Wi-Fi Mesh Networking: IEEE 802.11s

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Outline

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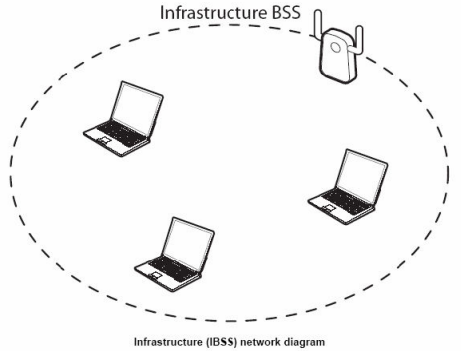
Mesh networking

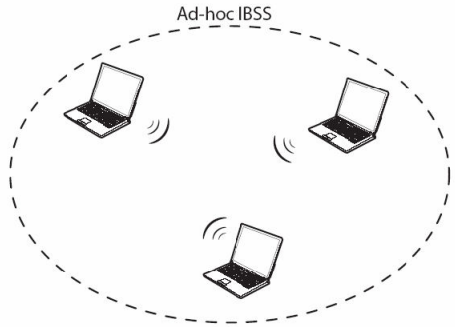
- Wired networks - full mesh topology
- All to all connections
- ”knotted material of open texture with evenly spaced holes” Merriam-Webster dictionary
- In wireless networking mesh is a wireless backbone

IEEE 802.11 reminder

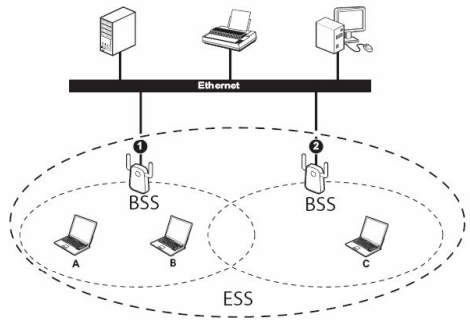
- Basic Service Set (BSS)
- Independent Basic Service Set (IBSS)
- Extended Service Set (ESS)



