Understanding the WPA/WPA2 Break

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Your Speaker

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Outline

- Attack Overview
- Attack Analysis
- Enterprise Defenses
- Summary, Question and Answer

The Bad News

- Martin Beck from the Technical University of Dresden discovered a flaw in the TKIP protocol
  - Assisted by Erik Tews from the Technical University of Darmstadt
- Allows an attacker to decrypt data to a wireless client, slowly
- Once a packet is decrypted, opportunity to transmit up to 7 forged packets of any content
- No authorization needed for success

The Good News

- Not a key recovery attack
  - Attacker can only decrypt one packet at a time; does not allow earlier/later frame decryption
- Does not affect AES-CCMP networks (required for FIPS 140-2)
- Workarounds will mitigate this flaw
  - Not perfect, but will buy some time
- Some APs can be configured to mitigate this flaw (at some cost)

Who Is Affected?

- All deployments of TKIP
  - Regardless of WPA or WPA2 use
  - Regardless of PSK or 802.1X/EAP authentication
- Current *exploits* target TKIP networks with QoS enabled
  - QoS is required for much of 802.11n

Attacker Opportunity

- Attacker can decrypt a plaintext packet from AP to station (not station to AP)
  - Not more than 1 unknown byte per minute
  - Any packet can be selected for partial data
- Targeting an ARP packet, between 14 and 17 unknown bytes
  - 8 MIC, 4 ICV, 2-5 IP source and dest.
- Once plaintext is known, attacker can inject not more than 15 arbitrary packets
  - ARP poisoning, DNS manipulation, TCP/SYN request

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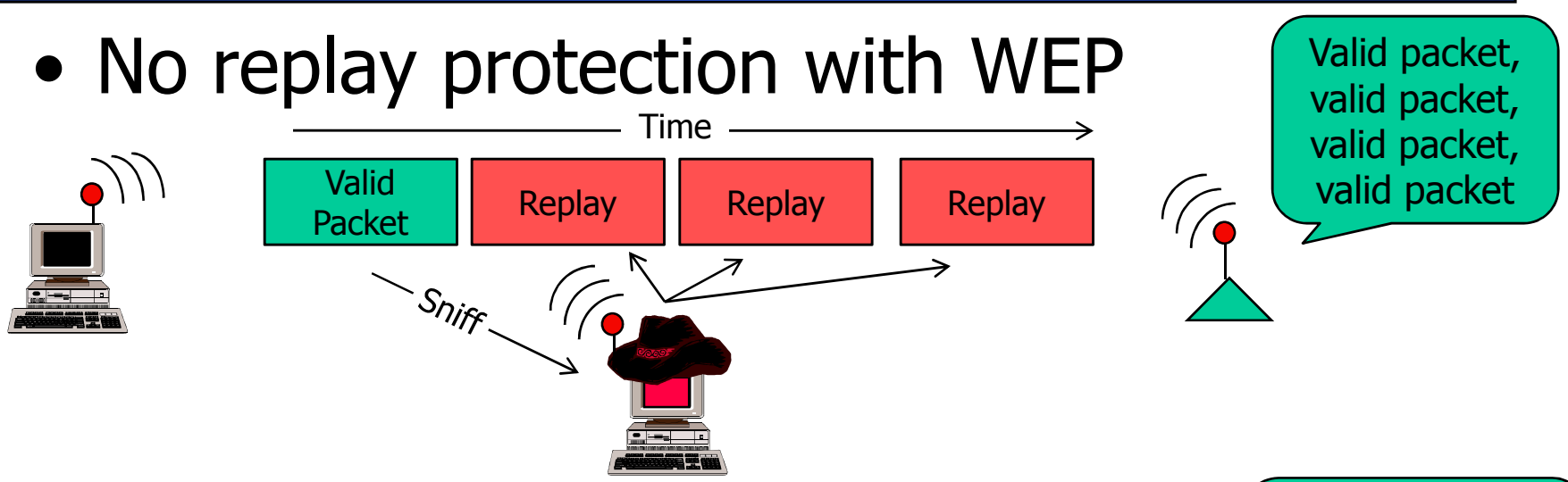
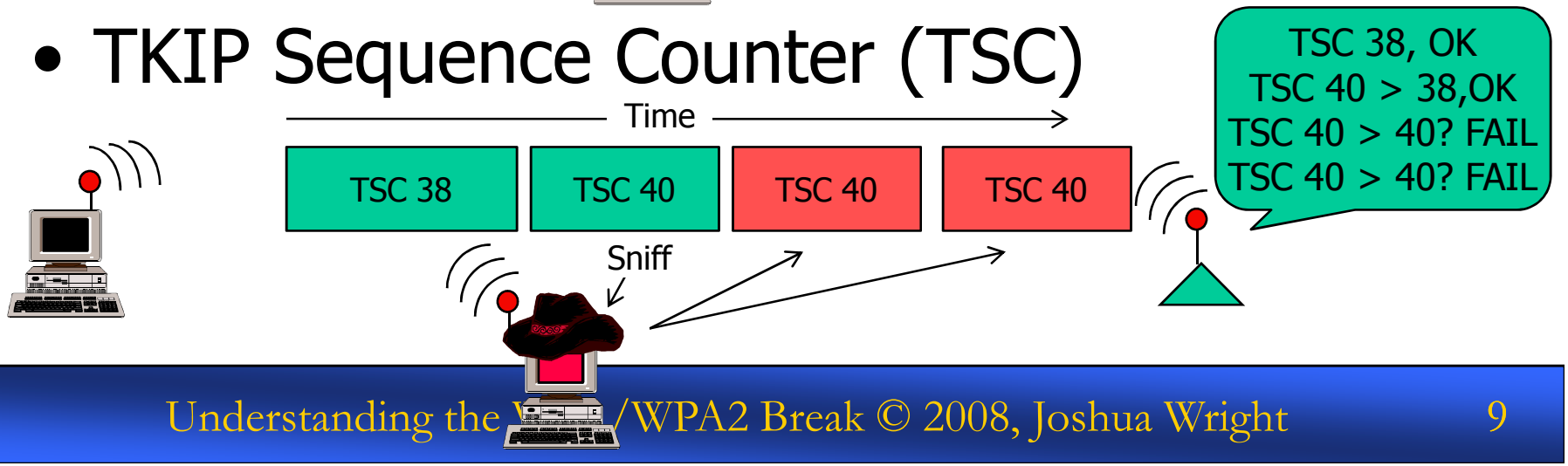
April 2003: TKIP Fixes WEP Flaw

