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SESSION ID: HT-F02

IT'S IN THE AIR(WAVES): RF SECURITY YEAR IN REVIEW

Matthew Knight

Senior Security Engineer
Cruise Automation
@embeddedsec

Who's This Guy

- Matt Knight
- Senior Security Engineer @ Cruise
- BE & BA from Dartmouth
- Background in electrical engineering, embedded software, etc.

- TumbleRF fuzzing framework
- Reverse engineered the LoRa PHY in 2016

Shoutout to Bastille

- My former employer!
  - Security startup specializing in wireless detection technologies
  - Enterprise product built on Software Defined Radio

- Good people who I learned a ton from

SOFTWARE DEFINED RADIO

AND WHAT IT CAN DO FOR YOU

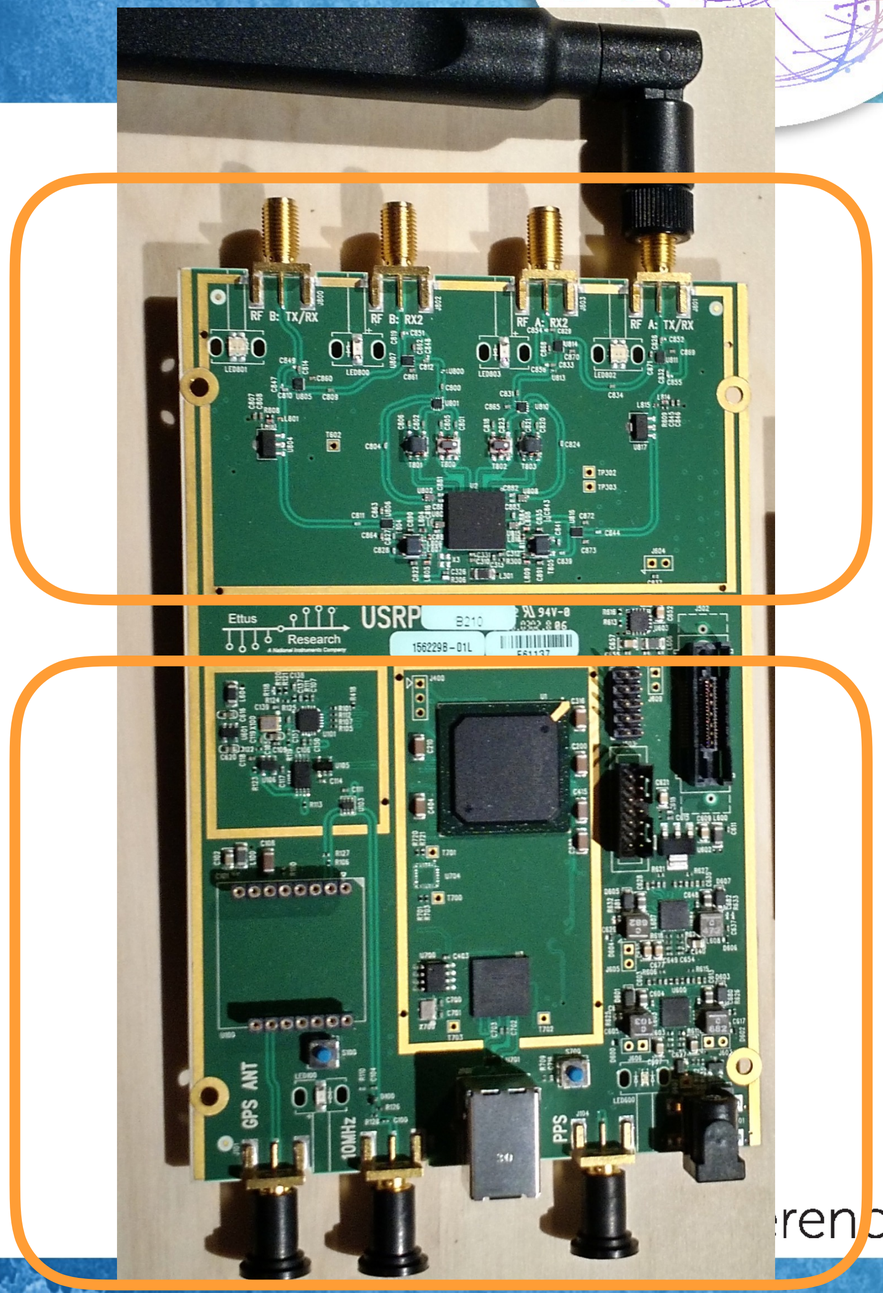
Software Defined Radio

- Architecture with flexible wideband RF frontend
  - Captures raw radio spectrum
  - Shuttles RF I/Q samples to DSP or host

- Implement arbitrary PHYs in:
  - Software
  - FPGA HDL

Fast iteration!

Flexible!



Agenda

1. Evolving radio technology landscape
2. Technical radio concepts
3. RF reverse engineering workflow
4. Conclusions and key takeaways

EVOLUTION OF NETWORK SECURITY

Historical Background

Packet sniffing in the

1990s

Protocols:

802.3

802.5

$8,000+ (in 1990s dollars)

NETWORK GENERAL PACKET SNIFFER

Installed on a Dolch lunchbox computer

PROPRIETARY

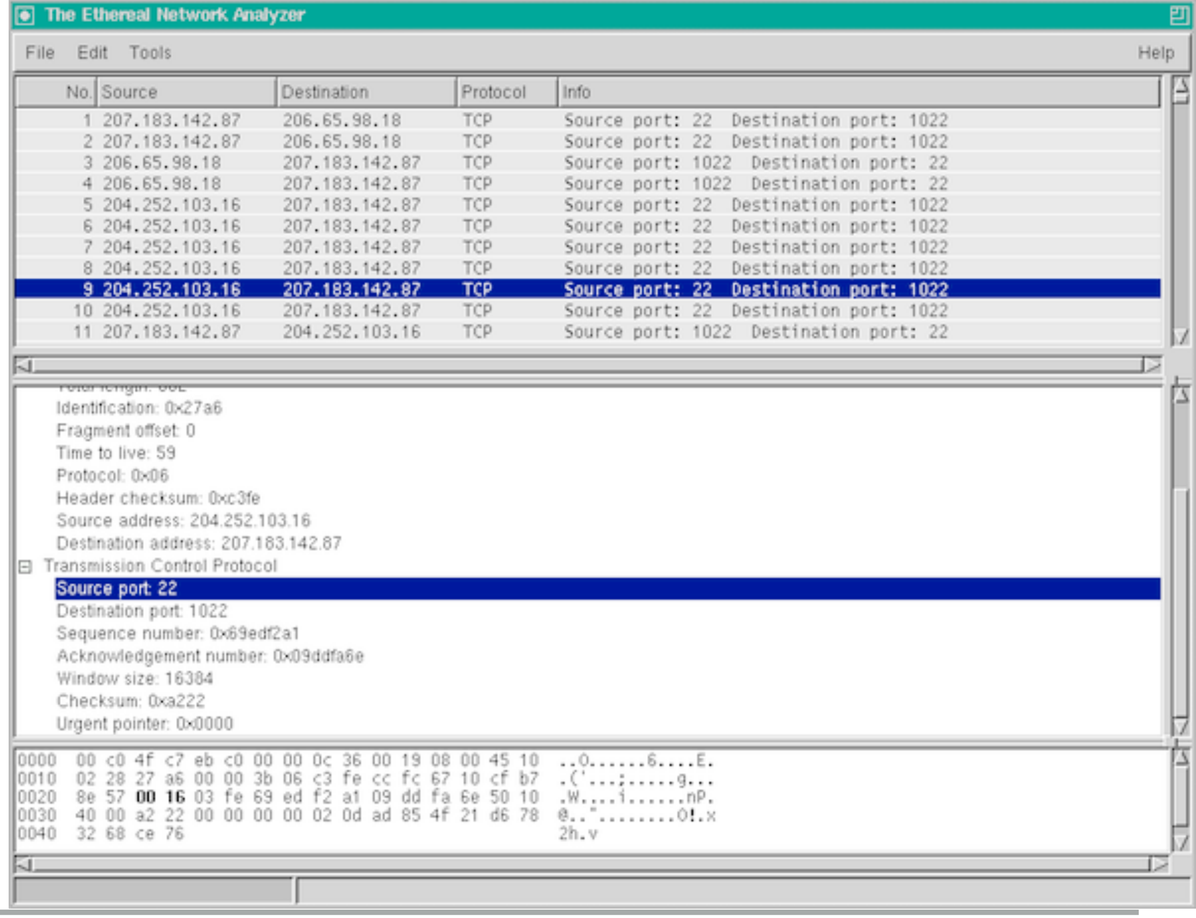
$8,000+ (in 1990s dollars)

