Blockchain-based System for Secure Data Storage with Private Keyword Search

DO, Hoang Giang; NG, Wee Keong. In: Services (SERVICES), 2017 IEEE World Congress on.

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Introduction

- There has been significant growth in the interest to **outsource data** as well as **operational services to clouds.**
- Traditional cloud storage has come to rely almost exclusively on large storage providers acting as trusted third parties to transfer and store data. **(performance, availability, security and high operation cost)**
- A decentralized cloud storage network has been introduced with **many advantages** over the datacenter-based storage.

Decentralized Cloud Storage

Decentralized cloud storage leverages clinet-side encryption to maintain data security. However, the management of encrypted data poses several challenges.

Challenges

- The data owners should have **the capability to grant permission for others to search on the remotely encrypted dataset and obtain partial but useful content.**
  - A trivial solution is that the data owner retrieves back the whole data set, filters and sends to the authorized client the useful parts of data.
  - This solution is **infeasible** due to the **heavy cost at the client-side** and **it defeats the very purpose of outsourcing data.**

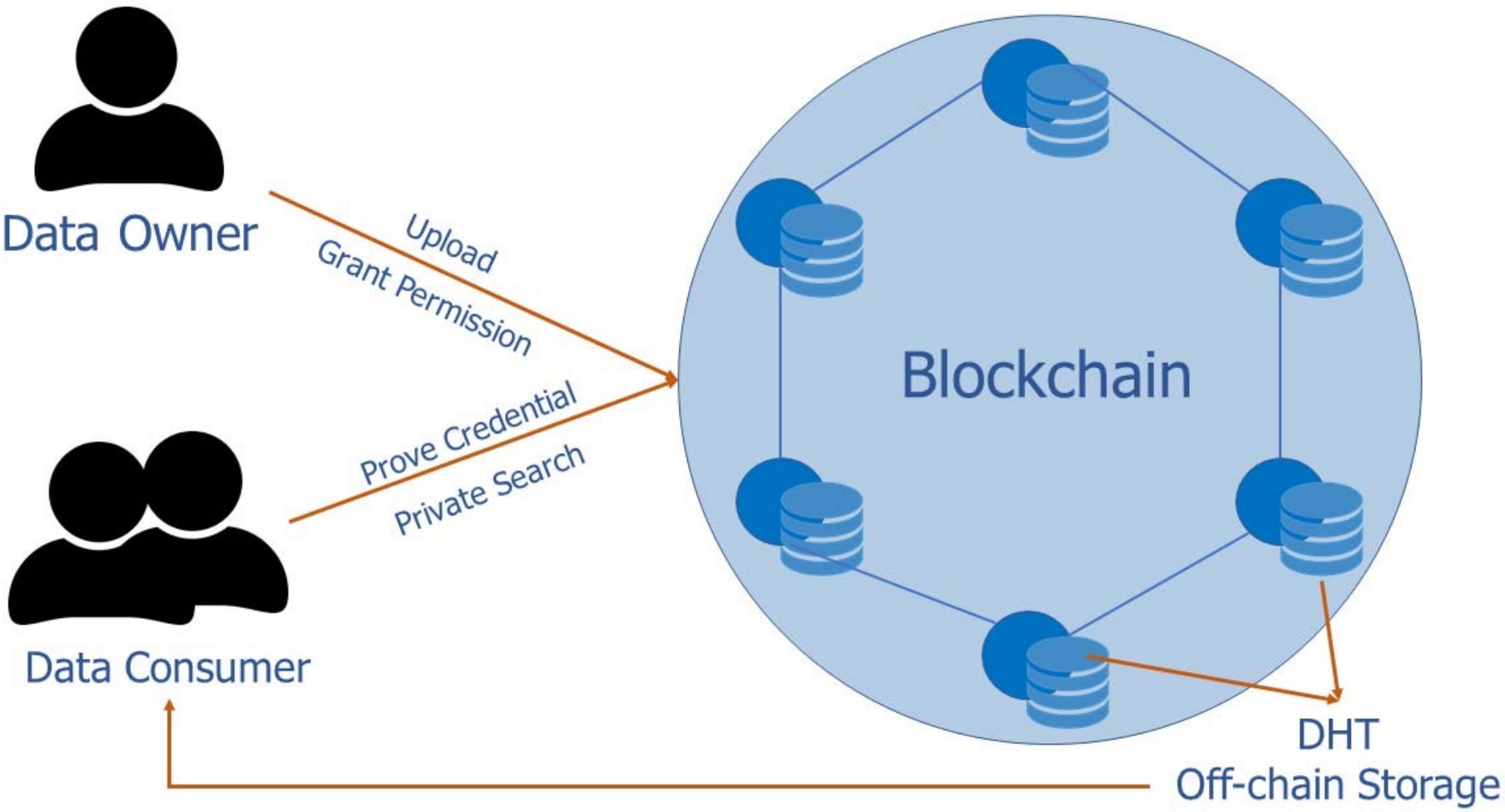
BlockDS

BlockDS addresses the aforementioned problem : **authorized keyword searching on distributed data storage.**

Blockchain

- Off-chain data storage access
- Permission grant and searches
- Encrypted keyword compare

