Cryptographic Hash Function

Cryptographic Hash Function

- Also called
  - One-way Hash function
  - Message Digest
  - One-way Hash Digest
  - Hash Digest
- Strictly speaking the term digest refers to the output of the function.
- So the term ‘cryptographic’ is sometimes understood (assumed) to be present and not explicitly used.

Cryptographic Hash Function

- “A Hash function is a function that can be used to map data of arbitrary size to data of a fixed size.”
- “The values returned by a hash function are called hash values, hash codes, digests, or simply hashes.”
- A cryptographic hash function is a hash function with a particular set of properties.

Four Properties of a Cryptographic Hash Function

- It is easy to compute the hash value for any given message.
- It is infeasible to modify a message without hash being changed.
- It is infeasible to find a message that has a given hash (invert the function)
- It is infeasible to find two different messages with the same hash (collision/clash)

Cryptographic Hash Function

- Normally a bunch of steps that mangle the input in a particular way.
- 'first 32 bits of the fractional parts of the cube roots of the first 64 primes'
- Lots of xor, rightshift, rightrotate, and operations
- Works on 512 bit chunks at a time.

Hash Sizes

Hash sizes

- Should hash values be for example 32 or 64 or 128, 256, 512 bits?
- We want to determine the minimum hash sizes required so for example
  - it is not feasible to find a string that hashes to a particular hash value.
  - it is not feasible to find two strings that hash to the same value (collision).

Throw a Dice

- Find the average number of throws before throwing a 6.
  - $P(6) = 1/6$
  - $P(x,6) = 5/6 . 1/6$
  - $P(x, x, 6) = 5/6 . 5/6 . 1/6$

- $P(k) = (1-p)^{k-1} p$
- [Prob that k throws required to throw a 6]

Throw a Dice

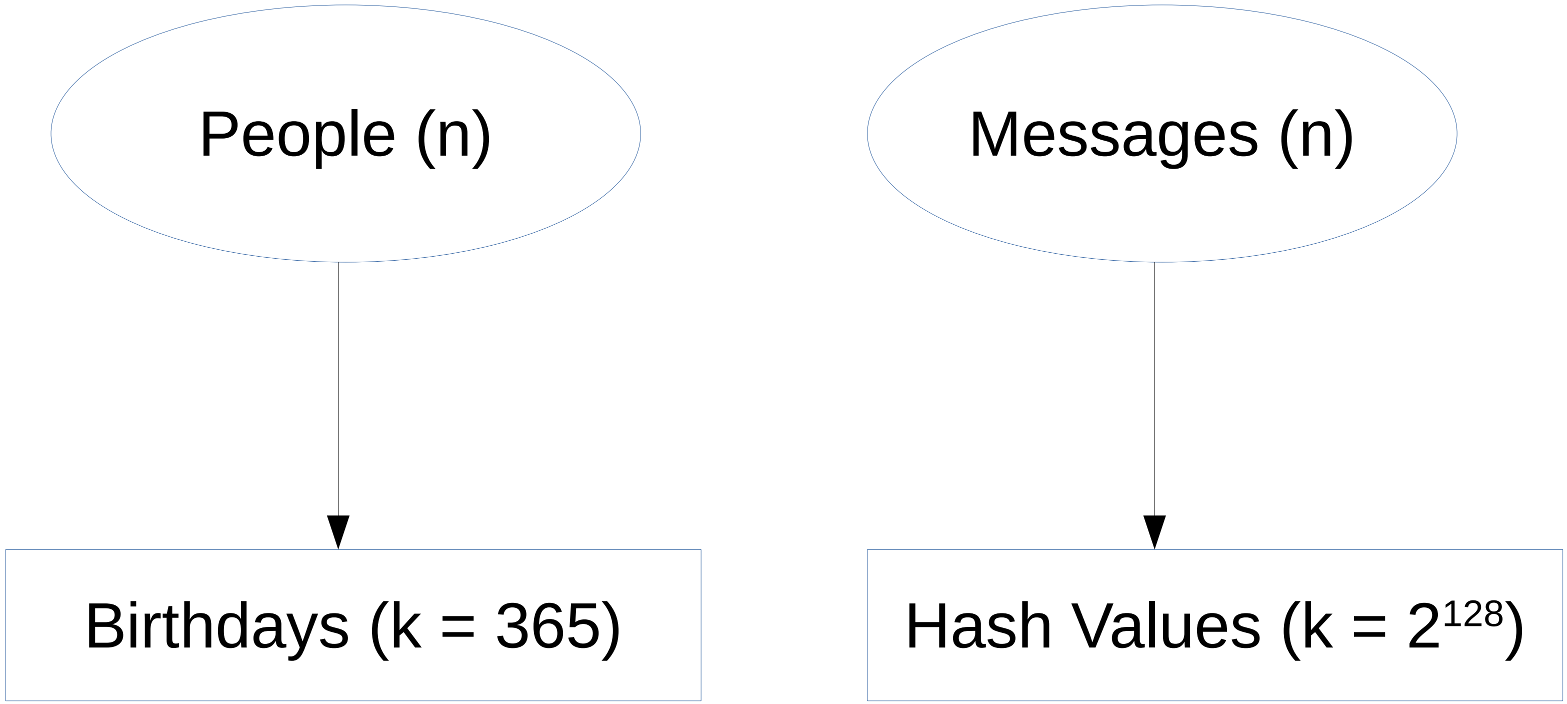
- Expected value of the number of throws required to throw a 6.
- $E(k) = \Sigma\ k \cdot P(k)$

  $= 1.\ P(1) + 2.P(2) + 3.\ P(3) + \ldots$

Result

$E(k) = k$ (i.e. 6)

Birthdays & Cryptographic 64 bit Hash Values



Birthdays - Invert

- n – number people in a room (corresponds to messages)
- k - number outcomes
  - birthdays, k = 365
  - (corresponds to hash values)
- The expected number of people required so that we have someone with a particular birthday is also equal to k (365).

