Random Numbers, CryptoFails & CryptoCurrencies


Cryptography is nightmare magic math that cares what kind of pen you use -@swiftonsecurity

A Lot of Uses for Random Numbers...

- The key foundation for all modern cryptographic systems is often not encryption but these "random" numbers!
- So many times you need to get something random:
  - A random cryptographic key
  - A random initialization vector
  - A random "nonce" (use-once item)
  - A unique identifier
  - Stream Ciphers
- If an attacker can ***predict*** a random number things can catastrophically fail

Breaking Slot Machines

- Some casinos experienced unusual bad "luck"
  - The suspicious players would wait and then all of a sudden try to play
- The slot machines have ***predictable*** pRNG
  - Which was based on the current time & a seed
- So play a little...
  - With a cellphone watching
  - And now you know when to press "spin" to be more likely to win
- Oh, and this ***never*** affected Vegas!
  - ***Evaluation standards*** for Nevada slot machines specifically designed to address this sort of issue

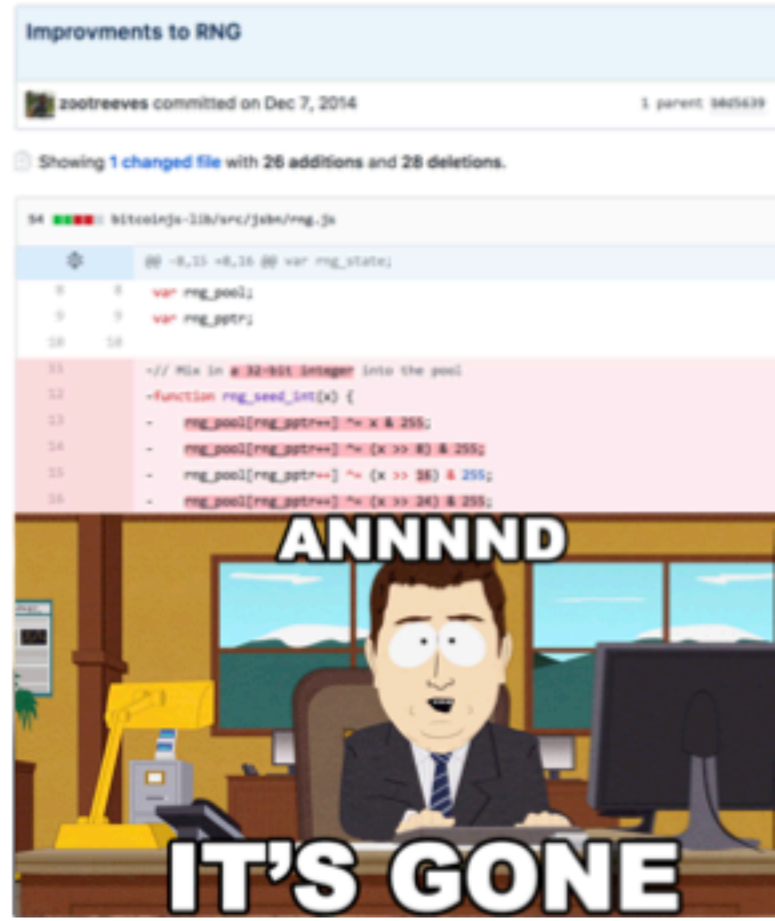
BRENDAN KOERNER SECURITY 02.06.17 07:00 AM

RUSSIANS ENGINEER A BRILLIANT SLOT MACHINE

IN EARLY JUNE 2014, accountants at the Lumiere Place Casino in St. Louis noticed that several of their slot machines had—just for a couple of days—gone haywire. The government-approved software that powers such machines gives the house a fixed mathematical edge, so that casinos can be certain of how much they'll earn over the long haul—say, 7.129 cents for every dollar played. But on June 2 and 3, a number of Lumiere's machines had spit out far more money than they'd consumed, despite not awarding any major jackpots, an aberration known in industry parlance as a

Breaking Bitcoin Wallets

- blockchain.info supports "web wallets"
  - Javascript that protects your Bitcoin
- The private key for Bitcoin needs to be random
  - Because otherwise an attacker can spend the money
- An "Improvment" [sic] to the RNG reduced the entropy (the actual randomness)
  - Any wallet created with this improvment was brute-forceable and could be stolen



TRUE Random Numbers

- True random numbers generally require a physical process
- Common circuit is an unusable ring oscillator built into the CPU
  - It is then sampled at a low rate to generate true random bits which are then fed into a pRNG on the CPU
- Other common sources are human activity measured at very fine time scales
  - Keystroke timing, mouse movements, etc
    - "Wiggle the mouse to generate entropy for a key"
  - Network/disk activity which is often human driven
- More exotic ones are possible:
  - Cloudflare has a wall of lava lamps that are recorded by a HD video camera which views the lamps through a rotating prism: It is just one source of the randomness