System Model



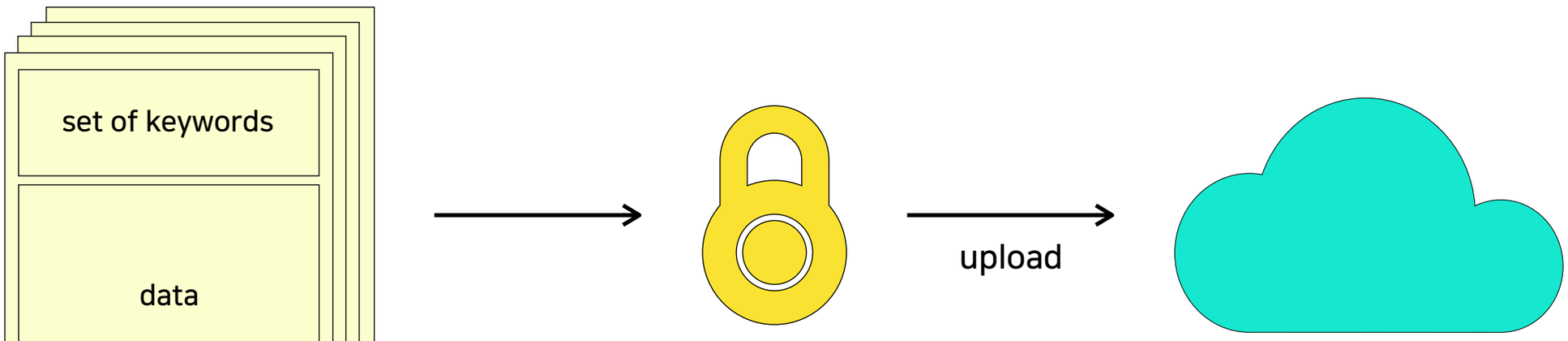
Data Owner

- Data owner poses a data set of document.
- Data owner wishes to outsource the dataset to save the cost of data storage and maintenance.
- Data owner wants to be **able to grant the permission for other clients to search on its outsourced dataset.**

Data Consumer

- A data consumer is a **subscriber for the dataset** provided by the data owner.
- If a data consumer subscribes for the dataset, **it is granted the permission.**
- It is able to interact with a blockchain node **to prove its credential** and **to** perform keyword search on the outsourced data.

Client-side Encryption

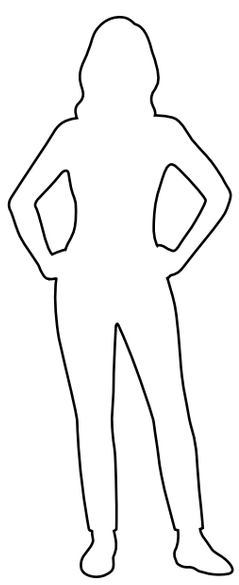


documents encryption federated cloud

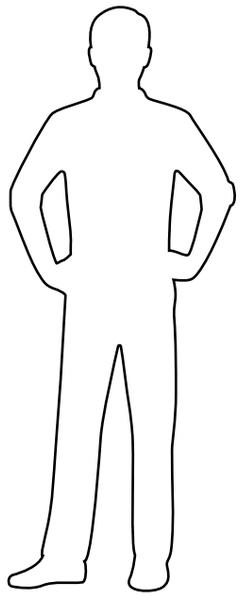
Set Up

- The uploaded data include the **encrypted documents** and the **encrypted keyword tags** that facilitate the keyword search process.
- The **encrypted dataset is stored distributedly by the cloud consortium**, while the **encrypted keyword tags are maintained by the blockchain**.
- The encrypted keyword tags are used for **indexing and providing a means** to access the matching encrypted documents.

Permission



permission

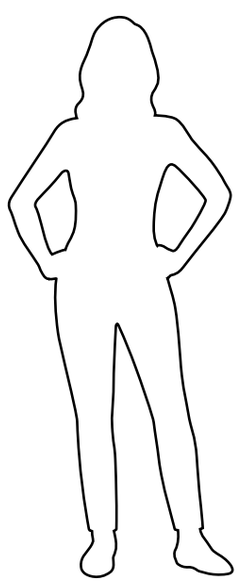


Data owner

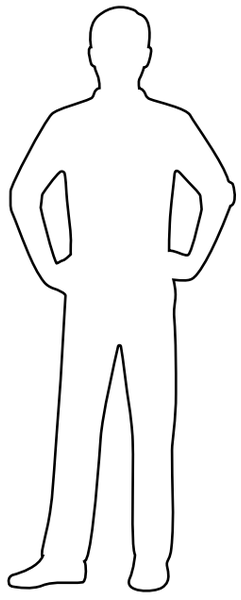
Data consumer

grant permission for a data consumer to search on the encrypted dataset

Permission



permission



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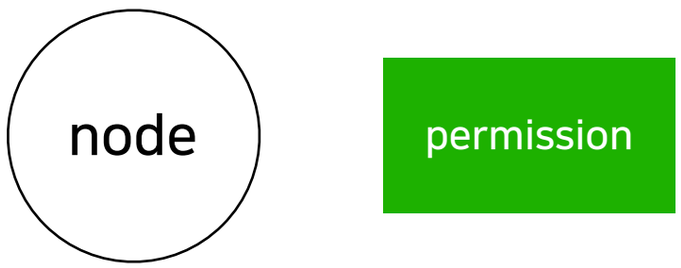
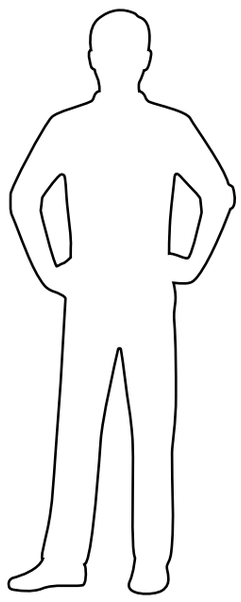


“OK”