Infrastructure (IBSS) network diagram



Ad-hoc (also known as peer-to-peer) network diagram



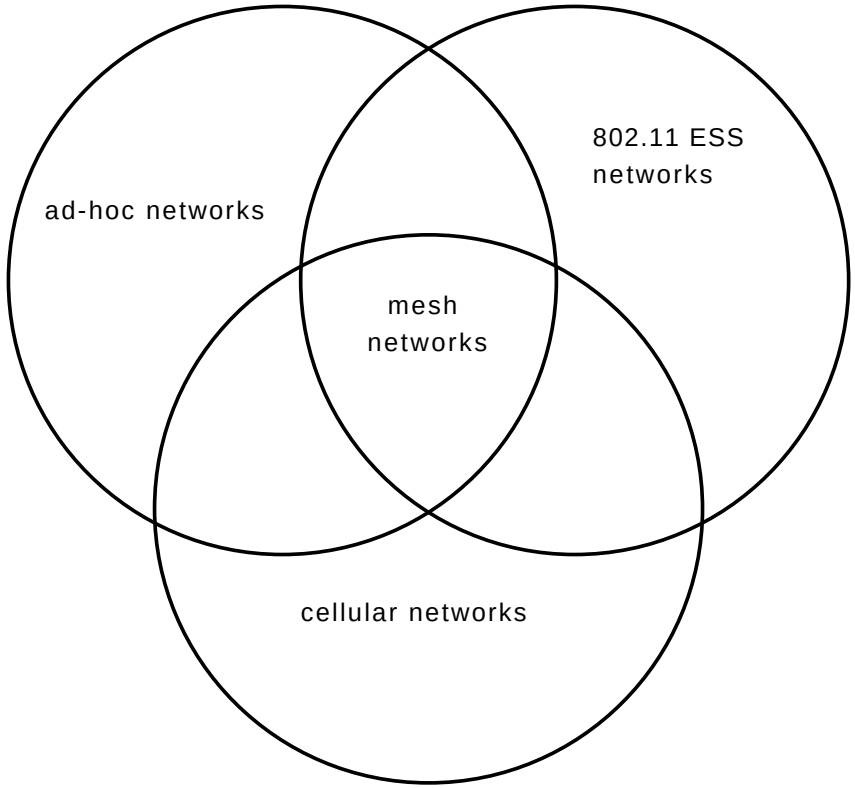
Infrastructure (ESS) network diagram

Outline

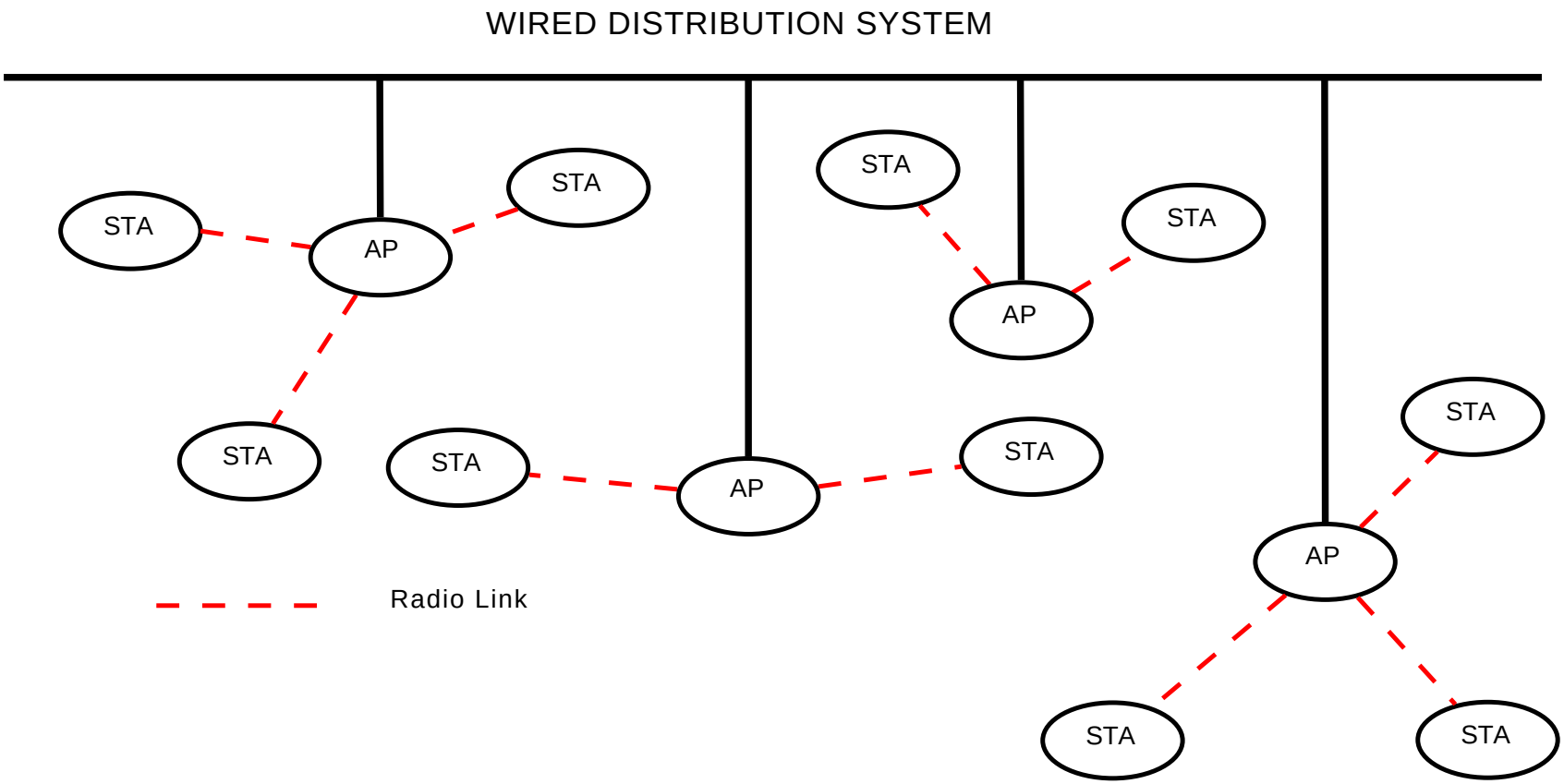
Wireless Mesh Networks

Main Features

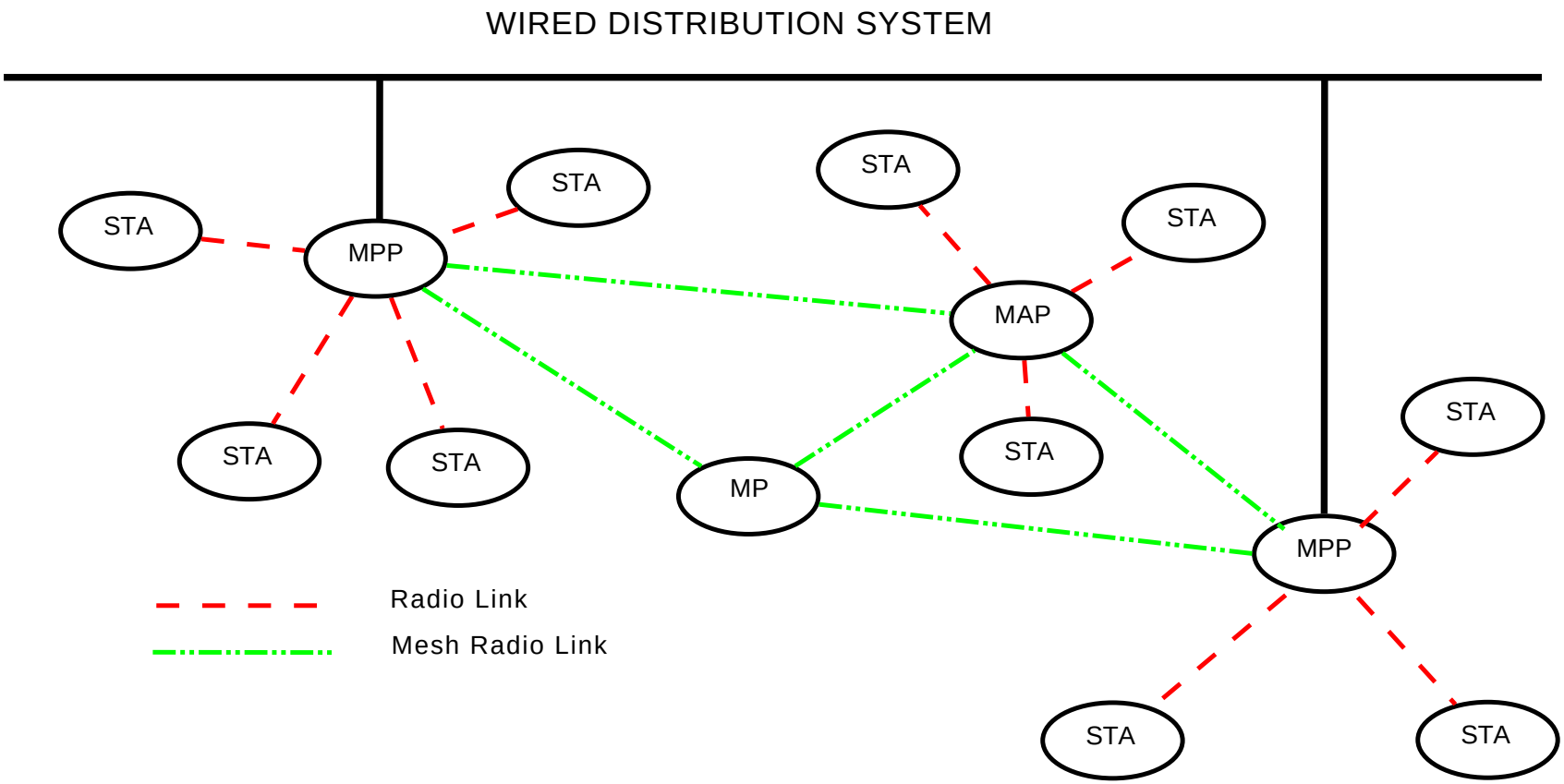
- Self-organizing backbone
- Overlapping coverage
- Lack of wired distribution system
- Freedom in selecting the node location



Exteneded Service Set



Mesh Extended Service Set



Advantages

- Fast deployment
- Low cost
- Removes dead spots
- Very scalable
- Easy network maintenance
- Robust
- etc...

