenarios.

References

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