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1. New CAESAR project: Competition for Authenticated Encryption: Security, Applicability, Robustness

http://competitions.cr.yp.to

NIST has generously provided some funding, 2013–2017.
2. Feistel modes redivivus: wide-block online ciphers

Joint work with:
Mridul Nandi and Palash Sarkar,
Indian Statistical Institute,
Kolkata

3. SipHash:
a fast short-input PRF

Joint work with:
Jean-Philippe Aumasson,
Kudelski Security (NAGRA)

https://131002.net/siphash/
Feistel motivation:

Tor is an Internet service that tries to provide low-latency anonymity for human-rights activists, police investigators, Chinese Internet users, corporate browsing, etc.

Currently 3000 relays, more than 2 GB/second, estimated $>500000$ users/day.
Part of Nick Mathewson’s talk “Cryptographic challenges in and around Tor” five days ago at Workshop on Real-World Cryptography in Stanford:

“We should replace our old relay cell protocol . . .” which currently uses AES-CTR to encrypt 509-byte blocks, something horrific to authenticate. Easy “tagging” attacks.

“A chained wide-block cipher seems like a much better idea!”
Many wide-block SPRP papers; some chaining-SPRP papers. Mathewson lists LIONESS, CMC, XCB, HCTR, XTS, XEX, HCH, TET for wide-block SPRP.

e.g. STOC 1997/JCrypt 1999 Naor–Reingold “LR revisited”:

Encrypt $2n$-bit blocks using $n$-bit PRF in 4 Feistel rounds.

Replace PRF with AXU in first round (1996 Lucks), last round.

Section 7, “SPPE on many blocks”: $2nb$-bit hash; $b \times$ ECB on $2n$ bits; $2nb$-bit hash.
4-round HFFH Feistel:
Naor–Reingold for $b = 2$:
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Chaining? Almost free.
Several SipHash motivations:

1. Optimize secret-key crypto for short messages.

2. Build a PRF/MAC that’s secure, efficient, simple.

3. Application: authenticate Internet packets.


5. Analyze security of other hash-flooding defenses. Followup work with Martin Boßlet pushes this much further.
Focus: hash flooding

July 1998 article
“Designing and attacking port scan detection tools” by Solar Designer (Alexander Peslyak) in Phrack Magazine:

“In scanlogd, I’m using a hash table to lookup source addresses. This works very well for the typical case . . . average lookup time is better than that of a binary search. . . .
However, an attacker can choose her addresses (most likely spoofed) to cause hash collisions, effectively replacing the hash table lookup with a linear search. Depending on how many entries we keep, this might make scanlogd not be able to pick new packets up in time. . . . I’ve solved this problem by limiting the number of hash collisions, and discarding the oldest entry with the same hash value when the limit is reached.
This is acceptable for port scans (remember, we can’t detect all scans anyway), but might not be acceptable for detecting other attacks. . . . It is probably worth mentioning that similar issues also apply to things like operating system kernels. For example, hash tables are widely used there for looking up active connections, listening ports, etc. There’re usually other limits which make these not really dangerous though, but more research might be needed.”
December 1999, Bernstein, dnscache software:

    if (++loop > 100) return 0;
    /* to protect against
       hash flooding */

Discarding cache entries trivially maintains performance if attacker floods hash table.

But what about hash tables in general-purpose programming languages and libraries? Can’t throw entries away!
We present a new class of low-bandwidth denial of service attacks... if each element hashes to the same bucket, the hash table will also degenerate to a linked list.

Attack examples:
Perl programming language,
Squid web cache, etc.
No attack on dnscache.
2011 (28C3), Klink–Wälde, “Efficient denial of service attacks on web application platforms”; oCERT advisory 2011–003:

No attack on dnscache, fixed Perl, fixed Squid; but still problems in Java, JRuby, PHP 4, PHP 5, Python 2, Python 3, Rubinius, Ruby, Apache Geronimo, Apache Tomcat, Oracle Glassfish, Jetty, Plone, Rack, V8 Javascript Engine.
Defending against hash flooding

My favorite solution:
switch from hash tables
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Guaranteed high speed +
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But hash tables are perceived as being smaller, faster, *simpler* than other data structures. Can we protect hash tables?
Classic hash table:

\( l \) separate linked lists
for some \( l \in \{1, 2, 4, 8, 16, \ldots \} \).

Store string \( s \) in list \( \#i \)
where \( i = H(s) \mod l \).

With \( n \) entries in table,
expect \( \approx n/l \) entries
in each linked list.
Choose \( l \approx n \):
expect very short linked lists,
so very fast list list operations.

(What if \( n \) becomes too big?
Rehash: replace \( l \) by \( 2l \).)
Basic hash flooding: attacker provides strings $s_1, \ldots, s_n$ with $H(s_1) \mod \ell = \cdots = H(s_n) \mod \ell$.

Then all strings are stored in the same linked list. Linked list becomes very slow.
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But implementors are unhappy: this solution throws away the simplicity of hash tables.
Non-solution:
Use SHA-3 for $H$.
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Why this is bad: $H(s) \mod \ell$ is not collision-resistant.

$\ell$ is small: e.g., $\ell = 2^{20}$.
No matter how strong $H$ is, attacker can easily compute $H(s) \mod 2^{20}$ for many $s$ to find multicollisions.
1977, Carter–Wegman, “Universal classes of hash functions”: “This paper gives an *input independent* average linear time algorithm for storage and retrieval on keys. The algorithm makes a random choice of hash function from a suitable class of hash functions.”

2003 Crosby–Wallach: About 6 cycles/byte on P2 for
\[ H(m_1, m_2, \ldots, m_{12}) = m_1 k_1 + m_2 k_2 + \cdots + m_{12} k_{12}. \]
\( k_1, k_2, \ldots, k_{12} \): random, 20-bit. This is “provably secure”!
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Advanced hash flooding: use, e.g., server timing to detect hash collisions; figure out the hash key; choose inputs accordingly.

2005 Crosby: Maybe trouble for any function with a short key, and for $m_1 k_1 + m_2 k_2 + \cdots$. 
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Finding $n$-collision in $H(s) \mod \ell$ requires trying $\approx nl \approx n^2$ inputs. Damage is only $\sqrt{\text{communication}}$. 
The importance of overhead

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Wow, MD5 is really fast;
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The hash-table perspective:
These speed advertisements
are only for long inputs,
ignoring huge overheads!
This is SipRound. Next page: SipHash-2-4 applied to 16 bytes.
Much more in paper:
- Specification: padding etc.
- Discussion of features.
- Statement of security goals.
- Design rationale and credits.
- Preliminary cryptanalysis.
- Benchmarks. e.g. Ivy Bridge: 1.65 cycles/byte + 27 cycles.

Positive SipHash reception: many third-party implementations; now used for hash tables in Ruby, Redis, Rust, OpenDNS, Perl 5.