Wireless Security

Wireless Security

- What is Wireless Security?
- The usual: confidentiality, integrity, availability?
- Or Butler Lampson's "Gold" (Au) standard: authentication, authorization, audit?
- Both!

Confidentiality

- Obvious danger — it's easy to intercept traffic
- Obvious countermeasure — cryptography
- But it's harder to use here than it looks

Integrity

- At first glance, integrity seems ok
- This is radio — how can an attacker change messages in mid-packet?
- Solution: the "Evil Twin" (or "Sybil") attack

Wireless Architecture

- The obvious architecture is pure peer-to-peer — each machine has a radio, and talks directly to any other machine
- In fact, 802.11 (WiFi) can work that way, but rarely does
- More common scenario: *base stations* (also known as access points)

Access Points

- An ordinary wireless node *associates* with an access point (AP)
- More precisely, it associates with the AP having a matching network name (if specified) and the strongest signal
- If another AP starts sending a stronger signal (probably because the wireless node has moved), it will reassociate with the new access point
- All transmissions from the laptop go to the access point
- All transmissions to the laptop come from the access point

Which AP?

- Which AP is your laptop associated with?
- Which network (SSID)?
- Many people know neither
- "My ISP is NETGEAR"
- Those who specify anything specify the SSID

The Evil Twin Attack

- Simplest way: carry an access point with you
- Simpler solution: many laptops can emulate access points
- On Linux, use

```
iwconfig eth0 mode Master
```

- Force others to associate with your laptop, and send you all their traffic...

Why This Works

- Conventionally, we worry about authenticating the client to the server
- Here, we need to authenticate the server to the client
- The infrastructure wasn't designed for that; more important, users don't expect to check for it (and have no way to do so in any event)
- How do you know what the access point's key *should* be?

Integrity Attacks

- We now see how to do integrity attacks
- We don't tinker with the packet in the air, we attract it to our attack node
- You don't go through strong security, you go around it

Availability

- Simple version: black-hole evil twin
- Sophisticated version: battery exhaustion

Black Holes

- Emulate an access point
- Hand out IP addresses
- Do nothing with received packets
- More subtly, drop 10-15% of them — connections will work, but *very* slowly

Battery Exhaustion

“ Wi-Fi is also a power-hungry technology that can cause phone batteries to die quickly in some cases, within an hour or two of talk time.

When you turn on the Wi-Fi it does bring the battery life down, said Mike Hendrick, director of product development for T-Mobile.”

New York Times, 27 November 2006

Battery Exhaustion

- Send your enemy large "ping" packets
- The reply packets will be just as big — and transmitting such packets uses a lot of power
- The more you transmit, the more power — often battery power — you use up

WEP

WEP — Using a Flawed Cipher in a Bad Way for the Wrong Application

- It was obvious from the start that some crypto was needed
- Choice: WEP — *Wireline Equivalent Privacy* for 802.11 netorks
- Many different mistakes
- Case study in bad crypto design