Combining Entropy

- The general procedure is to combine various sources of entropy
- The goal is to be able to take multiple crappy sources of entropy
  - Measured in how many bits:
    A single flip of a true random coin is 1 bit of entropy
  - And combine into a value where the entropy is the minimum of the sum of all entropy sources (maxed out by the # of bits in the hash function itself)
  - **N-1** bad sources and **1** good source -> good pRNG state

Pseudo Random Number Generators (aka Deterministic Random Bit Generators)

- Unfortunately one needs a ***lot*** of random numbers in cryptography
  - More than one can generally get by just using the physical entropy source
- Enter the pRNG or DRBG
  - If one knows the state it is ***entirely predictable***
  - If one doesn't know the state it should be ***indistinguishable*** from a random string
- Three operations
  - Instantiate: (aka Seed) Set the internal state based on the real entropy sources
  - Reseed: Update the internal state based on both the previous state and ***additional entropy***
    - The big different from a simple stream cipher
  - Generate: Generate a series of random bits based on the internal state
    - Generate can also optionally add in additional entropy
- **instantiate(entropy)**
  reseed(entropy)
  generate(bits, {optional entropy})

Properties for the pRNG

- Can a pRNG be truly random?
  - No. For seed length **s**, it can only generate at most $\mathbf{2^s}$ distinct possible sequences.
- A cryptographically strong pRNG "looks" truly random to an attacker
  - Attacker ***cannot distinguish*** it from a random sequence:
    If the attacker can tell a sufficiently long bitstream was generated by the pRNG instead of a truly random source it isn't a good pRNG

Prediction and Rollback Resistance

- A pRNG should be predictable only if you know the internal state
  - It is this predictability which is why its called "pseudo"
- If the attacker does not know the internal state
  - The attacker should not be able to distinguish a truly random string from one generated by the pRNG
- It should also be rollback-resistant
  - Even if the attacker finds out the state at time T, they should not be able to determine what the state was at T-1
  - More precisely, if presented with two random strings, one truly random and one generated by the pRNG at time T-1, the attacker should not be able to distinguish between the two
- Not all pRNGs have rollback resistance:
  it isn't ***technically*** required of a pRNG.
  EG, CTR mode with a random key doesn't have rollback resistance

Why "Rollback Resistance" is Essential

- Assume attacker, at time T, is able to obtain all the internal state of the pRNG
  - How? E.g. the pRNG screwed up and instead of an IV, released the internal state, or the pRNG is bad...
- Attacker observes how the pRNG was used
  - T_{-1} = Session key
    T_0 = Nonce
- Now if the pRNG doesn't resist rollback, and the attacker gets the state at T_0, attacker can know the session key! And we are back to...

More on Seeding and Reseeding

- Seeding should take all the different physical entropy sources available
  - If one source has 0 entropy, it ***must not*** reduce the entropy of the seed
  - We can shove a whole bunch of low-entropy sources together and create a high-entropy seed
- Reseeding ***adds*** in even more entropy
  - **F(internal_state, new material)**
  - Again, even if reseeding with 0 entropy, it ***must not*** reduce the entropy of the seed

Probably the best pRNG/DRBG: HMAC_DRBG

- Generally believed to be the best
  - ***Accept no substitutes***!
- Two internal state registers, ***V*** and ***K***
  - Each the same size as the hash function's output
- ***V*** is used as (part of) the data input into HMAC, while ***K*** is the key
- If you can break this pRNG you can ***either break the underlying hash function*** or ***break a significant assumption about how HMAC works***
  - Yes, security proofs sometimes are a very good thing and actually do work

HMAC_DRBG Update

- Used for both instantiate (**state.k = state.v = 0**) and reseed (keep **state.k** and **state.v**)
- Designed so that even if the attacker controls the input but doesn't know **k**:
  The attacker should not be able to predict the new **k**

```
function hmac_drbg_update (state, input) {
  state.k = hmac(state.k, state.v || 0x00
                          || input)
  state.v = hmac(state.k, state.v)
  state.k = hmac(state.k, state.v || 0x01
                          || input)
  state.v = hmac(state.k, state.v)
}
```

