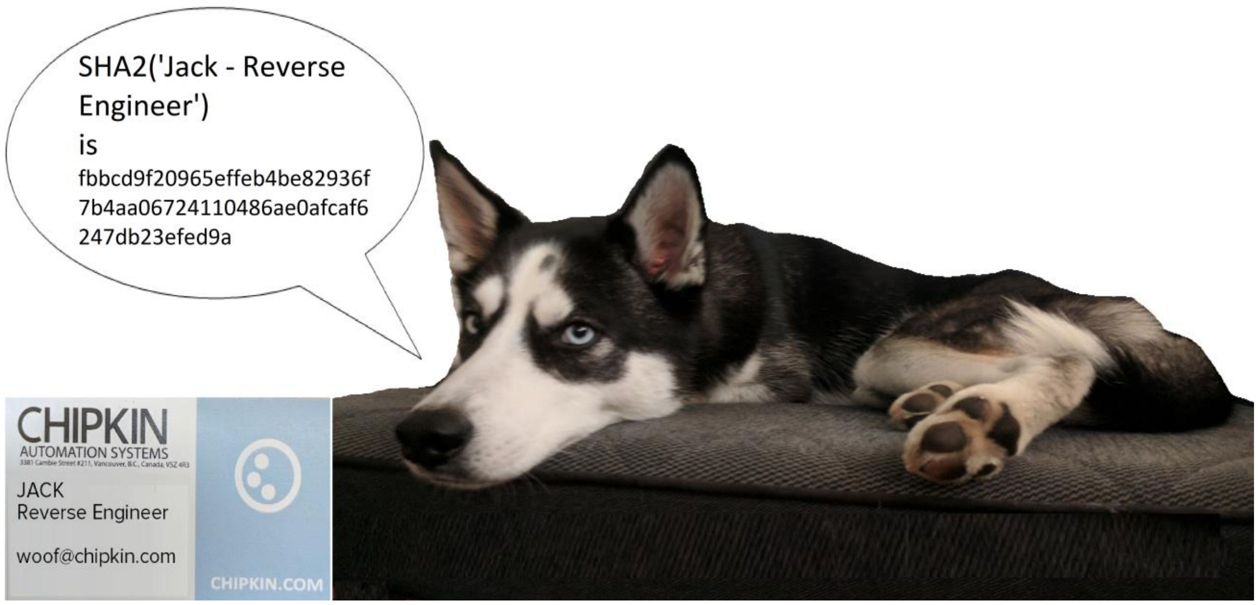
Checksums and Hash’s

The roots of the blockchains.

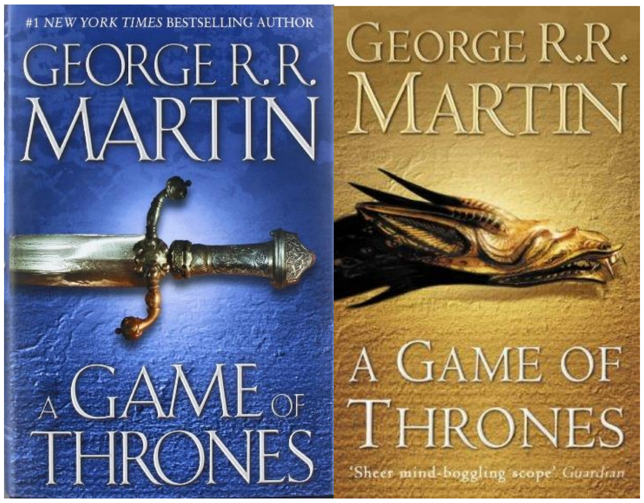
Peter Chipkin


SHA2('Jack - Reverse Engineer') is fbbcd9f20965effeb4be82936f7b4aa06724110486ae0afcaf6247db23efed9a
CHIPKIN AUTOMATION SYSTEMS
JACK
Reverse Engineer
woof@chipkin.com
CHIPKIN.COM

Contents

Introduction

How do you compare two editions of the same book to see that they contain the same text.


#1 NEW YORK TIMES BESTSELLING AUTHOR
GEORGE R.R. MARTIN
A GAME OF THRONES
GEORGE R.R. MARTIN
A GAME OF THRONES
'Sheer mind-boggling scope' Guardian

Method 1 – word for word comparison

Method 2 – Feed both into a hashing algorithm. If the hashes are the same then the books are the same.

So what is hashing?

In simple terms, hashing means taking an input string of any length and giving out an output of a fixed length. A hashing algorithm is a mathematical function that condenses data to a fixed size.

Credit Card Numbers

Credit card numbers are often typed in, input, transferred and quoted. All of this transmission can cause errors, especially considering that humans are involved. Humans often make mistakes in transferal. To try and minimize this, credit card numbers contain a check digit.