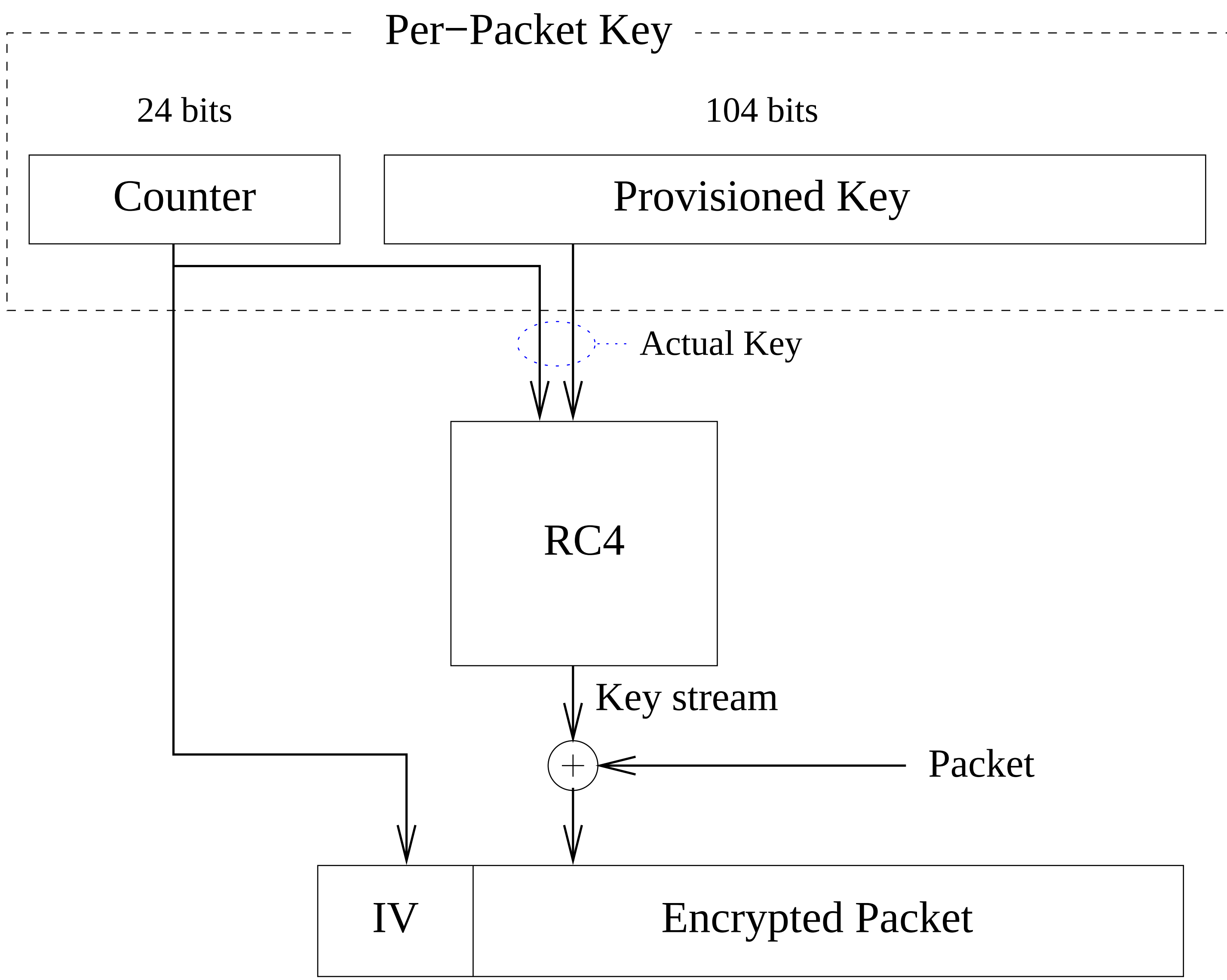
Datagrams and Stream Ciphers

- WEP uses RC4 because RC4 is very efficient
- But 802.11 is datagram-oriented; there's no inter-packet byte stream to use

⇒ Must rekey for every packet

- But you can't reuse a stream cipher key on different packets. . .

Key Setup


Per−Packet Key
24 bits
104 bits
Counter
Provisioned Key
Actual Key
RC4
Key stream
Packet
IV
Encrypted Packet

Key Setup for WEP

- Each WEP node keeps a 24-bit packet counter (the IV)
- Actual cipher key is configured key concatenated with counter
- Two different flaws. . .
- 2^{24} packets isn't that many — you still get key reuse when the packet counter overflows
- RC4 has a cryptanalytic flaw
- But it's worse than that

Cryptanalysis of RC4

- In 2001, Fluhrer, Mantin and Shamir showed that RC4 could be cryptanalyzed if the keys were “close” to each other — a *related key* attack
- Because of the IV algorithm, they are close in WEP
- Key recovery attacks are feasible and have been implemented

IV Replay

- Suppose you recover the complete plaintext of a single packet
- You can generate new packets that use the same counter
- Receiving nodes don't — and can't — check for rapid counter reuse
- Indefinite forgery!