NETWORK GENERAL PACKET SNIFFER

Installed on a Dolch lunchbox computer

Packet sniffing in

1998



$0

ETHEREAL // WIRESHARK

+ Monitor mode NICs

https://blog.wireshark.org/wp-content/uploads/2013/10/ethereal-0.2.0.png

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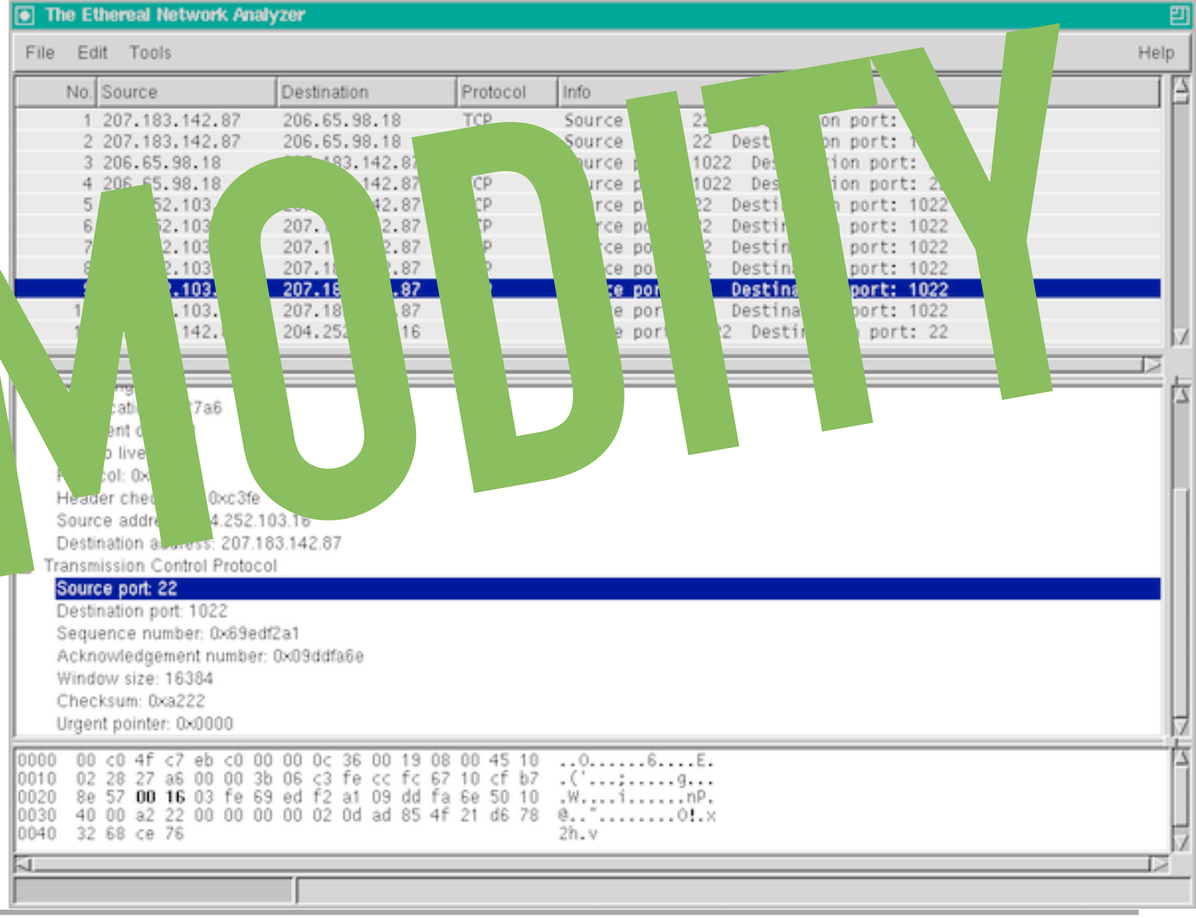
COMMODITY



ETHEREAL // WIRESHARK

+ Monitor mode NICs

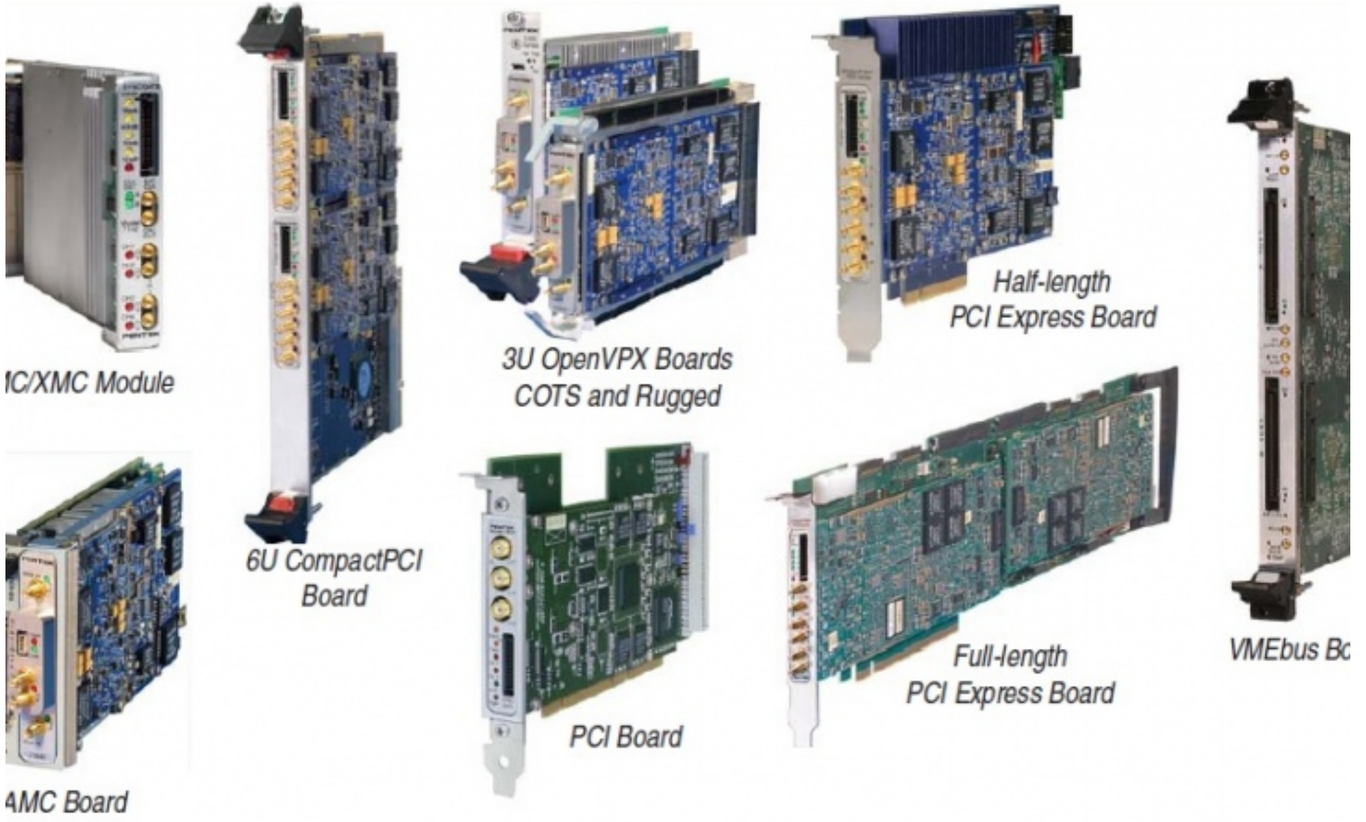
https://blog.wireshark.org/wp-content/uploads/2013/10/ethereal-0.2.0.png

Packet sniffing since the

2000s


Protocols:
802.15.4
6LoWPAN
nRF24
EDGE
HSPA
GPS
DECT
ERS
Bluetooth
802.11
3-Wave
NB-IoT
Ethernet
CDMA
LTE
WiMax
802.15.4
LoRa
GSM
Bluetooth LE
SIGFOX
802.16

