Scalability:
A communication perspective

French-Japanese Workshop on Blockchain technologies
and application to digital trust

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Université de Strasbourg

Slides available on https://bramas.fr

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Who am I ?

カンタ　　ブラマス

Quentin Bramas,

Associate Professor in Strasbourg, France

I work on Blockchain, BlockDAG

And also in distributed algorithms:

- mobile autonomous robots
- routing protocols
- dynamic graphs

Scalability ?

- Consensus protocol
- Storage
- Throughput
- Latency
- …

Two of my work on Scalability

- Consensus Protocol
- Throughput / Application

Scalability of the consensus protocol

Two main category of blockchains:

- permisionless (Bitcoin, …):

  PoW, Arbitrary number of participants, very slow

- permisionned, consortium (RedBelly, …):

  DBFT, limited number of validators, fast

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Idea: use the interactions between the participants to elect the next block writer.

Current limitation: fixed set of participants, but can be very large.

The guided tour puzzle

Mehmud Abliz and Taieb Znati. *A Guided Tour Puzzle for Denial of Service Prevention.*
In Proceedings of the Annual Computer Security Applications Conference (ACSAC) 2009

The guided tour puzzle

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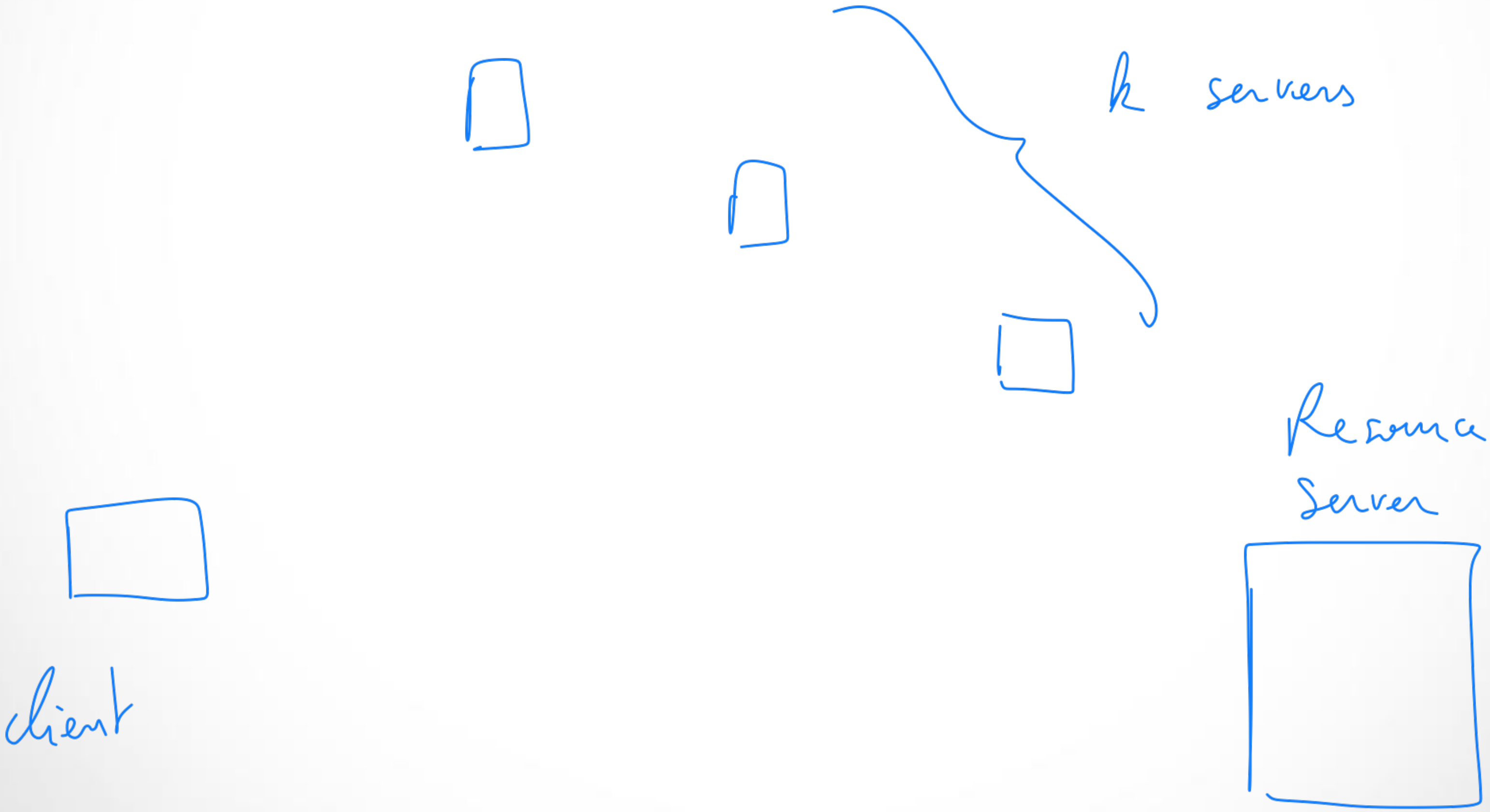