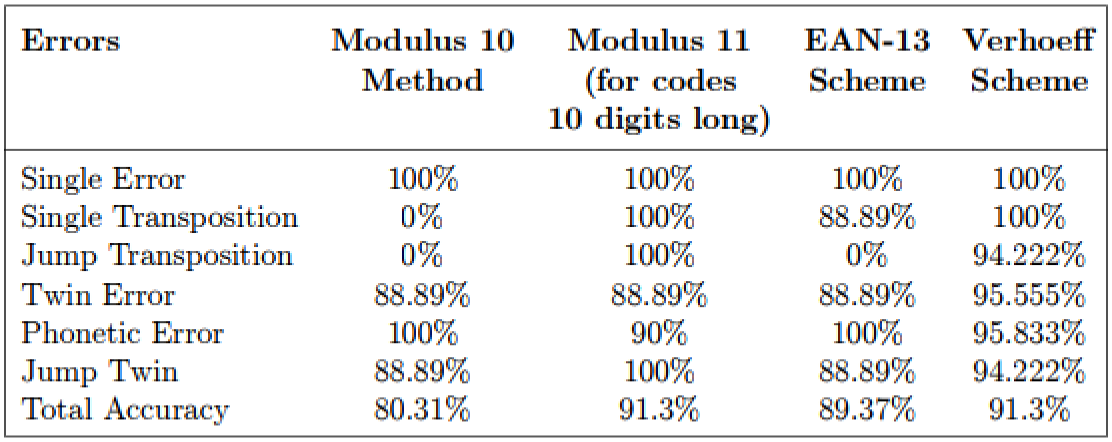
16 Digit Credit Card numbers actually contain a 15 digit number. The last digit, the 16th, is calculated using the other 15 digits and a special formula.

The formula is specially designed to catch the common errors that are made by humans when they type their number in. Like transposing – switching 2 digits around.

5457623898234113

Measuring Success

On the table below you can see the Moduslus11 checksum detects 100% of ‘Single Error’, ‘Single Transposition’ ….. In other words, Moddulus11 is truly excellent at its job



Errors	Modulus 10 Method	Modulus 11 (for codes 10 digits long)	EAN-13 Scheme	Verhoeff Scheme
Single Error	100%	100%	100%	100%
Single Transposition	0%	100%	88.89%	100%
Jump Transposition	0%	100%	0%	94.222%
Twin Error	88.89%	88.89%	88.89%	95.555%
Phonetic Error	100%	90%	100%	95.833%
Jump Twin	88.89%	100%	88.89%	94.222%
Total Accuracy	80.31%	91.3%	89.37%	91.3%

Checksums in Data Communications

We don't choose checksums, the protocols we use do. But what if were designing a protocol from scratch ?

CHIPKIN has reviewed the science for you.

Here are the main conclusions.

1. Ethernet, TCP and IP Checksums in almost all cases make the protocol checksum redundant.
2. If your data isn't random you should take care not to assume general purpose checksums are applicable.

Example – you choose to use CRC as a protocol checksum for messages relayed over TCP/IP. This could be an error because CRCs are particularly good at detecting common errors caused by noise in transmission channels. That is your least likely source of error on an ethernet packet so your choice of checksum seems inappropriate.

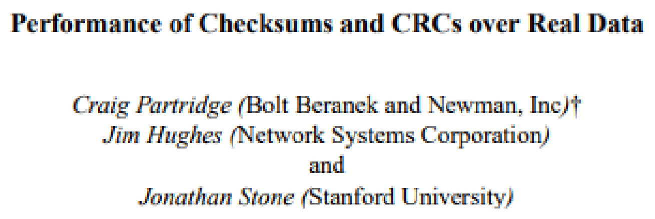
IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING, VOL. 6, NO. 1, JANUARY-MARCH 2009 59

The Effectiveness of Checksums for Embedded Control Networks

Theresa C. Maxino, *Member, IEEE*, and Philip J. Koopman, *Senior Member, IEEE*

Conclusions :

The error detection properties of checksums vary greatly. The probability of undetected errors for a k-bit checksum is not always 1=2k in realistic networks as is sometimes thought. Rather, it is dependent on factors such as the type of algorithm used, the length of the code word, and the type of data contained in the message. The typical determining factor of error detection performance is the algorithm used, with distinct differences evident for short messages typical of embedded networks.



Performance of Checksums and CRCs over Real Data

Craig Partridge (Bolt Beranek and Newman, Inc)†
Jim Hughes (Network Systems Corporation)
and
Jonathan Stone (Stanford University)

Conclusions :

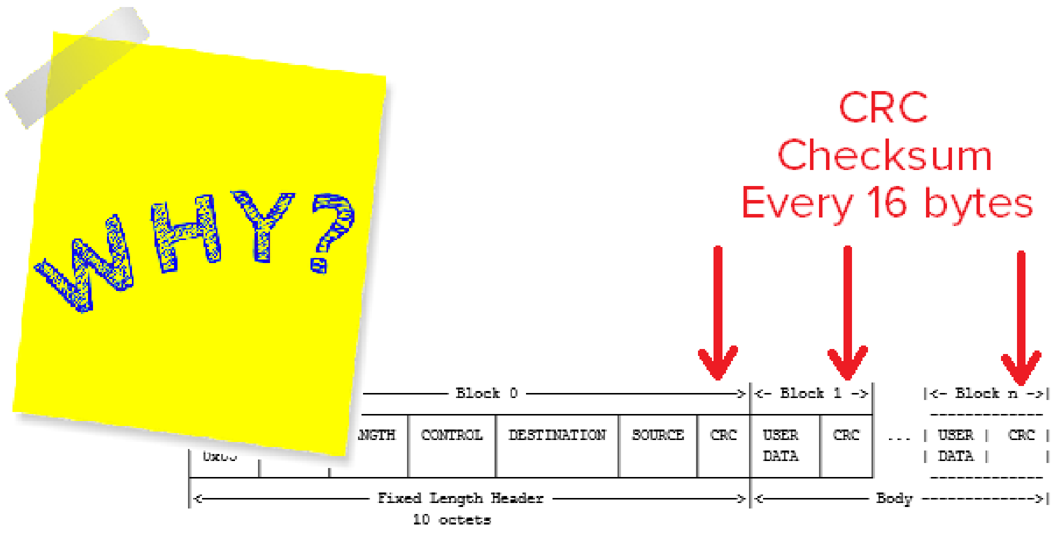
Checksum and CRC algorithms have historically been studied under the assumption that the data fed to the algorithms was uniformly distributed. This is false.