Outline

Motivation

- Many companies were developing proprietary mesh solutions independently
- Lack of interoperability between vendors
  - Nortel, MITRE, Philips, Thomson, etc. (Wi-mesh)
  - Intel, Motorola, Nokia (SEEMesh Simple Efficient Extensible)
  - BelAir Networks, Tropos Networks, Strix Systems (outsiders)
- IEEE 802.11s Task Group formed in July 2004
- Joint proposal contributed to the first draft (1.0) of the standard

New network entities

- Mesh Point (MP)
  implements the basic functionality of path selection and forwarding the traffic of other MPs. It might be used to interconnect two remote parts of the mesh cluster.
- Mesh Access Point (MAP)
  Same functionality as bare MP. Additionally, it serves as a legacy AP for the STA nodes. In simpler terms, it is an MP collocated with AP.
- Mesh Portal (MPP)
  Same functionality as bare MP. Moreover, it is a gateway to the external network, e.g. Ethernet or WiMax. It is an MP collocated with a gateway.

Usage Scenarios

- Residential/Consumer Electronics
  - single building or flat
  - audio and video streaming
  - eliminate the dead spots and low quality areas
- Office
  - cabling not feasible
  - scalability
  - cost reduction
- Campus/Community/Public Access Network
  - wider coverage
  - lower cost and higher bandwidth
  - fast deployment and scalability

Usage scenarios

- Public Safety
  - emergency response: such as fire, police and emergency workers at the accident scene
  - video surveillance, voice communication, collection of the data from sensors
- Military
  - non-combat and combat
  - extreme mode mobility
  - fully automated network management
  - power preservation schemes for detached nodes

IEEE 802.11s

- Routing
  - Hybrid Wireless Mesh Protocol (HWMP)
  - First standard to define layer 2 routing
- Medium Access techniques
  - Enhanced Distributed Channel Access (EDCA)
    - mandatory
  - Mesh Deterministic Access (MDA)
    - introduces novel medium access method
    - optional

Open source implementation

- http://www.open80211s.org/
- Present in the Linux Kernel since 2.6.26
- Supported wireless drivers: ath5k, b43, libertas_tf, p54, zd1211rw
- Sponsors: Nortel, cozybit, olpc, google,

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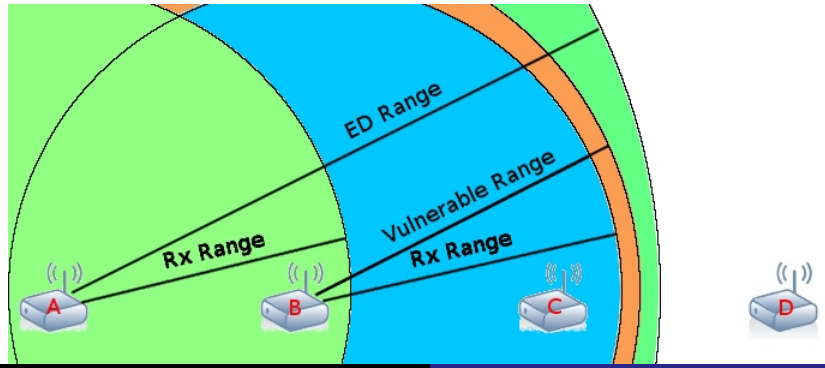
EDCA drawbacks in multihop environmnent

- Designed for single hop wireless networks
- Dense deployment of MPs leads to large amount of exposed terminals
- No means to prioritize backbone traffic over locally generated traffic
- Unaware station problem
  Ongoing transmission between A and B blocks node C being close to B. Node D placed outside A's Energy Detection (ED) range is an unaware station. It may try several retransmissions to not responding C node