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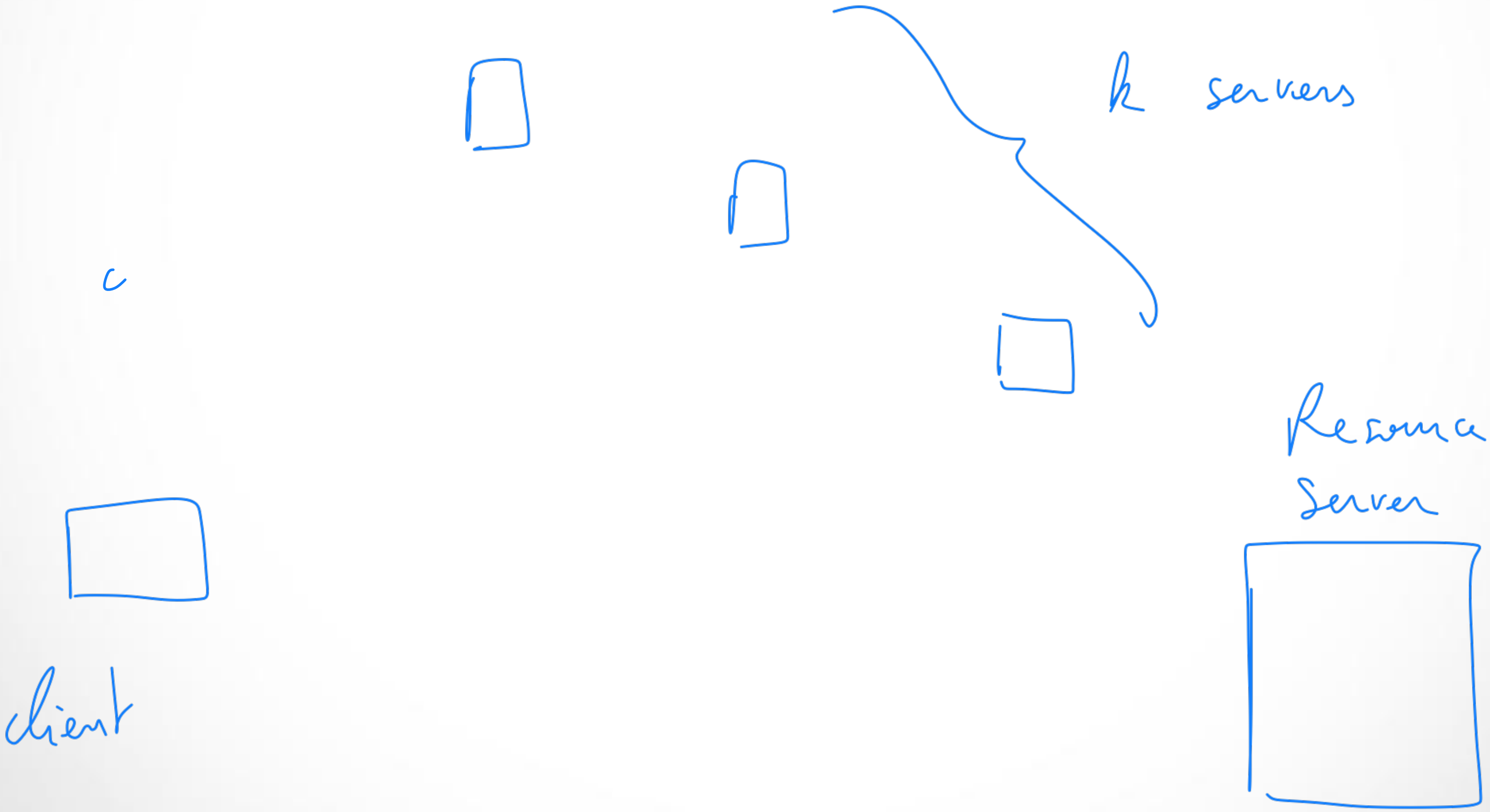

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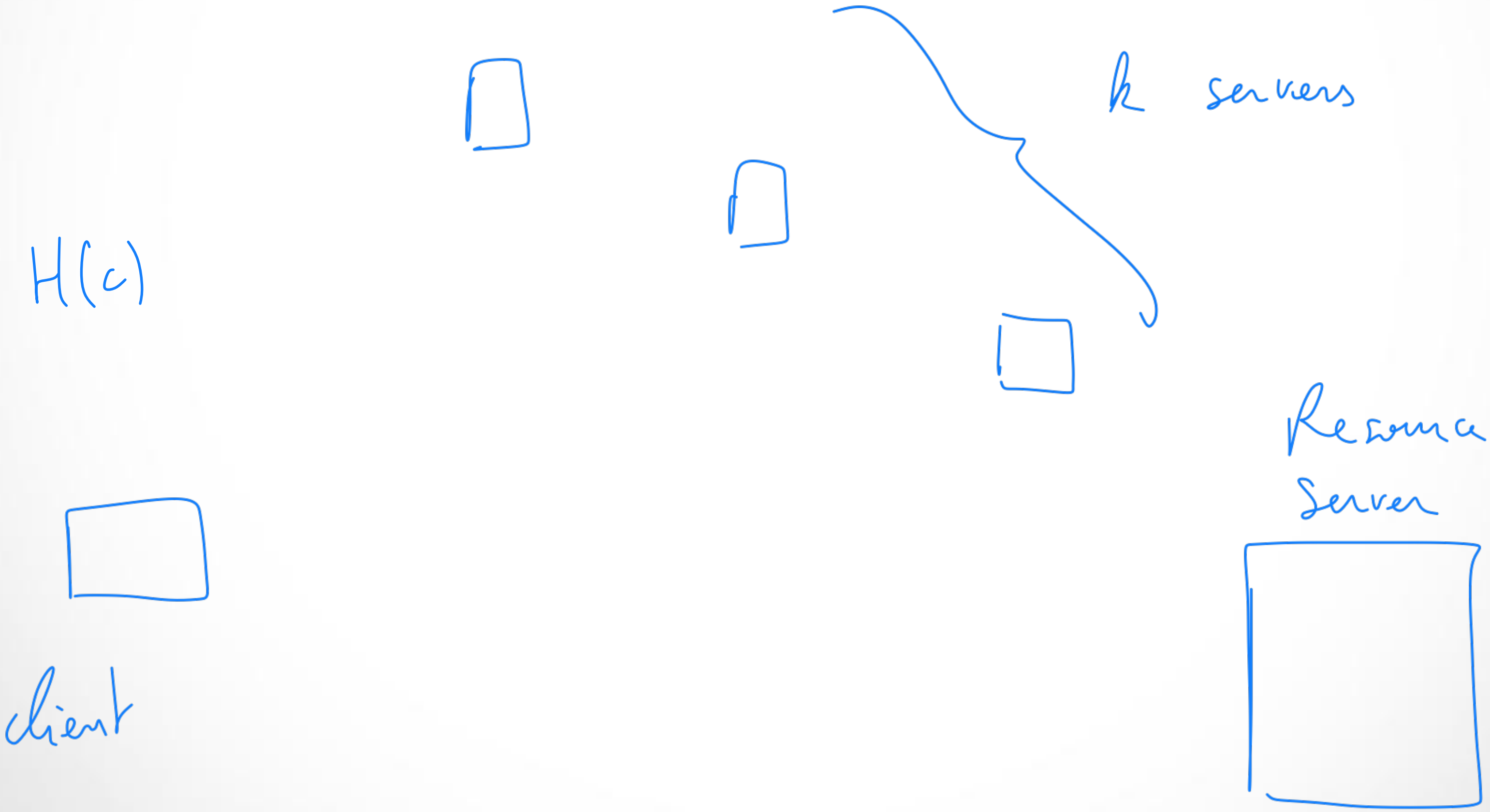

