Return of the Hidden Number Problem

A Widespread and Novel Key Extraction Attack on ECDSA and DSA

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What is ROHNP?

- Key extraction attack on DSA and ECDSA
- Uses an old technique to target a new part of the algorithm
- Common (11/20 tested implementations were vulnerable)
- Easy attack to understand and apply

Prior Attacks on (EC)DSA

$$r = f(k * G)$$
$$s = k^{-1}(m + rx)$$

- The attacker knows r, s, m, and G.
- Recover information about nonce k.
- Derive information about private key x.

Nonce Leaks and the Hidden Number Problem

$$r = f(k * G)$$
$$s = k^{-1}(m + rx)$$

- Observe multiplication *k*G* happens quickly
- Infer *k* is "small"
- Rewrite DSA equations [HGS01]

$$k = s^{-1}m + (s^{-1}r)x < q/2^l$$

- Solve system of inequalities [BV96]
- Fix nonce leaks with constant time multiplication

Return of the Hidden Number Problem

Return of the Hidden Number Problem

$$r = f(k * G)$$
$$s = k^{-1}(m + rx)$$

- The attacker knows *r*, *s*, *m*, and *G*.
- Target the addition in the calculation of *s*.

Modular Addition

```
def AddMod(a, b, q):
    # Assuming a and b are reduced modulo q,
    # return (a + b) % q
    c = a + b
    if c >= q:
        c = c - q
    return c
```

Return of the Hidden Number Problem

- Observe the calculation of *m + rx*
- Use a side channel to see if the addition wraps around
- If not,

$$m + rx < q \Rightarrow 0 + rx < \ q - m$$

- If so,

$$m + rx \geq q \Rightarrow q - rx < \ m + 1$$

- Result is a system of HNP inequalities

Benefits of the ROHNP attack

- Information can leak through many side channels
- Attacker can choose m to tune the bits leaked per HNP inequality
- Can detect the presence of this vulnerability in a black box
  - Signatures with large m are more likely to include the extra subtraction
  - Run statistical analysis to see if this case takes longer
  - Exploit with a side channel that detects subtraction in an individual sample
- Avoids prior countermeasures
- Common

Affected Implementations

Cryptographic Libraries

- LibreSSL
- Mozilla NSS
- OpenSSL
- WolfCrypt
- Botan
- Libgcrypt
- Libtomcrypt
- matrixSSL
- OpenJDK libsunec
- CryptLib
- Golang crypto/tls
- BouncyCastle
- mbedTLS
- C#/Mono
- Trezor Crypto
- BoringSSL
- Nettle
- Crypto++
- BearSSL
- Libsecp256k1
- NaCl
- Netflix MSL
- ZeroMQ
- Pyca/cryptography
- Amazon s2n
- GnuTLS
- Cloudflare CFSSL
- NanoSSL
- Microsoft Schannel
- Apple Secure Transport
- RSA BSAFE
- SharkSSL
- Microsoft CryptoAPI/CNG
- JCA
- CryptoComply
- Oracle JSSE

Closed Source

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Wraps (EC)DSA

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Closed Source
Wraps (EC)DSA
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Constant Time

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Open Source Implementations

Constant Time
Wrong Operation Order

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- Mozilla NSS
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Constant Time
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Vulnerable