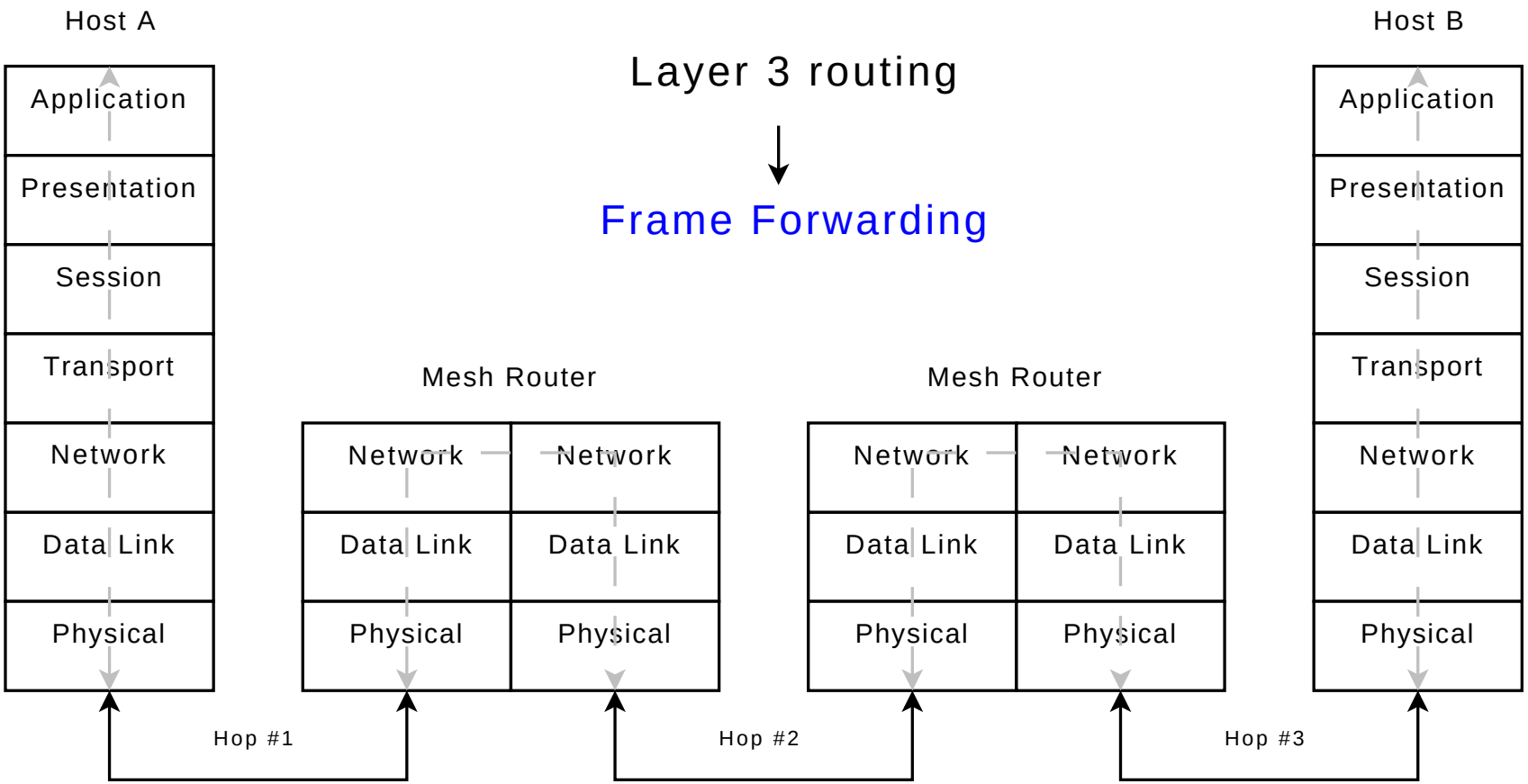


MDA

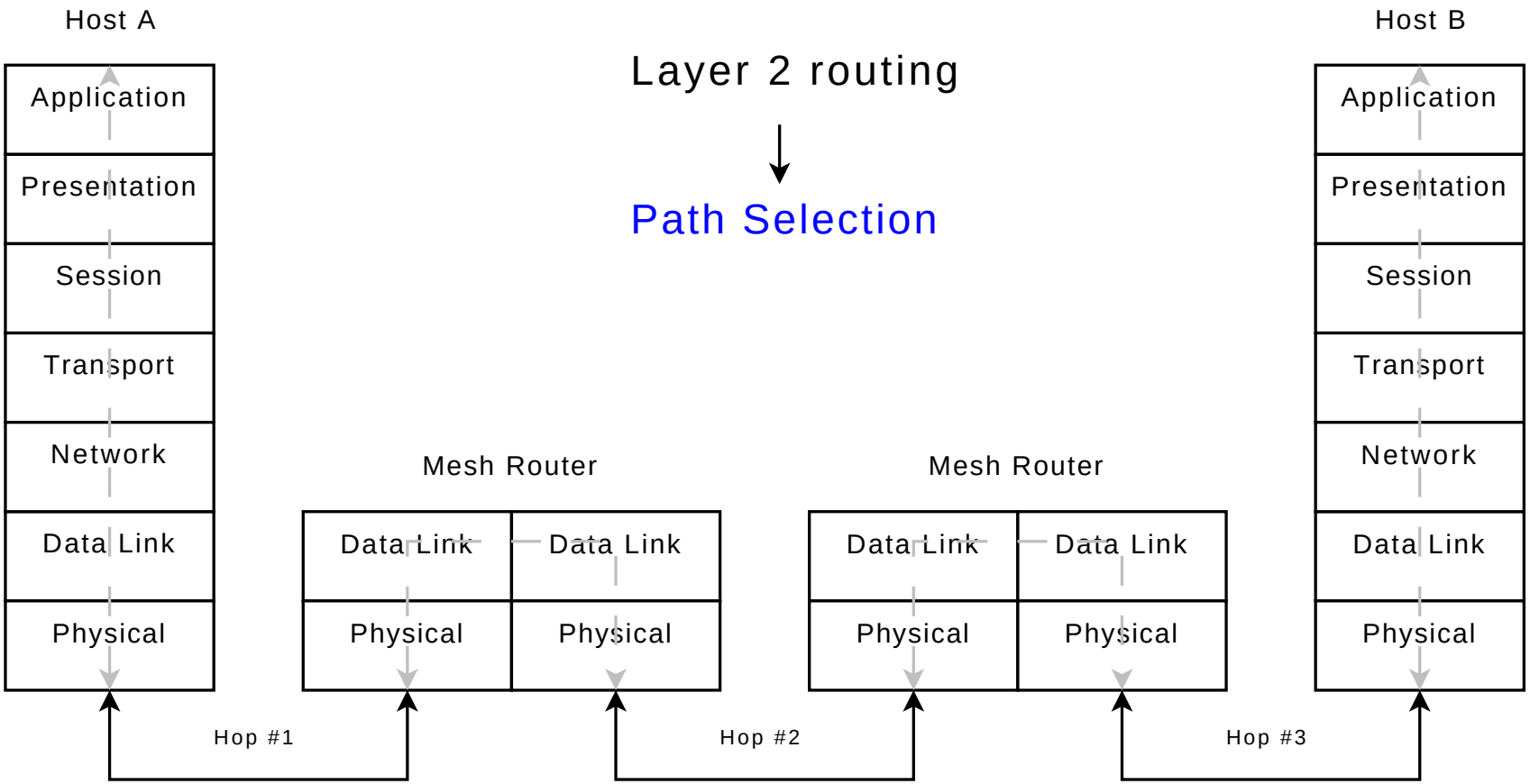
- Currently 802.11 does not include any multi-hop scheme allowing two stations outside mutual radio range to communicate
- Separates a negotiation process and medium reservation
- More awareness of the difficult radio environment
- Mitigates unaware station problem
- MP exchange the information about:
  - Their own Tx and Rx transmission periods (MDAOP)
  - Their neighbors' Tx and Rx transmission periods, interference reports

Outline

Network layer routing



IEEE 802.11s ESS



HWMP overview

- Routing protocol must be aware of rapidly changing radio environment
- Combines on-demand routing with proactive tree-based approach, not exclusive
- The protocol specifies four information elements:
  1. PREQ – Path Request
     Contains cumulative metric and destination address
  2. PREP – Path Reply
  3. PERR – Path Error
  4. RANN – Root Announcement
- Sequence numbers in use

HWMP Proactive tree building mode

1. Utilizing PREQ
   - One node acts as a tree root
   - Root node sends proactively PREQs
   - Formation of paths between root and all other nodes
2. Utilizing RANN
   - Root node periodically broadcasts RANNs
   - Each node creates or updates the path to the root

HWMP Reactive path selection mode

1. Node A needs to discover a path to the destination
2. Node A broadcasts PREQ
3. The recipients process the PREQ based on two flags:
   - Destination Only (DO)
   - Reply and Forward (RF)

