

# CS61065: Theory and Applications of Blockchain

## Basic Crypto Primitives - I

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# What You'll Learn

- Basic cryptographic primitives behind the blockchain technology
  - **Cryptographically Secure Hash Function**
  - **Digital Signature**
- **Hash Function:** Used to connect the “blocks” in a “chain” in a tamper-proof way
- **Digital Signature:** Digitally sign the data so that no one can “deny” about their own activities. Also, others can check whether it is authentic.

# Cryptographic Hash Functions

- Takes any arbitrarily sized string as input
  - Input  $M$ : The message
- Fixed size output (We use 256 bits in Blockchain)
  - Output  $H(M)$ : We call this as the message digest
- Efficiently computable

# Cryptographic Hash Function: Properties

- **Deterministic**

- Always yield identical hash value for identical input data

- **Collision-Free**

- If two messages are different, then their digests also differ

- **Hiding**

- Hide the original message; remember about the **avalanche effect**

- **Puzzle-friendly**

- Given  $X$  and  $Y$ , find out  $k$  such that  $Y = H(X||k)$  - used to solve the mining puzzle in Bitcoin Proof of Work

# Collision Free

- Hash functions are one-way; Given an  $x$ , it is easy to find  $H(x)$ . However, given an  $H(x)$ , cannot find  $x$
- It is **difficult to find**  $x$  and  $y$ , where  $x \neq y$ , but  $H(x) = H(y)$
- Note the phrase **difficult to find**, collision is **not impossible**
- Try with randomly chosen inputs to find out a collision – but it takes too long

# Hash as A Message Digest

- If we observe  $H(x) = H(y)$ , it is safe to assume  $x = y$
- We need to remember just the hash value rather than the entire message – we call this as the **message digest**
- To check if two messages  $x$  and  $y$  are same, i. e., whether  $x = y$ , simply check if  $H(x) = H(y)$ 
  - This is efficient because the size of the digest is significantly less than the size of the original messages

# Hashing - Illustration

- <http://www.blockchain-basics.com/HashFunctions.html>

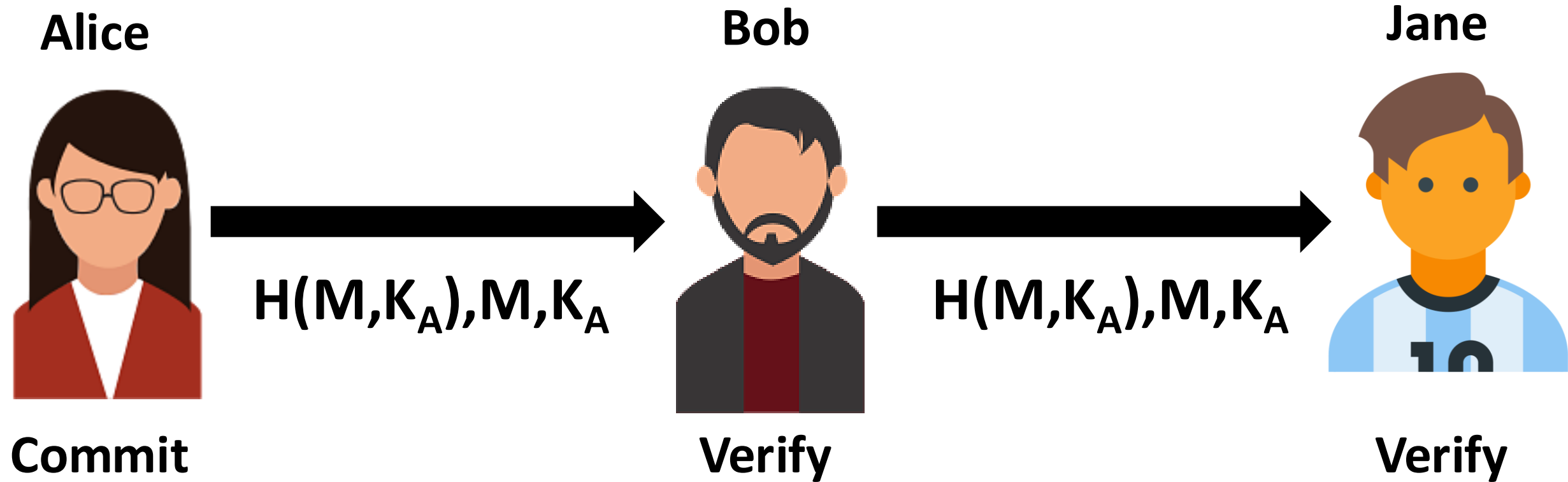
Courtesy: Blockchain Basics: A Non-Technical Introduction in 25 Steps by Daniel Drescher