What this work simply shows is that checksums are even less effective error detection method than first thought, because real data is not random, and in particular, contains a lot of zeros.

We also suggest that protocol designers consider avoiding the practice of placing checksums in a protocol header, but instead append them as a trailer to the data being checksummed. …

Checksums gone nuts

Consider a DNP3 (the protocol use in the power generation and distribution business) packet. The protocol designers went mad. ‘



Checksum or Hash – Jargon Watch

We call a hash that has been designed to detect data transmission errors and which are embedded in the data – we name these checksums.

It also depends where you live. If you live in a world of block chain nerds you will be talking about hash's. If you live in a room of embedded communications people then you will be talking about checksums. Checksums tend to be one or two bytes long. Most commonly used hash's in 2017 are 16 or 32 bytes long).

What is a hash (and checksum) – A simple example

Say each letter of the alphabet has a number assigned to it.

A=1 , B=2 etc

Then

Adam = 1,4,1,13

With Hashing Rule = sum all the letters

hash = 1 + 4 + 1 + 13 = 19

With Hashing Rule = sum all the letters and take the last digit of the sum

1 + 4 + 1 + 13 = 19 , last digit = 9 therefore hash = 9

This hashing rule make the hash fixed length.

- A "hash" (also called a "digest", and informally a "checksum") is a kind of "signature" for a stream of data that represents the contents.
- Hashes are "digests", not "encryption"
- Encryption transforms data from a cleartext to ciphertext and back (given the right keys)
- "Encryption" is a two-way operation. Hashing is not.

File Hashing

The publisher provides the file to download and the MD5 hash of the file.

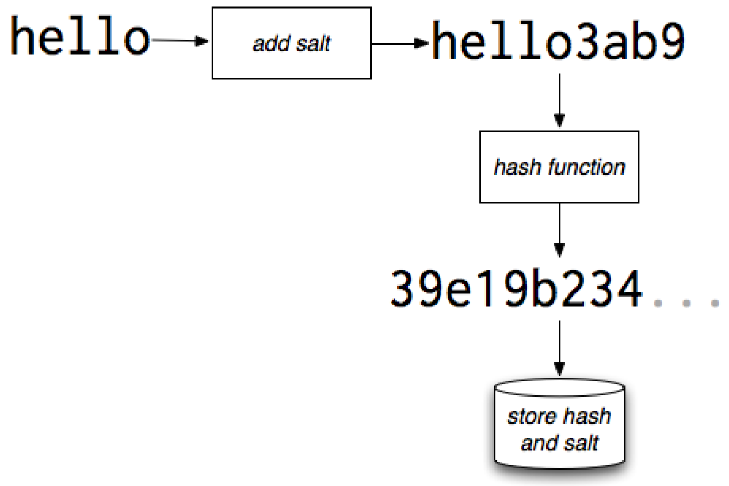
You download the file. You calc the MD5 hash. You compare it to the publishers. Now you know you have the authentic file.

Used to use MD5 but now that is considered cracked.

Now often use PGP signatures.

Password Hashing

- It's a bad idea for computer systems to store passwords in cleartext (in their original form)
- A more secure way is to store a hash of the password, rather than the password itself.
- Since these hashes are not reversible, there is no way to find out for sure "what password produced this hash?" - and the so consequence of a compromise is much lower.
- Also means employees cant steal passwords
- Salt = extra string added to make it a bit harder to reverse.



MD5 Hash

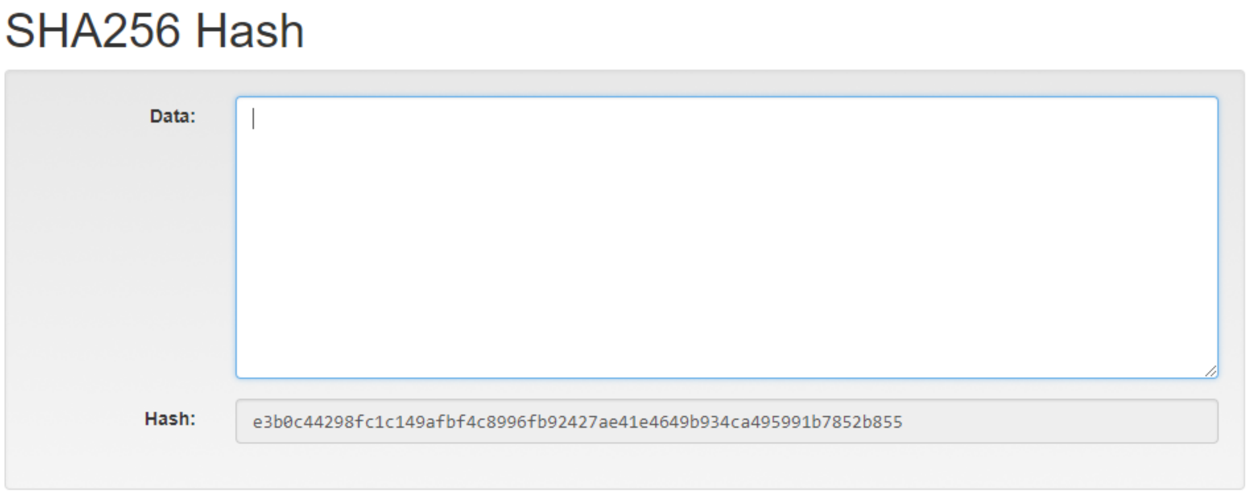
Not considered safe anymore after collisions were found.

