FreeBSD Wireless Networking

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Project Goals

- Device-independent 802.11 support
- Use full hardware functionality
- Production quality
- Reusable code:
  - Portable code but no portability layer
  - Native management API (e.g. Wireless Extensions)
- Dual BSD/GPL license

802.11 Basics

- Network of wireless STAtions
- Stations organized in an adhoc or structured topology
- Communication via PHY's that support multiple transmit rates
- Frequency usage controlled; can operate in 2.4GHz and 5GHz bands
- Medium access done with DCF (Ethernet-like) or PCF (centralized polling--rare)
- Time in a BSS is synchronized (TSF)

802.11 Basics (cont)

- 802.11b:
  - 2.4GHz
  - CCK
  - 1Mb/s to 11Mb/s
- 802.11a:
  - 5Ghz
  - OFDM
  - 6Mb/s to 54Mb/s
- 802.11g:
  - 2.4GHz
  - CCK+OFDM
  - 11b+11a xmit rates

- 802.11n (draft):
  - 2.4GHz or 5GHz
  - 20MHz/40MHz operation
  - MIMO
  - CCK+OFDM
  - Block acks
  - Transmit beamforming
  - 802.11e (QoS)
  - 802.11g coexistence

http://www.enhancedwirelessconsortium.org

Background

- Original version by Atsushi Onoe
- Overhaul (1) for multi-mode devices
- Overhaul (2) for security protocols
- Overhaul (2.5) multimedia extensions
- Overhaul (3) for multi-BSS support

Background: Original Version

- Circa 2001 (NetBSD)
- Simple devices (e.g. only 11b)
- Mostly firmware-based devices
- Pre-shared key WEP for crypto

Background: Multi-mode Devices

- Summer 2003 (started Fall 2002)
- Multi-band: 2.4GHz, 5GHz, etc.
- Multi-mode: 11a, 11b, 11g, Turbo, etc.
- 11g protocol

BIG CHANGE... All the world is not 11b

Background: Security Protocols

- Summer 2004
- WPA protocol
- 802.11i, aka WPA2, protocol
- TKIP, CCMP, etc.: cipher modules
- Hardware crypto acceleration

BIG CHANGE...

All the world is not WEP

Background: Multimedia Protocols

- Fall 2004
- WME/WMM protocol
- QoS traffic handling
- Hardware acceleration

BIG CHANGE... All traffic is not equal

Background: Multi-BSS Support

- 2005
- Multiple BSS with one device
- WDS support
- Repeater/bridge applications
- Foundation for mesh support

BIG CHANGE... Separation of BSS and device

Comparison to Other Projects

- **Microsoft “Native WiFi”**
- **Various proprietary**
- **MultiNet**
- **Linux**

Microsoft Native WiFi

- Windows-specific
- Device independent
- Single BSS
- Expected in WinVista
- Code access not generally available

Proprietary Products

- Usually device specific
- Often OS-specific
- Single BSS (mostly)
- Code sometimes available for a price

MultiNet

- Research project
- Multiple BSS
- Windows only (NDIS)

MORE INFO...

http://research.microsoft.com/~bahl/MS_Projects/MultiNet/default.htm

Linux

- "Generic 802.11 Stack"
- Recent development (March 2005)
- Linux-specific
- Two competing stacks:
  - Intel: single BSS
  - DeviceScape: multi BSS (?)
- Early stage--limited usability

MORE INFO...

http://marc.theaimsgroup.com/?l=linux-netdev&m=111174142325384&w=2

Security Protocols: Standards

- **Wi-Fi Protected Access (WPA)**
  - **April 2003**
  - **Based on IEEE 802.11i Draft 3.0**
  - **Authenticated key management**
  - **TKIP+Michael (WEP on ‘roids)**
  - **AES-CCMP (optional)**