- No replay protection with WEP

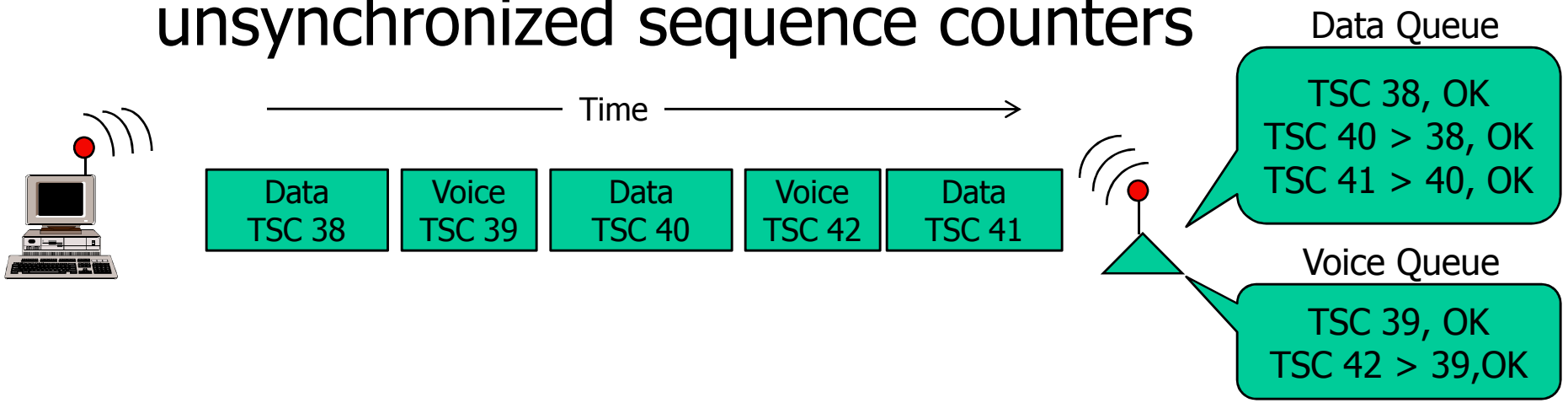


- TKIP Sequence Counter (TSC)