SHA256 Hash

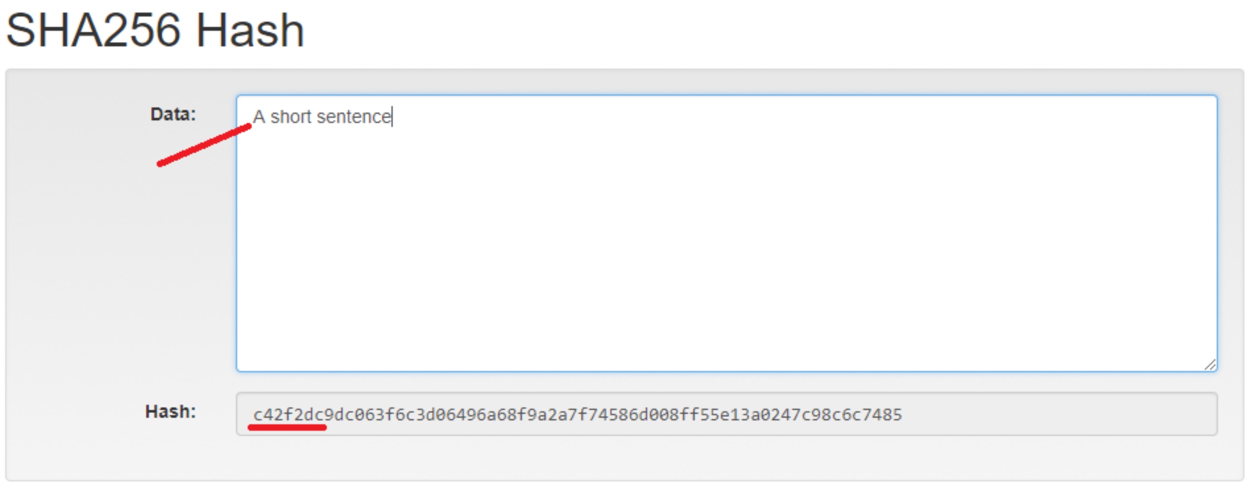
The SHA (Secure Hash Algorithm) is one of a number of cryptographic hash functions. A cryptographic hash is like a signature for a text or a data file. SHA-256algorithm generates an almost-unique, fixed size 256-bit (32-byte) hash.

Hash is a one way function – it cannot be decrypted back.

NOTE: **Tiny change in input produces a big change in the hash.**

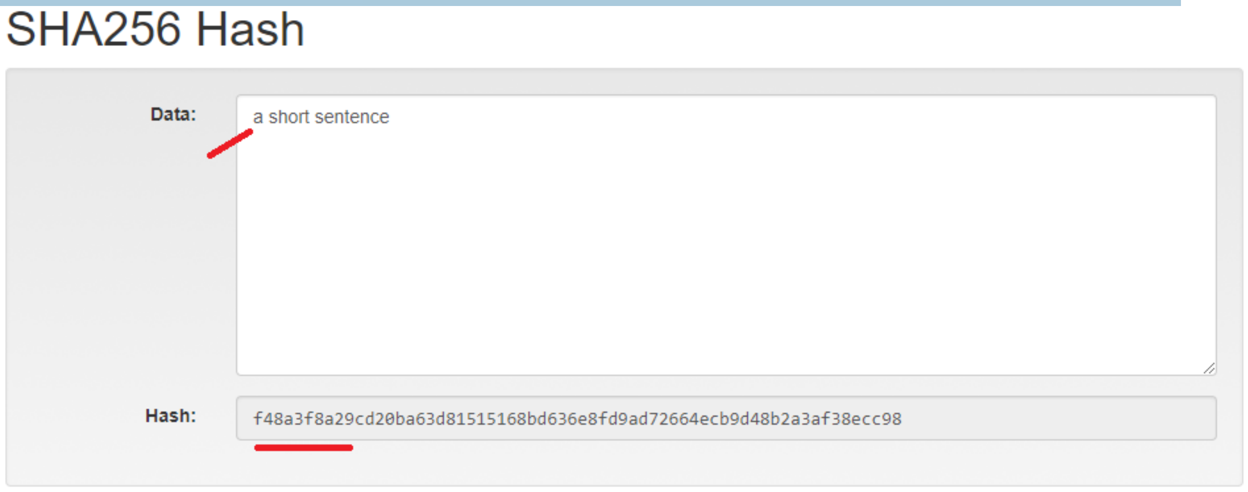


Hash: e3b0c44298fc1c149afbf4c8996fb92427ae41e4649b934ca495991b7852b855



Data: A short sentence

Hash: c42f2dc9dc063f6c3d06496a68f9a2a7f74586d008ff55e13a0247c98c6c7485



SHA256 Hash

Data: a short sentence

Hash: f48a3f8a29cd20ba63d81515168bd636e8fd9ad72664ecb9d48b2a3af38ecc98

AND THEREFORE

From now on we assume that if the hash is different then the input data / text is different.

1. If the hash is the same then the data is the same
2. The assumption is not true but its statistically effective.

As you can see, in the case of SHA-256, no matter how big or small your input is, the output will always have a fixed 256-bits length. This becomes critical when you are dealing with a huge amount of data and transactions.

So basically, instead of remembering the input data which could be huge, you can just remember the hash and keep track. Before we go any further we need to first see the various properties of hashing functions and how they get implemented in the blockchain.

Attributes of a Useful Hash

Attrribute #1 - Deterministic

This means that no matter how many times you parse through a particular input through a hash function you will always get the same result. This is critical because if you get different hashes every single time it will be impossible to keep track of the input.

