The properties of RSA key generation process in software libraries

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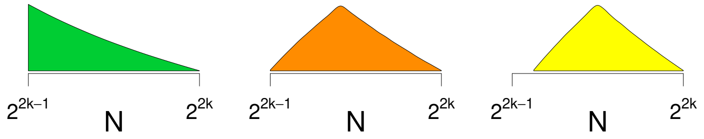
Motivation and contributions

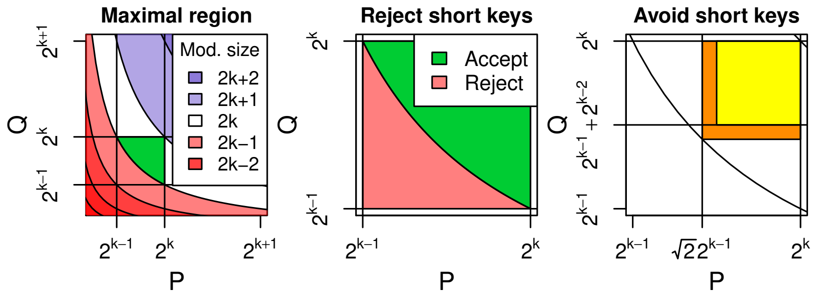
- How different are implementations of RSA keypair generation?
- The keys for the RSA cryptosystem require 2 primes, P and Q; the public modulus N is the product of the primes.
- 18 libraries examined and compared to 6 cryptographic standards.
- 17 methods producing statistically distinct keys found.
- Biased parts identified for 3 levels of knowledge about the keys.

Level 1: Public keys – distribution of the moduli



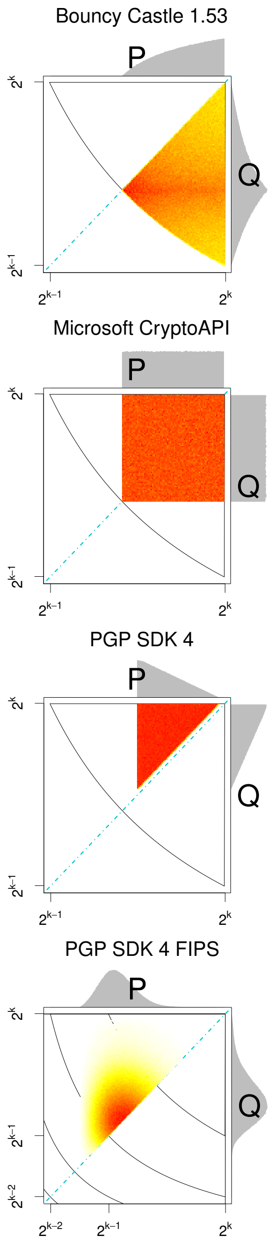
- 3 main distinct distributions of public moduli with many variations were observed, as well as a few unusual methods.
- Software bugs in OpenSSL and GNU Crypto add characteristic properties to the generated keys, effectively fingerprinting them.

Level 2: Private keys – distribution of the prime pairs

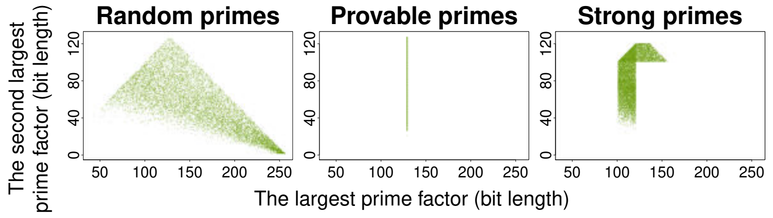


- Both primes are k bits long. Their multiple may be 1 bit shorter than the $2k$-bit modulus. Short keys are rejected or avoided.
- The exact prime generation intervals are revealed – the modulus does not show whether the primes are ordered or not. Similar modulus distributions may hide very different prime regions.

Example prime distributions

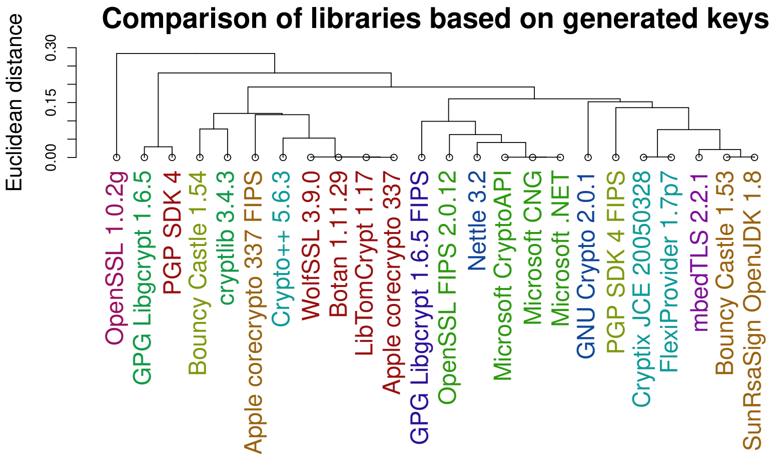


Level 3: Detecting the type of the primes by factorization



- The type of a prime P is revealed by factoring P-1 and $P+1$.
- The libraries use random, provable and "strong" primes, with implications for efficiency and security. Several variations exist.

Results



- The proposed methodology extends well to RSA key sources without published source code (proprietary libraries, smart cards).
- An information leakage vulnerability was revealed, which can be exploited as described in our paper (awarded **Best Paper**).
- P. Švenda, M. Nemec, P. Sekan, R. Kvašňovský, D. Formánek, D. Komárek and V. Matyáš: **The Million-Key Question – Investigating the Origins of RSA Public Keys.** In Proceedings of the 25th USENIX Security Symposium, pages 893–910. 2016.

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