TONS OF WIRELESS

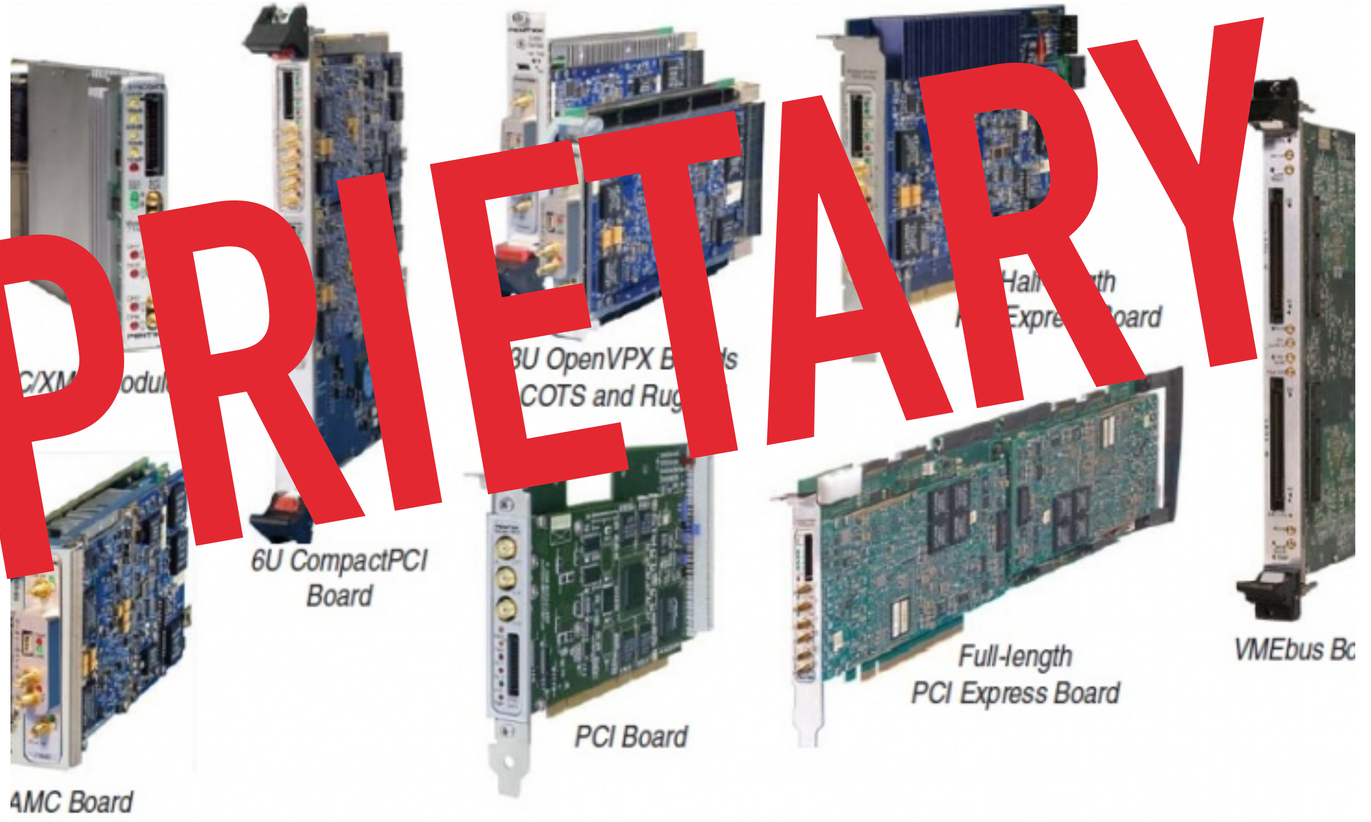


>>$100K

EARLY SDRS

>>$100K

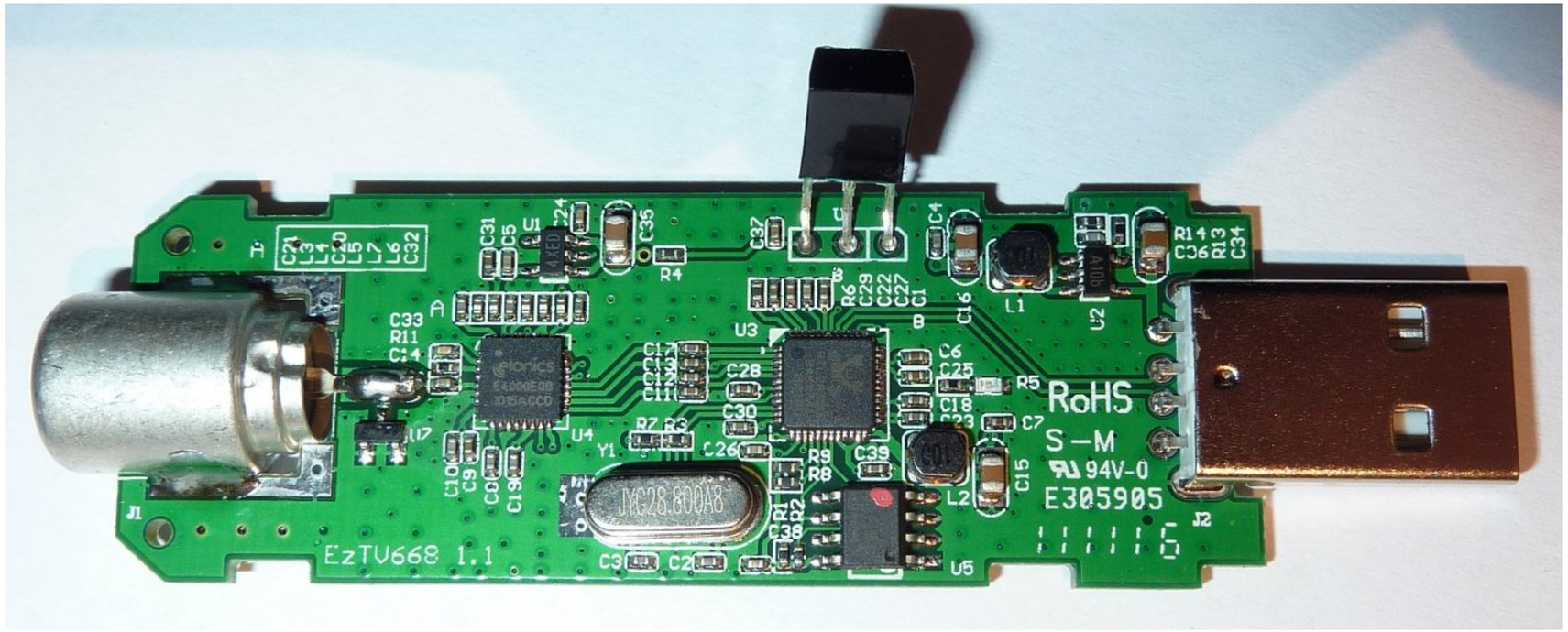
PROPRIETARY



EARLY SDRS

Wireless sniffing in

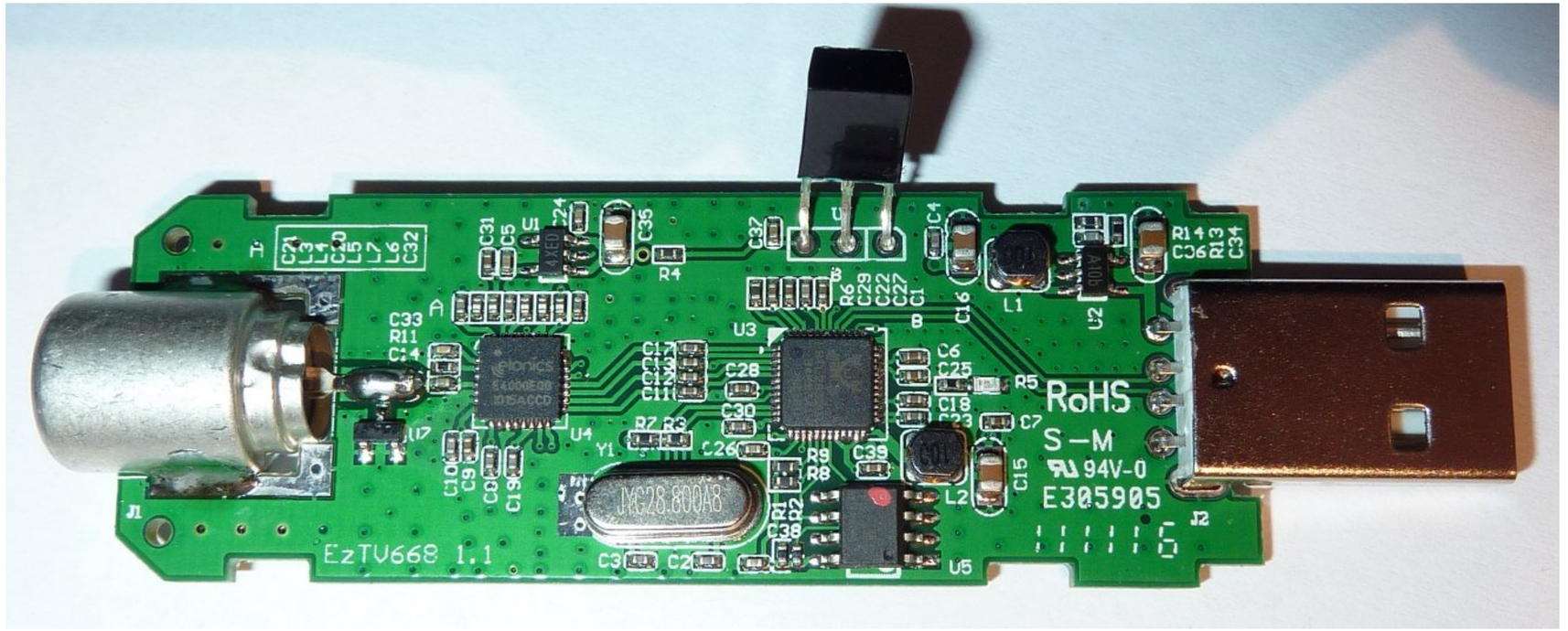
2012



$8

RTL 2832 USB STICK

(not pictured: promiscuous mode driver)



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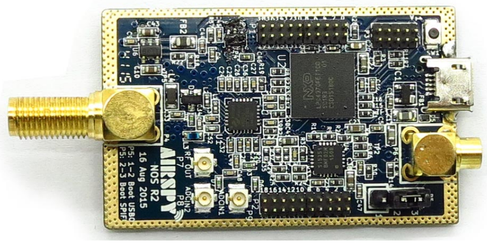
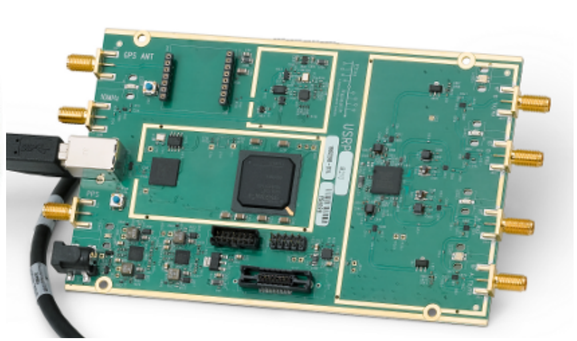
RTL 2832 USB STICK

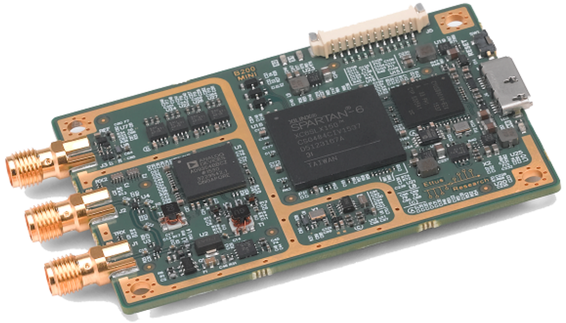
(not pictured: promiscuous mode driver)