HMAC_DRBG
Generate

- The basic generation function
- Remarks:
  - It requires one HMAC call per blocksize-bits of state
  - Then two more HMAC calls to update the internal state
- Prediction resistance:
  - If you can distinguish new **K** from random when you don't know old **K**:
    You've distinguished HMAC from a random function!
    Which means you've either broken the hash or the HMAC construction
- Rollback resistance:
  - If you can learn old **K** from new **K** and **V**:
    You've reversed the hash function!

```
function hmac_drbg_generate (state, n, input)
{
  tmp = ""
  while(len(tmp) < N){
     state.v = hmac(state.k,state.v)
     tmp = tmp || state.v
  }
  if input == null {
  // Update state with no input
    state.k = hmac(state.k, state.v || 0x00)
    state.v = hmac(state.k, state.v)
  } else {
    hmac_drbg_update(state, input);
  }
  // Return the first N bits of tmp
  return tmp[0:N]
}
```

UUID: Universally Unique Identifiers

- You got to have a "name" for something...
  - EG, to store a location in a filesystem
- Your name ***must*** be unique...
  - And your name ***must*** be unpredictable!
- Just chose a ***random*** value!
  - UUID: just chose a 128b random value
    - Well, it ends up being a 122b random value with some signaling information
  - A good UUID library uses a cryptographically-secure pRNG that is properly seeded
- Often written out in hex as:
  - 00112233-4455-6677-8899-aabbccddeeff

What Happens When The Random Numbers Goes Wrong...

- Insufficient Entropy:
  - Random number generator is seeded without enough entropy
- Debian OpenSSL CVE-2008-0166
  - In "cleaning up" OpenSSL (Debian 'bug' #363516), the author 'fixed' how OpenSSL seeds random numbers
    - Because the code, as written, caused Purify and Valgrind to complain about reading uninitialized memory
  - Unfortunate cleanup reduced the pRNG's seed to be ***just*** the process ID
    - So the pRNG would only start at one of ~30,000 starting points
- This made it easy to find private keys
  - Simply set to each possible starting point and generate a few private keys
  - See if you then find the corresponding public keys anywhere on the Internet

http://blog.dieweltistgarnichtso.net/Caprica,-2-years-ago

And Now Lets
Add Some RNG Sabotage...

- The Dual_EC_DRBG
  - A pRNG pushed by the NSA behind the scenes based on Elliptic Curves
- It relies on two parameters, ***P*** and ***Q*** on an elliptic curve
  - The person who generates ***P*** and selects ***Q=eP*** can predict the random number generator, regardless of the internal state
- It also ***sucked!***
  - It was horribly slow and even had subtle biases that shouldn't exist in a pRNG: You could distinguish the upper bits from random!
- Now this was spotted fairly early on...
  - Why should anyone use such a horrible random number generator?

Well, anyone not paid that is...

- RSA Data Security accepted ~~30 pieces of silver~~ $10M from the NSA to implement Dual_EC in their RSA BSAFE library
  - And ***silently*** make it the default pRNG
- Using RSA's support, it became a NIST standard
  - And inserted into other products...
- And then the Snowden revelations
  - The initial discussion of this sabotage in the NY Times just vaguely referred to a Crypto talk given by Microsoft people...
    - That everybody quickly realized referred to Dual_EC

But this is insanely powerful...

- It isn't just forward prediction but being able to run the generator backwards!
  - Which is why Dual_EC is so nasty:
    Even if you know the internal state of HMAC_DRBG it has rollback resistance!
- In TLS (HTTPS) and Virtual Private Networks you have a motif of:
  - Generate a random session key
  - Generate some other random data that's ***public visible***
    - EG, the IV in the encrypted channel, or the "random" nonce in TLS
    - Oh, and an NSA sponsored "standard" to spit out even more "random" bits!
- If you can run the random number generator ***backwards***, you can find the session key

It Got Worse: Sabotaging Juniper

- Juniper also used Dual_EC in their Virtual Private Networks
  - "But we did it safely, we used a different **Q**"
- Sometime later, someone else noticed this...
  - "Hmm, **P** and **Q** are the keys to the backdoor...
    Lets just hack Juniper and rekey the lock!"
    - And whoever put in the first Dual_EC then went "Oh crap, we got locked out but we can't do anything about it!"
- Sometime later, someone else goes...
  - "Hey, lets add an ssh backdoor"
- Sometime later, Juniper goes
  - "Whoops, someone added an ssh backdoor, lets see what else got F'ed with, oh, this # in the pRNG"
- And then everyone else went
  - "Ohh, patch for a backdoor. Lets see what got fixed. Oh, these look like Dual_EC parameters..."

