Improving Openstack Tacker's Accountability Using Blockchain Technology

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Outline

Laying The Groundwork

- Cloud Computing & Virtualization
- SDN & NFV
- Service Function Chaining
- The Blockchain Technology

Improving Tacker's Accountability Using Blockchain

- Probelm Space Definition
- Openstack Tacker
- Logs Immutabilization
- Blockchain for Record-Keeping
- Analysis & Conception
- Implementation

Perspective & Future Work

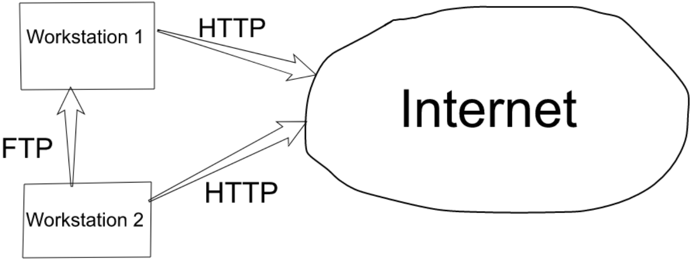
Cloud Computing & Virtualization

- Computing paradigm that relies heavily on outsourcing of (especially) physical resources.
- Abstraction of software from hardware
- Several advantages in combining Cloud Computing and Virtualization (Performance, Scalability, High Availability, Pay per use,...etc)

Software Defined Networks

- Traditional networks are rigid and offer little flexibility.
  - ► Make networks more "programmable".
  - ► Abstract networking technology/protocols (control plane) from networking hardware (forwarding plane).

Example



Network Functions Virtualization

- Various networking hardware provided by different vendors (vendor lock-in issue).

- Specific hardware for each networking function (Firewall, NAT, DNS,...etc)

- ▶ Provide common hadrware platform for the different networking functions, and make it manageable from computing devices (servers, laptops, mobile,...etc)

SDN & NFV Upgrades

- Central Management
- Direct Programmability
- Flexibility
- Vendors-Neutral

Service Function Chaining

- Improved flexibility in networking functions.

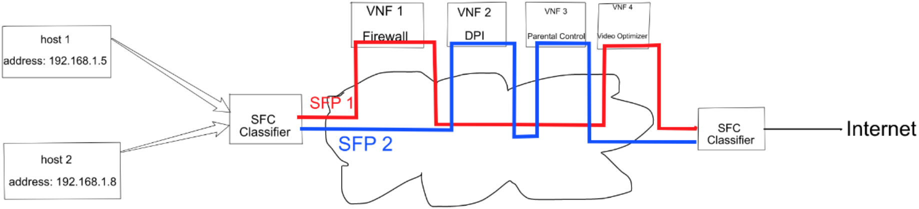
- Instead of building a rigid networking system, instances of simple networking functions (NAT, DNS, DPI,...etc) are composed and "chained" together as required to form more complex service functions.

- SFC offers low complexity, high maintenance ability and improved adaptability.

SFC Main Components

- **Service Function (SF)** A virtual instance of a basic networking function (Firewall, DPI, NAT, DNS,...etc)
- **Service Function Forwarder (SFF)** Logical component that forwards the incoming packets to SFs according to the information carried in the SFC encapsulation.
- **Service Function Path (SFP)** The actual path of a packet chosen by the SFF after taking into account the network's constraints (network load, availabilty of SF instances,...etc)
- **SFC Metadata** Exchanged context information among the different SFC components.

SFC Components (Example)



- if source ip == 192.168.1.5 then forward following SFP 1
- if source ip == 192.168.1.8 then forward following SFP 2

The Blockchain Technology

Your Connection to ICT Research

- Introduced to the IT field as the technology behind the Bitcoin cryptoccurency in 2009 by Satoshi Nakamoto.