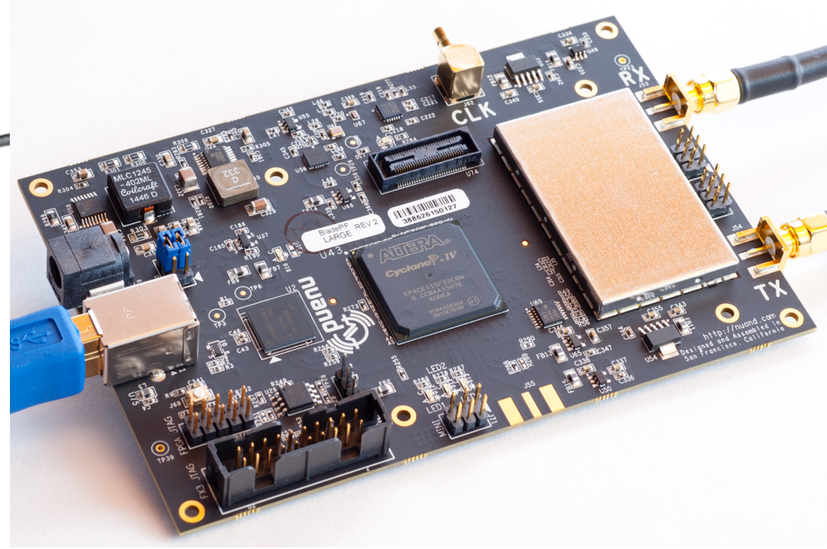
Wireless sniffing in

2018









$8 -> $1150

ALL THE SDRS

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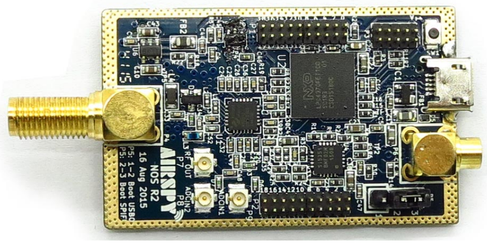

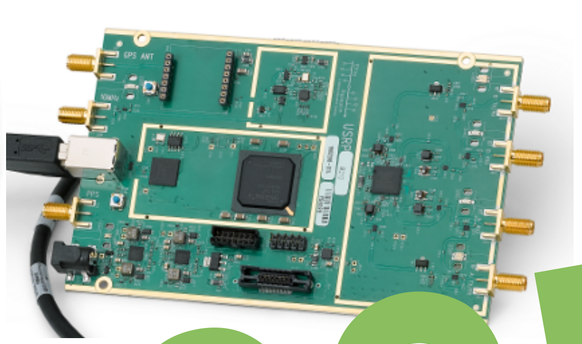

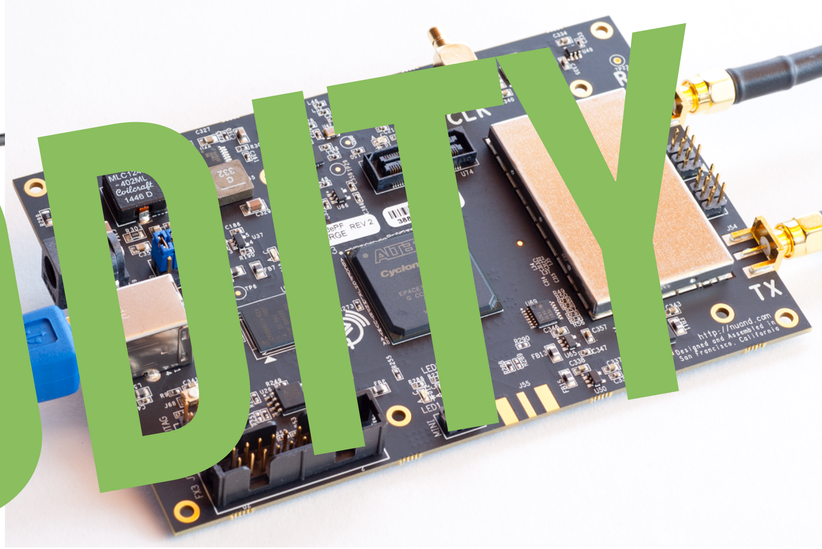

COMMODITY

$8 -> $1150

ALL THE SDRS

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https://www.ettus.com/product/details/UB210-KIT
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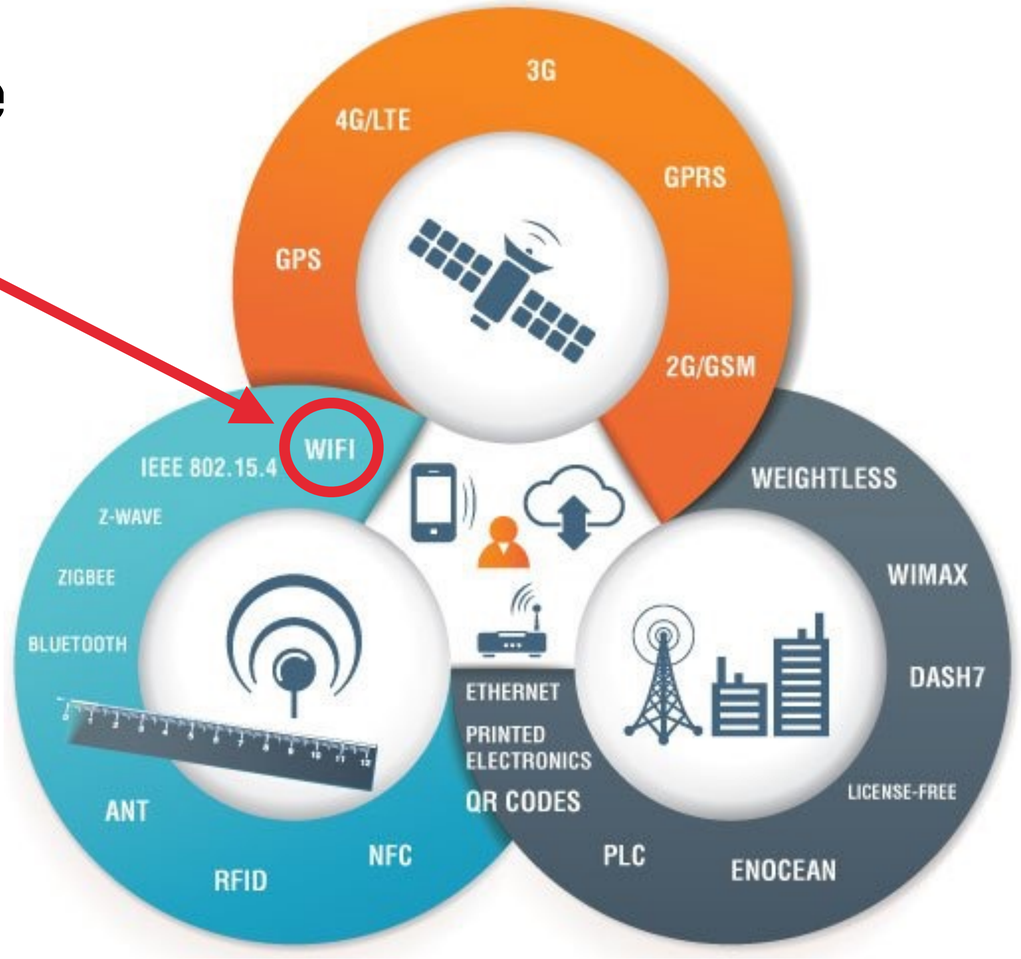
Wireless in 2018

- 802.11 is just one piece of the puzzle

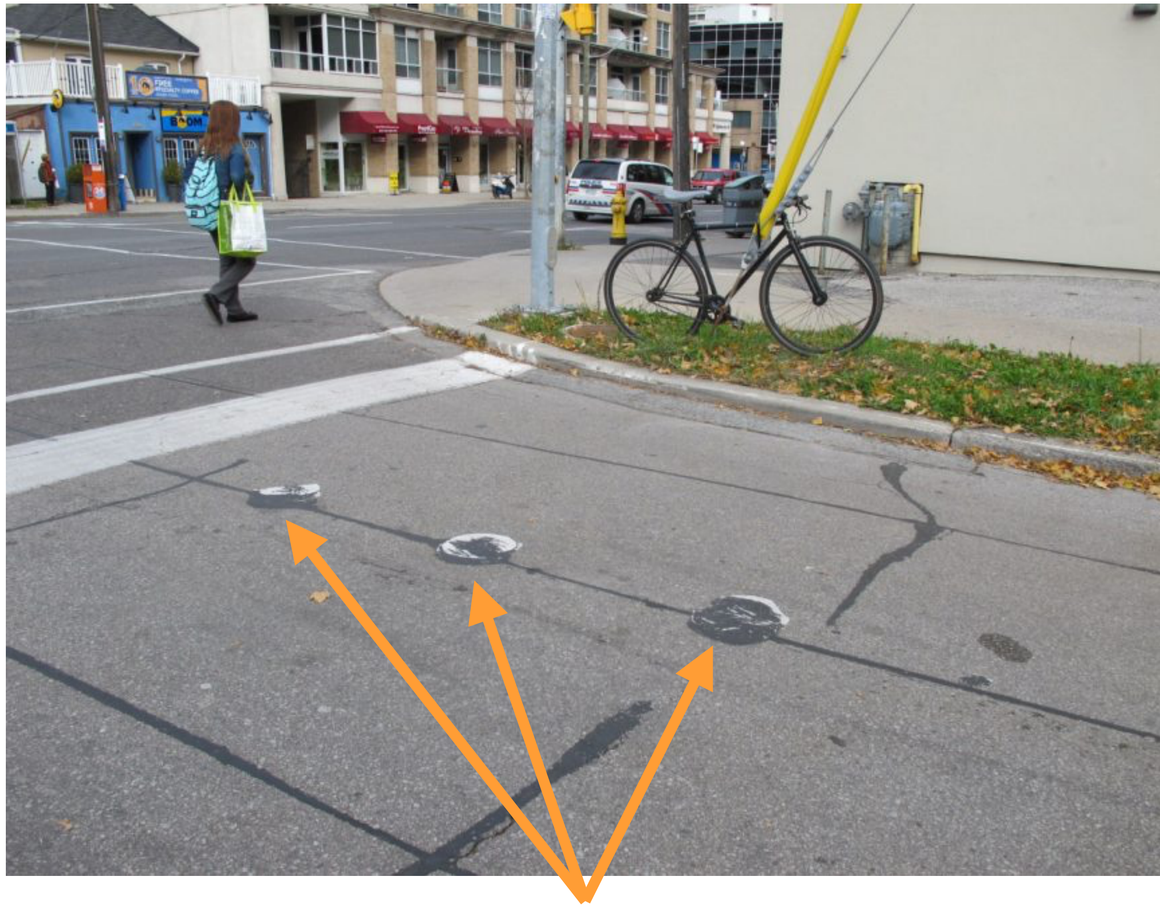
- There's a PHY for every use case
  - Explosion of IoT and Mobile means embedded systems are everywhere



Embedded == Design by Compromise

- Battery powered
- Limited user interaction
- Lack of crypto
- Unsuitable network for firmware updates

- Performance, UX, cost, and delivery are more important than best practices



Literal embedded systems

Industry reliance on

SECURITY THROUGH OBSCURITY

means...