July 2005: QoS Complicates Matters

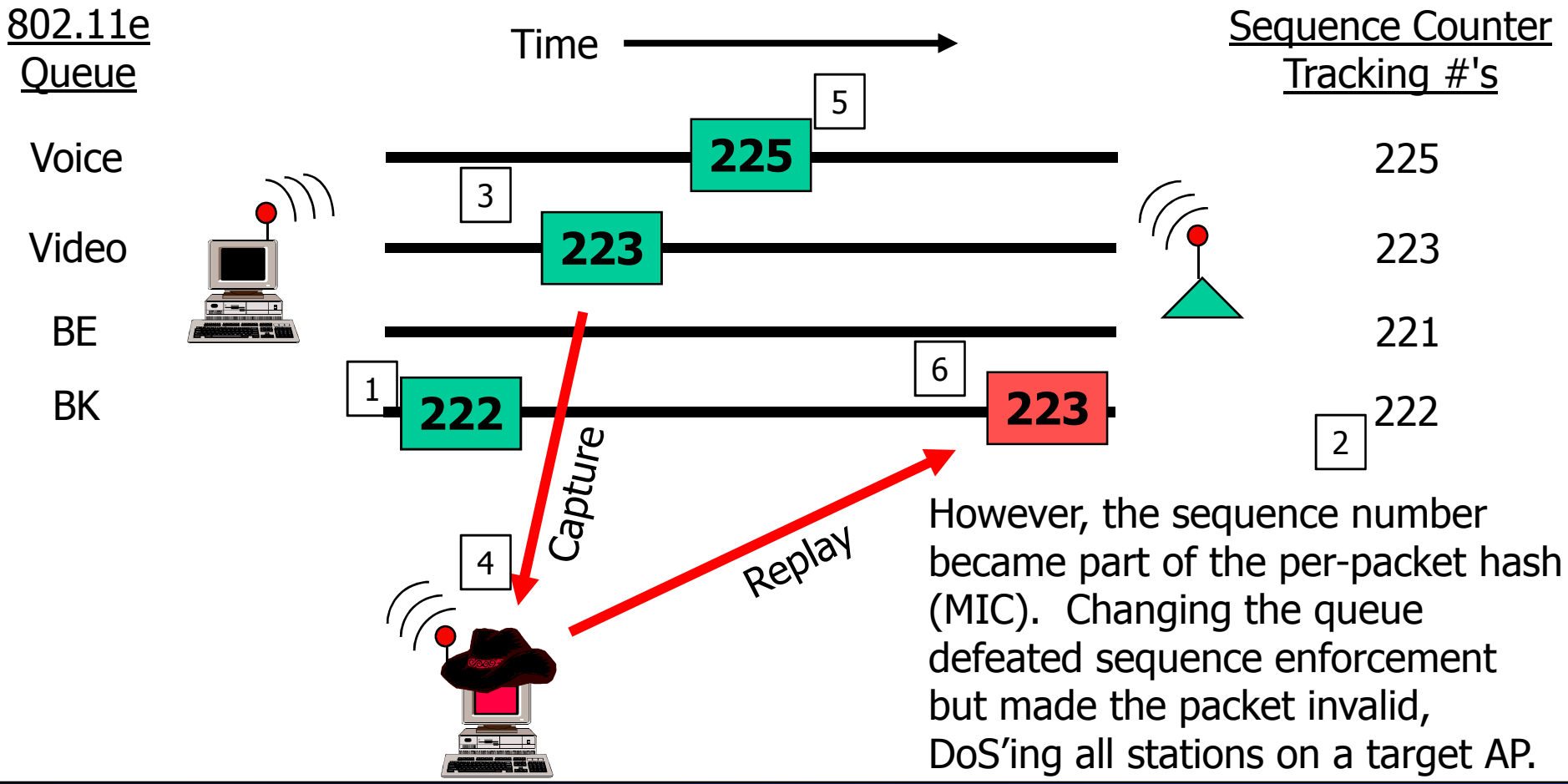
- QoS relies on the ability to reorder packets for delivery
- This requirement conflicts with TKIP sequence delivery
- Solution: Maintain multiple independent, unsynchronized sequence counters



Wait … Really? They Did That?