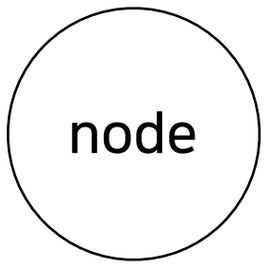
Blockchain node

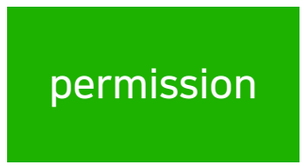
Data consumer

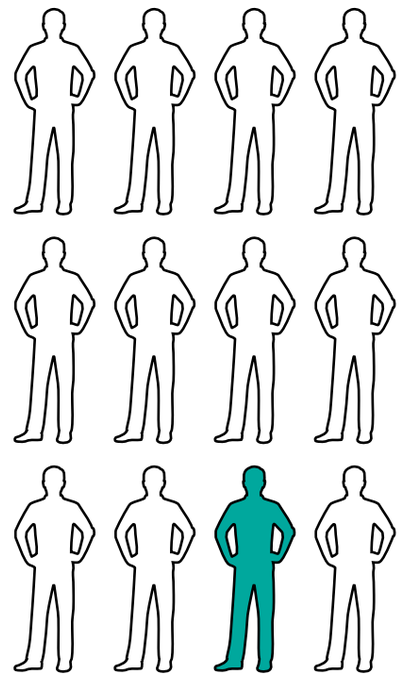
prove to the blockchain nodes that he has a particular permission for searching

Privacy Policy

"Oh, You're one of the subscribers"





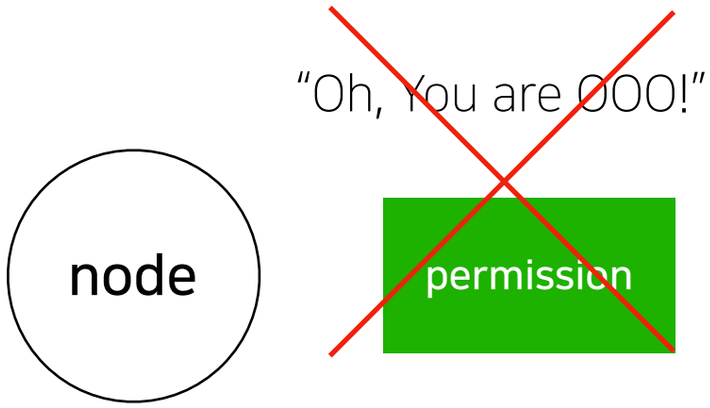


Blockchain node

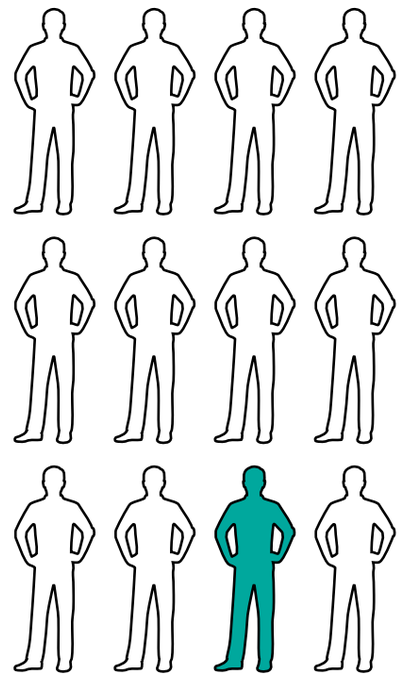
Subscribers

The blockchain can only verify that he is one of the subscribers.

Privacy Policy



Blockchain node



Subscribers

But the blockchain **cannot** extract his identify from the proof.

Strength

- Instead of having to download the whole dataset, **Data consumer should have the capability to search for a keyword to retrieve only the necessary documents from the federated cloud.**

BlockDS System

BlockDS consists of three main components

1. Distributed Data Storage
   - The component provides a decentralized cloud storage platform.
   - The data are **distributedly stored by the federated cloud.**
2. Anonymous Access Control
   - The anonymous access control component allows **the data consumer to anonymously convince the blockchain nodes of the possession of a certificate issued by the data owner.**
   - The blockchain nodes **do not know** who is the data consumer, and how many times he has shown the credential proof.

BlockDS System

3. Private Keyword Search
   - The component provides an elegant mechanism for a data consumer **to identify the specific encrypted data.**
   - Rather than downloading the whole data set, the data consumer **interacts with blockchain nodes and the blockchain content to get the fingerprint of the specific data content based on the keywords.**
   - The data consumer **retrieves the encrypted documents from the distributed off-chain data storage.**