[PIÑATAS]

Same applies to the

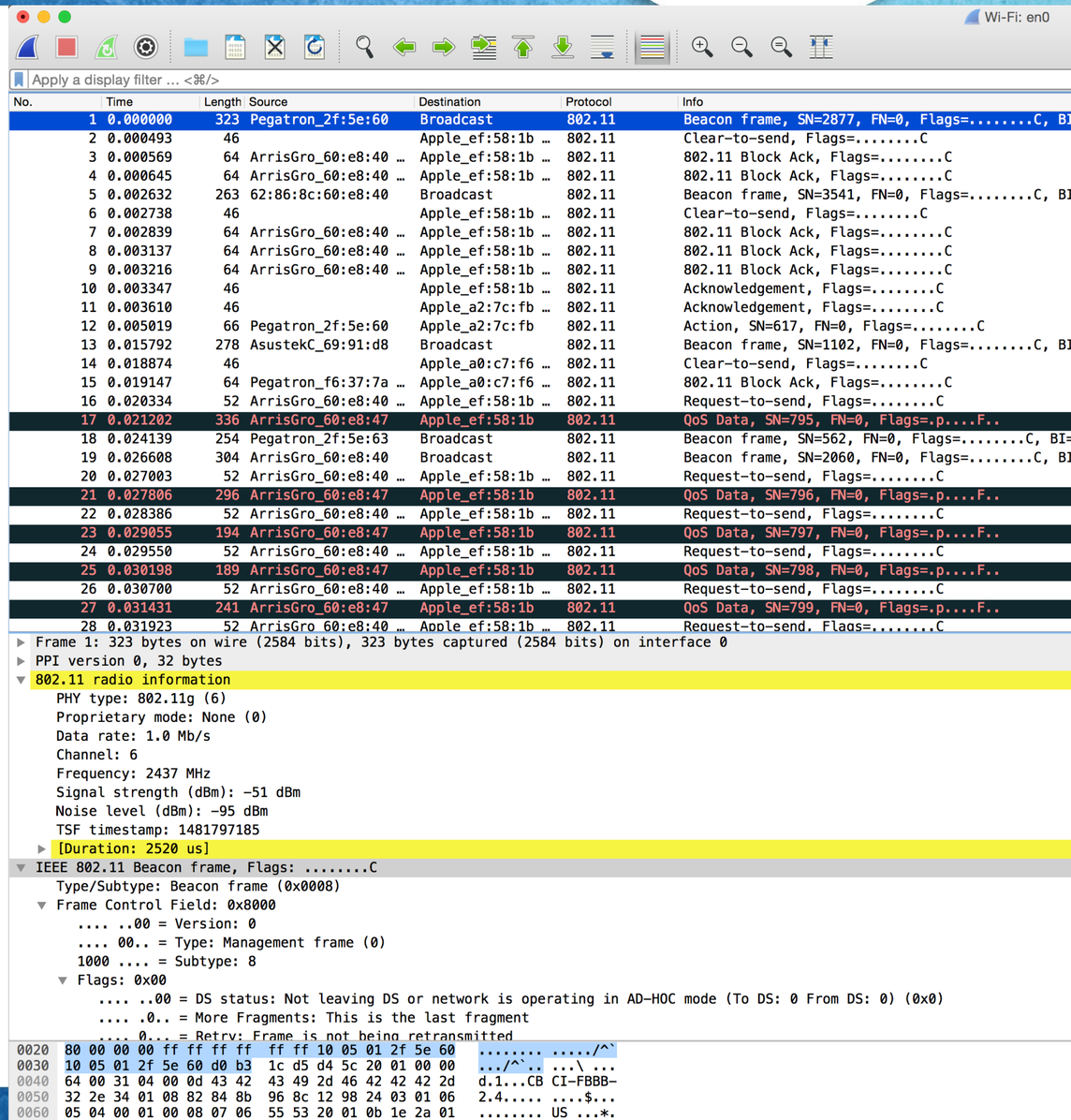
LACK OF VISIBILITY

into PHY layers

WHAT DOES IT TAKE TO HACK WIRELESS?

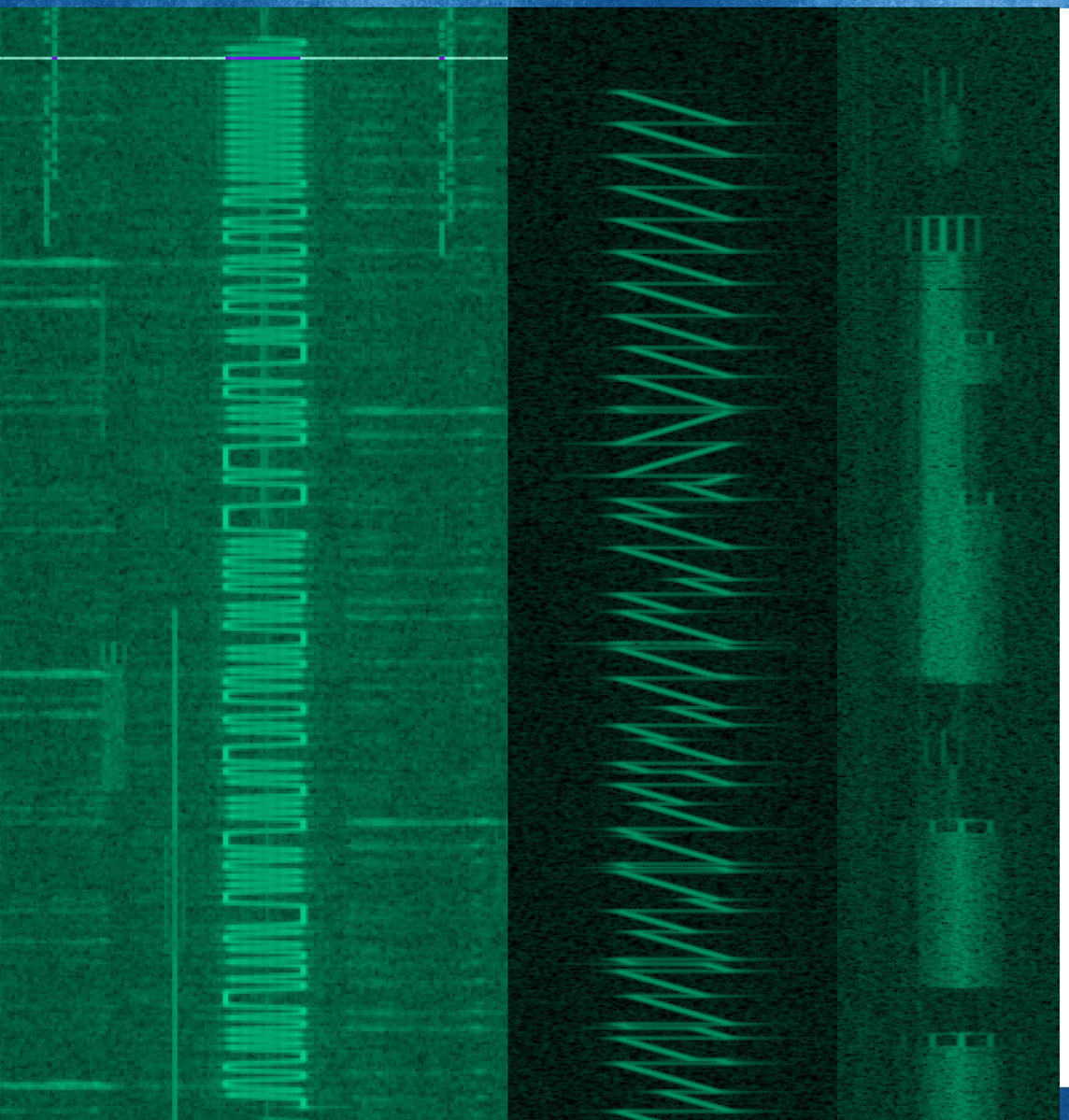
IP Network Sniffing is Easy

- Interfacing with an IP network is trivial
  - Commodity NICs
  - Monitor mode
- Known Layer 2 // MAC frame protocols
  - 802.3 // Ethernet for wired IP traffic
  - 802.11 // Wi-Fi for wireless IP traffic