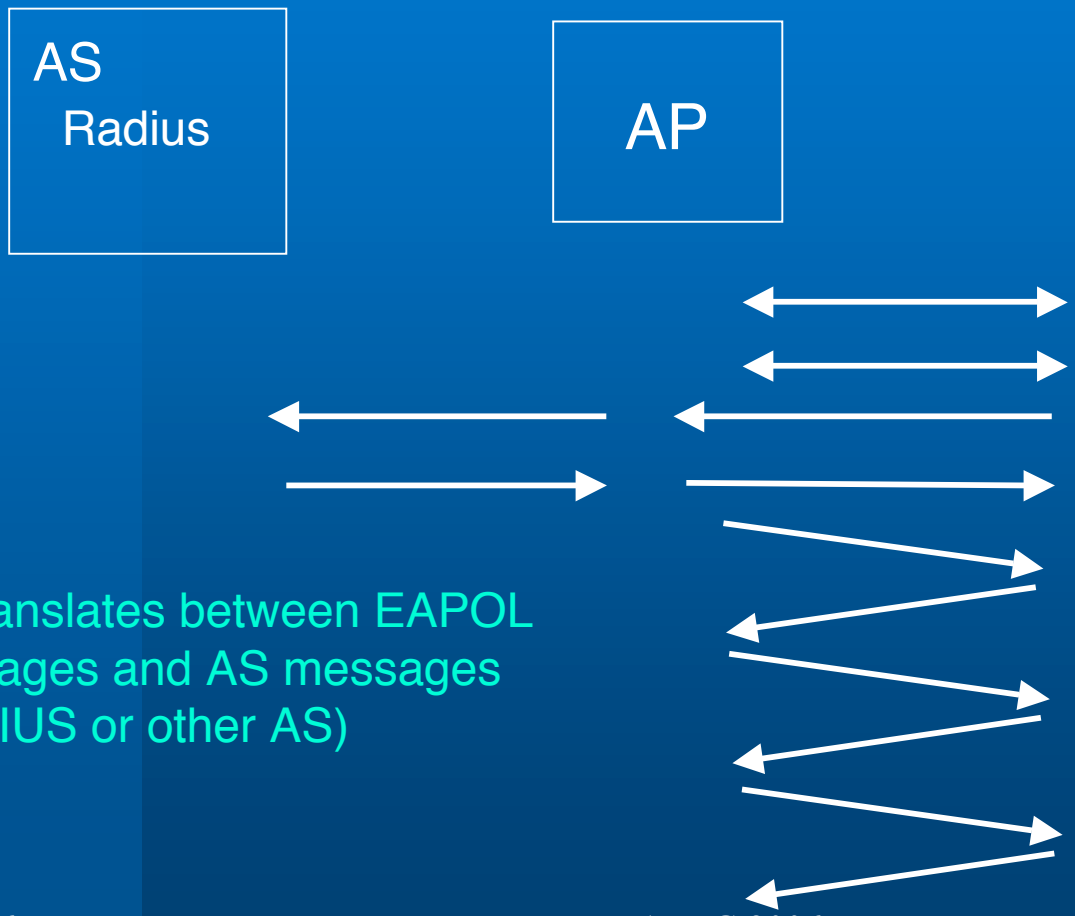
MISSING… **Preauthentication and fast handoff**

Security Protocols: Standards

- **IEEE 802.11i (aka WPA2/RSN)**
  - **Approved July 2004**
  - **AES-CCMP required**
  - **Preauthentication and fast handoff**
- **Management frames still not encrypted**

GOOD INFO… http://www.drizzle.com/~aboba/IEEE/
http://www.wi-fi.org/OpenSection/

Security Protocols: Key Handling



AP translates between EAPOL Messages and AS messages (RADIUS or other AS)

Security Protocols: How it Works

- **Kernel support:**
  - **802.11 protocol (e.g. mgt frames)**
  - **cipher support**
- **User-mode support:**
  - **supplicant (station operation)**
  - **authenticator (AP operation)**

Security Protocols: Kernel Support

- 802.11 protocol: beacon, auth, etc.
- Extensible crypto framework
- Cipher modules
- Management ioctls
- Application control of scanning
- 802.11 events via routing socket

FULL PERFORMANCE…

No degradation with hardware crypto

Security Protocols: Supplicant

- wpa_supplicant from Jouni Malinen:
  - WPA/802.11i protocol
  - EAP/802.1x support
  - scanning and AP selection
  - driver_bsd.c for net80211 glue
  - driver_ndis.c for ndis glue (Bill Paul)
- BSD/GPL license