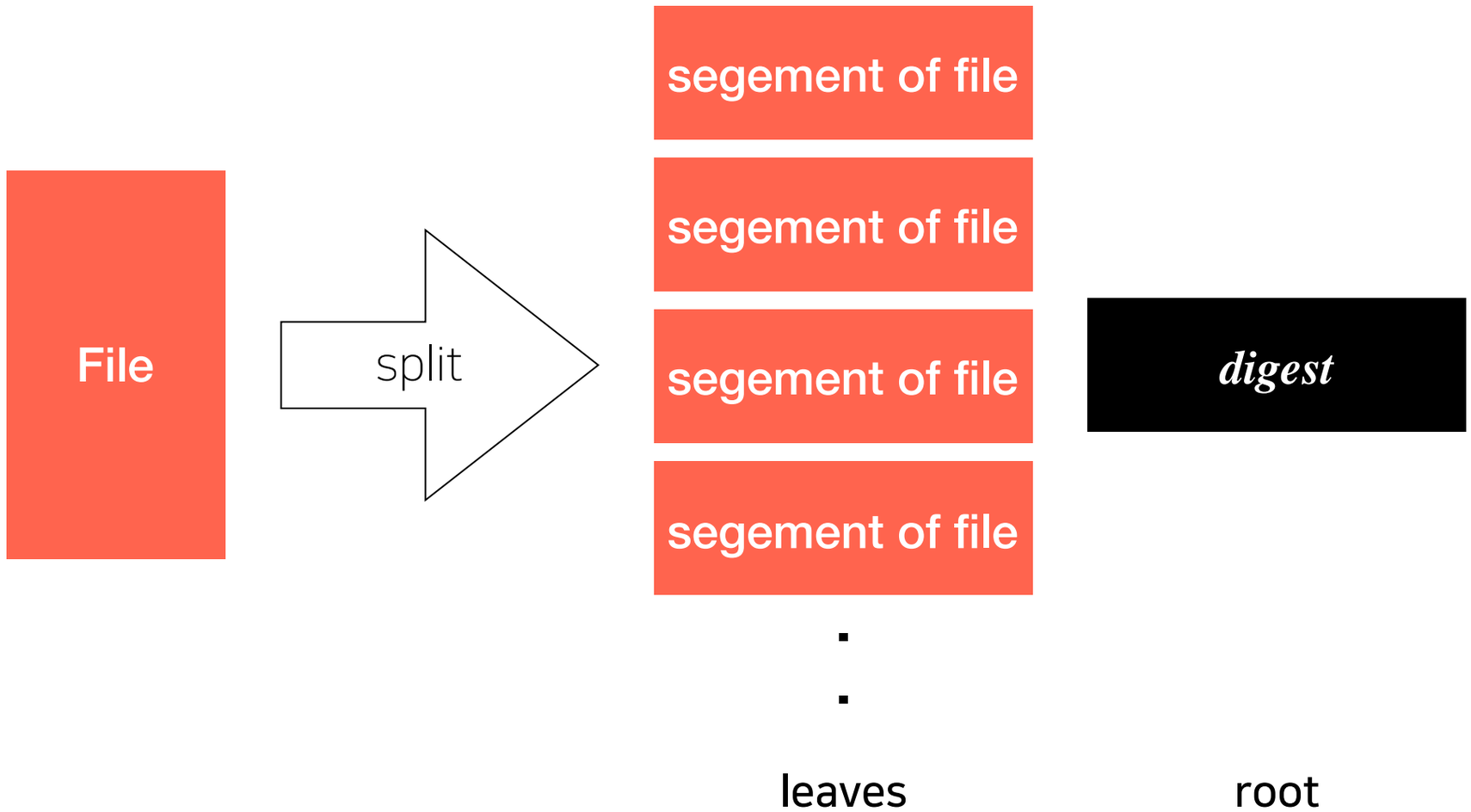
Distributed Encrypted Data Storage

- BlockDS allows data owner to outsource a large amount of data to the system.
- The system **shards the data content and distributes the shards across peer nodes** to reduce the impact of content delivery on any given node.
- In order to maintain the access to the encrypted files, BlockDS leverages **decentralized off-chain distributed hash-table (DHT)** that is accessible through the **blockchain**, **which stores references to the data but not the data themselves.**
- DHTs have been widely used to coordinate and maintain metadata about peer-to-peer systems.

Proof-of-Retrievability

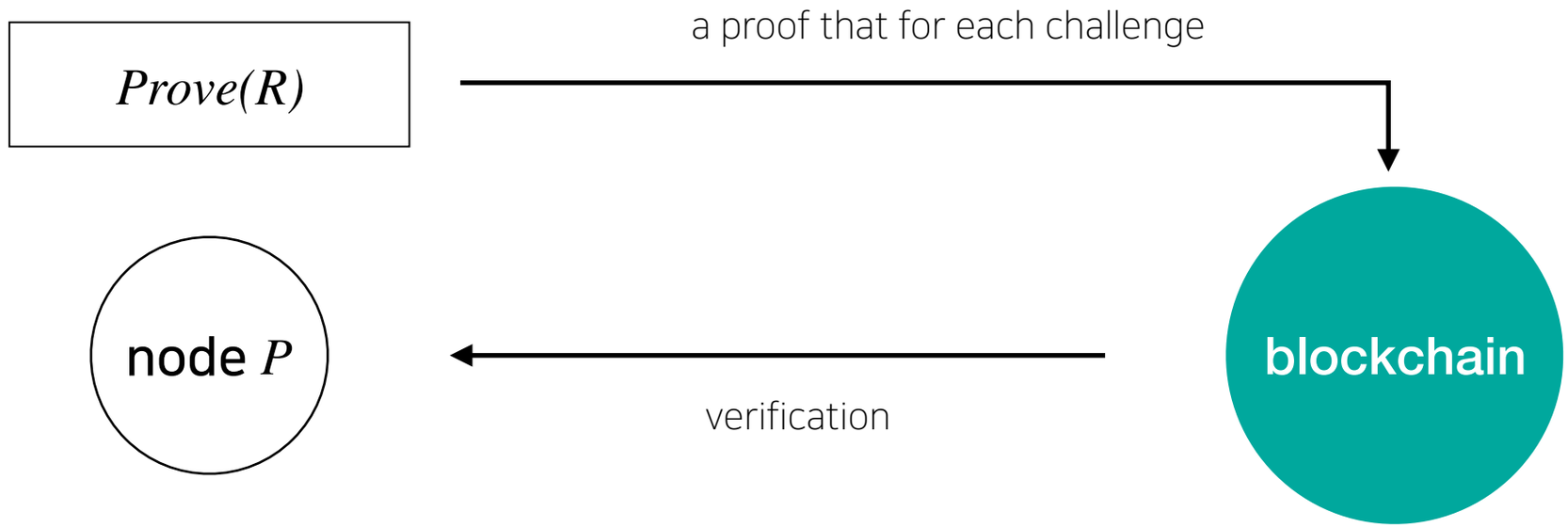
- The system leverages distributed Proof-of-Retrievability (PoR) to maintain the integrity of the storage.
- We consider a particular file F consist of n data segments : $F = (F_1, F_2, \cdots, F_n)$.
- A basic PoR takes the form of a **challenge-response protocol** in which a node P demonstrates its possession of a file F and the fact that it can be correctly retrieved.
- To audit P's possession of F, P receives a random challenge c at regular basis; it produces a response r, which it can be publicly verified without possessing F.