Wireless* Network Sniffing is Hard

*non-802.11



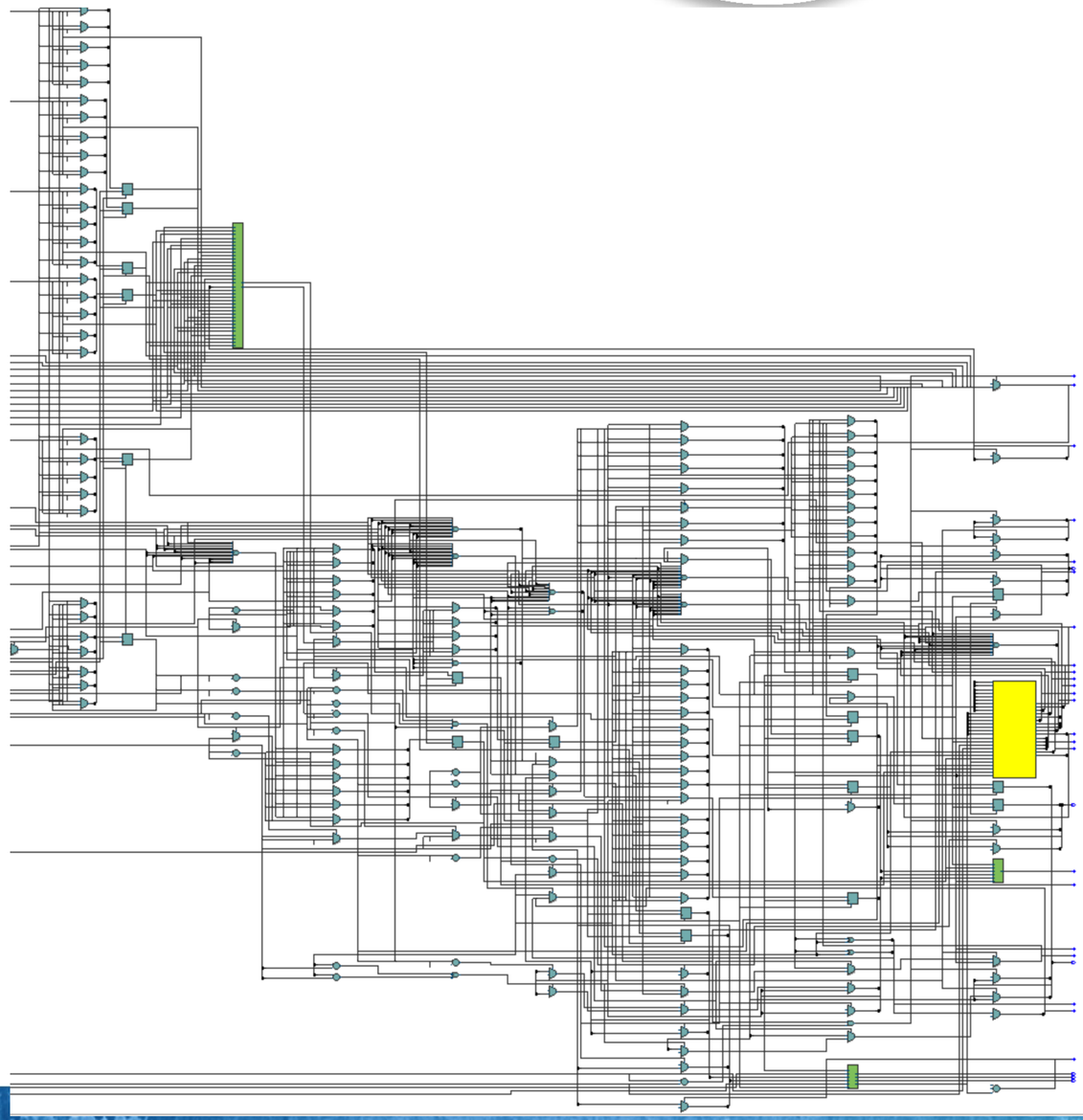
- Network interface is totally non-trivial
  - Your Wi-Fi NIC can't sniff wireless traffic from your home security system
- Arbitrary Layer 1 // PHYs
  - There are many ways to make a PHY
  - 802.11 // Wi-Fi is just one example
- How does one speak arbitrary RF?

Enter…

SOFTWARE DEFINED RADIO

Prototype Integrated Designs

- Develop complex radio algorithms at the speed of software
- Simulate and test in hardware before committing capital to fab an IC
- Right: RTL for an 802.15.4 decoder I wrote

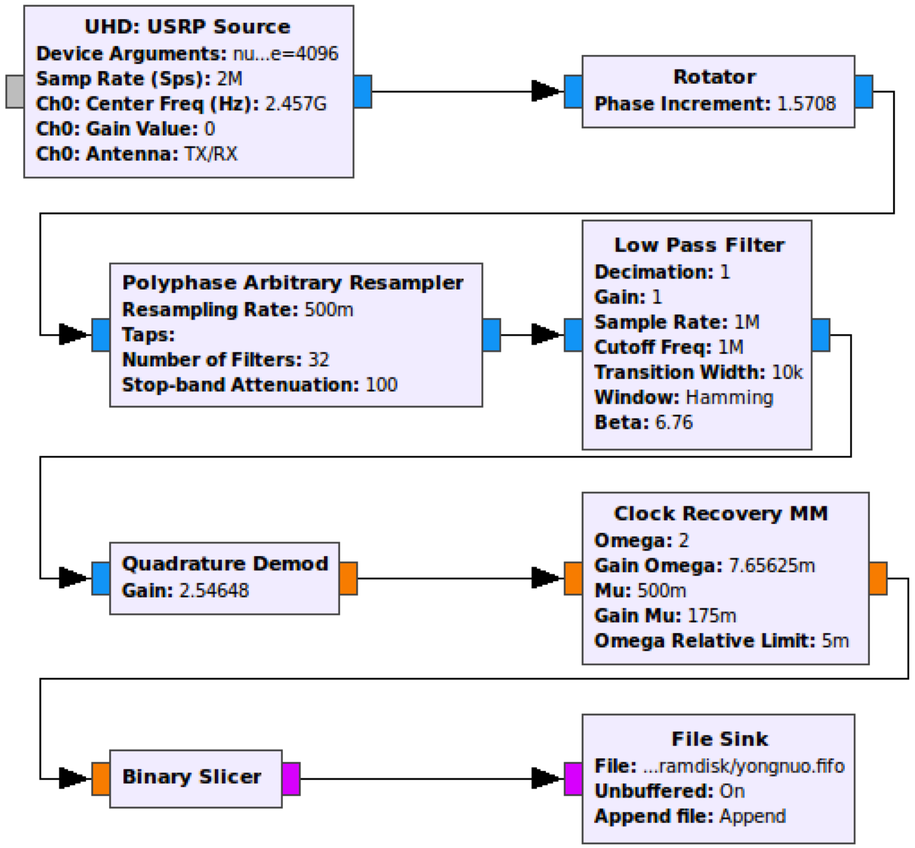


Surveying

Budget Spectrum Analyzer

Design Optimization

- Experimentation platform for physical layer technologies
- Most SDR logic can be run in simulation
- See GNU Radio



Offensive Security Research

- Physical layer attacks, including:
  - Sniffing
  - Jamming / denial of service
  - Selective receiver targeting / IDS evasion
- “Radio Exploitation 101” at DEF CON 25

RF Fuzzing

- TumbleRF
  - Framework for fuzzing RF protocols and fingerprinting chipsets
  - Extensible! Abstracts radio driver specific interface functions into a common API
  - Developed by yours truly and Ryan Speers from River Loop Security
- Released at Troopers 18
  - https://github.com/riverloopsec/tumblerf

Defensive Security Applications

- Real-time monitoring of the entire RF spectrum
  - Single or networked array of Software Defined Radios
  - Real-time analytics and insight
  - Not tied to a single protocol or chipset!

- Better understanding of PHY layer vulnerabilities

WHY IS SECURING RF DIFFICULT?

vs. Wired Interfaces

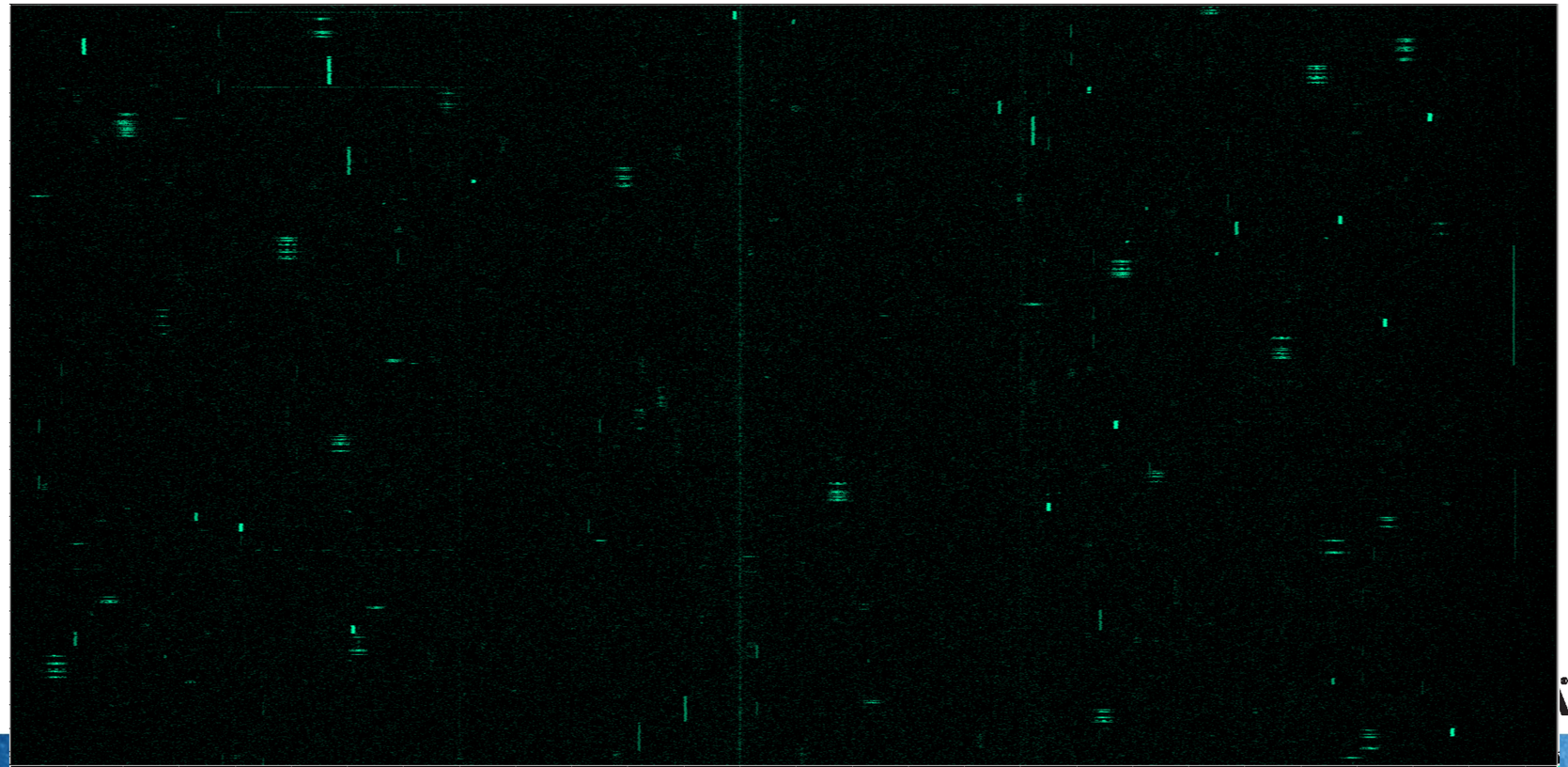
RF vs. Wired: Defining Attributes

RF Interface

- Promiscuity
  - RF spectrum is a giant bus!