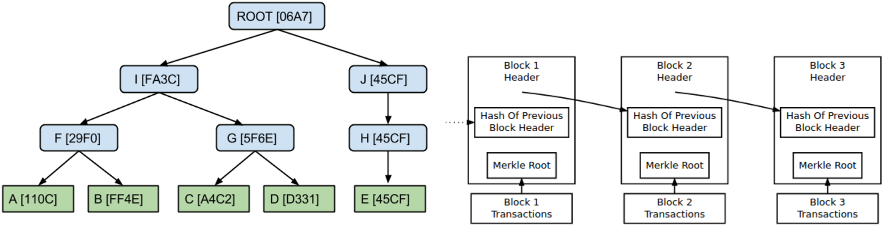
- Blockchain is basically a massive distributed database (i.e: distributed ledger) where transactions between different peers are being recorded.

- Blockchain use cases are being expanded to other fields beside cryptocurrencies (Health care, copyrights,...etc)

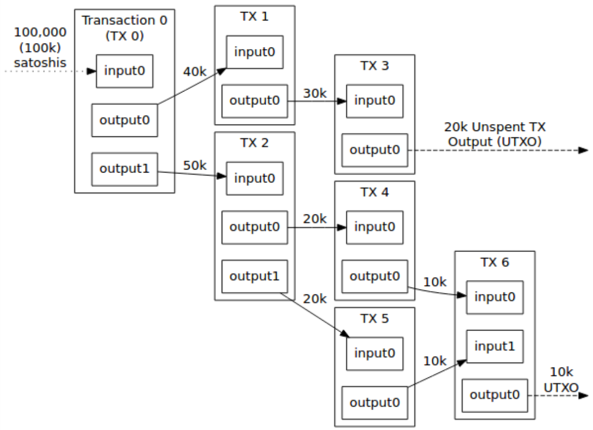
Why The Blockchain Is Differrent (1)

- Blockchain solves the "double spending" issue in digital transactions.
- Spares the need for central "trust" authority in transactions.
- Complex cryptographic computations and a huge network (7692 full node on average in July 2017).

Why The Blockchain Is Differrent (2)



Why The Blockchain Is Differrent (3)



Problem Space Definition

- How secure is the SFC architecture ?
- How can the Blockchain make a system more secure ?
- Is there any use case where the Blockchain can improve SFC's security ?

Problem Space Definition: The 3 A's

- Systems' security is generally evaluated following 3 criteria:
  - Authentication
  - Authorization
  - Accountability

Openstack Tacker

- New component (v 0.7 currently) in the IaaS provider Openstack.
- Tacker is released as the platform's main component for managing VNFs instances in a virtualized environment.
- Tacker relies on Openstack's other components (Keystone, Heat,...etc) to orchestrate and provide the required infrastructure for the VNFs (see NFV MANO framework).

Problem Space Considerations

- Tacker still facing major issues in its setup as well as providing its use cases.
- The availabe NFV platforms still don't adhere completely to the NFV MANO framework.
  - Problem space adaptation considering the available tools and Blockchain's strength: Improving Openstack Tacker's accountability.

Logs Immutabilization

- To make Tacker more "auditable", we ensure the log files authenticity in terms of content.
- We rely on Blockchain's strength in keeping records to store a proof about the logs' content.
- Log files must be secured before storing their proof of authenticity in the Blockchain.

Logs Immutabilization Mechanisms (1)

Your Connection to ICT Research

- We use logs immutabilization mechanisms used in a previous research work (Distributed immutabilization of secure logs (Jordi Cucurull and Jordi Puiggal))
- The secure logs generated will have 2 types of entries: Regular entries and Checkpoint entries.
- This approach allows us to detect where the alteration of content has occured (see equations).

Logs Immutabilization Mechanisms (2)

- Regular entries are generated as the following:

$$L_i = (LogInfo_i, h_i) \quad \text{where} \quad h_i = HMAC(K_j, (h_{i-1} | LogInfo_i)) \quad (1)$$

- Meanwhile, a Checkpoint entry is generated after an arbitrary number of lines (50 lines in our implementation), in accordance with the equation:

$$Chk_j = L_i = (LogInfo_i, K_{j-1}, E(P_{enc}, K_j), Sig_j, h_{i-1}, h_i) \quad \text{where} \qquad (2)$$

$$h_i = HMAC(K_b, (h_{i-1} | K_{j-1} | LogInfo_i))$$

$$Sig_j = S(S_{sig}, (h_{i-1} | K_{j-1} | E(P_{enc}, K_j) | h_i | LogInfo_i)$$

Benchmarking of Blockchain-based Solutions (1)