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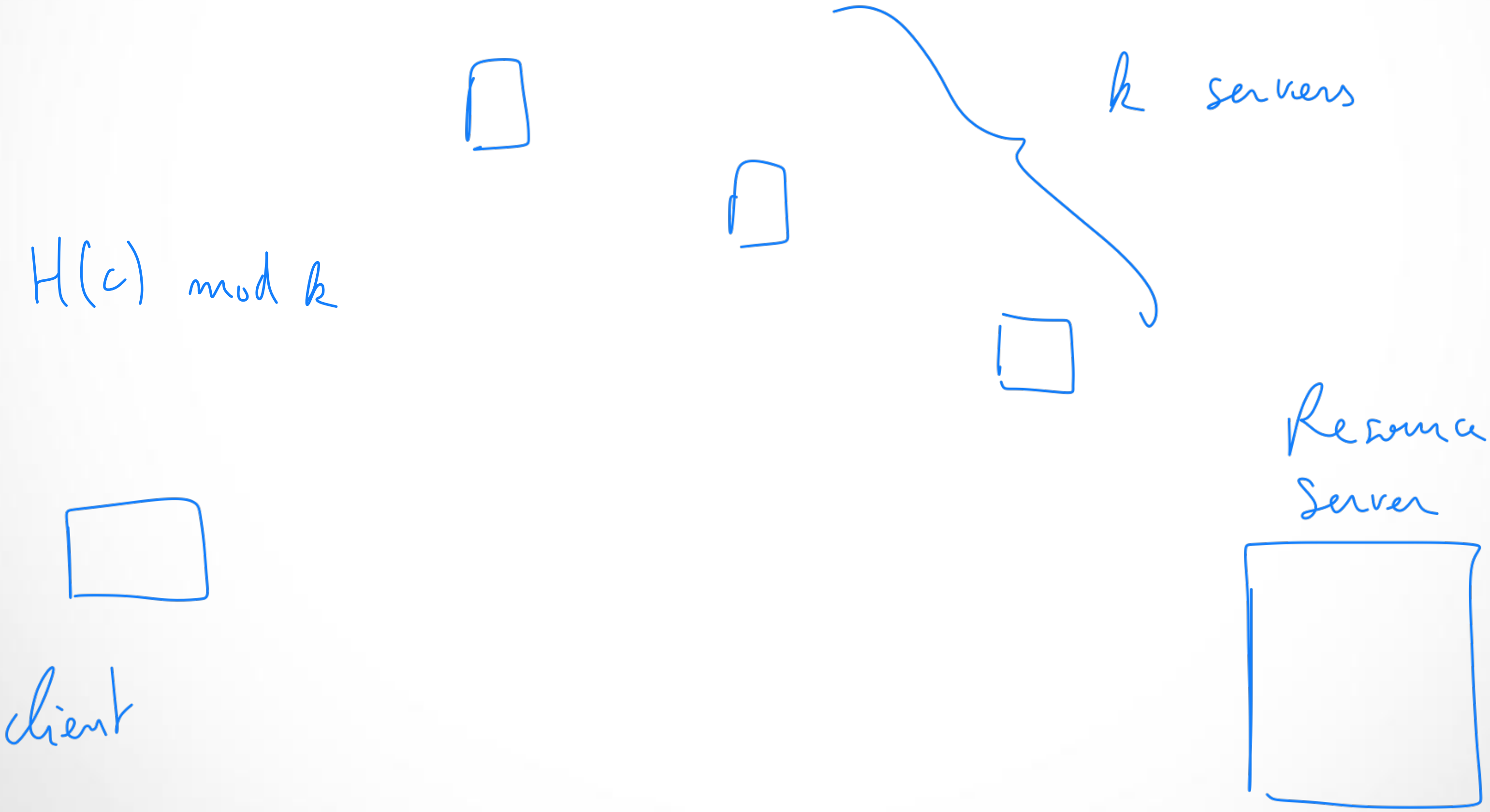

