FINE-GRAINED AND CONTROLLED REWRITING IN BLOCKChAINS

Chameleon Hashing Gone Attribute-Based

David Derler (DFINITY), Kai Samelin (TÜV), Daniel Slamanig (AIT), Christoph Striecks (AIT)
RESEARCH IN DISTRIBUTED LEDGERS TECHNOLOGIES

• Massive progress beyond Bitcoin, very hyped in recent years

• Signs that hype is turning into extensive research within the cryptographic community
  • (Cryptographic) research centers are established

• Many Cryptographic building blocks are applied to DLs
  • zk-SNARKs, Multi-Signatures, Verifiable Random Functions/Delay Functions/Secret Shares, Threshold Signatures, Multi-Party Computation, …

• Less research is known on rewriting DLs …
  » … wait, isn’t that counterintuitive?
IMMUTABLE DATA IN THE BLOCKCHAIN

Sources: reddit.com; marketwatch.com; theguardian.com
IMMUTABLE DATA IN THE BLOCKCHAIN

Child abuse imagery found within bitcoin's blockchain

Researchers discover illegal content within the distributed ledger, making possession of it potentially unlawful in many countries

Sources: reddit.com; marketwatch.com; theguardian.com
A Quantitative Analysis of the Impact of Arbitrary Blockchain Content on Bitcoin

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Abstract. Blockchains primarily enable credible accounting of digital events, e.g., money transfers in cryptocurrencies. However, beyond this original purpose, blockchains also irrevocably record arbitrary data, ranging from short messages to pictures. This does not come without risk for users as each participant has to locally replicate the complete blockchain, particularly including potentially harmful content. We provide the first systematic analysis of the benefits and threats of arbitrary blockchain content. Our analysis shows that certain content, e.g., illegal pornography, can render the mere possession of a blockchain illegal. Based on these insights, we conduct a thorough quantitative and qualitative analysis of unintended content on Bitcoin’s blockchain. Although most data originates from benign extensions to Bitcoin’s protocol, our analysis reveals more than 1600 files on the blockchain, over 99% of which are texts or images. Among these files there is clearly objectionable content such as links to child pornography, which is distributed to all Bitcoin participants. With our analysis, we thus highlight the importance for future blockchain designs to address the possibility of unintended data insertion and protect blockchain users accordingly.

Sources: reddit.com; marketwatch.com; theguardian.com
JUST DO A HARD FORK …

• Simple solution: **hard forks**, but *not* really useful (i.e., chain from change point has to be “re-written”)
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- Ateniese, Magri, Venturi, Andrade (EuroS&P 2017) motivated to rethink immutable blockchain:
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In this work, focus is on transaction-level rewriting.
SEPTEMBER 20, 2016

Accenture Debuts Prototype of ‘Editable’ Blockchain for Enterprise and Permissioned Systems

Invention addresses blockchain ‘immutability’ challenges for permissioned systems, including the legal ‘right to be forgotten,’ human error, illegal actions

Co-developers Accenture and Dr. Giuseppe Ateniese register U.S. and E.U. patents
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wrong and to meet new and changing regulatory and legal requirements, like the ‘right to be forgotten’ and other data-privacy and retention rules. An editable form of blockchain will make the technology more practical and useful for enterprise systems and accelerate its adoption. It combines the confidence that comes from immutability with the pragmatism required in an imperfect world.

“The clever work of the bitcoin creators and leaps of progress in applied cryptographic research are opening the door to bold new uses of blockchain,” said Dr. Giuseppe Ateniese, a leading
CHAMELEON HASHING
Finding collisions for hash functions (if you know a trapdoor)
PRIMER: CRYPTOGRAPHIC HASH FUNCTIONS

Hash function are a central ingredient to DLs, e.g., RIPEMD-160 used in Bitcoin

- One-way
- Collision-resistant
- Short output

Message → H( ) → "Fingerprint"
CHAMELEON HASH (CH) FUNCTIONS

1. One-way
2. Collision-resistant
3. Short output

… but only if \(td\) is unknown.