- Yes, they really did.
- 802.11e displaced sequence enforcement across multiple queues (Wireless MultiMedia)
- This is a significant security failure
- The WMM author was informed … and chose not to act to resolve

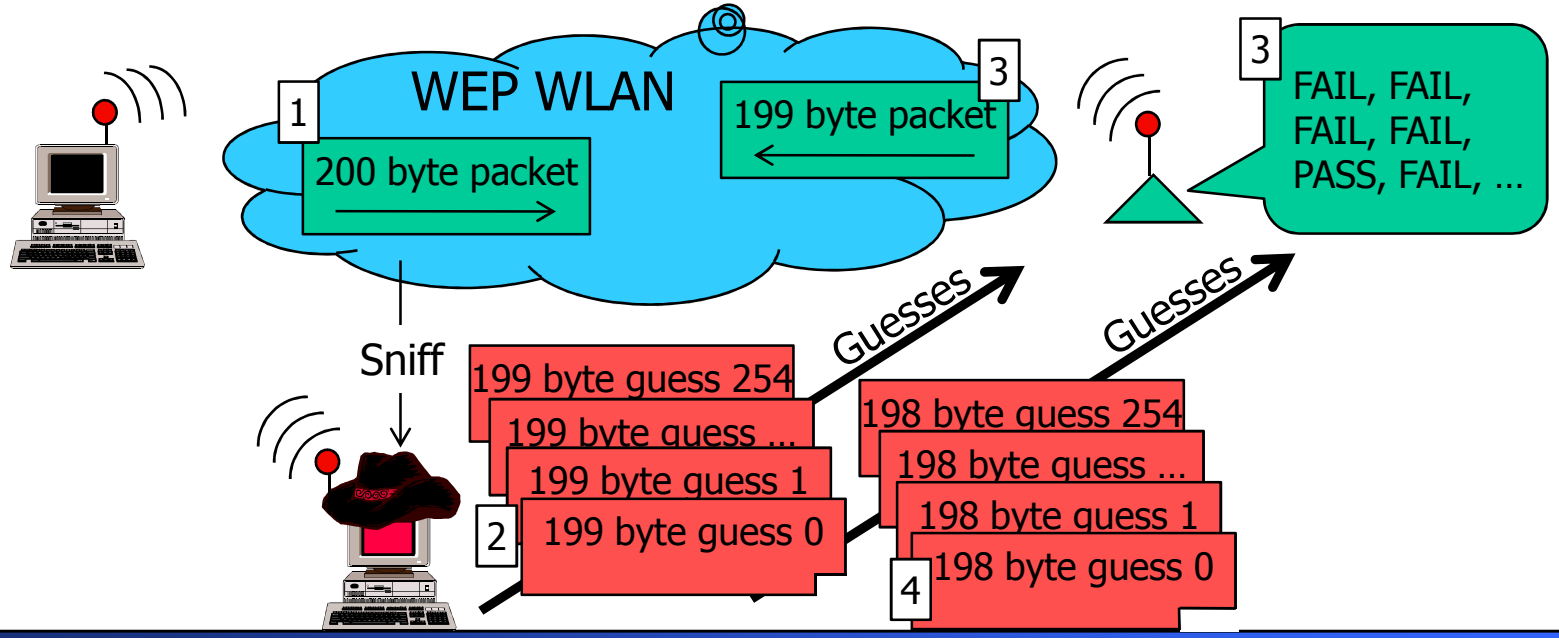
802.11e Replay Attack



However, the sequence number became part of the per-packet hash (MIC). Changing the queue defeated sequence enforcement but made the packet invalid, DoS'ing all stations on a target AP.