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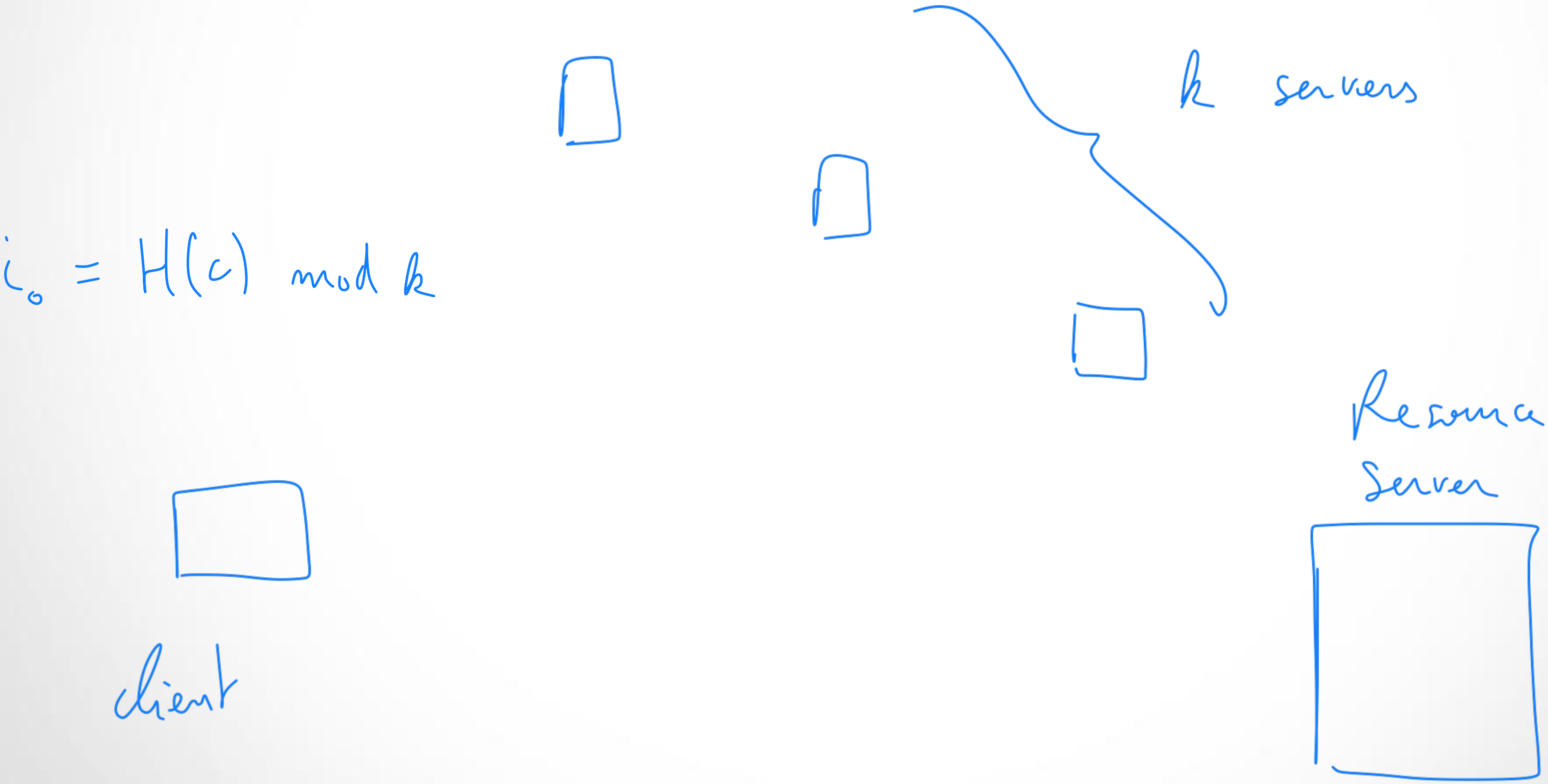
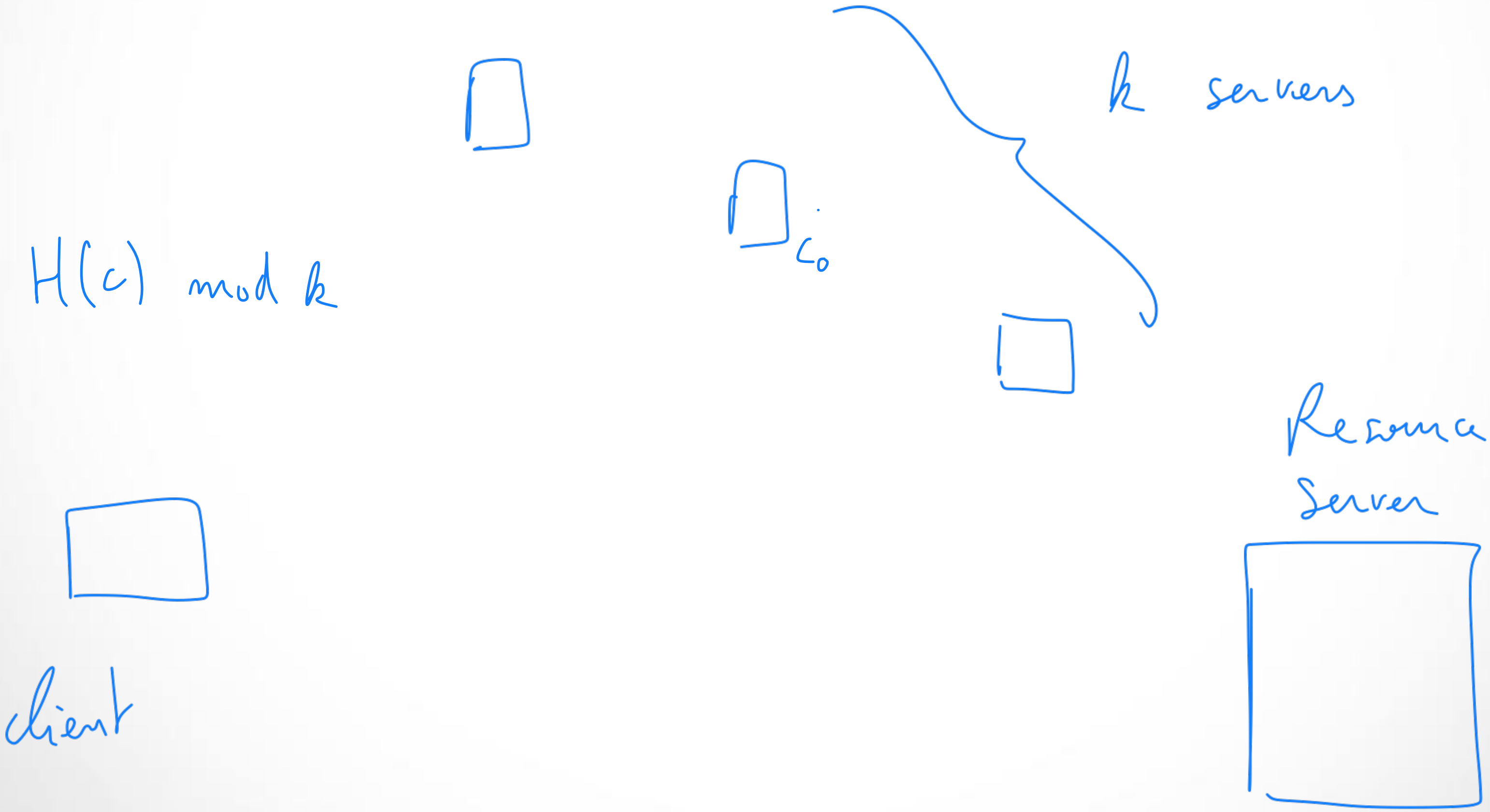