Setup



Node P computes a Merkle tree whose leaves are segments of the file F and whose root is $digest$.

Prove and Verify



node have ownership of the file F

nodes do not have ownership of the file F

Node P outputs a proof that for each challenge index r_i in R, F contains F_{r_i}
and the accompanying path π_{r_i} in the Merkle tree.
The validation process verifies the Merkle path for each segment against $digest$.

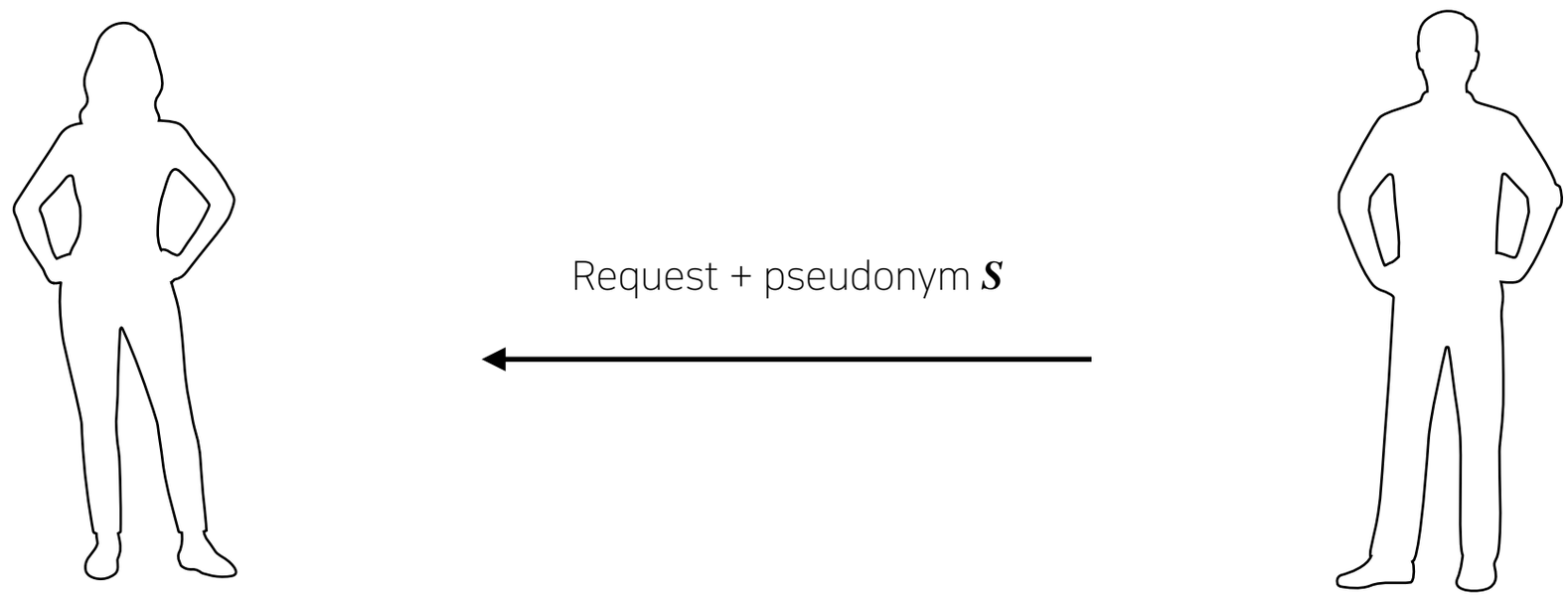
Effect of PoR

- PoR provides a strong guarantee, namely that with overwhelming probability, if P provides correct responses, F can be retrieved completely from P.
- The correctness of the proof can be verified by every other nodes so that **the integrity of the data storage is maintained.**