WHERE TO FIND IT…

http://hostap.epitest.fi/wpa_supplicant/

usr.sbin/wpa/wpa_supplicant

Security Protocols: Authenticator

- **hostapd from Jouni Malinen:**
  - **WPA/802.11i protocol**
  - **EAP/802.1x support**
  - **some built-in AS support**
  - **driver_bsd.c for net80211 glue**
- **BSD/GPL license**

WHERE TO FIND IT…

http://hostap.epitest.fi/hostapd/

usr.sbin/wpa/hostapd

Multimedia Protocols: Standards

- **Wireless Multimedia Enhancements (WME)**
  - **July 2003**
  - **Based on IEEE 802.11e draft**
  - **Capabilities negotiation**
  - **Quality of Service (QoS)**
  - **Enhanced DCF (EDCF)**

APPLICATIONS… **Streaming video and VoIP**

Multimedia Protocols: How it Works

- **Kernel support:**
  - **802.11 protocol (e.g. beacon frames)**
  - **Traffic classification**
  - **Device support (no software fallback, hard)**
- **User-mode support:**
  - **ifconfig report/set parameters**

Multi-BSS: Motivation

- **Multiple BSS with a single radio**
  - **Multiple virtual AP's (different security policies)**
  - **Multiple IBSS's**
  - **Mesh networks**
  - **Special-purpose applications (e.g. Atheros XR mode)**
- **Combo applications:**
  - **Repeater (station + AP)**
  - **Extender (AP + WDS links)**

Single-BSS: Previous Model

- **One network (BSS) per device:**
  - **ath0 is the device and the network**
- **Device configuration/operation is modal:**

```
ifconfig wi0 mediaopt hostap
ifconfig awi0 mediaopt adhoc
```

- **Combination modes require special handling (repeater = station + AP)**

Multi-BSS: New Model

- **Device is a blank substrate:**

```
# ifconfig iwi0
iwi0: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 2290
      ether 00:03:7f:04:a0:a4
      media: IEEE 802.11 Wireless Ethernet autoselect
      status: no carrier
```

- **Network devices are cloned:**

```
# ifconfig wlan create wlandev wi0 wlanmode adhoc
wlan0
# ifconfig wlan0
wlan0: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
      ether 00:03:7f:04:a0:a4
      media: IEEE 802.11 Wireless Ethernet autoselect <adhoc>
      status: no carrier
      ssid ""
      authmode OPEN privacy OFF txpowmax 100 ff
```

DEFINITION… **wlanX is a *Virtual AP* (VAP)**

Multi-BSS: New Model (2)

- **Multi-BSS = multiple vaps:**

```
# ifconfig wlan create wlandev ath0 wlanmode ap
# ifconfig wlan create wlandev ath0 wlanmode ap
# ifconfig
ath0:  flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 2290
       ether 00:03:7f:04:a0:a4
       media: IEEE 802.11 Wireless Ethernet autoselect (autoselect <hostap>)
       status: associated
wlan0: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
       ether 00:03:7f:04:a0:a4
       media: IEEE 802.11 Wireless Ethernet autoselect <hostap>
       status: no carrier
       ssid ""
       authmode OPEN privacy OFF txpowmax 100 ff dtimperiod 1
wlan1: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
       ether 00:03:7f:04:a0:a4
       media: IEEE 802.11 Wireless Ethernet autoselect <hostap>
       status: no carrier
       ssid ""
       authmode OPEN privacy OFF txpowmax 100 ff dtimperiod 1
```

Multi-BSS: New Model (3)

- **Multi-use = combined vaps:**

```
ifconfig wlan create wlandev ath0 wlanmode ap
ifconfig wlan create wlandev ath0 wlanmode sta wds
```

[repeater = ap + sta in 4-address mode]

Multi-BSS: VAP Creation

- VAP create succeeds only if all info is provided:
  - Parent device
  - Operating mode
  - Mode-specific state (e.g. BSSID for WDS link)
- VAP mode is fixed at create; simplifies work:
  - Check if multiple instances are supported
  - Check if combination is supported
  - Check if too many instances
- Device is involved so it can impose policy

Multi-BSS: Fixed Operating Mode

- **Fixing the operating mode enables the use of mode-specific code:**
  - **Reduced memory footprint (e.g. no AP support)**
  - **Simpler (optimized) code**
  - **Existing code can still be reused**
- **Devices can load mode-specific firmware**