Wired Interface

- Dedicated interfaces
  - Direct electrical access required



Promiscuity Makes Recon Easy

- Promiscuity makes discovering vulnerable devices easy
  - Sniffing
  - Active wardriving
  - Can be done stood off at a distance

Promiscuity and Attribution

- Promiscuity means attribution is difficult
- Is the attacker:
  - On your network
  - On a box on your network
  - In the parking lot?
  - A USPS box delivered to the CEO's office?

TOP WIRELESS* ATTACKS OF 2017

*proprietary RF protocols and PHY layers

Dallas Tornado Siren Attack

- April 2017, Tuesday @ 1:30AM
- All 156 Tornado emergency sirens in Dallas metro area turned on
- 90 minutes to turn them off

https://www.washingtonpost.com

Dallas Tornado Siren Attack

- Vector
  - RF replay attack
  - Retransmitted previously captured PHY frame
  - Sirens were tested quarterly, providing source material
- Theoretical Mitigation
  - Cryptographic authentication w/ freshness (sequence number)

https://www.washingtonpost.com

Dallas Tornado Siren Attack Demo

- Fortress Security System Panic Button
  - Tornado Siren surrogate 😏
- 433 MHz on-off keying
  - No freshness or authentication
  - Raw IQ replay or decode/resynthesize
- Raw IQ replay demo

https://www.washingtonpost.com/news/the-intersect/wp/2017/08/09/someone-hacked-every-outdoor-siren-in-dallas-it-was-loud-then-it-got-hard

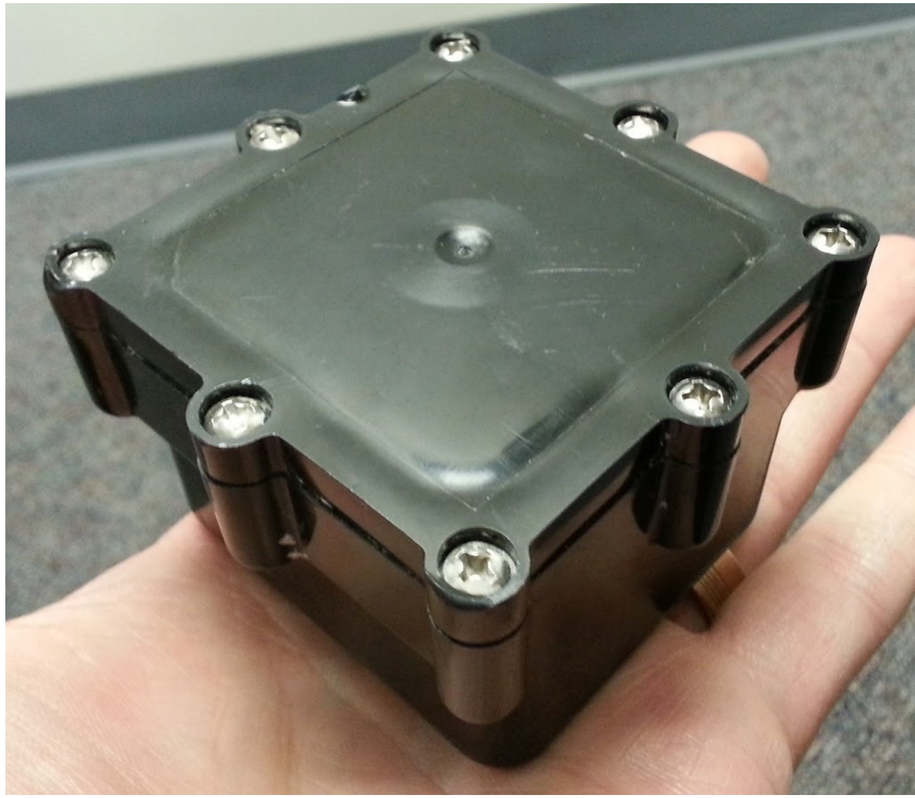
[DEMO]

St. Jude Pacemaker Attack

- Pacemaker vulnerabilities
  - 0-days dropped by MedSec + short seller
- RF attacks:
  - Depleting battery in implanted pacemaker
  - Authentication vulnerabilities

Wireless IoT Worms

- Traffic Light Controller Worm
  - Theorized by Cesar Cerrudo
  - Traffic flow sensors and traffic light controllers
    - No encryption
    - No authentication
    - No code signing



Wireless IoT Worms

- Phillips Hue Firmware Worm
  - Eyal Ronen, Colin O'Flynn, Adi Shamir, Achi-Or Weingargen
  - Recovered Phillips Hue firmware signing key via side-channel attack
  - Exploited ZigBee Light Link firmware OTA process to self-propagate

- Excellent paper and video
  - http://iotworm.eyalro.net/

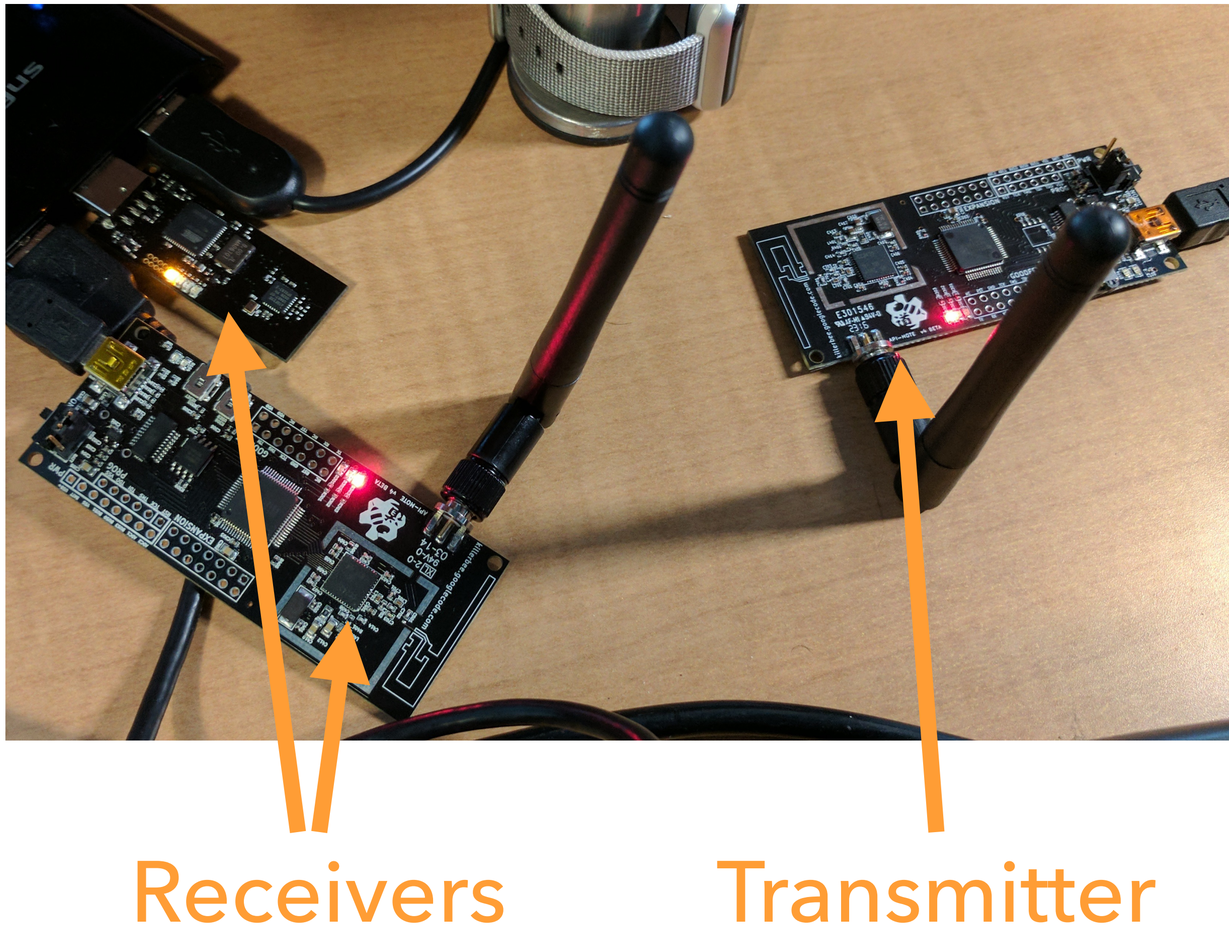
http://www.wisdom.weizmann.ac.il/~eyalro/iotworm/index_files/image011.jpg