Sabotaging "Magic Numbers" In General

- Many cryptographic implementations depend on "magic" numbers
  - Parameters of an Elliptic curve
  - Magic points like ***P*** and ***Q***
  - Particular prime ***p*** for Diffie/Hellman
  - The content of S-boxes in block cyphers
- Good systems should cleanly describe how they are generated
  - In some sound manner (e.g. AES's S-boxes)
  - In some "random" manner defined by a pRNG with a specific seed
    - Eg, seeded with "Nicholas Weaver Deserves Perfect Student Reviews"... Needs to be very low entropy so the designer can't try a gazillion seeds

Because Otherwise You Have Trouble...

- Not only Dual-EC's ***P*** and ***Q***
- Recent work: 1024b Diffie/Hellman moderately impractical...
  - But you can create a sabotaged prime that is 1/1,000,000 the work to crack!
    And the most often used "example" ***p***'s origin is lost in time!
- It can cast doubt ***even when a design is solid***:
  - The DES standard was developed by IBM but with input from the NSA
    - Everyone was suspicious about the NSA tampering with the S-boxes...
    - They did: The NSA made them ***stronger*** against
      an attack they knew but the public didn't
  - The NSA-defined elliptic curves P-256 and P-384
    - I trust them because they are in Suite-B/CNSA so the
      NSA uses them for TS communication:
      A backdoor here would be absolutely unacceptable...
      but ***only because I actually believe the NSA wouldn't go and try to shoot itself in the head!***

Announcements!

- Midterm 1 tonight, 7-9 pm
  - See Piazza for your room assignments
  - Bring your student ID
- Project 2: Get Started ***now!***
  - This project doesn't necessarily require writing a lot of ***code***, but it does require a ***good design***!
  - It will be not quite but almost impossible to get 100%, you have been warned!

Snake Oil Cryptography: Craptography

- "Snake Oil" refers to 19th century fraudulent "cures"
  - Promises to cure practically every ailment
  - Sold because there was no regulation and no way for the buyers to know

- The security field is practically ***full*** of Snake Oil Security and Snake Oil Cryptography
  - https://www.schneier.com/crypto-gram/archives/1999/0215.html#snakeoil

Anti-Snake Oil: NSA's CNSA cryptographic suite

- Successor to "Suite B"
  - Unclassified algorithms approved for Top Secret:
    - There is nothing higher than TS, you have "compartments" but those are access control modifiers
    - https://www.iad.gov/iad/programs/iad-initiatives/cnsa-suite.cfm
  - Symmetric key, AES: 256b keys
  - Hashing, SHA-384
  - RSA/Diffie Helman: >= 3072b keys
  - ECDHE/ECDSA: 384b keys over curve P-384
- In an ideal world, I'd only use those parameters,
  - But a lot of "strong" commercial is 128b AES, SHA-256, 2048b RSA/DH, 256b elliptic curves, plus the DJB curves and cyphers (ChaCha20)
  - NSA has a requirement where a Top Secret communication captured today should not be decryptable by an adversary 40 years from now!

Snake Oil Warning Signs...

- Amazingly long key lengths
  - The NSA is super paranoid, and even they don't use >256b keys for symmetric key or >4096b for RSA/DH public key
  - So if a system claims super long keys, be suspicious
- New algorithms and crazy protocols
  - There is ***no reason*** to use a novel block cipher, hash, public key algorithm, or protocol
    - Even a "post quantum" public key algorithm should not be used alone: Combine it with a conventional public key algorithm
  - Anyone who roles their own is asking for trouble!
  - EG, Telegram
    - "It's like someone who had never seen cake but heard it described tried to bake one. With thumbtacks and iron filings." Matthew D Green
    - "Exactly! GLaDOS-cake encryption. Odd ingredients; strange recipe; probably not tasty; may explode oven. :)" Alyssa Rowan

Lots in the Cryptocurrency Space…

- The biggest being IOTA (aka IdiOTA), a “internet of Things” cryptocurrency…
  - That doesn’t use public key signatures, instead a hash based scheme that means you can ***never*** reuse a key…
    - And results in 10kB+ signatures! (Compared with RSA which is <450B, and those are big)
  - That has created their own hash function…
    - That was quickly broken!
  - That is supposed to end up distributed…
    - But relies entirely on their central authority
  - That uses ***trinary math!?!***
    - Somehow claiming it is going to be better, but you need entirely new processors…

Snake Oil Warning Signs...

- "One Time Pads"
  - One time pads are secure, if you actually have a true one time pad
  - But almost all the snake oil advertising it as a "one time pad" isn't!
  - Instead, they are invariably some wacky stream cypher
- Gobbledygook, new math, and "chaos"
  - Kinda obvious, but such things are never a good sign
- Rigged "cracking contests"
  - Usually "decrypt this message" with no context and no structure
    - Almost invariably a single or a few unknown plaintexts with nothing else
  - Again, Telegram, I'm looking at you here!