Anonymous Access Control

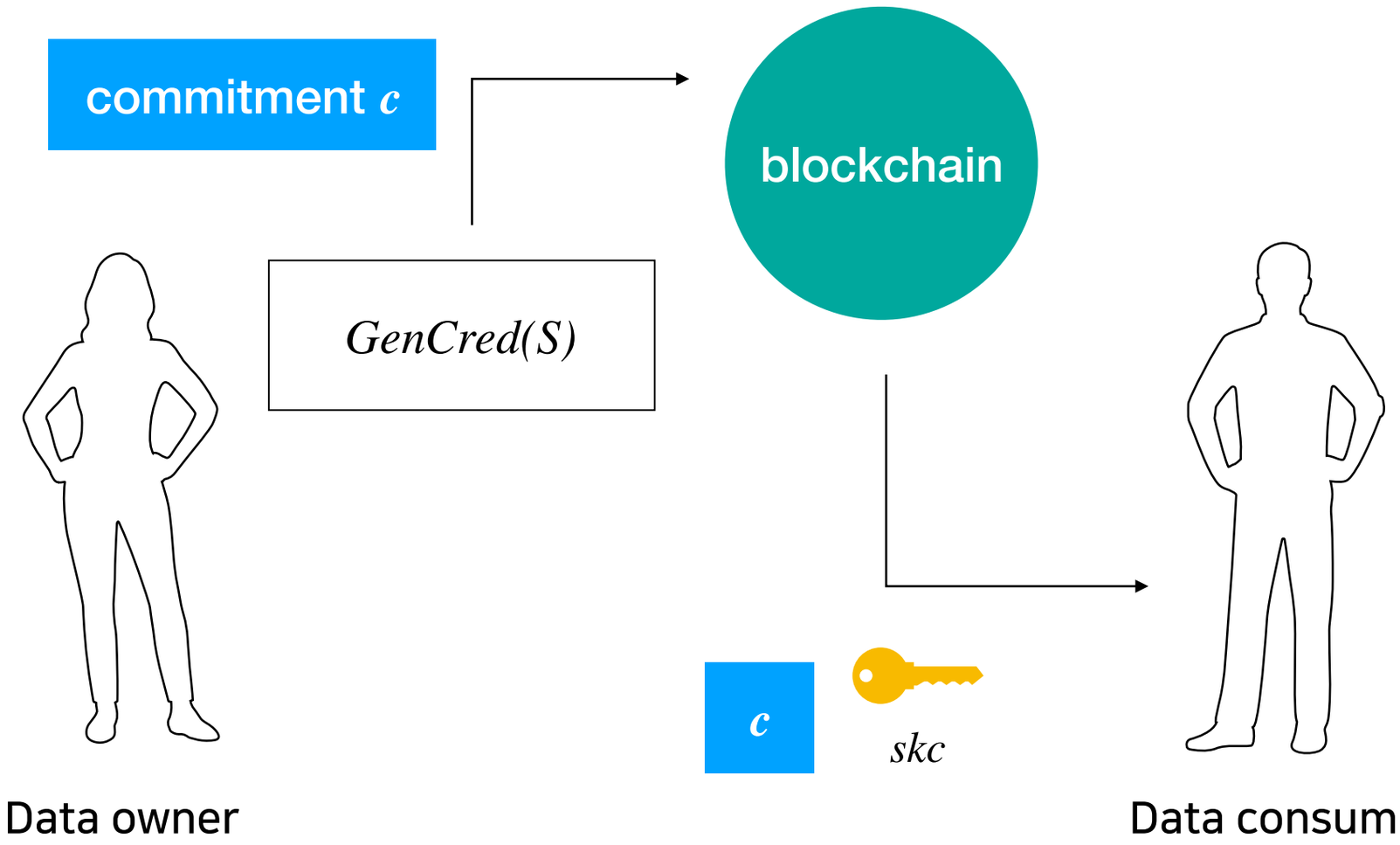
- Anonymous access control component allows a data consumer to obtain a **credential** from the data owner so that at some later points of time, **he is able to construct a non-interactive proof for his credential.**
- The blockchain nodes accept the **request only if the attached proof is valid.**

Anonymous Access Control Process



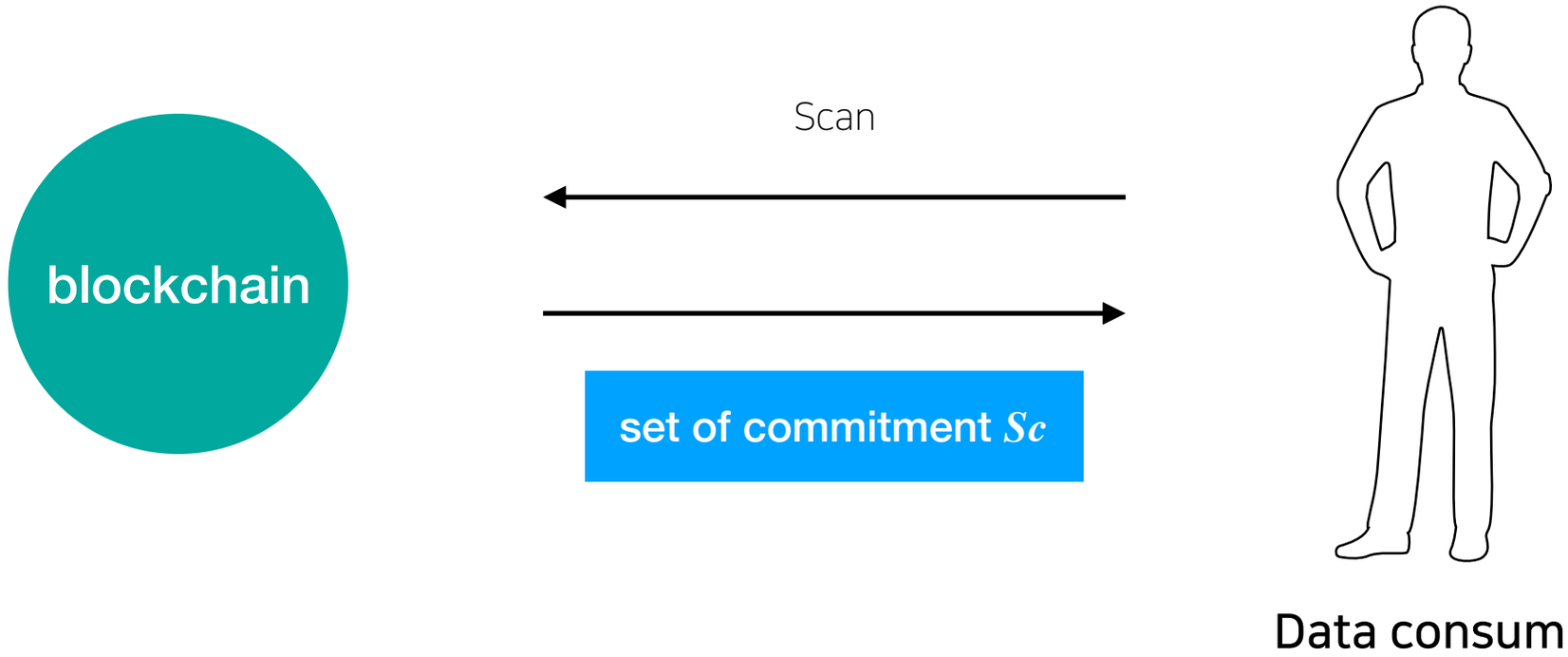
When the data consumer wishes to obtain a credential for data access, he sends a request to data owner together with his pseudonym S.