Additional collision-finding algorithm

\[\text{Col}(\, , \, , \, \text{td})\]

\[\text{H}(\, )\]

“Fingerprint”
CHAMELEON HASH (CH) FUNCTIONS

- Very useful cryptographic primitive envisioned by Krawczyk and Rabin (NDSS 2000), based on work by Brassard, Chaum, Crépeau (JCS 1988)
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• **Problem:** coarse-grained, if one is in possession of the trapdoor $td$, all security guarantees are lost
MAIN RESULT:
POLICY-BASED CHAMELEON HASHING
A new primitive for fine-grained hash-collision finding
POLICY-BASED CHAMELEON HASHING (PBCH)

- Enhances Chameleon Hashing with attributes and access structure/policies
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Mimics fine-grained collision finding for chameleon hashing and strong security guarantees.
POLICY-BASED CHAMELEON HASHING (PBCH)

Collision-finding algorithm

\[ \text{Col}(\text{SM}, \text{SM}, \text{td}_S) \]

\[ H(\text{SM}, A) \]

\[ H(\text{SM}, A) \]

Main feature: Fine-grained collision finding if attribute set \( S \) fulfills the access structure \( A \)

Same value!
INSTANTIATING PBCH
Combining Chameleon Hashing (with Ephemeral Trapdoors) and Attribute-Based Encryption
INGREDIENT 1: CHAMELEON HASHING WITH EPHEMERAL TRAPDOORS (CHET)

Collision-finding algorithm

\[ \text{Col}(\text{td}, \text{etd}) \]

Ephemeral trapdoor key which is generated during hashing

\[ H(\text{td}) \]

\[ H(\text{etd}) \]

Main feature: collision finding possible if \( \text{td} \) and \( \text{etd} \) are present.

Due to Camenisch et al. (PKC 2017)
INGREDIENT 2: ATTRIBUTE-BASED ENCRYPTION (ABE)
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pk → Contract A 💻💻

Factory 🏭
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Security guarantee: looks random without knowing secret keys
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Security guarantee: looks random without knowing secret keys

pk

sk

kxcas32sdc9wg
Engineer AND Development

TA

Engineer, Research

Frontdesk

Engineer, Development
INGREDIENT 2: ATTRIBUTE-BASED ENCRYPTION (ABE)

**Properties:**
- Enables **fine-grained** one-to-many communication
- Enforces access control on the cryptographic level
- Need of **pk-related** authority **TA** that distributes secret keys
PUTTING EVERYTHING TOGETHER

Col(\(\mathcal{E}, \mathcal{A}, \text{td}_S, \text{etd}\))

\[ H(\mathcal{E}, A) \]

\[ H(\mathcal{A}, A) \]

Ephemeral trapdoor

Trapdoor key associated to ABE secret key for attribute set S

Hashing also encrypts etd for access structure A with ABE

Main feature: collision finding possible if ABE secret key for \(S\) that fulfills access structure \(A\) for encrypted etd is known.

Same value!

22/10/2019
POLICY-BASED CHAMELEON HASHING (PBCH)

Gen($k$): Outputs the secret key $sk_{PBCH} \leftarrow (msk_{ABE}, sk_{CHET})$ and public key $pk_{PBCH} \leftarrow (pk_{ABE}, pk_{CHET})$.

Key($sk_{PBCH}, S$): Outputs a secret key $sk_S \leftarrow (sk_{CHET}, sk_{ABE,S})$.

Hash($pk_{PBCH}, m, A$): Outputs a hash $h \leftarrow (h_{CHET}, C_A)$ and randomness $r \leftarrow r_{CHET}$, for $(h_{CHET}, r_{CHET}, etd) \leftarrow \text{Hash}_{CHET}(pk_{CHET}, m)$ and $C_A \leftarrow \text{Enc}(pk_{ABE}, A, etd)$.

Verify($pk_{PBCH}, m, h, r$): Return 1 if Verify$_{CHET}(pk_{CHET}, h, h_{CHET}, r_{CHET})$, else 0.

Col($sk_S, m, m', h, r$): Outputs randomness $r' \leftarrow \text{Adapt}_{CHET}(sk_{CHET}, etd, m, m', h, r_{CHET})$, for $etd \leftarrow \text{Dec}_{ABE}(sk_{ABE,S}, C_A)$. 
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Ephemeral trapdoor \text{etd} can only be accessed with ABE secret key for attributes which fulfill the ciphertext access structure.
HIGH-LEVEL EXAMPLE

\[ A \leftarrow H(h) \quad B \leftarrow H(T_{i,2}) \quad C \leftarrow H(T_{i,3}) \quad D \leftarrow H(T_{i,4}) \]

\[(h, r_i) \leftarrow \text{PBCH.Hash}(pk, T_{i,1}, A)\]
CONCLUSION

• **Editing/re-writing** DLs interesting aspect to consider
  • Possible on block level and transaction level

• New primitive **Policy-Based Chameleon Hashing (PBCH)** to allow fine-grained re-writing on the **transaction** level in DLs

• Open questions
  • Who generates the trapdoor for chameleon hashes?
    • Ateniese et al. propose to use multi-party computation protocol
  • Can we get rid of such a requirement and build a fully decentralized solution based on chameleon hashing?
THANK YOU!

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