Hash Values - Invert

- Hash size – 128 bits
- Number hash values – 2^{128}
- The expected number of messages that we need to generate to find a message with a particular hash value is 2^{128}
- This is not feasible.
  - 2^{64} > number of seconds since the big bang.
  - 2^{33} ~ fastest clock speed for a processor

Birthdays – Clash

- For a room of n people there are n(n-1)/2 pairs of people [pairs ~ O(n2)].
- For 20 people there are ~ 400 pairs.
- (For 30 people there are 435 pairs)
- Each pair has a 1/365 chance of having the same birthday. Need 366 pairs for a 50% chance of a clash.
- Therefore need only about 30 people to have a better than 50% chance of birthday clash
- Need only ~ sqrt(365) for a 50% chance of a clash.

Hash Values - Clash

- Hash size – 128 bits
- Number hash values – 2^{128}
- The expected number of messages that we need to generate to find two message with the same hash value is $\text{sqrt}(2^{128}) = 2^{64}$
- This is feasible.
- => 128 bit hash is not safe.
- (Messages with the same hash values have been generated)

Hash Sizes

- So hash algorithm must be greater than 128 bits, to be safe.
- MD5 is 128 bit hash but was broken (shown not to be collision resistant) in 2004 and many times since.
- No longer considered safe.
- SHA algorithms now preferred.
- Conclusion – hash sizes should be greater than 128.

Uses of Hash/Message Digests

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- File CheckSums
- Password Hashing
- Message Integrity (HMAC)
- Digital Signature Efficiency

File CheckSums

- Often software to be downloaded have a MD5 and SHA-256 message digest quoted.
- Can be used to verify if you have the exact/correct copy of the software.

Password Hashing

- Passwords should not be stored in cleartext.
- They are hashed and the hash value is stored.
- When authenticating a user, the password supplied by the user is hashed and then compared with the stored has value.
- So even if the password database is compromised, this is of no use to the attacker.
- [Due to 'dictionary attacks' a salted hash should be used.]

Digital Signature Efficiency

- (Later). Hashes are used in digital signatures.
- You sign (encrypt with private key) a hash of a message rather than the message itself.
- Public/private key algorithms are computationally expensive.

Hash Digests / Java

Base64 Encoding

- A way of encoding binary data as text.
- Binary data is split into 6 bit parts with padding if necessary.
- (Padding is necessary if the number of bytes is not divisible by 3.)
- Each of these 6 bit values is represented by one of 64 characters.
- [$2^6 = 64$]

Base64 Encoding

Value	Char
0	A
1	B
25	Z
26	a
51	z
52	0
61	9
62	+
63	/

Base64 Encoding

- Binary values are padded with zeros.
- Zeros at the end ot the Base64 string are encoded as “=”.

Base64 Encoding and Decoding

```
String s = "qwerty" ;
byte[] sBytes = s.getBytes() ;
String encodedString = Base64.getEncoder().encodeToString(sBytes);
System.out.println("s is: " + s + "  Encoded: " + encodedString);

byte[] decodedBytes = Base64.getDecoder().decode(encodedString);
System.out.println("Encoded: " + encodedString +
                                        "  Decoded: " + new String(decodedBytes));



Outout:
s is: qwerty  Encoded: cXdlcnR5
Encoded: cXdlcnR5  Decoded: qwerty
```

Base64 Encoding and Decoding

Outout:
s is: qwerty Encoded: cXdlcnR5
Encoded: cXdlcnR5 Decoded: qwerty

Another example
s is: qwertyu Encoded: cXdlcnR5dQ==
Encoded: cXdlcnR5dQ== Decoded: qwertyu

Message Digests

Example – MD5

```
public class A1MessageDigestEx {
  public static void main(String[] args) {

    String password = "12345";
    MessageDigest algorithm = null;
    try {
      algorithm = MessageDigest.getInstance("MD5");
    } catch (NoSuchAlgorithmException e) {
      e.printStackTrace();
    }

    algorithm.reset();
    algorithm.update(password.getBytes());
    byte[] messageDigest = algorithm.digest();
```

Example – MD5 (cont)

```
    System.out.println("length " + messageDigest.length);

    String encodedDigest = Base64.getEncoder().encodeToString(messageDigest);;
    System.out.println("Base64 encoded message digest " + encodedDigest);

  }
}
```

java.security.MessageDigest

- update() - adds data to be hashed
- reset() - clears the data (not necessary in this case)
- digest() – calculates the hash digest

Apache Commons Codec Library

- commons-codec-1.6.jar
- http://commons.apache.org/codec/apidocs/index.html
- Has some convenience methods for getting digests.

Example – Apache Commons Codec Library

```
import org.apache.commons.codec.digest.DigestUtils;

public class E2MessageDigestEx {

      public static void main(String[] args) {

       String sessionid = "12345";
       String md5 = DigestUtils.md5Hex(sessionid);
       System.out.println("sessionid " + sessionid  +
                            " md5 version is " + md5);
       String sha256 = DigestUtils.sha256Hex(sessionid);
       System.out.println("sessionid " + sessionid +
                            " sha256 version is " + sha256);
      }
}
```

Summary

- What is a Hash Digest (or one way hash)
- Properties of a Hash Digest
- What size should a hash digest be.
- Uses of a Hash Digest