Anonymous Access Control Process



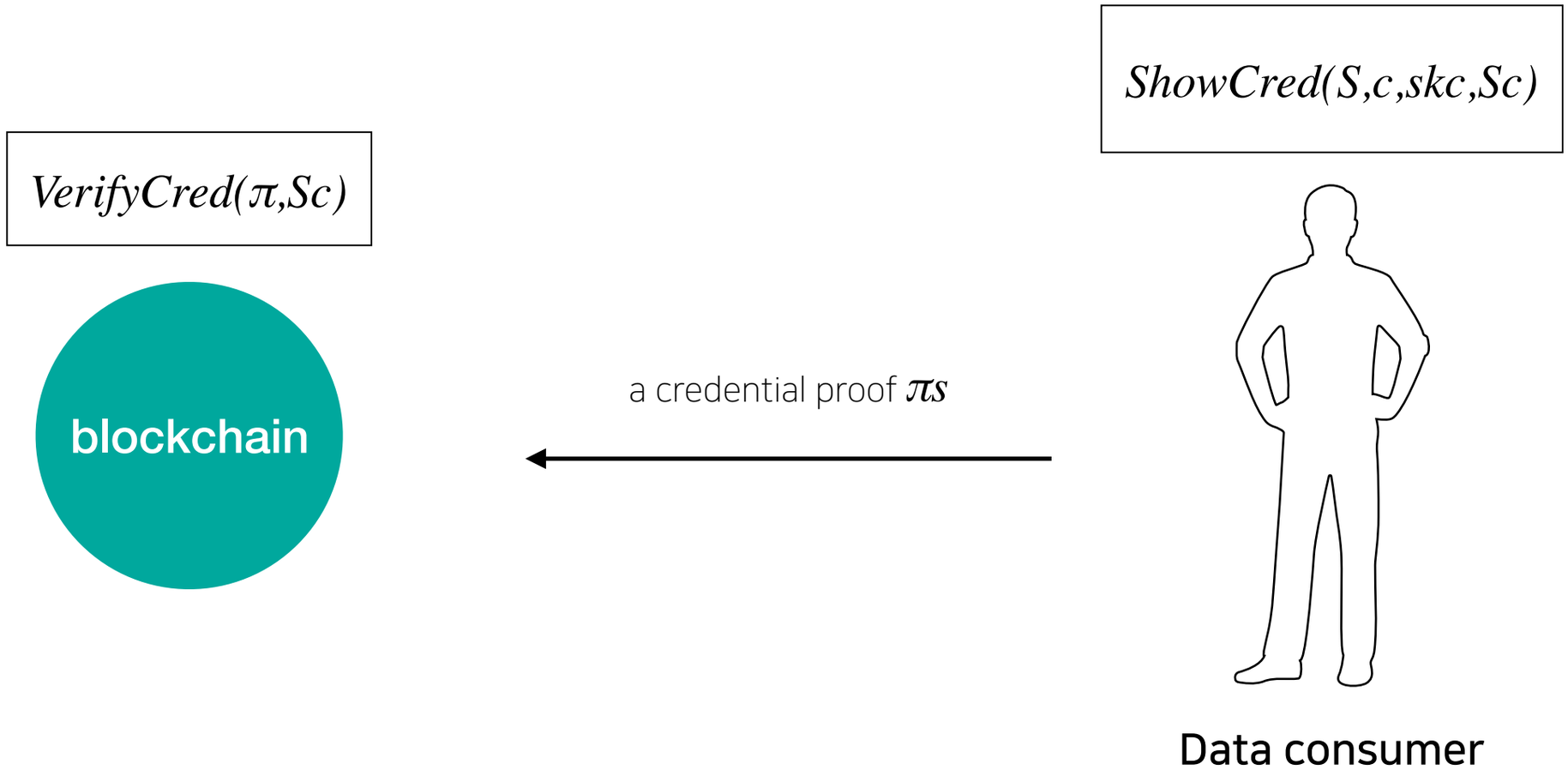
At this point, data owner runs $GenCred$ routine on the input S to generate a digital commitment c and its secret key skc.

Anonymous Access Control Process



When the data consumer wishes to show his credential, he first scan through the blockchain to obtain the set Sc consisting of all credential issued by the data owner.