Unusability:
No Public Keys

- The APCO Project 25 radio protocol
  - Supports encryption on each traffic group
    - But each traffic group uses a single ***shared*** key
- All fine and good if you set everything up at once...
  - You just load the same key into all the radios
  - But this totally fails in practice: what happens when you need to coordinate with s who doesn't have the same keys?
- Made worse by bad user interface and users who think rekeyin frequently is a good idea
  - If your crypto is good, you shouldn't need to change your crypto keys
- "Why (Special Agent) Johnny (Still) Can't Encrypt
  - http://www.crypto.com/blog/p25

Unusability: PGP

- I ***hate*** Pretty Good Privacy
  - But not because of the cryptography...
- The PGP cryptography is decent...
  - Except it lacks "Forward Secrecy":
    If I can get someone's private key I can decrypt all their old messages
- The metadata is awful...
  - By default, PGP says who every message is from and to
    - It makes it much faster to decrypt
  - It is hard to hide metadata well, but its easy to do things better than what PGP does
- It is never transparent
  - Even with a "good" client like GPG-tools on the Mac
  - And I don't have a client on my cellphone

Unusability:
How do you find someone's PGP key?

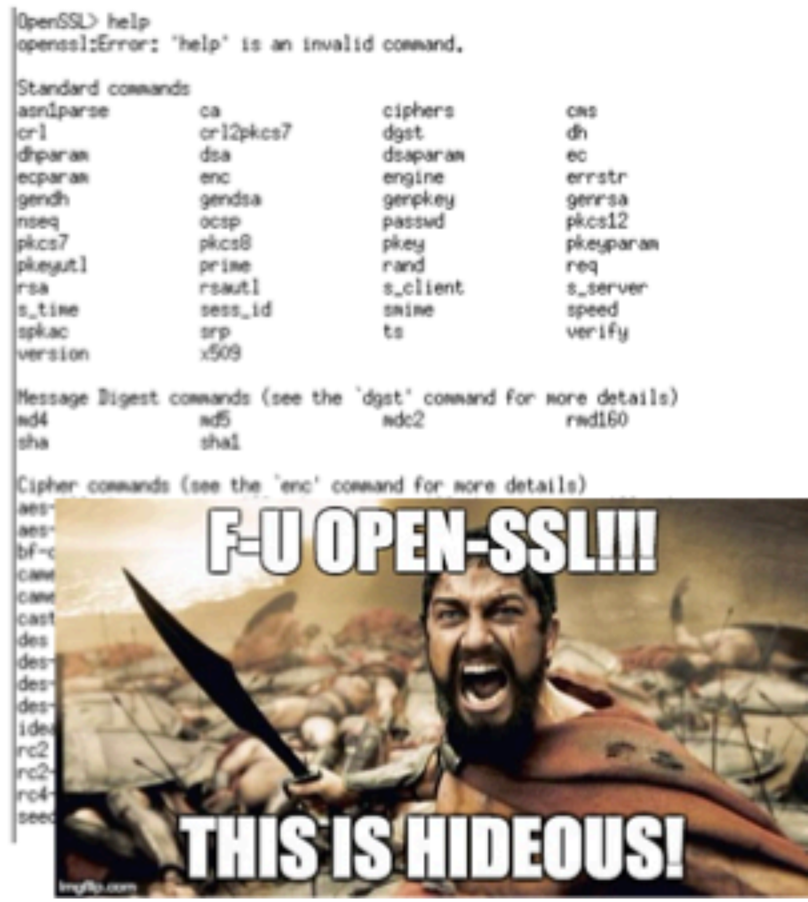
- Go to their personal website?
- Check their personal email?
- Ask them to mail it to you
  - In an unencrypted channel?
- Check on the MIT keyserver?
  - And get the old key that was mistakenly uploaded and can never be removed?

Search results for 'nweaver icsi edu berkeley'

Type	bits/keyID	Date	User ID
pub	4096R/8A46A420	2013-06-20	Nicholas Weaver <nweaver@icsi.berkeley.edu> Nicholas Weaver <n_weaver@mac.com> Nicholas Weaver <nweaver@gmail.com>
pub	2048R/442CF948	2013-06-20	Nicholas Weaver <nweaver@icsi.berkeley.edu>

Unusability: openssl libcrypto and libssl

- OpenSSL is a nightmare...
  - A gazillion different little functions needed to do anything
- So much of a nightmare that I'm not going to bother learning it to teach you how bad it is
  - This is why the old python-based project didn't give this raw even though it used OpenSSL under the hood
- But just to give you an idea:
  The command line OpenSSL utility options:



An Old Cryptofail: Too Short Keys

- During WWII, the Germans used ***enigma***:
  - System was a "rotor machine": A series of rotors, with each rotor permuting the alphabet and every keypress incrementing the settings
    - Key was the selection of rotors, initial settings, and a permutation plugboard
    - Which is not all that much entropy!
- The British built a system (the "Bombe") to brute-force Enigma
  - Required a known-plaintext (a "crib") to verify decryption: e.g. the weather report
  - Sometimes the brits would deliberately "seed" a naval minefield for a chosen-plaintext attack

Another Cryptofail: Two-Time Pad

- What if we reuse a key K jeeeest once in a One Time Pad?
- Alice sends **C = E(M, K)** and **C' = E(M', K)**
- Eve observes **M** ⊕ **K** and **M'** ⊕ **K**
  - Can she learn anything about M and/or M' ?
- Eve computes **C** ⊕ **C' = (M** ⊕ **K)** ⊕ **(M'** ⊕ **K)**
  = (M ⊕ **M')** ⊕ **(K** ⊕ **K)**
  = (M ⊕ **M')** ⊕ **0**
  = M ⊕ **M'**
- Now she knows which bits in **M** match bits in **M'**
- And if Eve already knew **M**, now she knows **M'**!
  - Even if not, Eve can guess **M** and ensure that **M'** is consistent

VENONA: Pad Reuse in the Real World

- The Soviets used one-time pads for communication from their spies in the US
  - After all, it is provably secure!
- During WWII, the Soviets started reusing key material
  - Uncertain whether it was just the cost of generating pads or what...
- VENONA was a US cryptanalysis project designed to break these messages
  - Included confirming/identifying the spies targeting the US Manhattan project
  - Project continued until 1980!
- ***Not declassified until 1995!***
  - So secret even President Truman wasn't informed about it.
  - But the Soviets found out about it in 1949, but their one-time pad reuse was fixed after 1948 anyway

2-Time Pad Cryptofail Remarkably Common

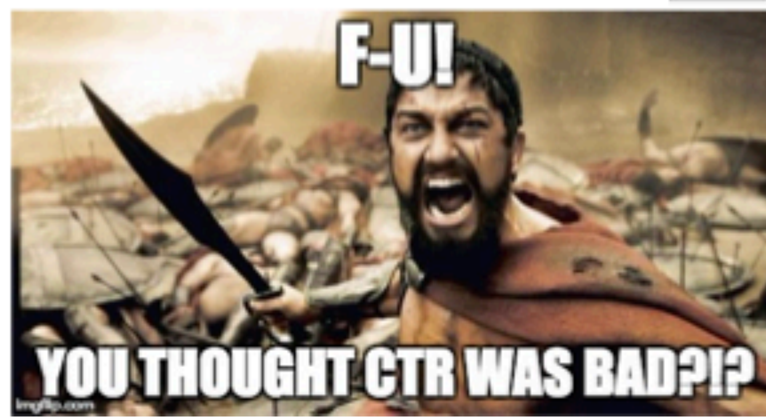
- Actually happens more often than you'd like...
  - Because if you use CTR mode and repeat the IV, you are doing the same thing!
- Recently discovered in WiFi implementations!
  - WiFi breaks up the message into a series of packets, each packet is encrypted separately

Cryptofail Hotness: KRACK attack...

- To actually encrypt the individual packets: IV of a packet is {Agreed IV || packet counter}
  - Thus for each packet you only need to send the packet counter (48 bits) rather than the full IV (128b)
- Multiple different modes
  - One common one is CCM (Counter with CBC-MAC)
    - MAC the data with CBC-MAC
      Then encrypt with CTR mode
  - The highest performance is GCM (Galois/Counter Mode)
- KRACK:
  - "Hey WiFi Device, reset your packet counter"
    "Okeydoke"
- But if you thought CTR mode was bad on IV reuse...
  - GCM is worse: A couple of reused IVs can reveal enough information to forge the authentication!
- Discovered a year and a half ago, fairly quickly patch, but still!

GCM...

- GCM is like CTR mode with a twist...
  - The confidentiality is pure CTR mode
  - The "Galois" part is a hash of the cipher text
    - The only secret part being the "Auth Data"
- Reuse the IV, what happens?
  - Not ***only*** do you have CTR mode loss of confidentiality...
  - But if you do it enough, you lose confidentiality on the Auth Data...
  - So you lose the integrity that GCM supposedly provided!



DSA Signatures...