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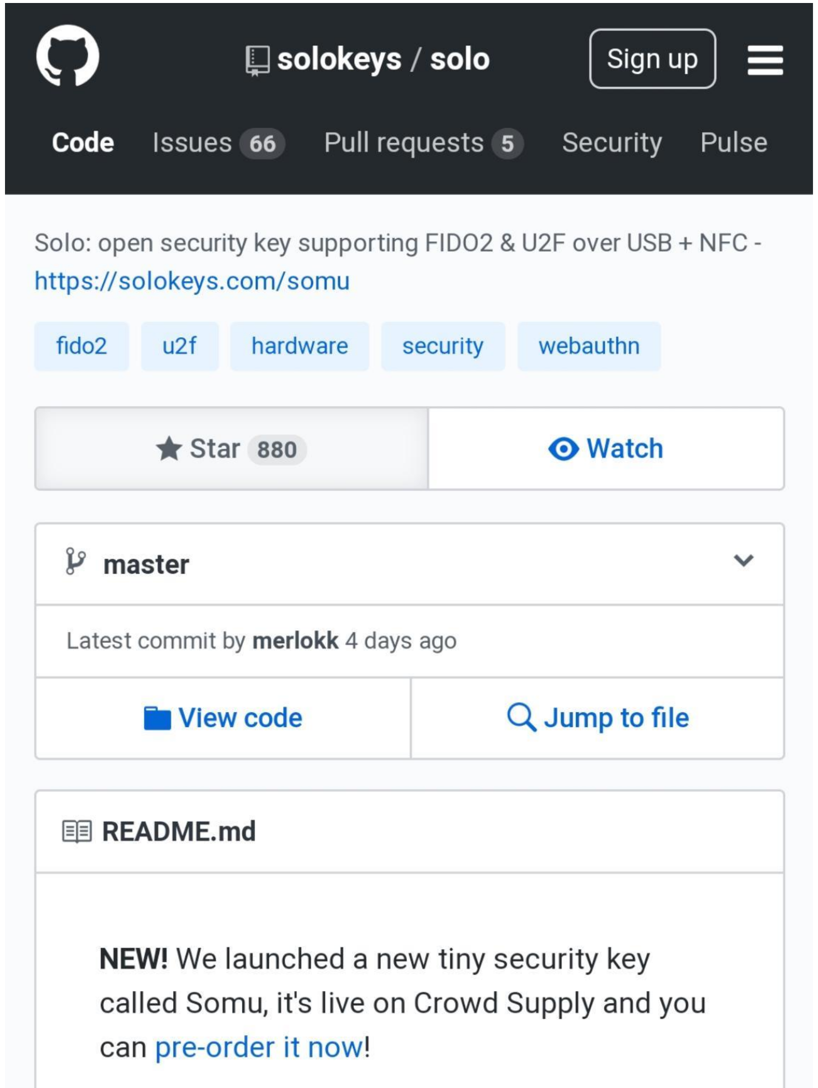
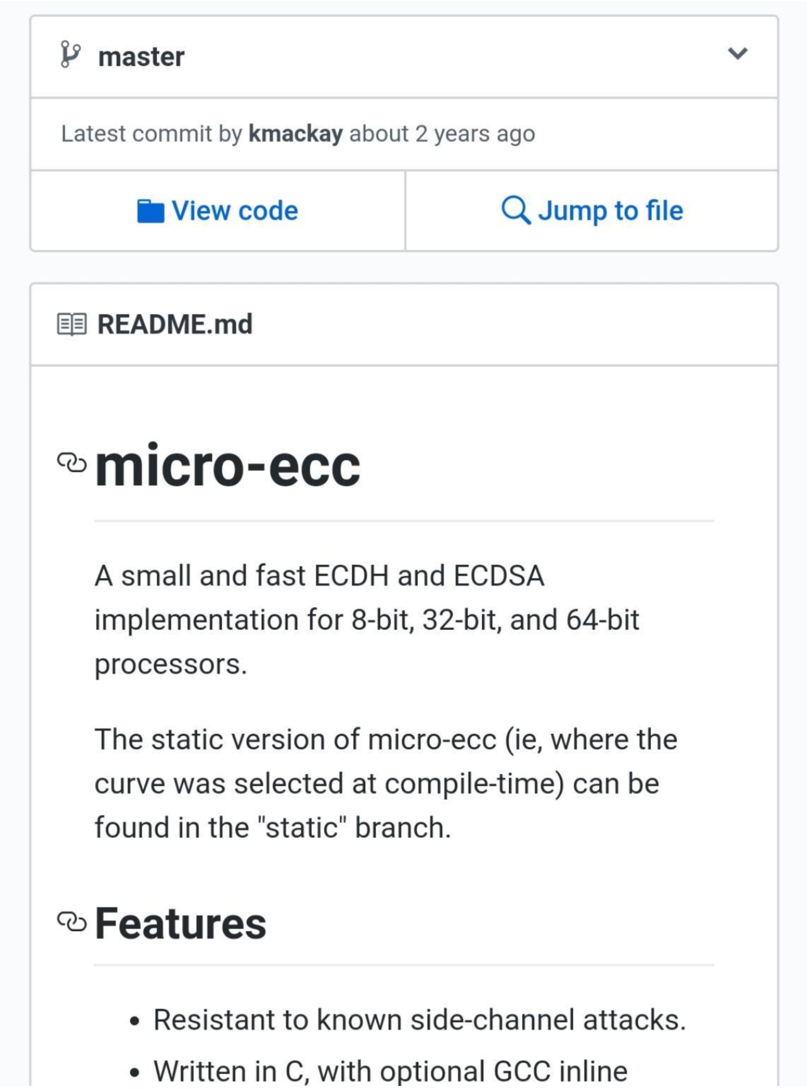
Example:

Solo


solokeys / solo
Sign up
Code
Issues 66
Pull requests 5
Security
Pulse
Solo: open security key supporting FIDO2 & U2F over USB + NFC - https://solokeys.com/somu
fido2
u2f
hardware
security
webauthn
Star 880
Watch
master
Latest commit by merlokk 4 days ago
View code
Jump to file
README.md
NEW! We launched a new tiny security key called Somu, it's live on Crowd Supply and you can pre-order it now!


master
Latest commit by kmackay about 2 years ago
View code
Jump to file
README.md
micro-ecc
A small and fast ECDH and ECDSA implementation for 8-bit, 32-bit, and 64-bit processors.
The static version of micro-ecc (ie, where the curve was selected at compile-time) can be found in the "static" branch.
Features
• Resistant to known side-channel attacks.
• Written in C, with optional GCC inline

Solo

```
/* Computes result = (left + right) % mod.
   Assumes that left < mod and right < mod, and that result does not overlap mod. */
uECC_VLI_API void uECC_vli_modAdd(uECC_word_t *result,
                                  const uECC_word_t *left,
                                  const uECC_word_t *right,
                                  const uECC_word_t *mod,
                                  wordcount_t num_words) {
    uECC_word_t carry = uECC_vli_add(result, left, right, num_words);
    if (carry || uECC_vli_cmp_unsafe(mod, result, num_words) != 1) {
        /* result > mod (result = mod + remainder),
           so subtract mod to get remainder. */
        uECC_vli_sub(result, result, mod, num_words);
    }
}
```

Conclusion

- ROHNP targets a different part of (EC)DSA signing
- It is widespread
- It is easy to understand and exploit

Thank You

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@inf_0_