Anonymous Access Control Process

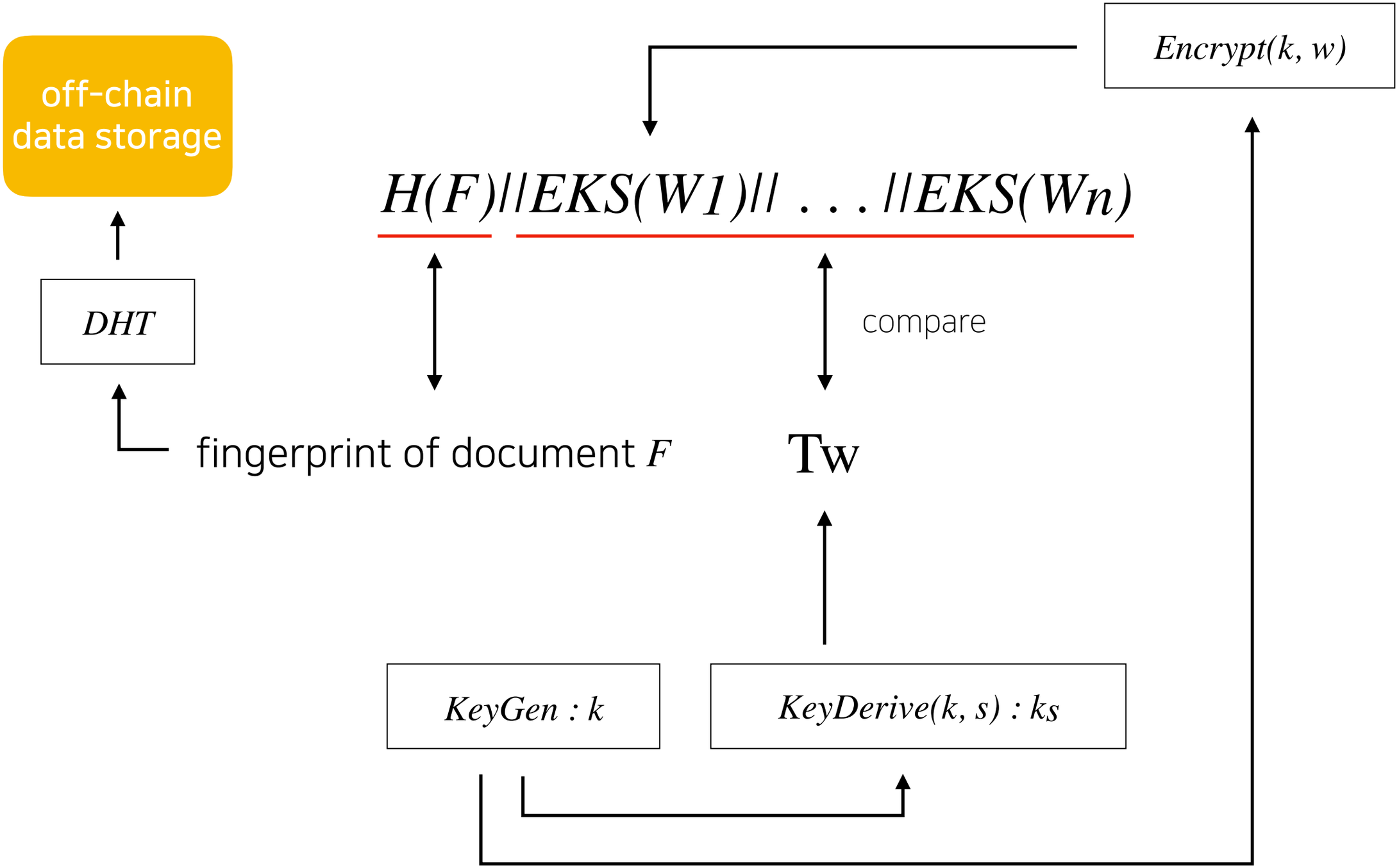


He then runs the *ShowCred* routine to generate a credential proof, and broadcast it to the blockchain nodes for verification.

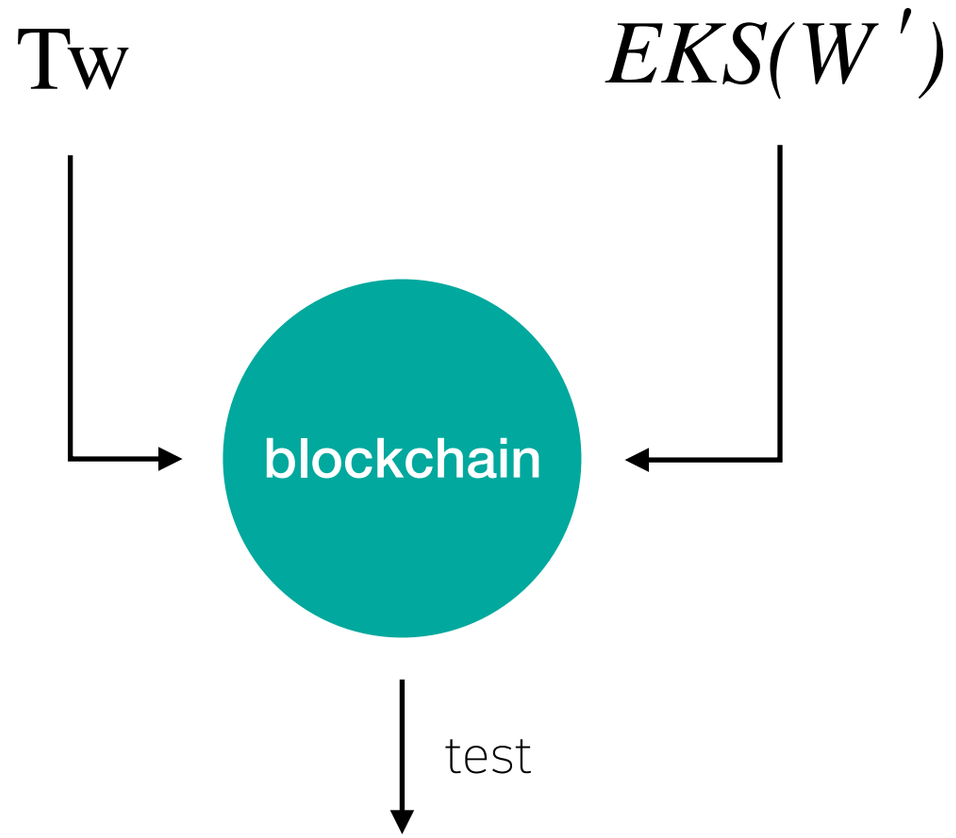
Private Keyword Search

- The component allows the data consumer to identify the specific encrypted data that he is interested in without the requirement of downloading the whole dataset.
- The **meta-data (the fingerprint) of the encrypted documents are stored in the blockchain**, and **only the authorized clients are able to search via it.**
- The blockchain does **not store actual content**, however, **it maintains the access key data** so that the data consumers are able to link to the DHT using blockchain.
- **The data owner appends to the access key a list of EKS ciphertext of each keyword and stores it in the permissoned blockchain.**

Structure of data in Blockchain



Role of Blockchain node



Conclusion

- The BlockDS system enables outsourcing of data storage to a fluid distributed network of service providers.
- The system makes use of blockchain technology to enforce the data integrity via PoR scheme.
- The processes of anonymous credential grant, proving credential, and private keyword search are also performed with the help of blockchain.
- **Future work** should address more complex requirements such as **credential revocation**, **boolean keyword search**, etc.