# Information Hiding through Hash

- Given an  $H(x)$ , it is “computationally difficult” to find  $x$
- The difficulty depends on the size of the message digests
- Hiding helps to commit a value and then check it later
  - Compute the message digest and store it in a digest store – commit
  - To check whether a message has been committed, match the message digest at the digest store



# Message Commitment through Multiple Parties



$K_A$  is the public key of Alice – A public identity that only Alice can have

# Puzzle Friendly

- Say  $M$  is chosen from a widely spread distribution; it is computationally difficult to compute  $k$ , such that  $Z = H(M||k)$ , where  $M$  and  $Z$  are known a priori.
- **A Search Puzzle** (Used in Bitcoin Mining)
  - $M$  and  $Z$  are given,  $k$  is the search solution
  - Note: It might be not exactly a particular value  $Z$ , but some properties that  $Z$  satisfies, i.e.,  $Z$  could be a set of possible values
- Puzzle friendly property implies that random searching is the best strategy to solve the above puzzle

# Hash Function – SHA256

- SHA256 is used in Bitcoin mining – to construct the Bitcoin blockchain
- Secure Hash Algorithm (SHA) that generates 256 bit message digest
- A part of SHA-2, a set of cryptographic hash functions designed by United States National Security Agency (NSA)

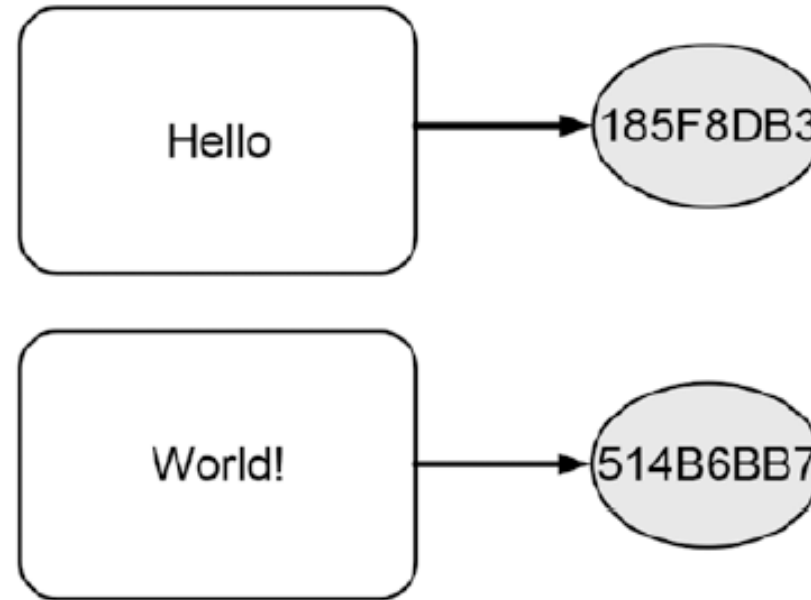
# Patterns of Hashing Data

- Independent hashing
- Repeated hashing
- Combined hashing
- Sequential hashing
- Hierarchical hashing