Multi-BSS: Multi-BSSID

- Desirable for VAP's to have unique station address (AP's can make do by hiding SSID)
  http://www.drizzle.com/~aboba/IEEE/virtual-APs.ppt
- Some VAP's want to share station address
- Requires device support (hardware ACKs)
- Use 802.3 Local Address Management for address provisioning

PER-VAP MAC ADDRESS… Depends on device capability

Multi-BSS: User Visible Changes

- **Clone device first:**

```
ifconfig wlan create wlandev ath0
```

- **After that everything is as before:**

```
dhclient wlan0
```

- **Parent device available via sysctl:**

```
# sysctl net.wlan.0
net.wlan.0.%parent: ath0
net.wlan.0.debug: 0
…
```

- **Changing shared state affects all vap's**

```
ifconfig wlan0 channel 36
```

Multi-BSS: Kernel Changes

- **State is split:**

```
struct xxx_softc + struct ieee80211com ->
   struct xxx_softc + struct ieee80211com +
   struct ieee80211vap + struct ieee80211vap + …
```

- **Reference `ieee80211vap` instead of `ieee80211com` (mechanical changes)**
- **VAP create/destroy callbacks to driver (policy)**
- **Changing shared state requires more care:**
  - **State may be created by another vap (e.g. scan cache)**
  - **Notify all vap's on state change**
  - **Restructure data to eliminate recalc of per-vap state**

Multi-BSS: Kernel Changes (more)

- **Eliminate "current mode": a channel uniquely defines mode/band**
- **Coordinate certain virtual state:**
  - **Multicast filtering**
  - **Promiscuous mode**
  - **WME**
  - **ACL's**
  - **11g**
  - **11h**
  - **Power save**
  - **Crypto**

Multi-BSS: Input Handling

- Common station/neighbor table
- RX frames find station/neighbor using sender MAC address and this identifies VAP
- Multicast/unknown senders are broadcast to all VAP's (can optimize if frame is unicast)

OVERHEAD… Typically the same as single-BSS design

Multi-BSS: Output Handling

- Per-VAP send queue
- 802.11 processing partly done before passing to device send queue
  - WME traffic classification
  - Traffic diversion for stations in power-save mode
- 802.11 encap still done in driver (required for fast frame aggregation)
- Separate transmit queues enable system traffic control (e.g. load balancing)

OVERHEAD… Additional handoff to net80211 layer

Multi-BSS: Beacons

- Each IBSS/HostAP VAP must transmit a beacon at a regular interval
- Beacon frames must have TSF that is a multiple of the beacon interval

- Two choices:
  - Burst frames together
  - Stagger frame transmission over beacon interval

Multi-BSS: Beacons (continue)

- **Bursting makes beacon delivery jittery from the stations' POV (can mitigate by permuting order)**
  - **Power save**
  - **VoIP**
- **Staggering is good but TSF must be adjusted for beacon interval (requires device support)**

OVERHEAD… **Additional beacon timer interrupts**

Multi-BSS: Crypto

- Unicast keys are easy
- Global key table is the issue:
  - WPA/802.11i Group keys: proper device support can deal with this
  - WEP keys: can do this in software but typically not hardware

OVERHEAD…

May need to fallback to software

Multi-BSS: Summary

- New user-visible device model
- Operating mode fixed for life of vap
- Multi-BSSID requires device support
- Staggered beacons require TSF adjust
- Group key requires multicast search support
- WEP is problematic but can be handled

OVERHEAD… Minimal unless we fallback to software

Other Work

- **Atheros SuperG support:**
  - **fast frames**
  - **dynamic turbo**
- **Scanning rewrite:**
  - **Modular policies (in-kernel and user-mode)**
  - **Background scanning**
  - **Roaming**
- **Atheros eXtended Range (XR) support (AP side)**

Ongoing/Future Work

- **Long distance links**
- **Mesh network protocols (e.g. 802.11s)**
- **Multi-channel support?**

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CORPORATE SPONSORS...

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Availability

- FreeBSD -current and -stable has everything up to the multi-BSS support
- Madwifi project for Linux now working from Atheros' multi-bss vap code
- NetBSD nearly in sync with FreeBSD

MULTI-BSS SUPPORT…

Available in FreeBSD developer perforce