- Based on Diffie-Hellman
  - Two initial parameters, **L** and **N**, and a hash function **H**
    - **L** == key length, eg 2048
      N <= len(H), e.g. 256
    - An N-bit prime **q**, an L-bit prime **p** such that **p - 1** is a multiple of **q**, and $\mathbf{g = h^{(p-1)/q} \bmod p}$ for some arbitrary **h** $(1 < h < p - 1)$
    - {**p, q, g**} are public parameters
- Alice creates her own random private key **x < q**
  - Public key $\mathbf{y = g^x \bmod p}$

Alice's Signature...

- Create a random value **k** < **q**
  - Calculate $\mathbf{r = (g^k \bmod p) \bmod q}$
    - If **r** = 0, start again
  - Calculate $\mathbf{s = k^{-1} (H(m) + xr) \bmod q}$
    - If **s** = 0, start again
  - Signature is {**r**, **s**} (Advantage over an El-Gamal signature variation: Smaller signatures)
- Verification
  - $\mathbf{w = s^{-1} \bmod q}$
  - $\mathbf{u_1 = H(m) * w \bmod q}$
  - $\mathbf{u_2 = r * w \bmod q}$
  - $\mathbf{v = (g^{u_1} y^{u_2} \bmod p) \bmod q}$
  - Validate that **v = r**

But Easy To Screw Up...

- **k** is not just a nonce... It must be random and ***secret***
  - If you know **k**, you can calculate **x**
- And even if you just reuse a random **k**...
  for two signatures sa and sb
  - A bit of algebra proves that $\mathbf{k = (H_A - H_B) / (s_a - s_b)}$
- A good reference:
  - How knowing k tells you x:
    https://rdist.root.org/2009/05/17/the-debian-pgp-disaster-that-almost-was/
  - How two signatures tells you k:
    https://rdist.root.org/2010/11/19/dsa-requirements-for-random-k-value/

And ***NOT*** theoretical: Sony Playstation 3 DRM

- The PS3 was designed to only run ***signed*** code
  - They used ECDSA as the signature algorithm
  - This prevents unauthorized code from running
  - They had an ***option*** to run alternate operating systems (Linux) that they then removed
- Of course this was catnip to reverse engineers
  - Best way to get people interested: ***remove*** Linux from a device...
- It turns for out one of the key authentication keys used to sign the firmware...
  - Ended up reusing the same k for multiple signatures!

And ***NOT*** Theoretical: Android RNG Bug + Bitcoin

- OS Vulnerability in 2013
  Android "SecureRandom" wasn't actually secure!
  - Not only was it low entropy, it would occasionally return the ***same value multiple times***
- Multiple Bitcoin wallet apps on Android were affected
  - "Pay B Bitcoin to Bob" is signed by Alice's public key using ECDSA
    - Message is broadcast publicly for all to see
  - So you'd have cases where "Pay B to Bob" and "Pay C to Carol" were signed with the same **k**
- So ***of course*** someone scanned for ***all*** such Bitcoin transactions

Cryptofail: MAC then Encrypt or Encrypt then MAC?

- You should ***never*** use the same key for the MAC and the Encryption
  - Some MACs will break completely if you reuse the key
  - Even if it is ***probably*** safe (eg, AES for encryption, HMAC for MAC) its still a bad idea
- MAC then Encrypt:
  - Compute **$T = MAC(M,K_{mac})$**, send **$C = E(M||T,K_{encrypt})$**
- Encrypt then MAC:
  - Compute **$C = E(M,K_{encrypt})$**, **$T = MAC(M,K_{mac})$**, send **$C||T$**
- Theoretically they are the same, but...
  - Once again, its time for ...

HTTPS Authentication in Practice

- When you log into a web site, it sets a "cookie" in your browser
  - All subsequent requests include this cookie so the web server knows who you are
- If an attacker can get your cookie...
  - They can impersonate you on the "Secure" site
- And the attacker can create multiple tries
  - On a WiFi network, inject a bit of JavaScript that repeatedly connects to the site
  - While as a man-in-the-middle to manipulate connections

The TLS 1.0 "Lucky13" Attack: "F-U, This is Cryptography"

- HTTPS/TLS uses MAC then Encrypt
  - With CBC encryption
- The Lucky13 attack changes the cipher text in an attempt to discover the state of a byte
  - But can't predict the MAC
  - The TLS connection retries after each failure so the attacker can try multiple times
    - Goal is to determine the status each byte in the authentication cookie which is in a known position
- It detects the ***timing*** of the error response
  - Which is different if the guess is right or wrong
    - Even though the underlying algorithm was "***proved***" secure!
- So always do Encrypt then MAC since, once again, it is more mistake tolerant

CryptoFail: Side Channels

- Anything outside the normal message
  - The ***time*** it takes to decrypt a message (or even just report an error)
  - The ***power*** it takes to decrypt a message
  - The ***cache state*** of a processor after another process completes encryption
  - Electromagnetic radiation when encrypting
    - TEMPEST attacks
- These are often how you break crypto systems in practice