- **Blockstack**
  - Naming system built on Bitcoin's Blockchain.
  - Allows tracking key-value pairs in form of (unique) names and their associated data.
  - Relies on Blockchain "as a communication channel for announcing state changes".
  - Uses a dedicated data plane for storing the name-data pairs records.
- **Proof of Existence**
  - An online service for storing and timestamping the existence of a document inside the Blockchain.
  - Keeps a hash of the file in the chain, with a referrence also to the time in which the document was stored.
  - Offers the advantage of validating the documents existence even if the online service is down (built on Bitcoin's Blockchain).
  - Uses the OP_RETURN field to pass information in Bitcoin's transactions.

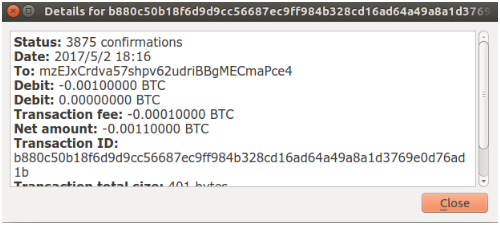
Benchmarking of Blockchain-based Solutions (2)

- **Hyperledger**
  - Smart contract blockchain platform.
  - A set of distributed ledger solutions based on different platforms and programming languages.
  - Based on the expectation that there will be many blockchain networks, with each network ledger serving a different goal.
  - Offers various services (Blockchain Explorer, Fabric,...etc).
- **Namecoin**
  - Another Blockchain-based solution for namespaces storage.
  - Hard fork of Bitcoin's Blockchain.
  - Allows secure storage of key value pairs (same value can exist within different namespaces though).

Bitcoin's OP_RETURN

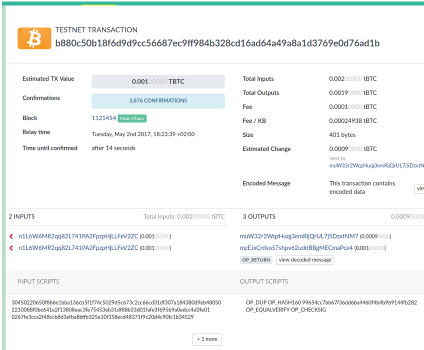
- Bitcoin's increasing popularity ==> Use cases outside finance ==> Need to send data within transactions.
- Developers tried different ways to work around this issue (adding values in outputs, manipulating Bitcoin's scripts,...etc).
- Large members of the Bitcoin's community did not like the bits of data added in transactions, especially as it affected (negatively) the mining process.
- An opcode (operation code that pushes data) called OP_RETURN was consequently standarized by Bitcoin and made available to developers in order to include up to 80 bytes of data in transactions.

OP_RETURN Transaction (Example) (1)



Details for b880c50b18f6d9d9cc56687ec9ff984b328cd16ad64a49a8a1d3769

Status: 3875 confirmations
Date: 2017/5/2 18:16
To: mzEJxCrdva57shpv62udriBBgMECmaPce4
Debit: -0.00100000 BTC
Debit: 0.00000000 BTC
Transaction fee: -0.00010000 BTC
Net amount: -0.00110000 BTC
Transaction ID:
b880c50b18f6d9d9cc56687ec9ff984b328cd16ad64a49a8a1d3769e0d76ad1b
Transaction total size: 401 bytes



TESTNET TRANSACTION
b880c50b18f6d9d9cc56687ec9ff984b328cd16ad64a49a8a1d3769e0d76ad1b

Estimated TX Value	0.00100000 TBTC	Total Inputs	0.00200000 tBTC
Confirmations	3,876 CONFIRMATIONS	Total Outputs	0.00190000 tBTC
Block	1121454 Main Chain	Fee	0.00010000 tBTC
Relay time	Tuesday, May 2nd 2017, 18:23:39 +02:00	Fee / KB	0.00024938 tBTC
Time until confirmed	after 14 seconds	Size	401 bytes
		Estimated Change	0.00090000 tBTC sent to muW32r2WqzHuqj3emRijQrUL7j5DzxtN
		Encoded Message	This transaction contains encoded data