- DO=1 (default)
  - Only the destination node is eligible to response with PREP,
  - RF flag has no influence,
  - All intermediate nodes learn the path to the destination
- DO=0 and RF=0
  - Intermediate node that knows the path to the destiantion may respond with unicast PREP,
  - Reduction of the path selection delay

HWMP Reactive path selection mode

- DO=0 and RF=1
  - The same behaviour as in the previous case, but
  - PREQ is being forwarded,
  - Intermediate node sets DO=1

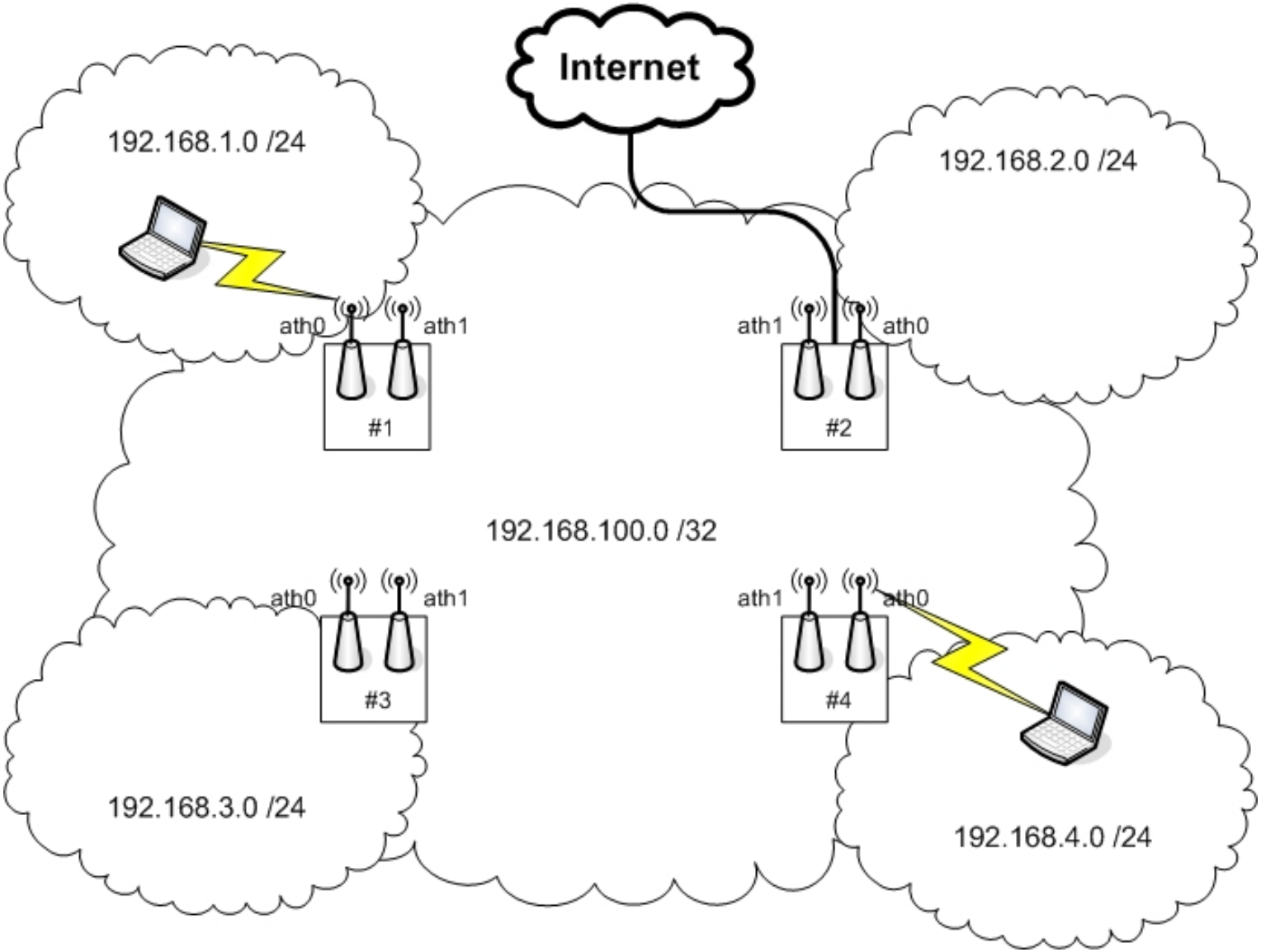
Outline

Motivation

To deploy Wireless Mesh Network testbed

- IEEE 802.11
- Free (open source) software
- Embedded platform
- Dual-radio

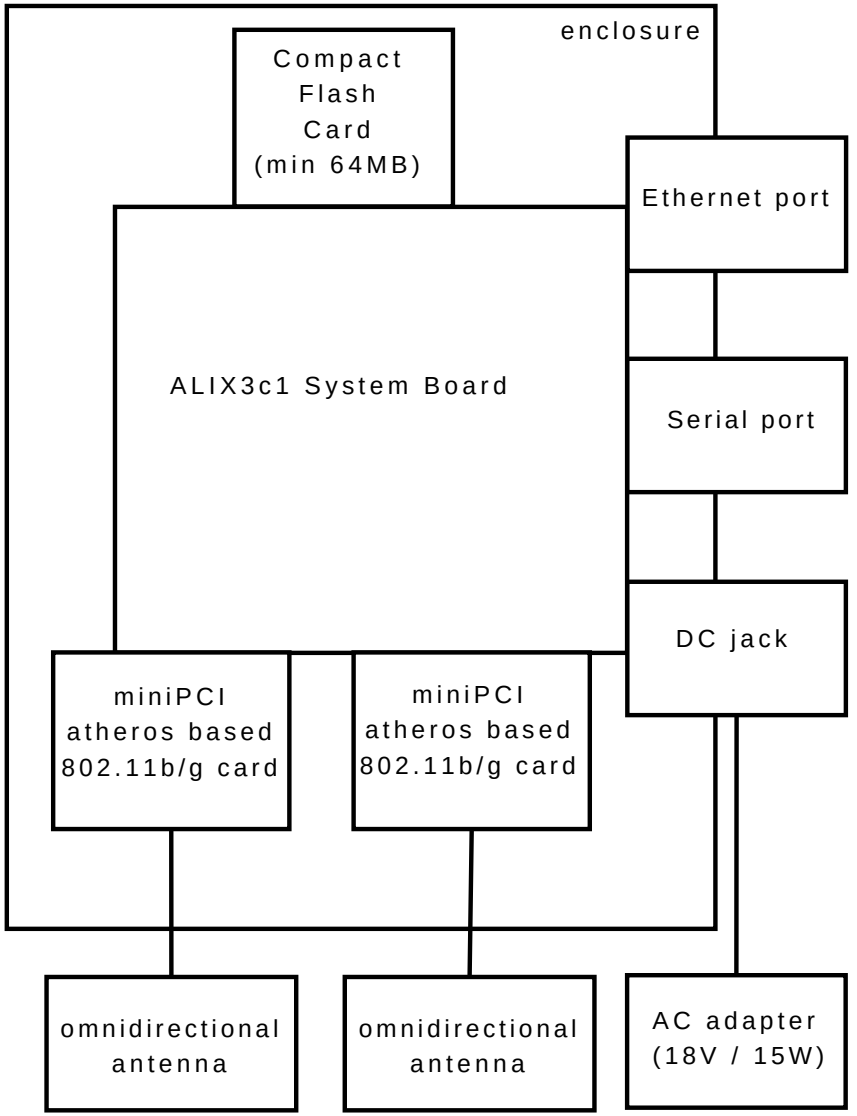
Testbed topology



Outline

Mesh Router

- Alix3c1 board - PC Engines
- 2 Compex MiniPCI 802.11b/g wireless cards
- 1GB Compact Flash (CF) card
- 2 5dBi omni-directional antennas



Mesh Router platform

PCengine's Alix3c1

CPU	433 MHz AMD Geode LX700
DRAM	128 MB DDR DRAM
Storage	Compact Flash socket
Power	DC jack
Expansion	2 miniPCI slots, LPC bus
Connectivity	1 Ethernet channel
I/O	DB9 serial port
Board size	100 x 160 mm
Firmware	tinyBIOS
Power consumption	2.5-3.5 W (peak 5 W)

Software selection

- Operating System - Debian-based linux
- Wireless Drivers - MadWiFi
- dnsmasq - DHCP daemon
- iptables - Masquerade on the gateway node
- olsrd - Ad-hoc routing daemon
- GRUB - GRand Unified Bootloader

That's all

THANK YOU