Tamperproof IoT with Blockchain

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Abstract—We investigate the tamper-resistant property of Blockchain and its effectiveness for IoT systems. In particular, we implemented an IoT testbed, and built a Blockchain into the testbed. A number of tamper-resistance experiments were conducted and analyzed to corroborate the process of block validation in Blockchain. Our analysis and experimental results demonstrate the tamper-resistant capability of Blockchain in securing trust in IoT systems. The demonstration video is provided at [1].

I. INTRODUCTION

The Internet of Things (IoT) is poised to transform our lives and unleash enormous economic benefit. However, inadequate data security and trust are seriously limiting its adoption. Blockchain, a distributed tamper-resistant database, has native resistance to data tamper by which it is practically impossible to modify the data retroactively once a transaction has been recorded. We believe such tamper-resistant property can be of significant value in ensuring trust in IoT systems.

We aim at demonstrating the tamper-resistant capability of Blockchain in securing trust in IoT systems. An IoT testbed was constructed in our lab, and Ethereum based Blockchain was built in the testbed. A number of tamper-resistance experiments have been carried out and analyzed to examine the process of block validation in Blockchain on both full node and light node. Our demonstrations reveal that Blockchain has a dedicated tamper-resistant capability, which can be applied to IoT to ensure trusted data collection and sharing. With this features used within P2P network, precisely by design, a Blockchain-based database can therefore constitute a trust-free decentralized consensus system. Note that trust-free means conventional 3rd party as an arbitral body is filled in by computation. However, not only difficulty

Fig. 1: Trusted digital Supply Chain

First of all, we point out the difference between the so-called 51% attack and chain reorganization. Nodes will never import a block that fails validation. A 51% attack consists of a 51% of the miners forking off from a block in the past and creating a new chain that eventually beats the current canonical chain in total difficulty.

A reorganization is done only if a block being imported on a side fork leads to a higher total difficulty on that particular fork than the canonical fork. The blocks nonetheless still need to be valid. Note that triggering re-organization function is based on TotalDifficult in Proof-of-Work [2].

Synchronization happens all the time across each node starting from an identical genesis block in a chain. Each node runs a validation function to validate each incoming block. No block will be accepted unless passing the validation.

B. Validation procedures

Throughout the validation procedures, the follow conditions are evaluated:

- if StateRoot ∈ local levelDB, throw errors;
- if ParentBlock ∈ local levelDB, throw errors;
- if StateRoot ∉ ParentBlock ∈ local levelDB, throw errors;
- if Validate(Header) where \{nonce, difficulty, mixDigest...\} ∈ Header not passed, throw errors;
- if Validate(UncleHeader) not passed, throw errors;
- if Validate(GasUsed) not passed || Validate(bloom) not passed, throw errors;
- if TxHash ≠ Hash(Txs) || ReceiptHash ≠ Hash(Receipts), throw errors;
- if StateRoot ≠ StateRoot ∈ CurrentStateRoot, throw errors.

The last validation points out that since there is no transaction sent to those normal nodes, the state root after a state change will never equal to the state root of the header of the incoming block coming from an abnormal node.

A simple fraud of database does not account for any PoW computation. However, not only difficulty, epochDataset and
mixhash, but also the HeaderHash is involved in calculating the targeting nonce. It means arbitrary but sufficient amount of computation should be carried out on the tampered block. Even if sufficient amount of computation is satisfied, the record can be recovered by the canonical chain with the fastest speed effort, unless the hacker has control over 51% computational power among the whole network.

III. TAMPER-RESISTANCE DEMONSTRATIONS

A. System setup

**Hardware setup (shown in Fig.1):**
- two workstations as mining nodes, shown in Fig.1(a);
- three Raspberry Pi 3 B+, shown in Fig.1(b), attached with IoT sensors as end-point nodes, which are only allowed to look up and upload data without mining.

![Image](a)(b)

**Software setup:**
- Ubuntu 14.04 Trusty and Mac OS on mining nodes;
- Raspbian on Raspberry Pi;
- Golang Ethereum 1.5.9 for Blockchain [3];
- Golang on hacking, tampering and logging;
- Python on data receiving and encapsulation;
- Javascript on Blockchain processing via web3 API [3].

**System Implementation:**
The Raspberry Pi IoT devices equipped with temperature sensors measure room temperatures in the lab every 30 minutes. An Ethereum based Blockchain is built in the testbed. The IoT measurement data are encapsulated and uploaded to a pre-built contract in the Blockchain.

B. Hacking scenarios and analysis

We demonstrate several distinct scenarios where blocks are tampered with fake solution to PoW. Scenario analysis and experimental results are presented.

1) **Non-mining node hacked:**
   When a non-mining node is hacked, and the total difficulty is smaller than that of a normal block, the canonical chain always chooses the block with larger total difficulty in the context of a valid block. Thus this tampered block will be seen as an uncle block, the canonical chain will be recovered back by those normal blocks from other normal nodes.

2) **Mining node hacked:**
   When a mining node hacked, and the total difficulty is smaller than that of a normal block, the results are the same as that of the non-mining node hacked case. Once this node starts mining, the uncle block will be broadcast at the same time for validation, contributing to errors throwing on other normal nodes as shown as in Fig.2.

![Image](Fig.2: Overview of testbed)

**Fig. 2: Overview of testbed**

When the total difficulty is greater than that of a normal block, it ends up being insufficient computational power. As a result, this tampered block will not be accepted by any other adversaries, and this mining node will be removed as a bad peer by other normal nodes, shown in Fig.3.

![Image](Fig.3: Bad Block with tampered uncle blocks)

**Fig. 3: Bad Block with tampered uncle blocks**

3) **Tampered Block on light node:**
   We now investigate the scenario that a light node is hacked, and the PoW verification passes and the height of this light node is greater than that of those mining nodes. In this scenario, there will be no suitable peers available for this light node and any transactions sent from local will be broadcast to null, until the height is transcended by canonical chain, shown in Fig.4.

![Image](Fig.4: Insufficient computation leading to incorrect nonce)

**Fig. 4: Insufficient computation leading to incorrect nonce**
IV. A PRACTICAL DEMONSTRATION

We now demonstrate the effectiveness of the tamper-resistant property of Blockchain in protecting the IoT data records. In our Blockchain secured IoT testbed, one Raspberry Pi device was hacked, its temperature record was changed from the original measure of 34°C to -4°C.

As soon as the tampering happened, the blockchain noticed this anomaly with a broken chain in the hacked node, which signals a tampering action.

Next, when the blockchain is synchronized, the abnormal block is automatically recovered back to the major one through the canonical chain. As a result the tampered record of -4°C has been replaced by the original record of 34°C. This is the chain reorganization process of the Blockchain. A log is generated to record which content had been changed unexpectedly, and this log is automatically uploaded onto Blockchain for future reference.

This demonstrated that the Blockchain can be applied to IoT to secure data records.

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