The guided tour puzzle

$i_0 = H(c) \bmod k$



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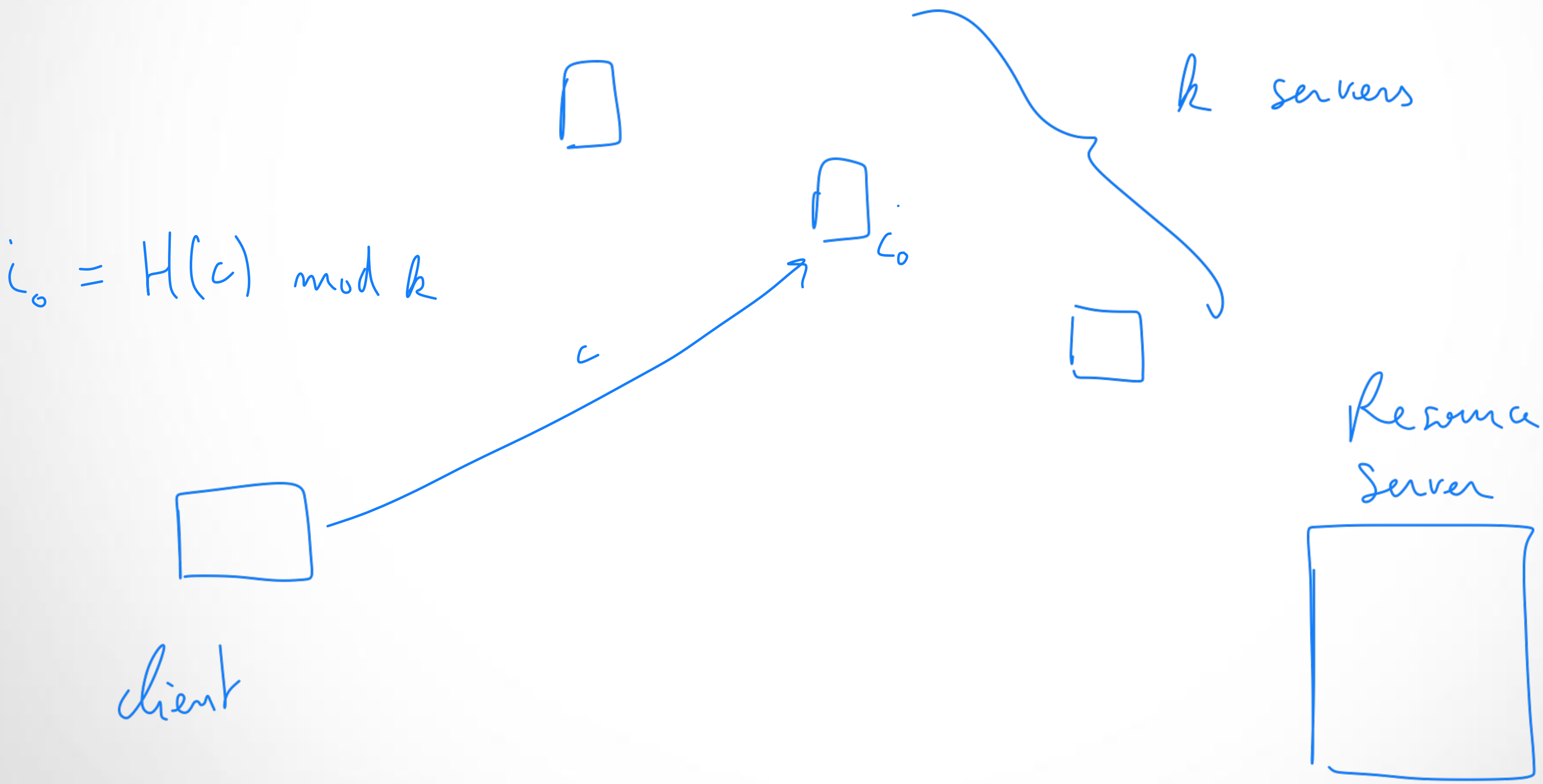

