FreeBSD Wireless Networking

Sam Leffler

Errno Consulting

sam@errno.com

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

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 Longhorn
- 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)
- Derived from device-specific code
- Linux-specific
- Single 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

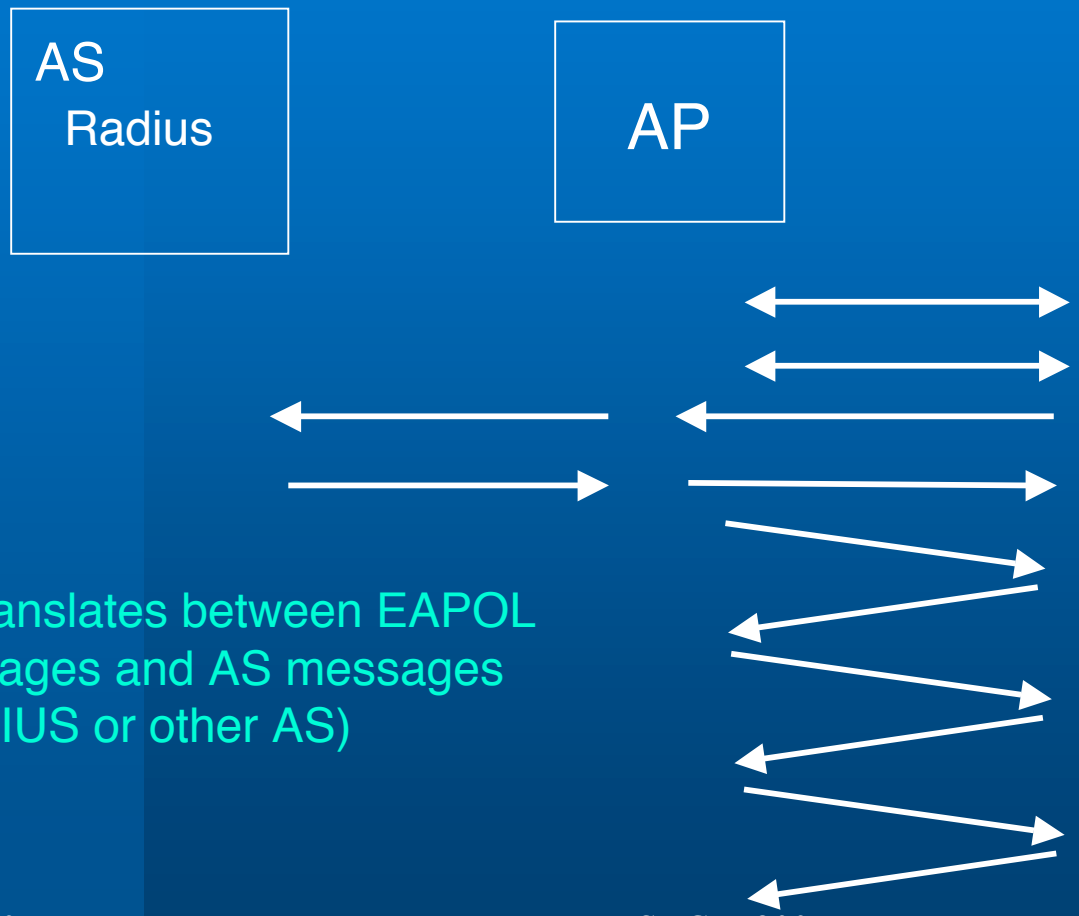
- IEEE 802.11i (aka WPA2/RSN)
  - Approved July 2004
  - AES-CCMP required
  - Preauthentication and fast handoff
- Management frames still not encrypted

GOOD INFO…

http://www.drizzle.com/~aboba/IEEE/

http://www.wi-fi.org/OpenSection/

Security Protocols: Key Handling



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
- BSD/GPL license

WHERE TO FIND IT…

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

ports/security/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/

ports/security/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

OVERHEAD… Minimal unless we fallback to software

Ongoing/Future 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
- Mesh network protocols (e.g. 802.11s)
- Multi-channel support?

Contributors include…

Joerg Albert
Satish Balay
John Bicket
Vivien Chappelier
Greg Chesson
Tong Chia
Jeffrey Chung
Richard Dawe
Srinivasa Duvvuri
Guy Erb
Joachim Gleissner
Raja Gobi
Kristian Hoffmann
William Kish
Mathieu Lacage

Eric Lammerts
Stephane Laroche
Divy Le Ray
Tai-hwa Liang
Warner Losh
Georg Lukas
Jouni Malinen
Tom Marshall
Nick Moss
Atsushi Onoe
Nick Petroni
Andy Patti
Henry Qian
Mark Rakes
Bruno Randolph

Michael Renzmann
Paul Stewart
Dieter Stolte
Jonas Tarnstrom
Bindu Therthala
Carl Thompson
Jim Thompson
Thorsten von Eicken
Carl Thompson
Sebastian Weitzel
Dale Whitfield
Alexander Wirtz
Michael Wong
David Young
Kevin Yu

CORPORATE SPONSORS...

Atheros, Vivato, Video54, 5Bridge, Red-M, Rincon Networks, Pelco, Visidaq, SuSE, 2Wire

Availability

- FreeBSD -current has everything up to the multi-BSS support
- Madwifi project for Linux tracks FreeBSD -current code
- NetBSD planning to import security and multimedia work

MULTI-BSS SUPPORT…

Available in FreeBSD developer perforce