Attrribute #2 - Quick Computation

The hash function should be capable of returning the hash of an input quickly. If the process isn’t fast enough then the system simply won’t be efficient.

Attrribute #3 - Quick Computation

The hash function should be capable of returning the hash of an input quickly. If the process isn’t fast enough then the system simply won’t be efficient.

Attrribute #4 - Small Changes In The Input Changes the Hash.

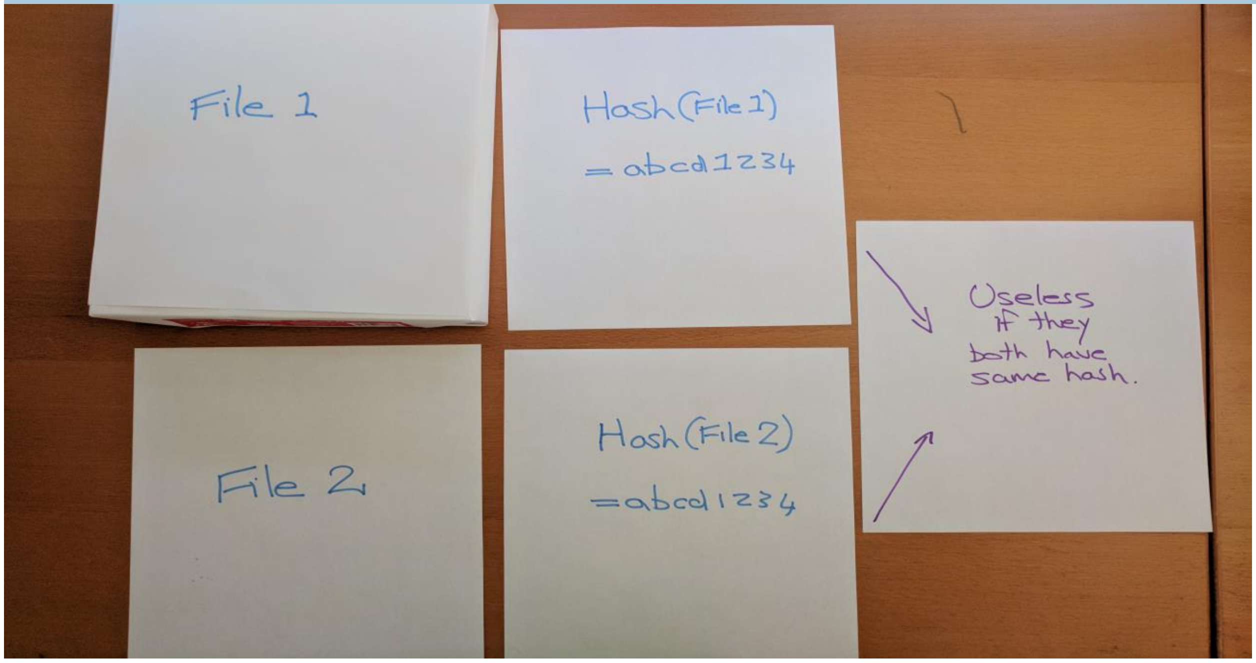
Even if you make a small change in your input, the changes that will be reflected in the hash will be hug

Input	SHA-256 Hash
Test12345	106ac304ae39bc4029db0faf0d1734bd5a1dc2474331e8e17039365847536d7
test12345	6fec2a9601d5b3581c94f2150fc07fa3d6e45808079428354b868e412b76e6bb

Attrribute #5 - Collision Resistant

Given two different inputs A and B where H(A) and H(B) are their respective hashes, it is infeasible for H(A) to be equal to H(B). What that means is that for the most part, each input will have its own unique hash

It is much easier to break collision resistance than it is to break preimage resistance. No hash function is collision free, but it usually takes so long to find a collision. So, if you are using a function like SHA-256, it is safe to assume that if H(A) = H(B) then A = B.



Attrribute #6 - Puzzle Friendly

For every output “Y”, if k is hugely it is infeasible to find an input x such that

H(k concatenated with x) = Y.

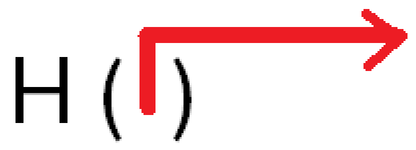
Hash Pointer

The pointer in a block that points to the next block has two components

1. The hash of the previous block header

   AND

2. The pointer to the previous block



How Hash Pointers are drawn

Examples of cryptographic hash functions

There are hundreds of hashing algorithms out there and they all have specific purposes – some are optimized for certain types of data, others are for speed, security, etc.