2 INPUTS Total Inputs: 0.00200000 tBTC

n1L6W6MR2qq82L741PA2FpzpHjLLFeV2ZC (0.00100000)
n1L6W6MR2qq82L741PA2FpzpHjLLFeV2ZC (0.00100000)

3 OUTPUTS 0.00090000

muW32r2WqzHuqj3emRijQrUL7j5DzxtNM7 (0.00090000)
mzEJxCrdva57shpv62udriBBgMECmaPce4 (0.00100000)
OP_RETURN

INPUT SCRIPTS

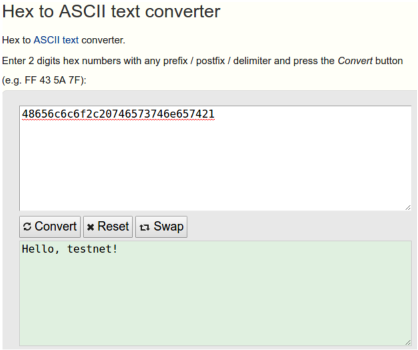
```
30450220650f8b6e1bba136cb5f1f74c5029d5c673c2cc66cd31df307a184380d9eb48050
2210088f0bc641e2f13808eac3fe75453eb31df88b33d01fafe3f69569a0edcc4d3fe01
0267fe3cca2f48ccb8d3efba8bffb325e10f358ecd48371f9c20d4c90fc1b34529
```

OUTPUT SCRIPTS

```
OP_DUP OP_HASH160 99654cc7bb67f36dd6ba4460f4b4b9b9144fb282
OP_EQUALVERIFY OP_CHECKSIG
```

OP_RETURN Transaction (Example) (2)

6a0f48656c6c6f2c20746573746e657421
Hello, testnet!



Hex to ASCII text converter

Hex to ASCII text converter.

Enter 2 digits hex numbers with any prefix / postfix / delimiter and press the *Convert* button (e.g. FF 43 5A 7F):

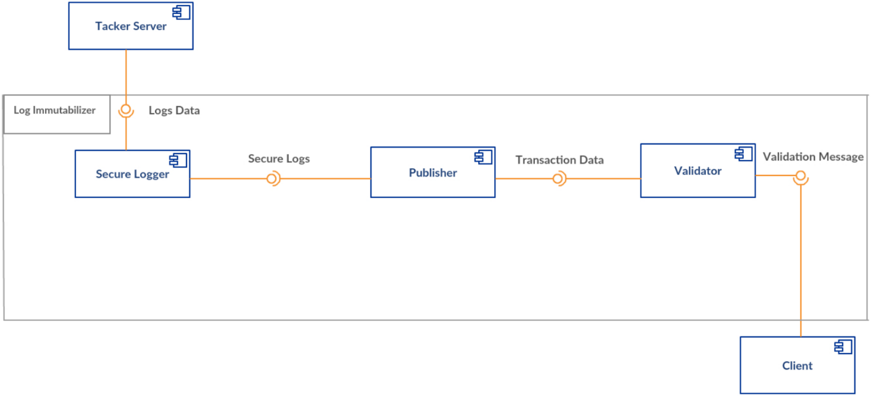
```
48656c6c6f2c20746573746e657421
```

```
Hello, testnet!
```

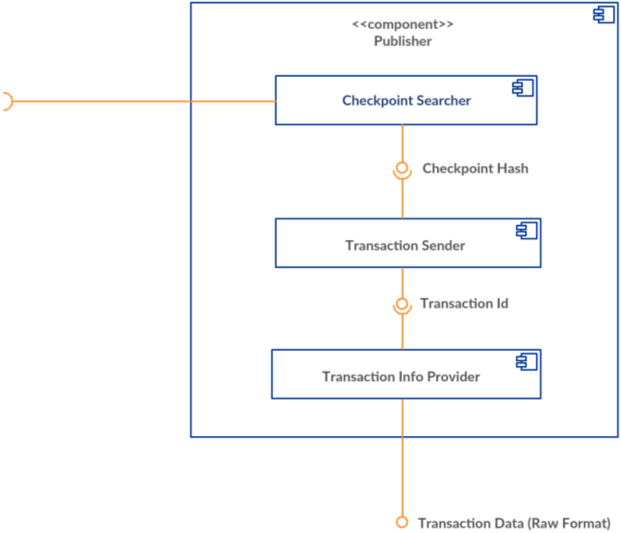
Analysis

- In order to implement the logs immutabilizer, we rely on a component-oriented system.
- Beside the components that will secure Tacker's log files (see previous equations), additionnal components are needed to store the authenticity proofs in the Blockchain.
- A final process of Checkpoints validation needs also to be taken into account.