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# Types of Hashing

- Independent hashing

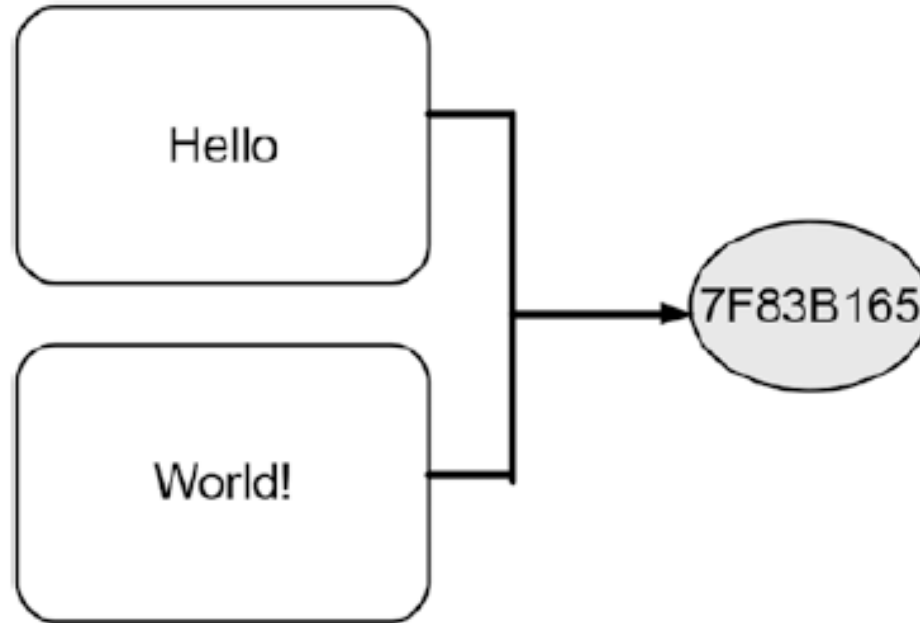


- Repeated hashing

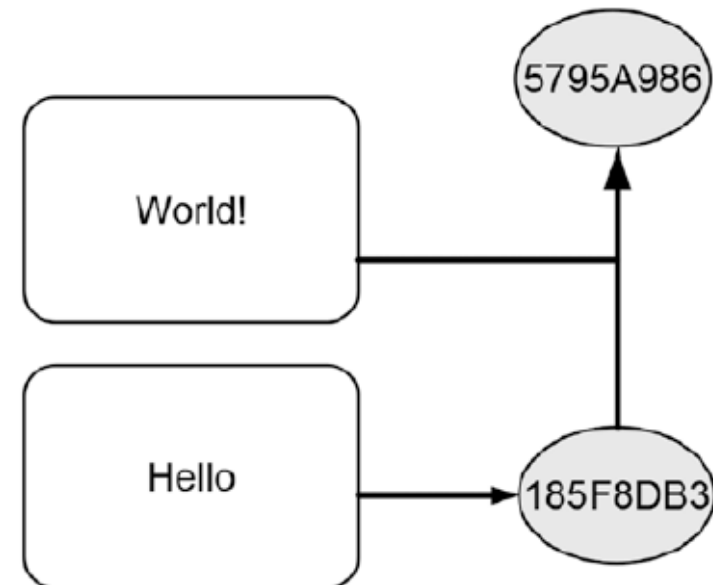


# Types of Hashing

- Combined hashing

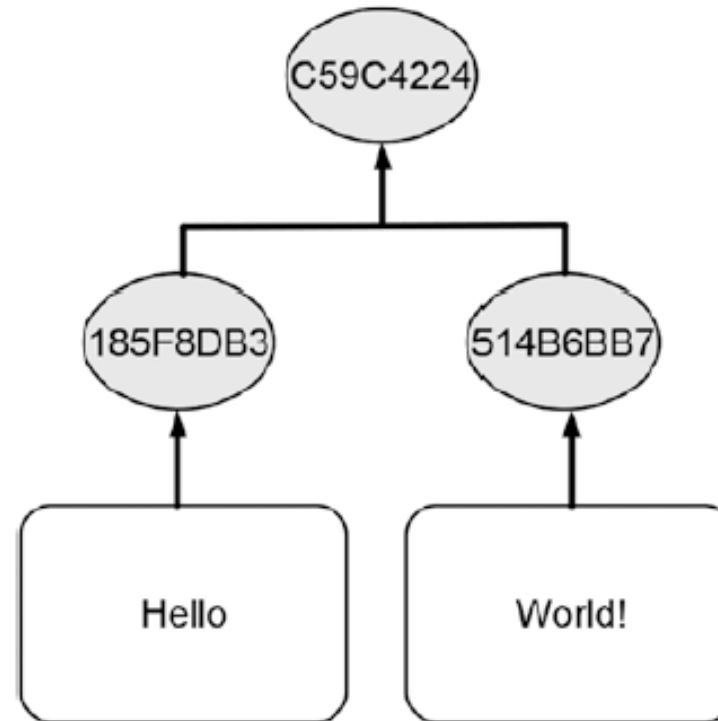


- Sequential hashing



# Types of Hashing

- Hierarchical hashing

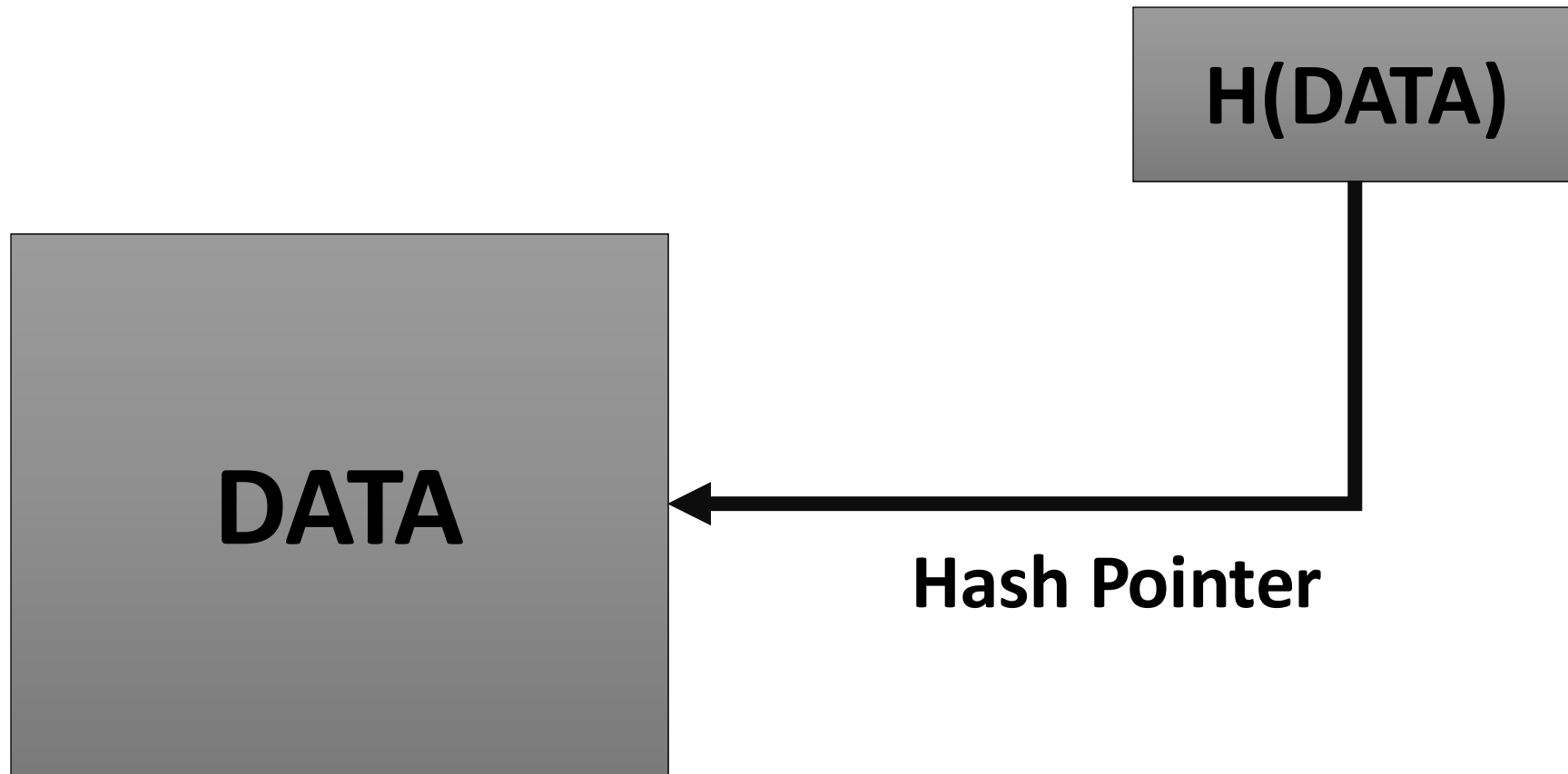


# Hash Pointer

- A **Cryptographic Hash Pointer** (Often called Hash Reference) is a pointer to a location where
  - Some information is stored
  - Hash of the information is stored
- With the hash pointer, we can
  - Retrieve the information
  - Check that the information has not been modified (by computing the message digest and then matching the digest with the stored hash value)



# Hash Pointer



Reminds you of a linked list??