Packet Redirection

- Suppose you know (or can guess) the destination IP address of a packet
- Because RC4 is a stream cipher, you can make controlled changes to the plaintext by flipping ciphertext bits
- Flip the proper bits to send the packet to you instead, and reinject it

Checksums

- WEP does use a checksum
- However, it's a CRC rather than a cryptographic hash
- It's also unkeyed
- Result: it's feasible to compensate for plaintext changes without disturbing the checksum

The Biggest Flaw in WEP

- There's no key management; all users at a site always share the same WEP key.
- (Again, fixed in WPA)

⇒ You can't rekey when the counter overflows

⇒ Everyone shares the same key; if it's cryptanalyzed or stolen or betrayed, everyone is at risk

⇒ It's all but impossible to rekey a site of any size, since everyone has to change their keys simultaneously and you don't have a secure way to provide the new keys

What WEP Should Have Been

- Use a block cipher in CBC mode
- Use a separate key per user, plus a key identifier like the SPI
- Provide dynamic key management
- WPA — WiFi Protected Access — is better than WEP; WPA2 uses AES.
- (WPA is particularly vulnerable to password-guessing attacks.)

War-Driving

War-Driving

- Put a laptop in network (SSID) scanning mode
- Drive around a neighborhood looking for access points
- Perhaps include a GPS receiver to log locations
- Detect presence or absence of WEP
- Name from movie "War Games"
- (Commercialized by Skyhook; used by iPhones!)

Unprotected Networks!

- Statistics show that only O(1/3) use even WEP
- The rest tend to be wide open
- Many people don't change or hide the SSID

The Consequences

- Some incidence of theft of service
- (Is it war-driving a crime? Unclear under US law)
- Sometimes done to hide criminal activity

Network Access Control

No Perimeter

- The fundamental difference: there's no physical boundary
- On a wired net, physical access control can compensate for lack of technical security
- Most of the attacks are the same, for wired or wireless nets
- But physical perimeters let us take shortcuts

Associations

- Wired nets don't have a base station that nodes associate with at layer 2
- However, ARP attacks can compensate
- ARP attacks are even harder to detect — there's no pop-up informing you about local Ethernet addresses

Aside: IPv6 Neighbor Discovery

- Instead of ARP, IPv6 uses a new protocol called *Neighbor Discovery* (ND)
- Hosts and routers can use *Cryptographically Generated Addresses* (CGAs), where (part of) the IP address is a hash of the node's public key
- ND messages can be signed with the host's private key, and verified by the recipient
- But — what is the proper IP address (and hence public key) of the default router in every Starbucks hotspot?

Tracing Attacks

- With wired networks, you can trace an attack to a given switch port
- With wirless networks, you can trace an attack to a given AP, but the AP might serve hundreds or thousands of square meters
- No good way to trace — all you can do is log and block MAC addresses

MAC Address Filtering

- Can allow or block endpoints based on MAC address
- However – MAC address spoofing is pretty easy
- Evade blocks and/or impersonate accepted hosts
- What's accepted? Look for machines that receive non-SYN TCP packets

Clayton's Spoofing Attack

- Impersonate a known-good IP and MAC address
- TCP replies will go to the real owner and the fake one
- The real one will send out a TCP RST packet
- Build a circuit that listens for the bit pattern of the RST and sends a jam signal instead

Windows XP SP2 and Spoofing

- With SP2, the built-in firewall blocks most inbound packets
- In particular, it only allows in replies to outbound packets
- The TCP reply packets don't match any outbound connections
- TCP never sees the reply, and hence doesn't generate RST
- No need for Clayton's attack

Network Access Control

- Fundamentally, the problem is network access control
- We have none with wireless
- Usual solution: let people onto your network, but require some sort of Web-based login

Evil Twin Redux

- Set up your evil twin in a hotspot
- Intercept the login session and/or the registration
- Registration often involves a credit card. . .

The Gold Standard

- No authentication at the WEP layer; higher-layer authentcation susceptible to evil twin attack
- Authorization based on MAC address and WEP key; both are vulnerable
- Rarely any logging for audit
- Oops. . .

Living with Wireless

- For residential use, turn off SSID broadcast
- (Hard to do in an enterprise)
- Put your wireless net outside the firewall
- Use WEP — it's still (marginally) better than nothing
- Better yet, use WPA
- Use a VPN
- Use end-to-end crypto
- Check the certificate on registration or login pages