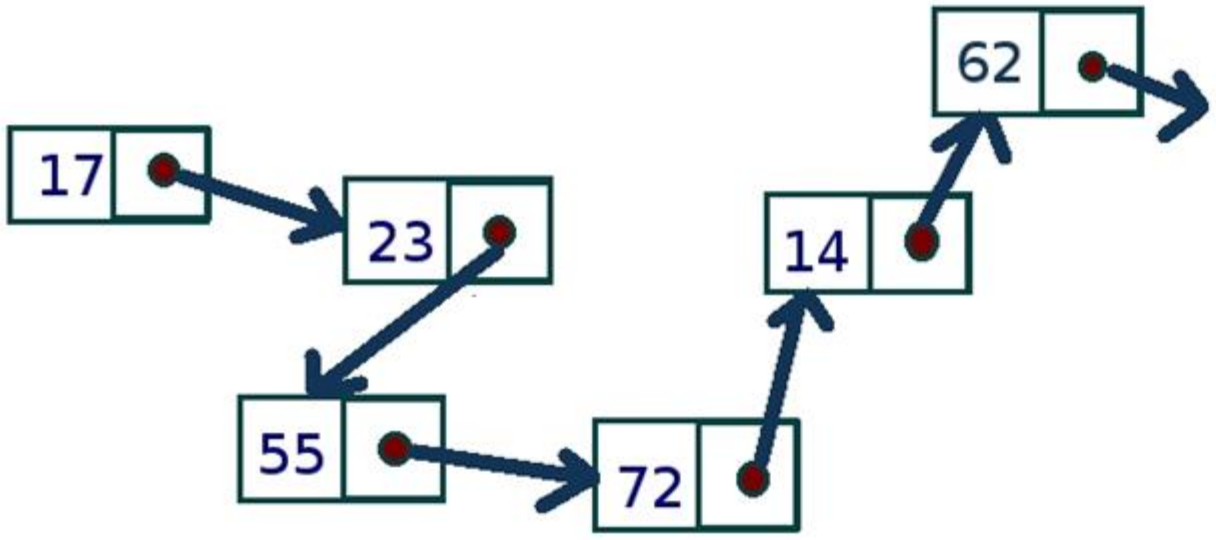
- MD 5: It produces a 128-bit hash. Collision resistance was broken after ~2^21 hashes.
- SHA 1: Produces a 160-bit hash. Collision resistance broke after ~2^61 hashes.
- SHA 256: Produces a 256-bit hash. This is currently being used by Bitcoin.
- Keccak-256: Produces a 256-bit hash and is currently used by Ethereum.

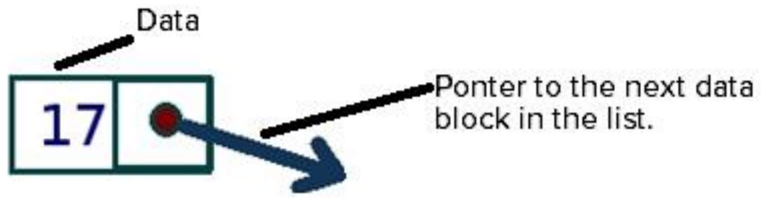
If you see “SHA-2,” “SHA-256” or “SHA-256 bit,” those names are referring to the same thing.

Linked List

Linked lists – Each object contains 2 elements – data and a pointer to the next item in the list.

Big advantage – Logical and physical order are now separate.

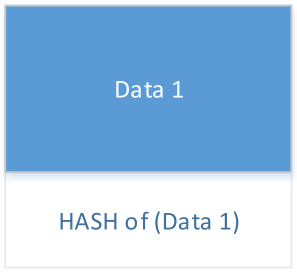




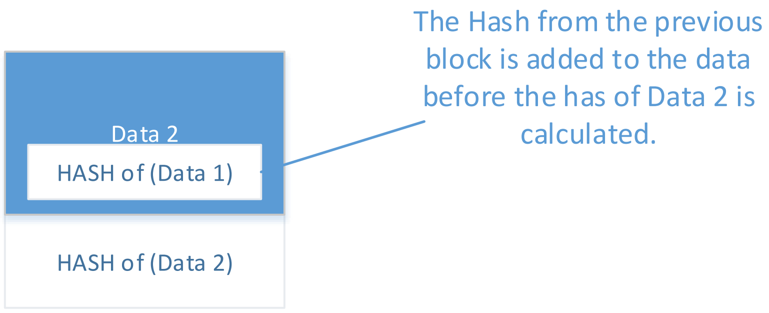
Linked List with Hash Pointers – The Foundation of Block Chain.

Data Block

HASH of this Data and append the Hash to the data.



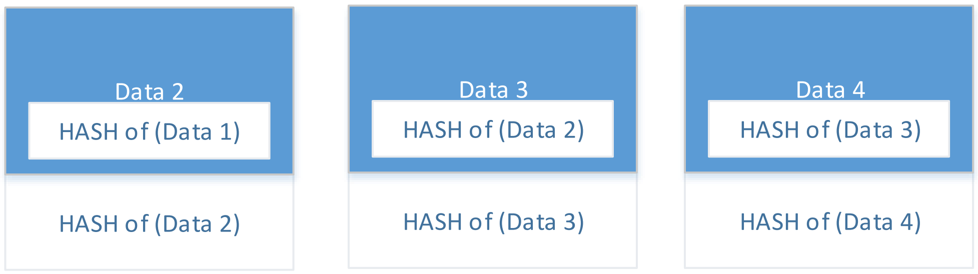
BUT This time before you calc the hash on your own data, you add the hash of the previous block to your data


Data 2
HASH of (Data 1)
HASH of (Data 2)
The Hash from the previous block is added to the data before the has of Data 2 is calculated.

NOW Block 3 knows when block 2 is changed because it knows what block 2 hash should be and it can recalc the hash and compare them.

AND

Block 3 will also know if someone tried to change the order of the blocks or insert a new block because the hash's wont be the same.



PROFOUND = Its easy to tell if anything changed. The data or the order of the blocks. If you can detect change easily then its easier to trust the data.

JARGON WATCH
Block Chain Ledger = Think of the Hashed linked list . This is the ledger.

Hashing Hashes – Building Blocks of the Blockchain ledger.