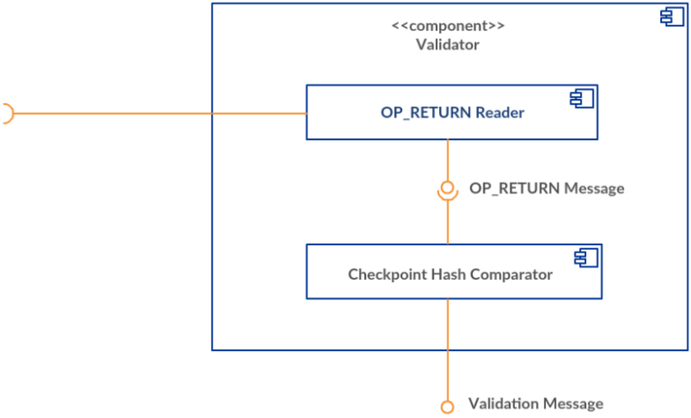
Conception: Components Diagram



Conception: The Publisher Component



Conception: The Validator Component



Conception: The Sequence Diagram

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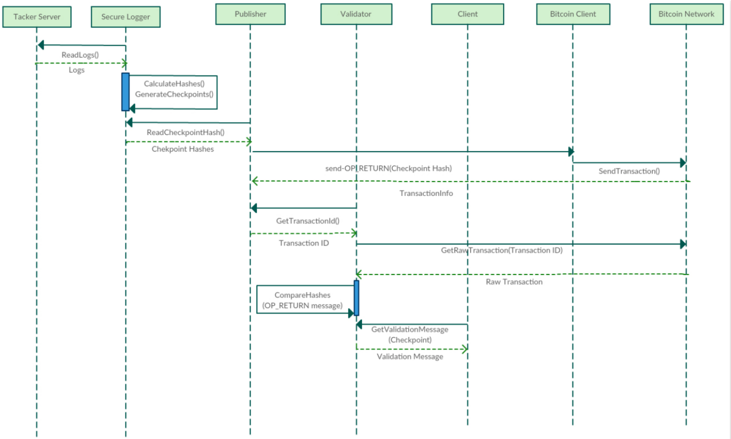

Technologies (1)

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- **OP_RETURN python library**
  - Interacts directly with Bitcoin's Blockchain.
  - Include the message taken as arguemnt through CLI command in the OP_RETURN opcode.
  - Allows 3 operations: send, store and retrieve.

- **Bitcoin Core**
  - Open source project that maintains and publishes the Bitcoin client software.
  - Besides validating transactions "locally" (160 Go need to be downloaded though !!), Bitcoin Core acts also as a Bitcoin Wallet.
  - Unlike Bitcoin's online clients, Bitcoin Core offers improved security.

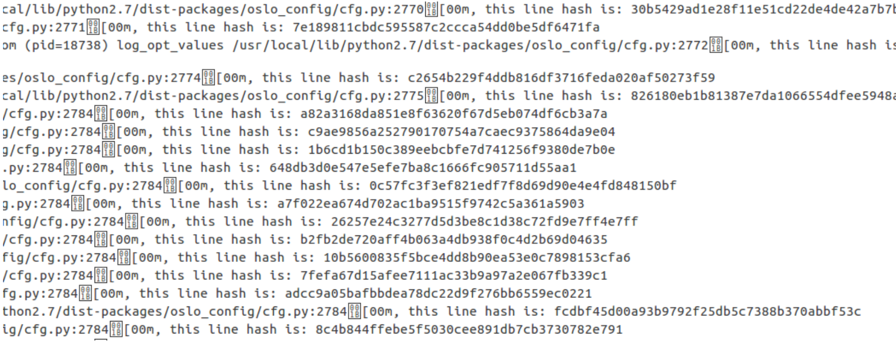
Technologies (2)

- **RabbitMQ Messaging**
  - A message broker typically used for building integration between applications (or components) using messages.
  - Relies on the producer/consumer communication via messaging queues.
  - Supports local communication as well as remote one.