The Facebook Problem/Crypto Success: Applied Cryptography in Action

- Facebook Messenger now has an encrypted chat option
  - Limited to their phone application
- The cryptography in general is very good
  - Used a well regarded asynchronous messenger library (from Signal) with many good properties, including forward secrecy
- When Alice wants to send a message to Bob
  - Queries for Bob's public key from Facebook's server
  - Encrypts message and send it to Facebook
  - Facebook then forwards the message to Bob
- Both Alice and Bob are using encrypted and authenticated channels to Facebook

Facebook's Particular Messenger Problem: Abuse

- Much of Facebook's biggest problem is dealing with abuse...
  - What if either Alice or Bob is a stalker, an a-hole, or otherwise problematic?
    - Aside: A huge amount of abuse is explicitly gender based, so I'm going to use "Alex" as the abuser and "Bailey" as the victim through the rest of this example
- Facebook would expect the other side to complain
  - And then perhaps Facebook would kick off the perpetrator for violating Facebook's Terms of Service
- But fake abuse complaints are also a problem
  - So can't just take them on face value
- And abusers might also want to release info publicly
  - Want sender to be able to ***deny to the public*** but not to Facebook

Facebook's Problem Quantified

- Unless Bailey forwards the unencrypted message to Facebook
  - Facebook ***must not*** be able to see the contents of the message
- If Bailey does forward the unencrypted message to Facebook
  - Facebook ***must ensure*** that the message is what Alex sent to Bailey
- Nobody ***but*** Facebook should be able to verify this: No public signatures!
  - Critical to prevent abusive release of messages to the public being verifiable

The Protocol In Action

What Is Bailey's Public Key?

Aside: Key Transparency...

- Both Alex and Bailey are trusting Facebook's honesty...
  - What if Facebook gave Alex a different key for Bailey? How would he know?
- Facebook messenger has a ***nearly*** hidden option which allows Alex to see Bailey's key
  - If they ever get together, they can manually verify that Facebook was honest
- The mantra of central key servers: ***Trust but Verify***
  - The simple option is enough to force honesty, as each attempt to lie has some probability of being caught
- This is the biggest weakness of Apple iMessage:
  - iMessage has (fairly) good cryptography but there is no way to verify Apple's honesty

The Protocol In Action

Alex

```
{message=E(K_pub_b,
  M={"Hey Bailey I'm going to
     say something abusive",
     k_rand}),
 mac=HMAC(k_rand, M),
 to=Bailey}
```

```
{message=E(K_pub_b,
  M={"Hey Bailey I'm going to
     say something abusive",
     k_rand}),
 mac=HMAC(k_rand, M),
 to=Bailey,
 from=Alex,
 time=now,
 fbmac=HMAC(K_fb,{mac, from,
                  to, time})}
```

Bailey

Some Notes

- Facebook ***can not*** read the message or even verify Alex's HMAC
  - As the key for the HMAC is in the message itself
- Only Facebook knows their HMAC key
  - And its the only information Facebook ***needs*** to retain in this protocol: Everything else can be discarded
- Bailey upon receipt checks that Alex's HMAC is correct
  - Otherwise Bailey's messenger silently rejects the message
    - Forces Alex's messenger to be honest about the HMAC, ***even thought Facebook never verified it***
- Bailey trusts Facebook when Facebook says the message is from Alex
  - Bailey does ***not verify*** a signature, because there is no signature to verify…
    But the Signal protocol uses an ephemeral key agreement so that implicitly verifies Alex as well

Now To Report Abuse

Alex

Bailey

```
{Abuse{
  M={"Hey Bailey I'm going to
      say something abusive",
      k_rand}},
 mac=HMAC(k_rand, M),
 to=Bailey,
 from=Alex,
 time=now,
 fbmac=HMAC(K_fb,{mac, from,
                    to, time})}
```

Facebook's Verification

- First verify that Bailey correctly reported the message sent
  - Verify **`fbmac=HMAC(`**K_{fb}**`,{mac,from,to,time})`**
    - Only Facebook can do this verification since they keep K_{fb} secret
  - This enables Facebook to confirm that this is the message that it relayed from Alex to Bailey
- Then verify that Bailey didn't tamper with the message
  - Verify **`mac=HMAC(`**k_{rand}**`,{M,`** k_{rand}**`})`**
- Now Facebook knows this was sent from Alex to Bailey and can act accordingly
  - But Bailey ***can't prove*** that Alex sent this message to anyone ***other than Facebook***
  - And Bailey ***can't tamper with the message*** because the HMAC is also a hash