Merkle Trees

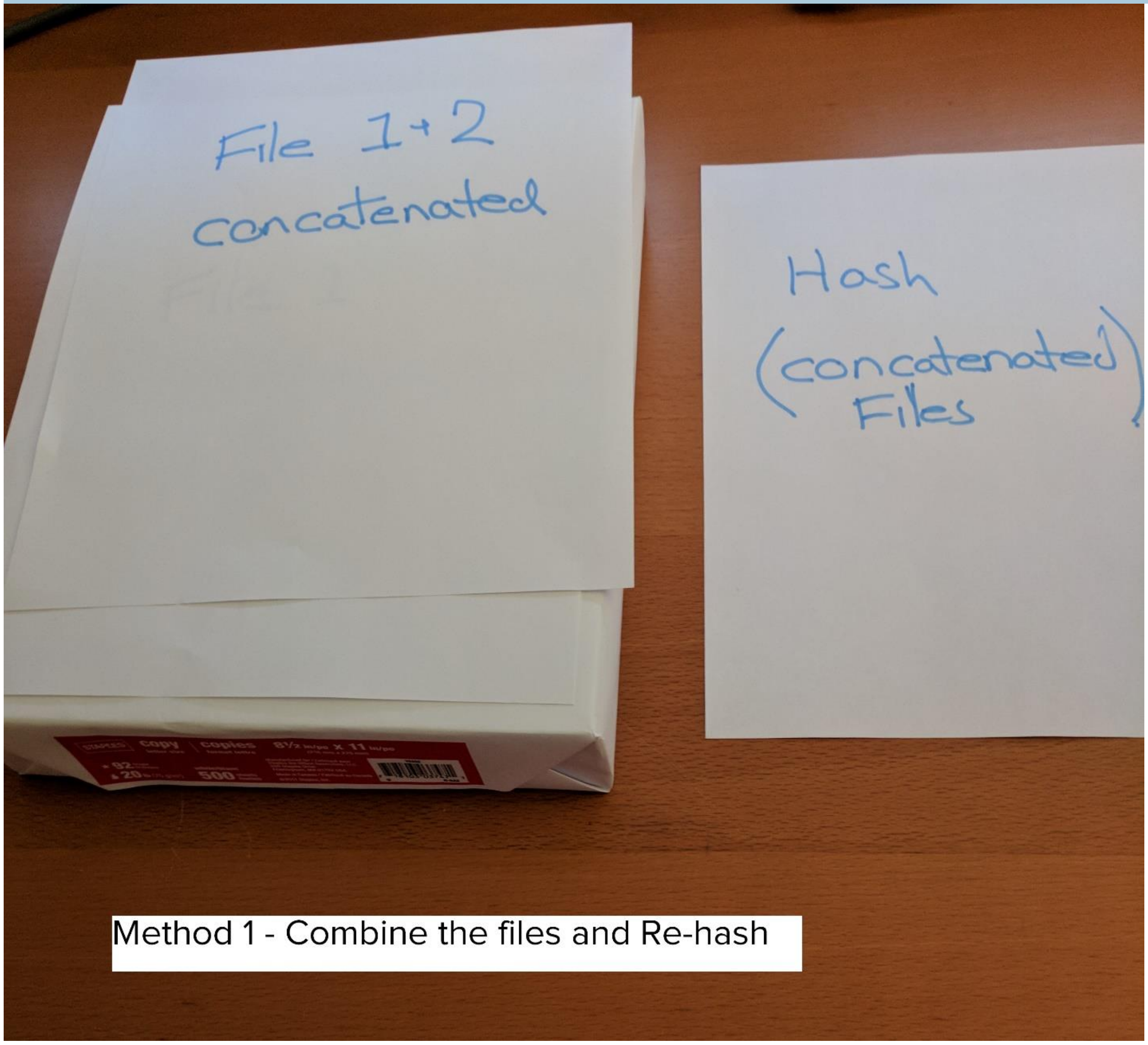
Merkle (a person) realized its easier working with hashes of hashes than with large original blocks of data that keep growing longer. He defined the maths and methods to a specific method of hashing hashes of blocks of data.

Each block contains thousands and thousands of transactions. It will be very time inefficient to store all the data inside each block as a series. Doing so will make finding any particular transaction extremely cumbersome and time-consuming. If you use a Merkle tree, however, you will greatly cut down the time required to find out whether a particular transaction belongs in that block or not.