Components' Implementation: The Secure Logger

- The component acts on text log files as the source of the incoming data.
- A sample log text file generated by Tacker server was stored, then secured as per the previous mechanisms.
- A Checkpoint entry is generated after evert 50 lines.
- We used the HMAC python module to calculate the hashes.

The Secure Log File



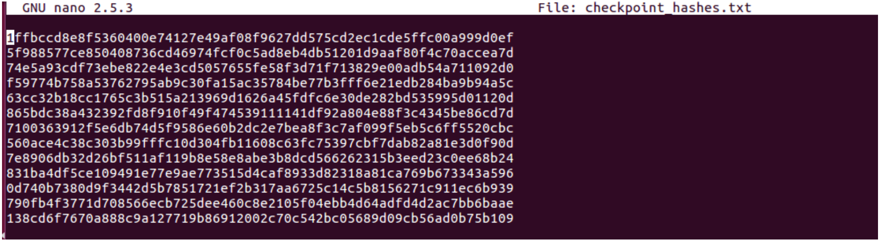
```
cal/lib/python2.7/dist-packages/oslo_config/cfg.py:2770␛[00m, this line hash is: 30b5429ad1e28f11e51cd22de4de42a7b7b
cfg.py:2771␛[00m, this line hash is: 7e189811cbdc595587c2ccca54dd0be5df6471fa
om (pid=18738) log_opt_values /usr/local/lib/python2.7/dist-packages/oslo_config/cfg.py:2772␛[00m, this line hash is

es/oslo_config/cfg.py:2774␛[00m, this line hash is: c2654b229f4ddb816df3716feda020af50273f59
cal/lib/python2.7/dist-packages/oslo_config/cfg.py:2775␛[00m, this line hash is: 826180eb1b81387e7da1066554dfee5948a
/cfg.py:2784␛[00m, this line hash is: a82a3168da851e8f63620f67d5eb074df6cb3a7a
g/cfg.py:2784␛[00m, this line hash is: c9ae9856a252790170754a7caec9375864da9e04
g/cfg.py:2784␛[00m, this line hash is: 1b6cd1b150c389eebcbfe7d741256f9380de7b0e
.py:2784␛[00m, this line hash is: 648db3d0e547e5efe7ba8c1666fc905711d55aa1
lo_config/cfg.py:2784␛[00m, this line hash is: 0c57fc3f3ef821edf7f8d69d90e4e4fd848150bf
g.py:2784␛[00m, this line hash is: a7f022ea674d702ac1ba9515f9742c5a361a5903
nfig/cfg.py:2784␛[00m, this line hash is: 26257e24c3277d5d3be8c1d38c72fd9e7ff4e7ff
/cfg.py:2784␛[00m, this line hash is: b2fb2de720aff4b063a4db938f0c4d2b69d04635
fig/cfg.py:2784␛[00m, this line hash is: 10b5600835f5bce4dd8b90ea53e0c7898153cfa6
/cfg.py:2784␛[00m, this line hash is: 7fefa67d15afee7111ac33b9a97a2e067fb339c1
fg.py:2784␛[00m, this line hash is: adcc9a05bafbbdea78dc22d9f276bb6559ec0221
thon2.7/dist-packages/oslo_config/cfg.py:2784␛[00m, this line hash is: fcdbf45d00a93b9792f25db5c7388b370abbf53c
ig/cfg.py:2784␛[00m, this line hash is: 8c4b844ffebe5f5030cee891db7cb3730782e791
```

Components' Implementation: The Hash Reader

- Reads the Checkpoint entries from the secure log file.
- Extract the checkpoints' hashes and store them in a separate file.
- The Checkpoint hashes file is provided for the Publisher component.