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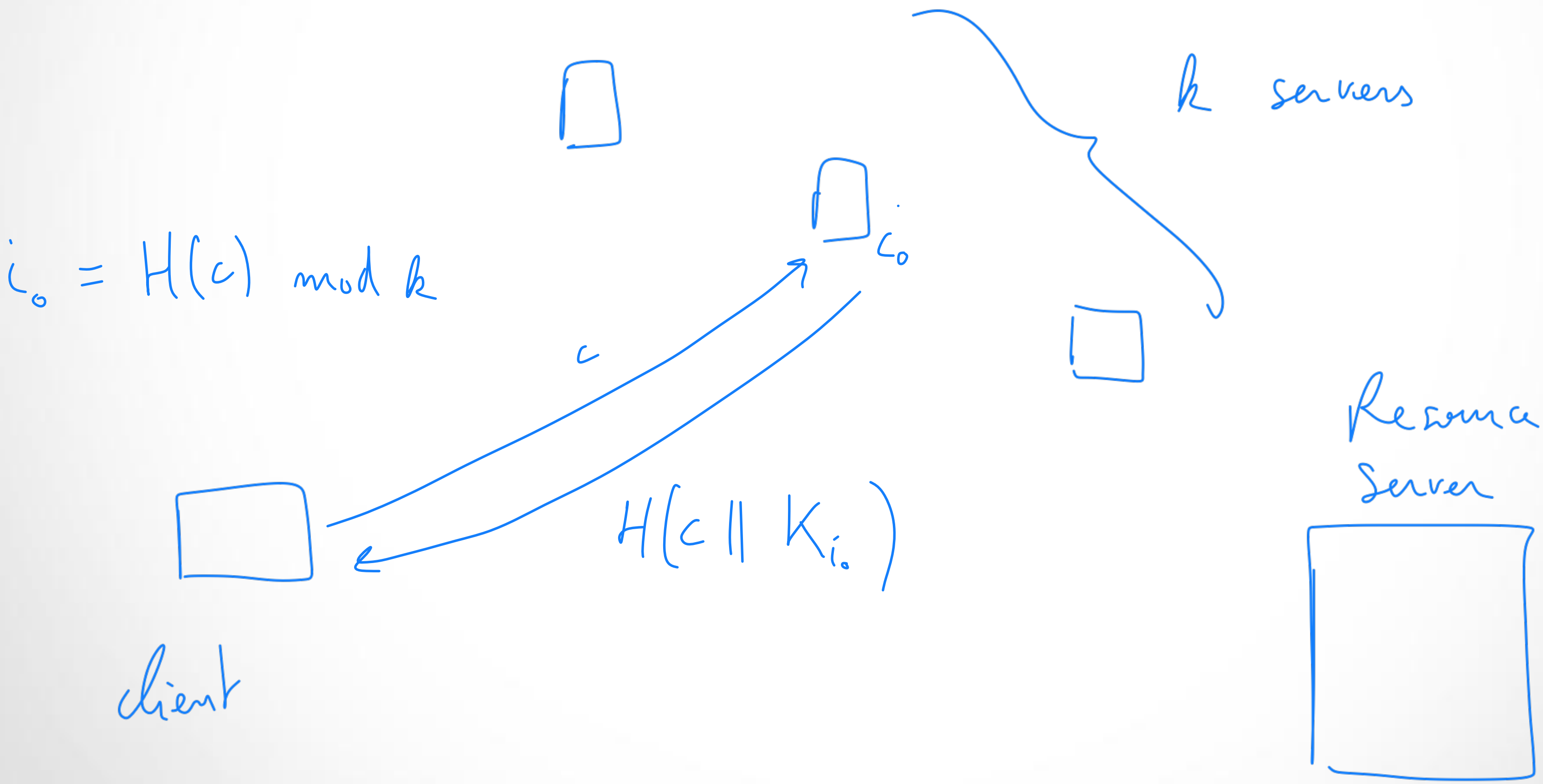

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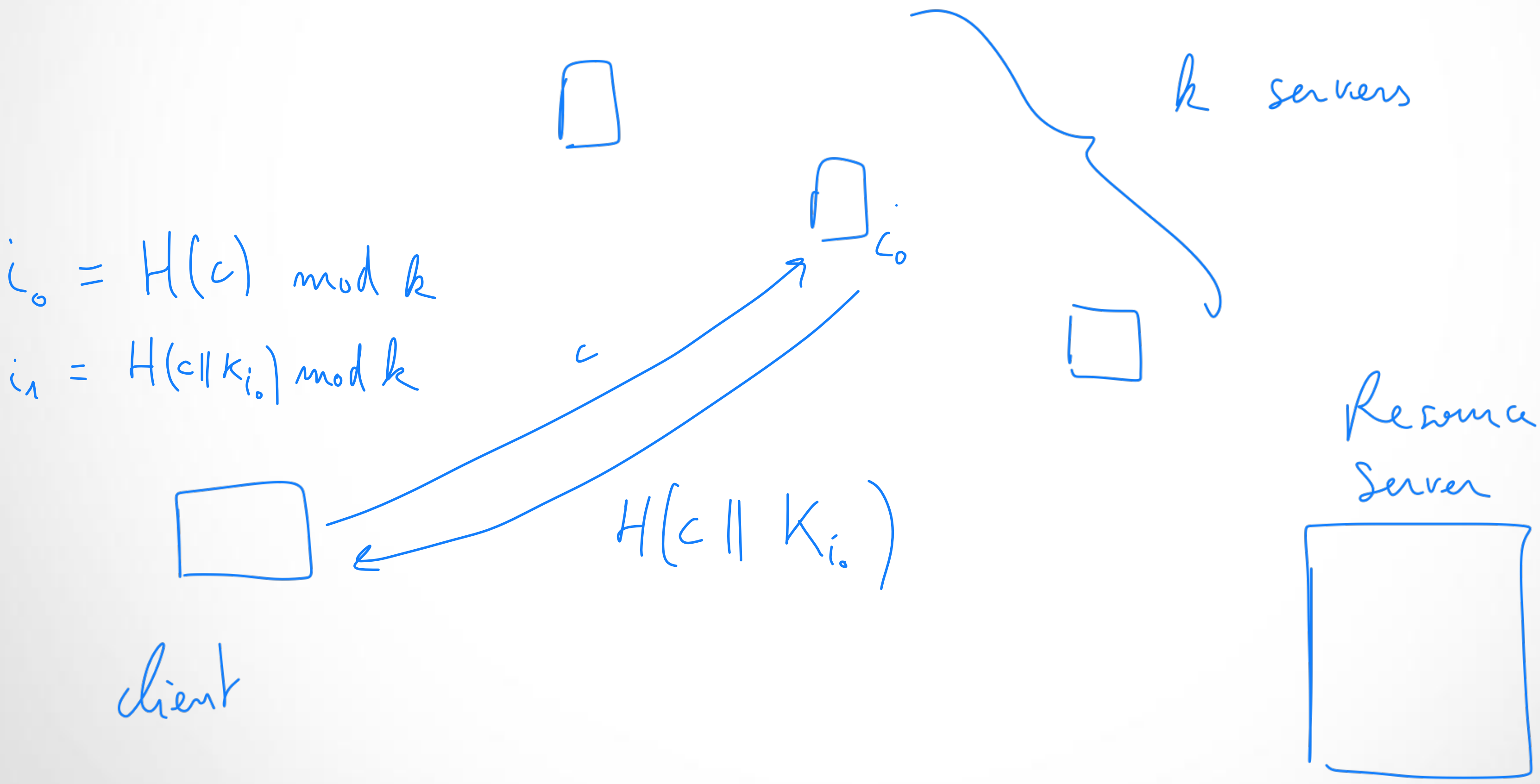