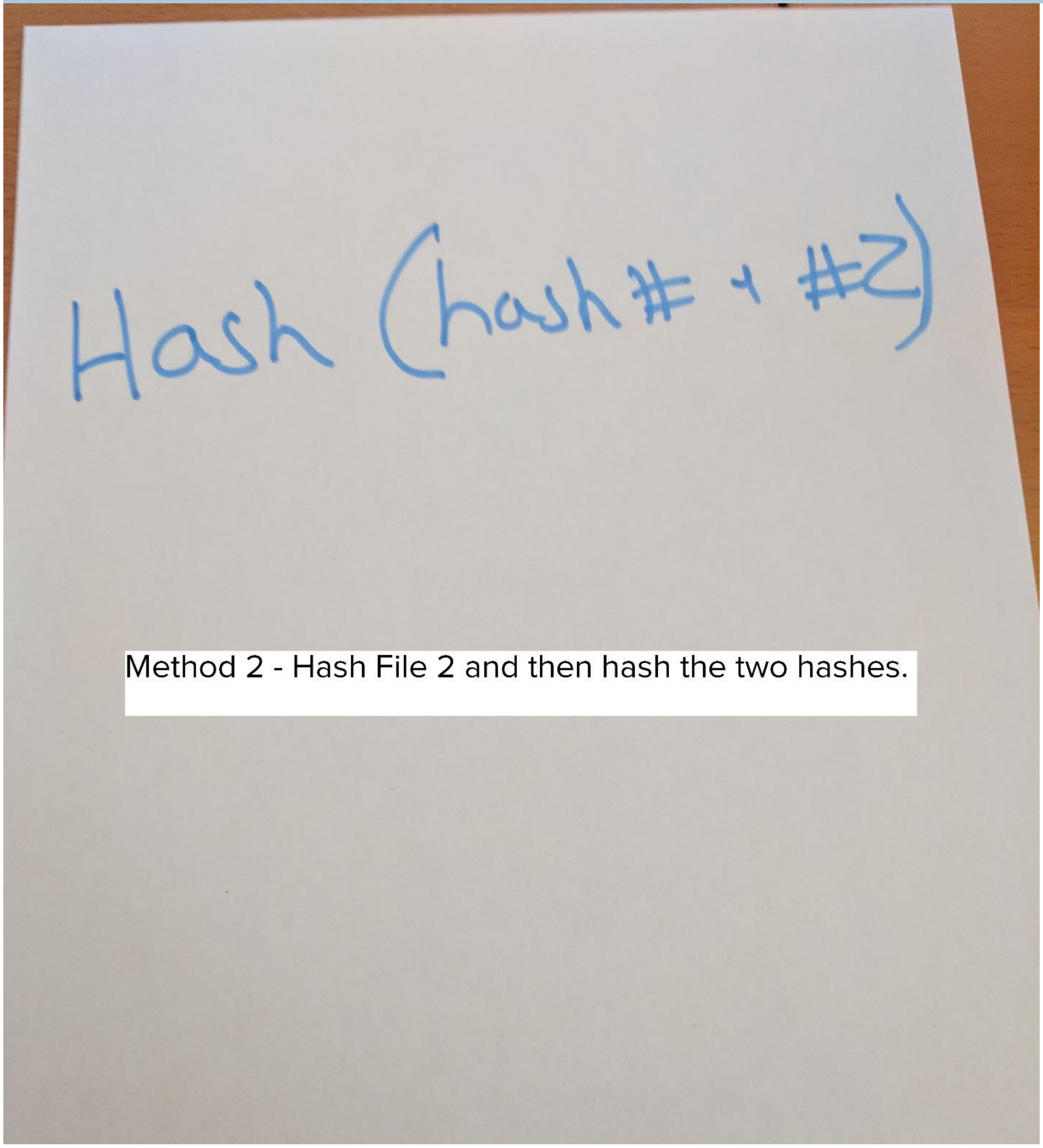
These notes assume that new data/changes are appended rather than edited in place in old data blocks which have already been hashed.

We want to add some data to a file. (Add file 2 to File 2)

File 1
copy
copies
8½ x 11
500
File 2
Add File 2 to File 1



Method 1 - Combine the files and Re-hash



Method 2 - Hash File 2 and then hash the two hashes.

Using a hash tree like a Merkle tree:

1. Significantly reduces the amount of data that a trusted authority has to maintain to proof the integrity of the data.
2. Significantly reduces the network I/O packet size to perform consistency and data verification as well as data synchronization.
3. Separates the validation of the data from the data itself -- the Merkle tree can reside locally, or on a trusted authority, or can itself reside on a distributed system (perhaps you only maintain your own tree.) Decoupling the "I can prove the data is valid" from the data itself means you can implement the appropriate and separate (including redundant) persistence for both the Merkle tree and the data store.

So the answer to the why is three-fold:

1. Merkle trees provide a means of proving that integrity / validity of your data.
2. Merkle trees require little memory / disk space and proofs are computationally easy and fast.
3. Merkle tree proofs and management requires only a very small and terse amount of information to be transmitted across a network.

Merkle trees (and variations) are used to provide:

- consistency verification
- data verification
- data synchronization

Consistency Verification

Merkel or Hash trees allow for easy consistency validation.

Instead of comparing the data, you compare the tree of hashes. This is fast and easy. It does NOT prove the data is the same but it proves the hash trees are consistent.

A "consistency proof" lets you verify that any two versions of a Hash Tree are consistent:

1. the later version includes everything in the earlier version
2. ...in the same order
3. ...and all new records come after the records in the older version

"If you can prove that a Hash Tree is consistent it means that:

- no certificates [records] have been back-dated and inserted into the Hash Tree
- no certificates have been modified in the Hash Tree,
- and the Hash Tree has never been branched or forked.

It is time consuming and computationally expensive to check the entirety of each file whenever a system wants to verify data. So, this why Merkle trees are used. Basically, we want to limit the amount of data being sent over a network (like the Internet) as much as possible. So, instead of sending an entire file over the network, we just send a hash of the file to see if it matches. The protocol goes like this:

1. Computer A sends a hash of the file to computer B.
2. Computer B checks that hash against the root of the Merkle tree.
3. If there is no difference, we're done! Otherwise, go to step 4.
4. If there is a difference in a single hash, computer B will request the roots of the two subtrees of that hash.
5. Computer A creates the necessary hashes and sends them back to computer B.
6. Repeat steps 4 and 5 until you've found the data blocks(s) that are inconsistent. It's possible to find more than one data block that is wrong because there might be more than one error in the data.

Data Synchronizaton

Merkle trees are useful in synchronizing data across a distributed data store because it allows each node in the distributed system to quickly and efficiently identify records that have changed without having to send all the data to make the comparison.

Making A Merkle Tree

They are binary.
Take any 2 records and calculate the hash of each.

Allocate a parant node to the two records (leaves)

In that node store the hash of the two child hashes.

Repeat until every 2 records (it's a binary process) has a parant

Repeat until each 2xparants have a parant

Repeat until you have reached the top of the pyramid. This is called the Root Node.

Merkle Tree More Reading

https://brilliant.org/wiki/merkle-tree/