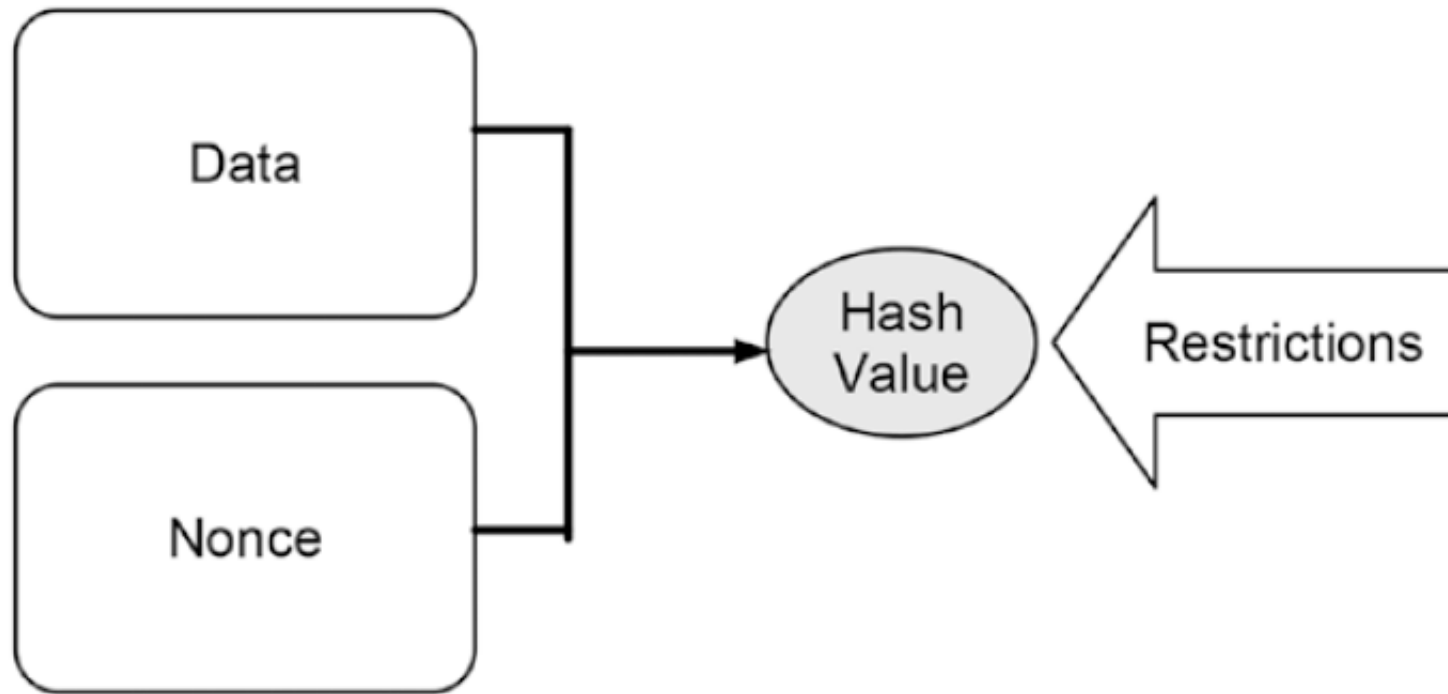
Reference: Coursera course on Bitcoin and Cryptocurrency Technologies

# Tamper Detection using Hash Pointer



Courtesy: Blockchain Basics: A Non-Technical Introduction in 25 Steps by Daniel Drescher