WEP ICV Attack - ChopChop

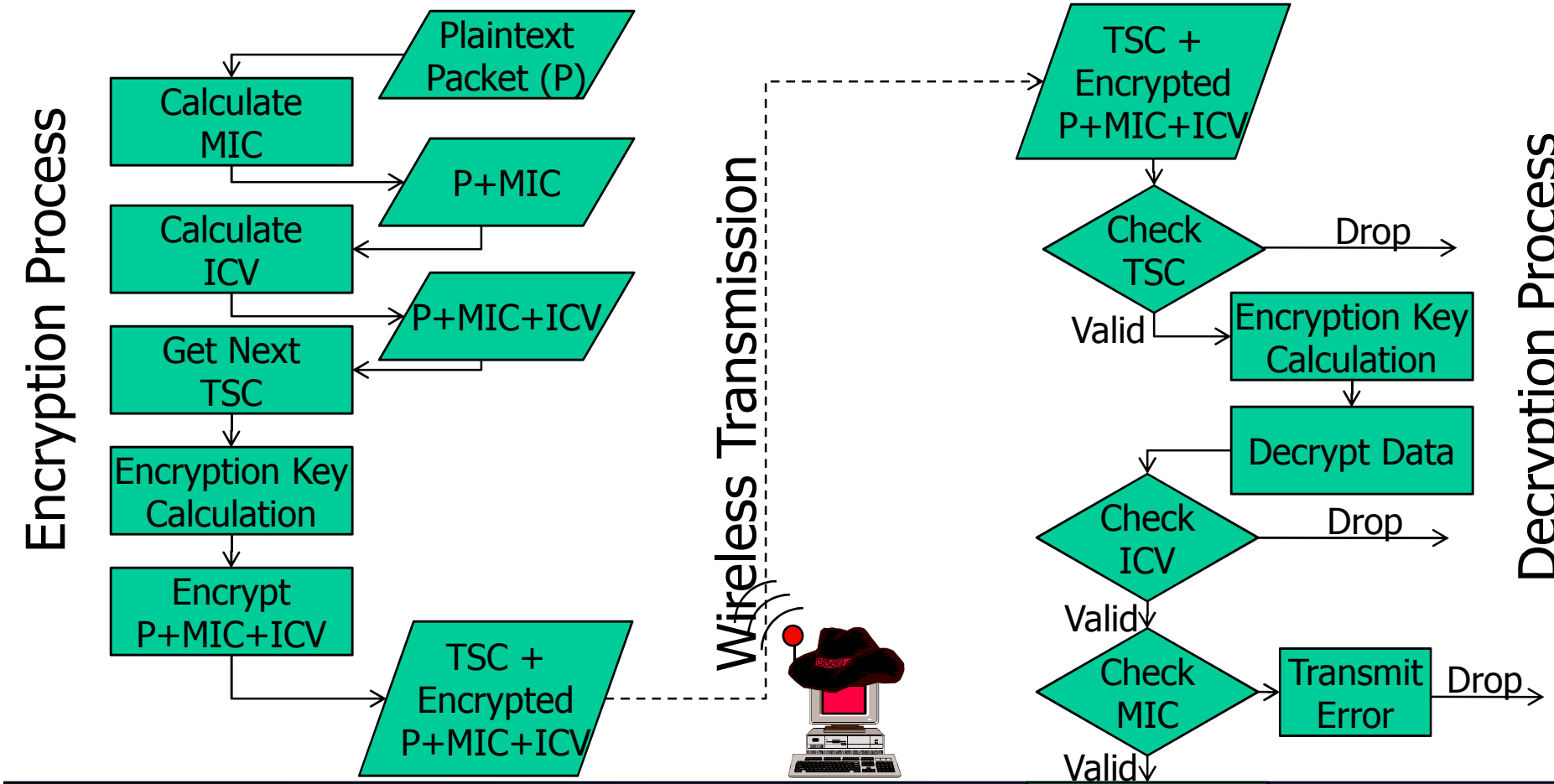
- Integrity Check Value (ICV) – WEP 32-bit CRC
- Vulnerable to modification and repeated guess until positive response observed (chopchop attack)
- Repeated to recover entire plaintext packet contents



Fixed(?) in TKIP

- TKIP adds a new per-packet hashing algorithm (MIC) known as Michael
- Weak algorithm, but best that could be accommodated on legacy WEP hardware
- Includes provision for countermeasures
  - Two invalid MIC's within 60 seconds shuts down AP and STA's for 60 seconds
  - Must pass ICV and TSC check first