Physical Layer State Machine Attacks

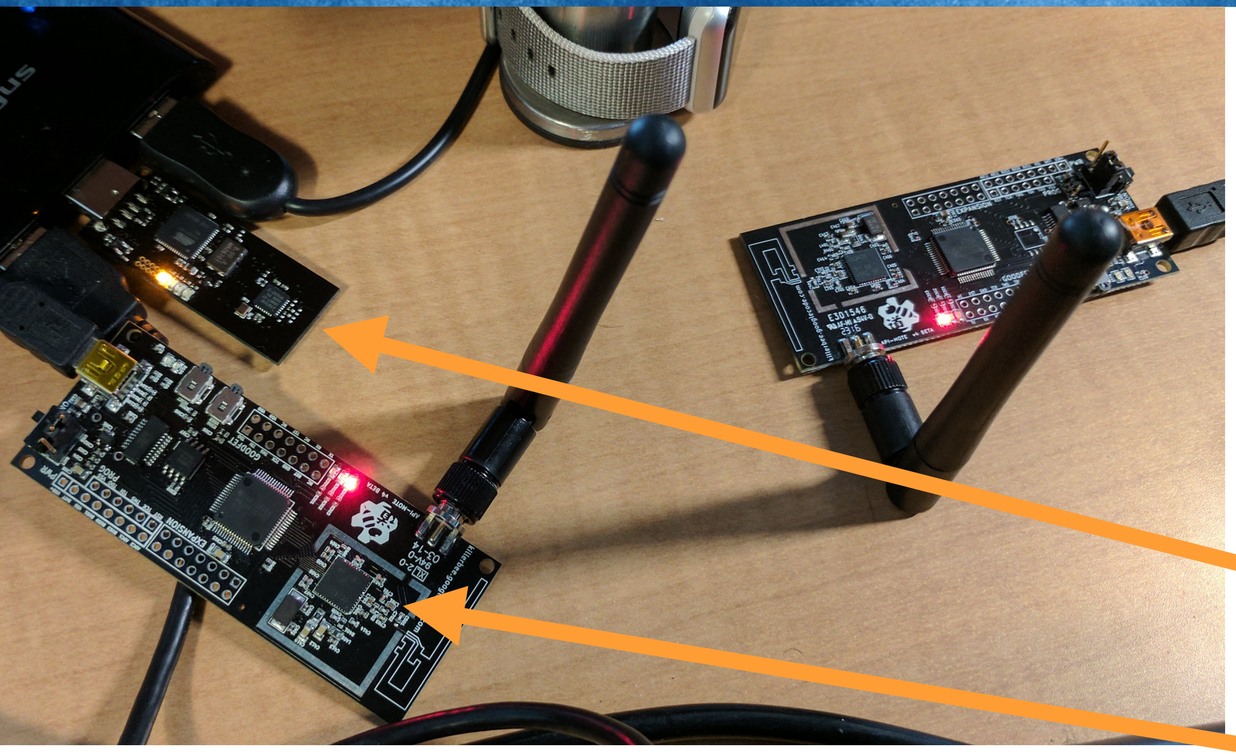
- Thesis
  - Chipset manufacturers implement complicated standards differently
- Attack
  - Send standards-noncompliant transmissions to exploit corner cases in specific PHY layer state machines
- Result
  - Targeted receiver evasion (IDS evasion)
  - Device fingerprinting

Physical Layer State Machine Attack Demo

- 802.15.4 Receiver Evasion
  - Original research by Travis Goodspeed, David Dowd, Ryan Speers, River Loop Security, and others from Dartmouth
- Transmitter:
  - TI CC2420 w/ configurable PHY state machine
- Receiver:
  - TI CC2420 w/ stock PHY configuration
  - Atmel AT86RF230



Physical Layer State Machine Attack Demo



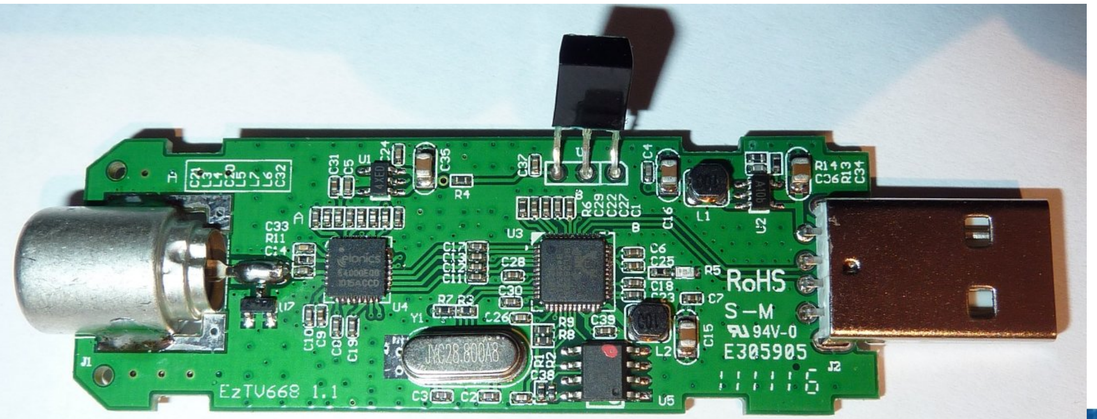
- Standard 802.15.4 preamble and SFD:
  - 0x00000000A7: 4 0x00s + 1 0xA7
- What if we screw with this?
  - 0x00000000FFA7: extra symbols in preamble
  - 0x000000A7: short preamble

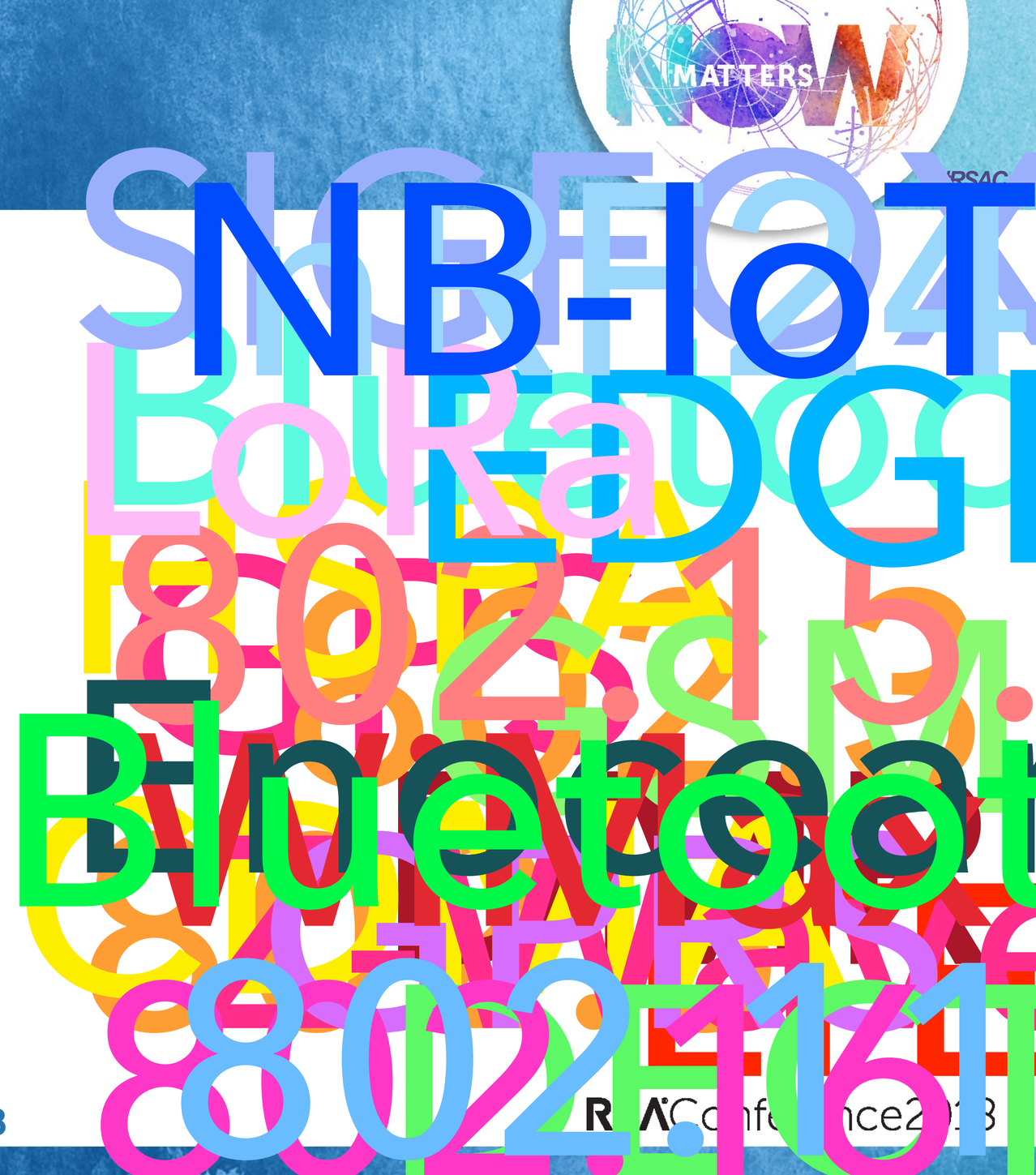
[DEMO]

CONCLUSIONS

Conclusions

- We have entered the Golden Age of RF Hacking
  - SDR has been commodity for >5 years
  - Every RF PHY is in scope!





Conclusions

- Next week you should:
  - Review whether your organization has IoT/BYOD device policies in place
- In the first three months following this presentation you should:
  - Consider adding non-802.11 RF vectors to your threat model

Awareness + Visibility = Empowerment

- Within six months you should:
  - Evaluate your organization's posture relative to RF threats

THANKS

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QUESTIONS?

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