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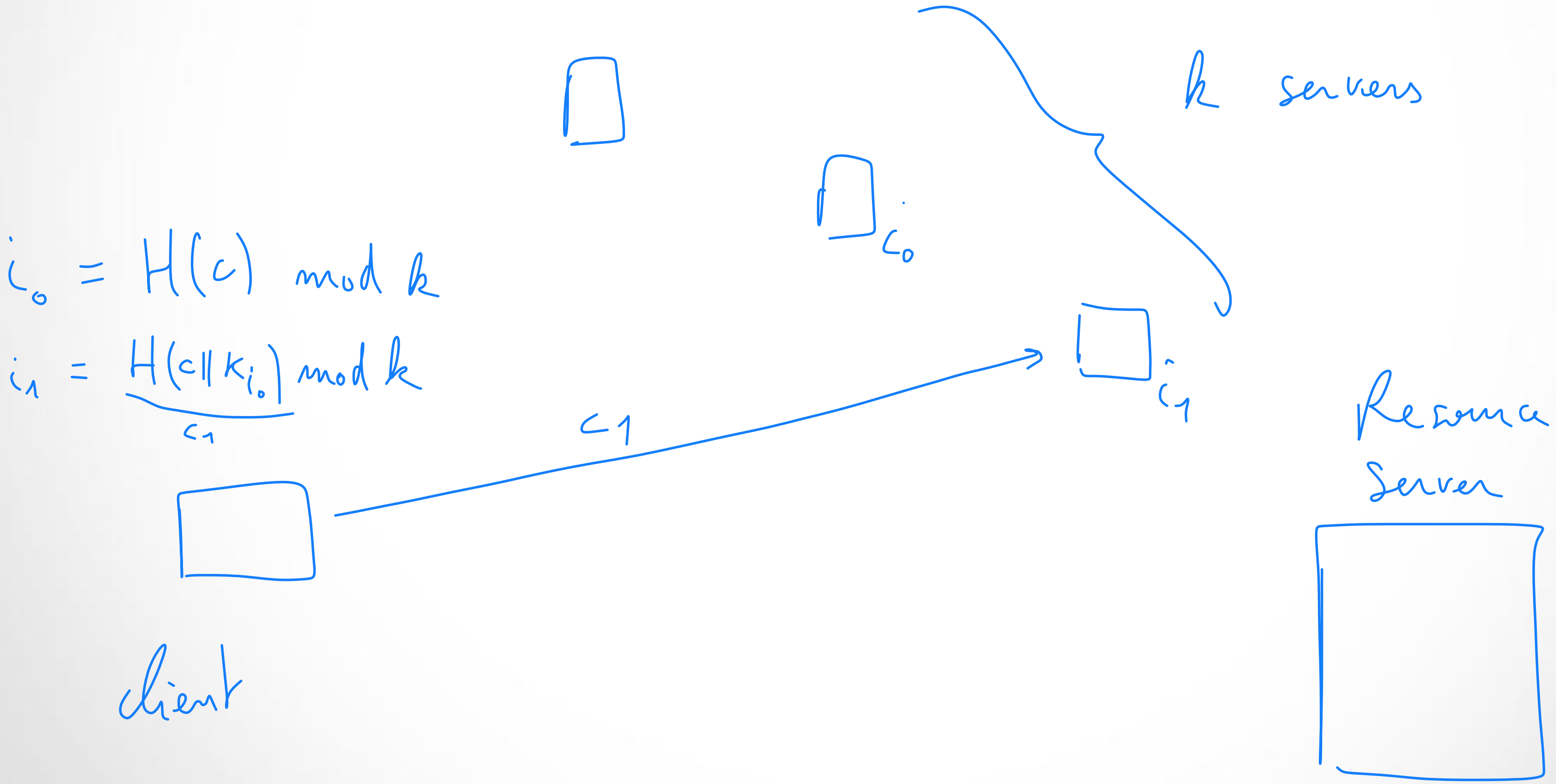