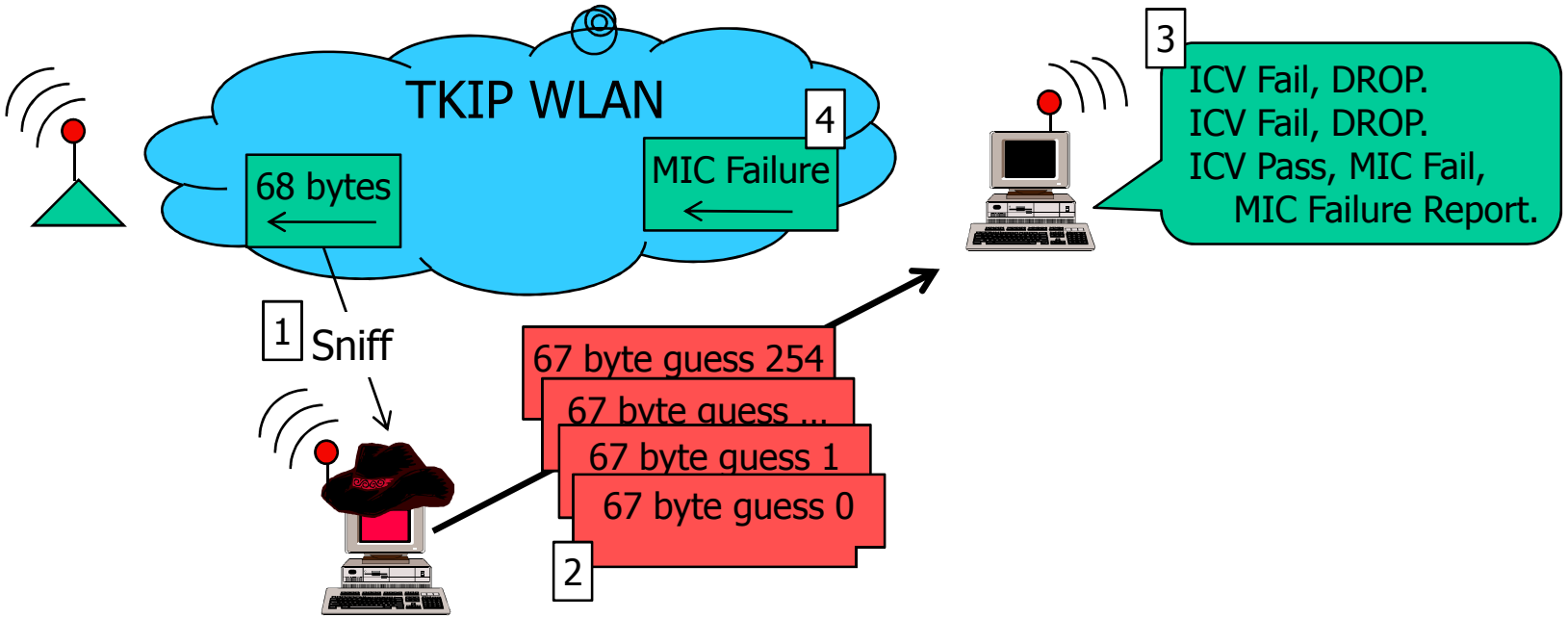
TKIP Encryption/Decryption



And This is Exploited How?

- ICV failure generates no network activity
- MIC failure causes the client to generate a notice the attacker can observe
- If MIC failure observed, ICV passed!
- Take a packet, chop last byte, guess fix and TX until MIC failure observed
- Wait 60 seconds to not trigger countermeasures
- Repeat for next-to-last byte

TKIP Chopchop ICV Attack



1. Attacker captures TKIP encrypted packet that looks like ARP	**2. Attacker removes last payload byte, invalidating ICV and MIC. Attempts to fix ICV with guess 0 and sends to station.**	**3. Client receives frame, most have ICV failures and are dropped. One passes ICV, but fails MIC.**	**4. A MIC failure message is sent to AP to coordinate Michael countermeasures. Though encrypted, attacker can observe this frame to identify valid ICV, revealing one byte of plaintext.**	**Attacker waits 60 seconds to avoid MIC countermeasures, then repeats process with 66 byte packet. Continues until all packet plaintext is known.**