The Checkpoints' Hashes



```
  GNU nano 2.5.3                                            File: checkpoint_hashes.txt

1ffbccd8e8f5360400e74127e49af08f9627dd575cd2ec1cde5ffc00a999d0ef
5f988577ce850408736cd46974fcf0c5ad8eb4db51201d9aaf80f4c70accea7d
74e5a93cdf73ebe822e4e3cd5057655fe58f3d71f713829e00adb54a711092d0
f59774b758a53762795ab9c30fa15ac35784be77b3fff6e21edb284ba9b94a5c
63cc32b18cc1765c3b515a213969d1626a45fdfc6e30de282bd535995d01120d
865bdc38a432392fd8f910f49f474539111141df92a804e88f3c4345be86cd7d
7100363912f5e6db74d5f9586e60b2dc2e7bea8f3c7af099f5eb5c6ff5520cbc
560ace4c38c303b99fffc10d304fb11608c63fc75397cbf7dab82a81e3d0f90d
7e8906db32d26bf511af119b8e58e8abe3b8dcd566262315b3eed23c0ee68b24
831ba4df5ce109491e77e9ae773515d4caf8933d82318a81ca769b673343a596
0d740b7380d9f3442d5b7851721ef2b317aa6725c14c5b8156271c911ec6b939
790fb4f3771d708566ecb725dee460c8e2105f04ebb4d64adfd4d2ac7bb6baae
138cd6f7670a888c9a127719b86912002c70c542bc05689d09cb56ad0b75b109
```

Components' Implementation: The Publisher

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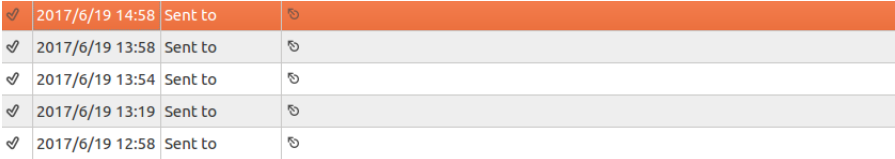
- Issues an OP_RETURN Bitcoin transaction containing the Checkpoint hash.
- Due to Bitcoin Core's scalability issues (see report), an OP_RETURN transaction is sent once per hour.
- Component implemented in Bash (rather than python) due to the OP_RETURN library's inconsistency.
- After each transaction, the transaction id is stored and sent to the next component.

Bitcoin's Transactions

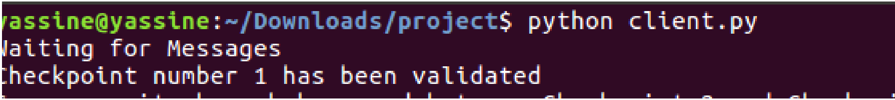


✓	2017/6/19 14:58	Sent to
✓	2017/6/19 13:58	Sent to
✓	2017/6/19 13:54	Sent to
✓	2017/6/19 13:19	Sent to
✓	2017/6/19 12:58	Sent to

Components' Implementation: The Validator

- Contains 4 subcomponents that communicate using RabbitMQ.
- JSON objects are passed through to send the recent transaction id as well as the transaction's hexadecimal format.
- The OP_RETURN message is identified using the prefix '6a20'.
- After reading the hash from the transaction, a comparison is made with the stored Checkpoint hashes, and a validation message is sent eventually to the client component.

Checkpoint Validation Message



```
yassine@yassine:~/Downloads/project$ python client.py
Waiting for Messages
Checkpoint number 1 has been validated
```

Design Decisions

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- A Checkpoint was issued after every 50 lines (arbitrary choice), given the log file contained circa 500 lines.
- Bitcoin Core was used in the testnet mode, so that tBTCs could be obtained for free.
- Each transaction was sent with a 0.1 tBTC fee, which limited the transaction validation time in almost 50 minutes.

Perspective & Future Work

- Packaging of the log immutabilzation application (Docker, Kubernetes,...etc).
- Working on the feasibility of the remaining A's (Keystone for Authentication? , Permissioned Blockchains for Authorization?).
- More tests on SFC platforms (Port Chaining in Neutron?)

Your Connection to ICT Research

Thank You For Your Attention