# Making Tampering a Hash Chain Computationally Challenging



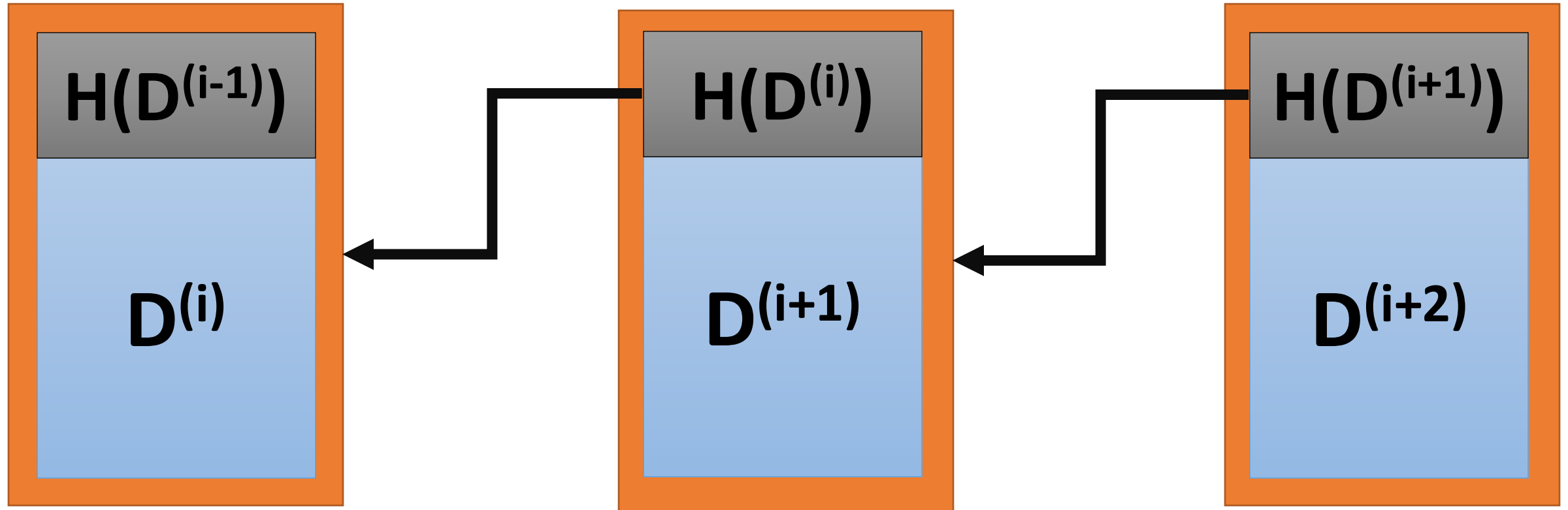
<http://www.blockchain-basics.com/HashFunctions.html>

Nonces for Solving a Hash Puzzle

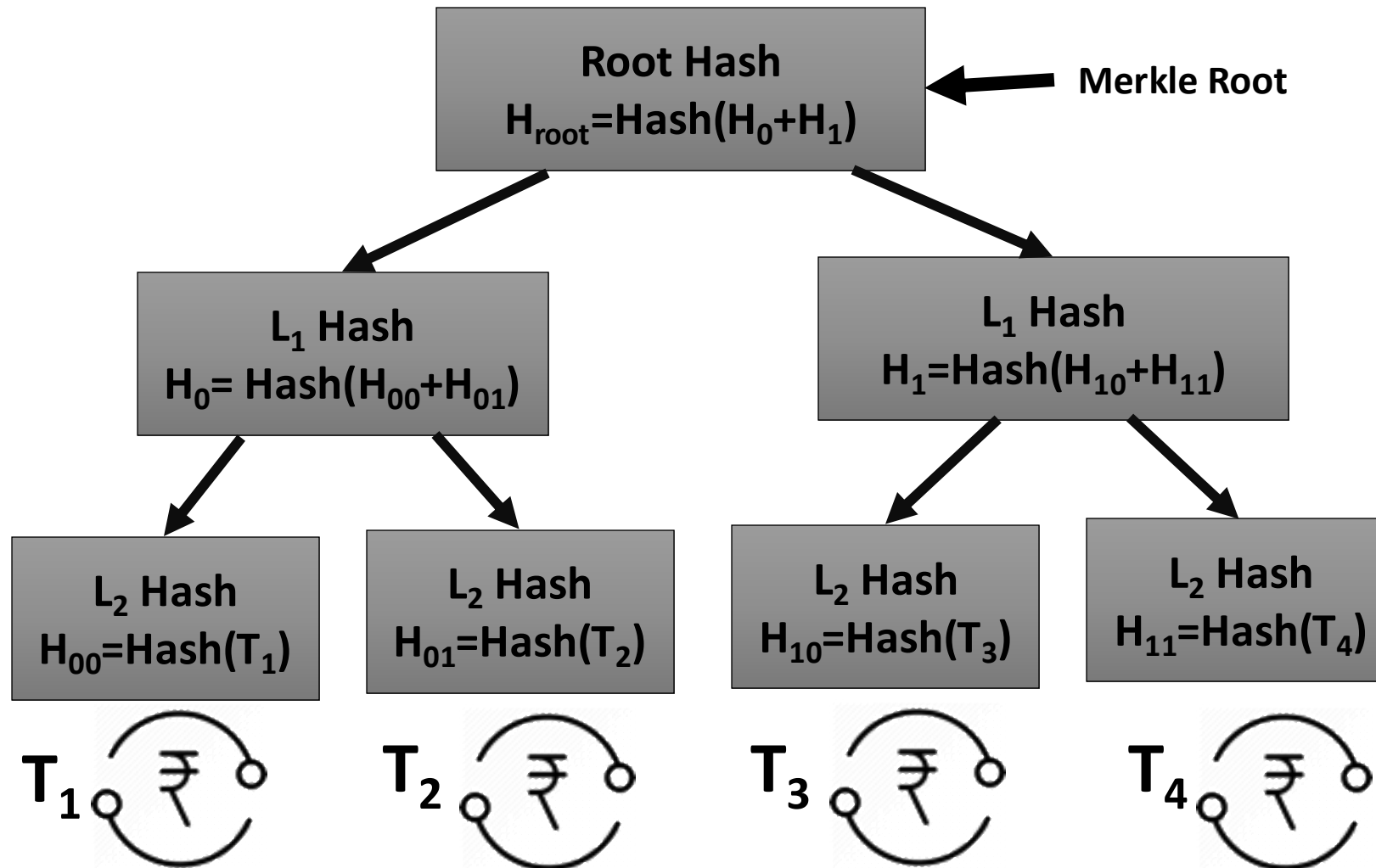
Nonce	Text to Be Hashed	Output
0	Hello World! 0	4EE4B774
1	Hello World! 1	3345B9A3
2	Hello World! 2	72040842
3	Hello World! 3	02307D5F
...		
613	Hello World! 613	E861901E
614	Hello World! 614	<b>00068A3C</b>
615	Hello World! 615	5EB7483F