Attack Result

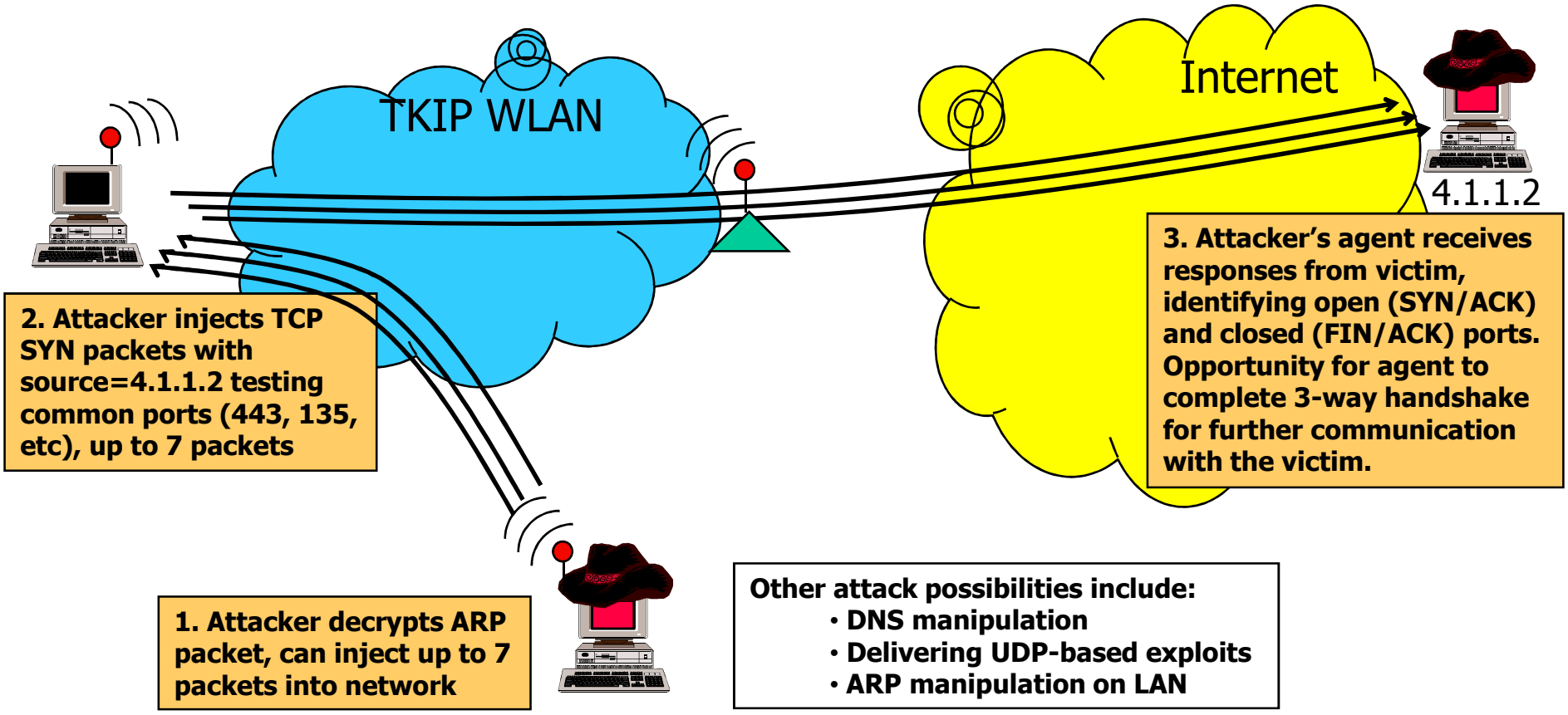
- Not more than 1 byte per minute decrypted
- ARP is mostly known plaintext
  - Five bytes unknown assuming /24 (A.B.C.Y and A.B.C.Z)
- Also need to determine ICV and MIC values (12 bytes)
- Only 17 bytes to recover, 14 if network is known (RFC1918 guess?)

Result: 68 bytes ARP, 8 bytes MIC, 4 bytes ICV known plaintext to the attacker in 14-17 minutes

Another Michael Weakness

- Michael is *invertible*; you can determine the key from plaintext + MIC
- Attacker decrypts ARP, knows Michael key and can craft any packet up to 68 bytes
- Attacker can use other QoS queues where attacked TSC is lower to inject arbitrary packets into network (can target any destination or protocol)
- Injection is blind, attacker cannot decrypt responses
- Attacker can only inject up to 7 packets (3 other standard 802.11e queues and 4 non-standard)
  - Potential for 15 injected packets, yet untested

Practical TKIP Attack Example



tkiptun-ng

- Attack tool in Aircrack-ng source repository
- Incomplete, doesn't work in current form
- Likely to implement attack described here, extracting plaintext, injecting new packets
- May be accompanied by TUN interface
  - Attacker uses any tool to inject packets

MIC DoS Attacks Easy Now

- Michael algorithm countermeasures
  - AP must disconnect all stations and shutdown the network following two MIC failures within 60 seconds
- Very easy for an attacker to trigger, shutting down AP for 60 seconds

DOT11-TKIP_MIC_FAILURE: TKIP Michael MIC failure was detected on a packet (TSC=0x0) received from [mac-address]

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Defense Strategies (1)

- Best approach: migrate away from TKIP to AES-CCMP
  - Will likely require moving to WPA2
- Difficult to implement if you need to support any legacy devices
  - Laptops and embedded devices (VoIP phones, handhelds, etc)
- Client re-configuration will be necessary, making this resource-intensive
  - Active Directory simplifies deployment

Defense Strategies (2)

- Forcing more frequent key rotation will limit how much plaintext can be derived
  - Each minute of key life can be used to determine a byte of plaintext
  - 4 minute key rotation = 4 bytes plaintext
- Consensus is to reduce key to 2 minutes
- Reducing key lifetime may burden AP

This defense is the best immediate-term option, but requires testing to understand the impact to all devices.

Product-Specific Steps

Aruba Networks – PTK and GTK rotation

```
configure terminal
aaa authentication dot1x <profilename>
multicast-keyrotation
unicast-keyrotation
timer mkey-rotation-period 120
timer ukey-rotation-period 120
```

Trapeze Networks – Disable QoS

```
set radio-profile <name> qos-mode svp
```

Motorola/Symbol

```
wlan <WLAN> dot11i key-rotation enable
wlan <WLAN> dot11i key-rotation-interval 120
```

Bluesocket

Bluesocket plans to add a unicast key rotation mechanism to a future product release.

Aerohive Networks

Aerohive currently detects and logs Michael MIC failures and in the next maintenance release of HiveOS Aerohive is implementing a PTK rekey feature. Watch the Aerohive support page for more information.

Cisco Autonomous – 802.1X reauthenticate
Warning: Significant negative impact

```
dot1x timeout reauth-period 120
broadcast-key change 120
```

Cisco WLC – 802.1X reauthenticate
Warning: Significant negative impact

```
config wlan session-timeout <wlanID> 120
devshell dot1xUpdateBroadcastRekeyTimer 120
```

Meru Networks

Meru Networks did not respond to multiple requests for information.

Defense Strategies (3)

- Disabling QoS support on an AP will defeat tools, does not solve issue
  - Not an option for 802.11n High-Throughput (HT) networks
- Vendors may choose to fix TKIP with implementation hacks
  - Keep an eye on your AP and client vendor software update pages

Monitoring (1)

- WIDS technology can identify this attack
  - You will need a software update to get new signature support
  - Action: contact your WIDS vendor today: "When will you detect the TKIP ICV attack?"
  - No signature in Kismet … yet
- Log monitoring on AP's

Cisco Autonomous APs

```
DOT11-TKIP_MIC_FAILURE_REPORT:
Received TKIP Michael MIC failure
report from the station [mac-address]
on the packet (TSC=0x0) encrypted and
protected by [key] key
```

Aruba Networks

```
Received TKIP Micheal MIC
Failure Report from the
Station [mac addr] [bssid]
[apnames]
```

Monitoring (2)

Aerohive APs

```
AP detected Michael MIC failure
in received frame from
abb:ccdd:eeff(wifi0.1) for sta
1122:3344:5566(TKIP)
```

Trapeze Networks

Logging message not supplied before presentation deadline.

Symbol/Motorola

```
Station [MAC_ADDR] reported a TKIP
message integrity check fail on
wlan [WLAN_ID]
```

Cisco Wireless LAN Controller
Identifies DoS, not TKIP attack

```
The AP '00:0b:85:67:6b:b0'
received a WPA MIC error on
protocol '1' from Station
'00:13:02:8d:f6:41'. Counter
measures have been activated and
traffic has been suspended for
60 seconds.
```

Bluesocket

```
Michael MIC failure detected in
received frame MLME-
MichaelMICFailure.
indication(00:12:cf:00:01:02)
```

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Summary

- This is a break in TKIP, affecting WPA and WPA2 regardless of authentication
- Immediate actions:
  - Start planning transition to AES-CCMP
  - Investigate and apply TKIP key rotation every 2 minutes
  - Capture and analyze logging data on AP's

Question and Answer

- Joshua Wright, josh@inguardians.com
  - 401-524-2911 Office/Mobile
- SANS Ethical Hacking Wireless course
  - 12/11/08: Washington DC (Luallen)
  - 3/2/09: Orlando, FL (Wright)
- InGuardians, Inc.
  - Services for research, vulnerability assessment, penetration testing, incident response and more
  - www.inguardians.com
- Wireless tools and information (Josh's site)
  - www.willhackforsushi.com

More Resources

- Tkiptun-ng documentation
  - www.aircrack-ng.org/doku.php?id=tkiptun-ng
- Tews/Beck paper on TKIP and WEP
  - http://dl.aircrack-ng.org/breakingwepandwpa.pdf
- Raul Siles attack analysis information
  - http://radajo.blogspot.com/2008/11/wpatkip-chopchop-attack.html
- Article: "Battered, but not broken: understanding the WPA crack"
  - http://arstechnica.com/articles/paedia/wpa-cracked.ars/