Courtesy: Blockchain Basics: A Non-Technical Introduction in 25 Steps by Daniel Drescher

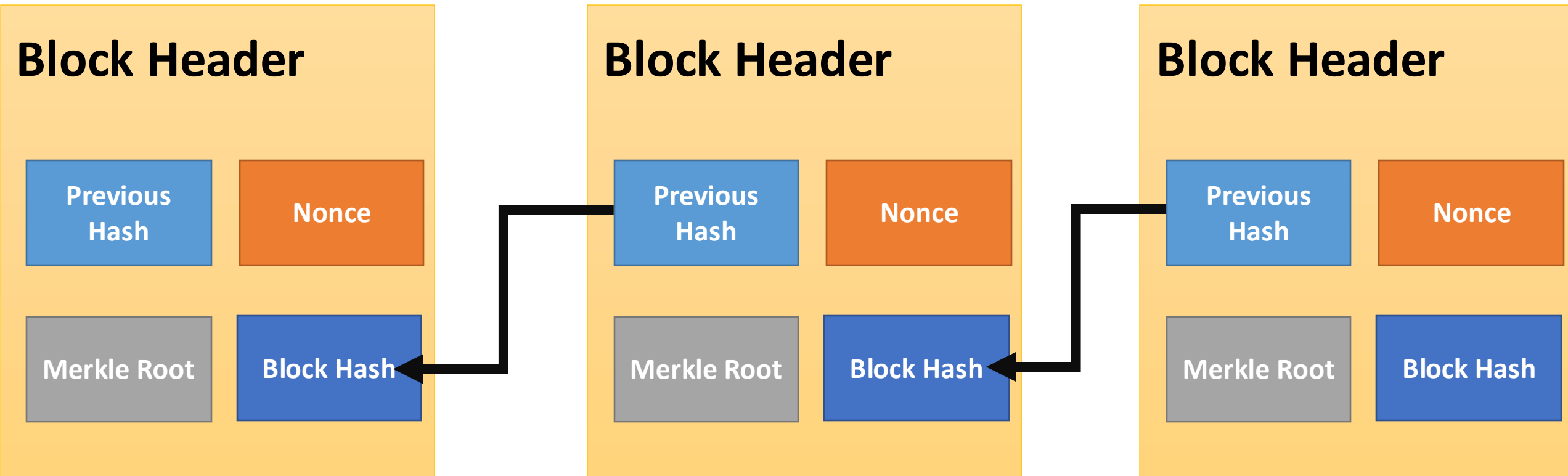
# Detect Tampering from Hash Pointers - Hashchain



# Merkle Tree – Organization of Hash Pointers in a Tree



# Blockchain as a Hashchain



thank you!