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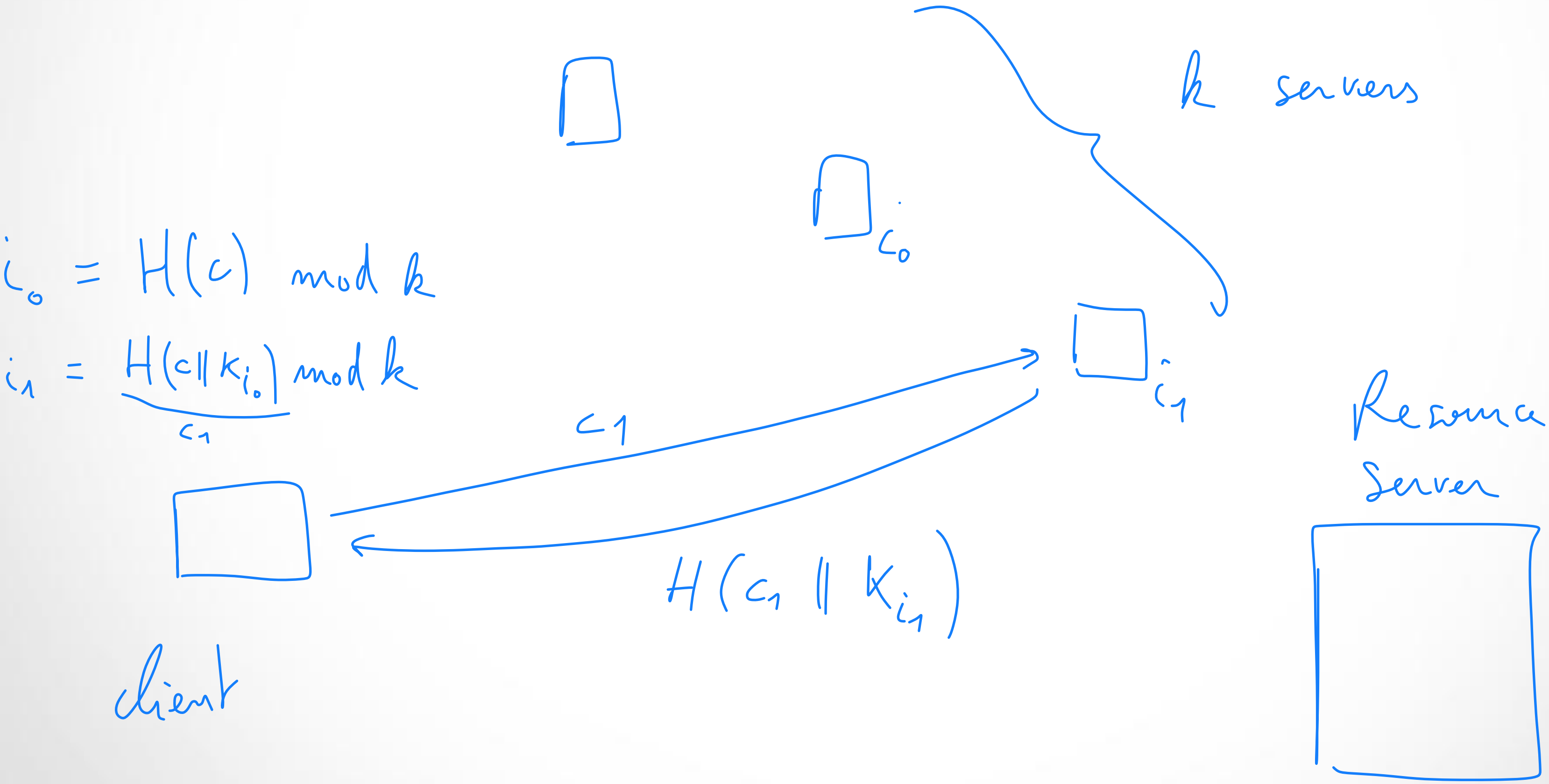

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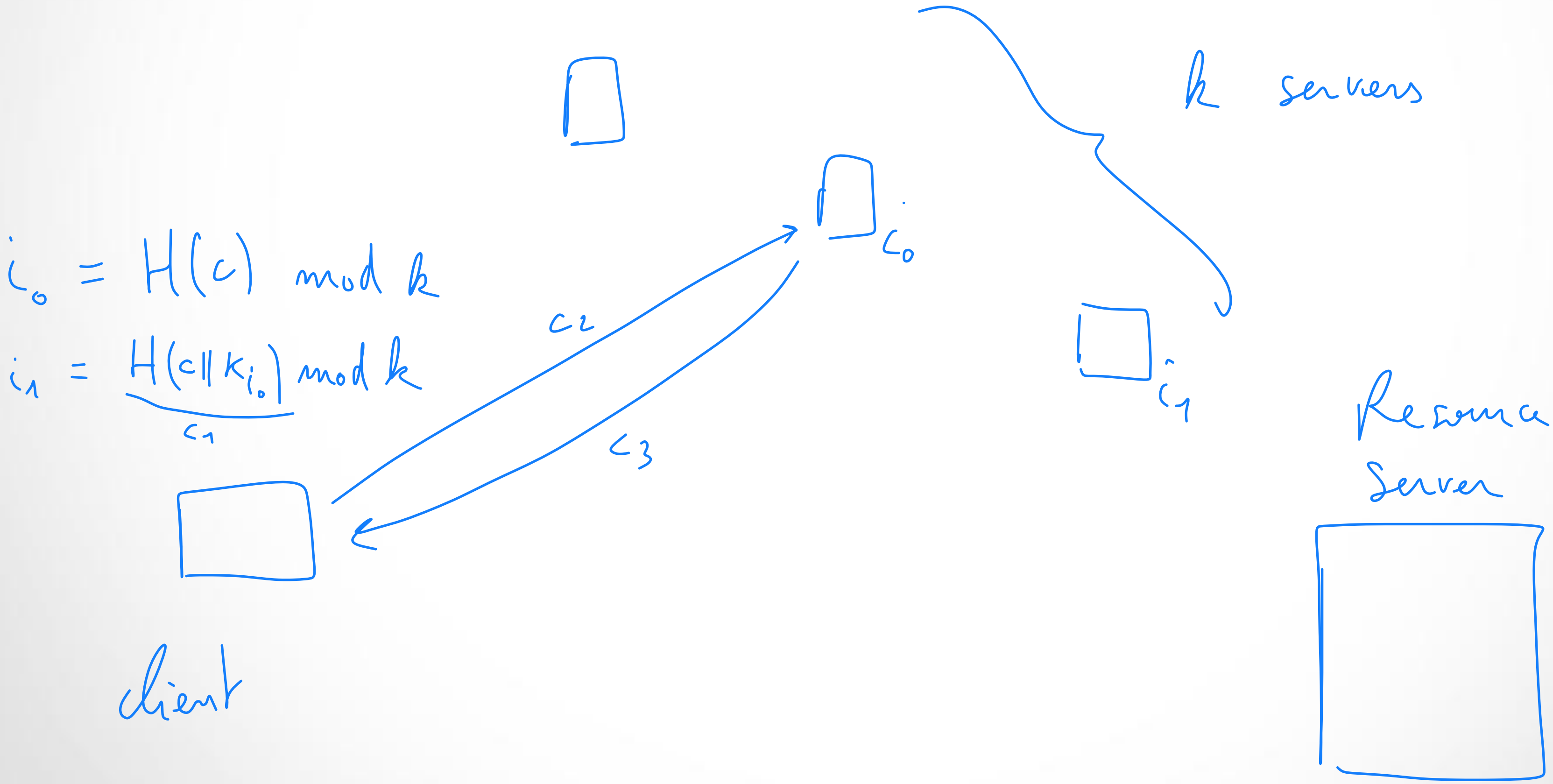

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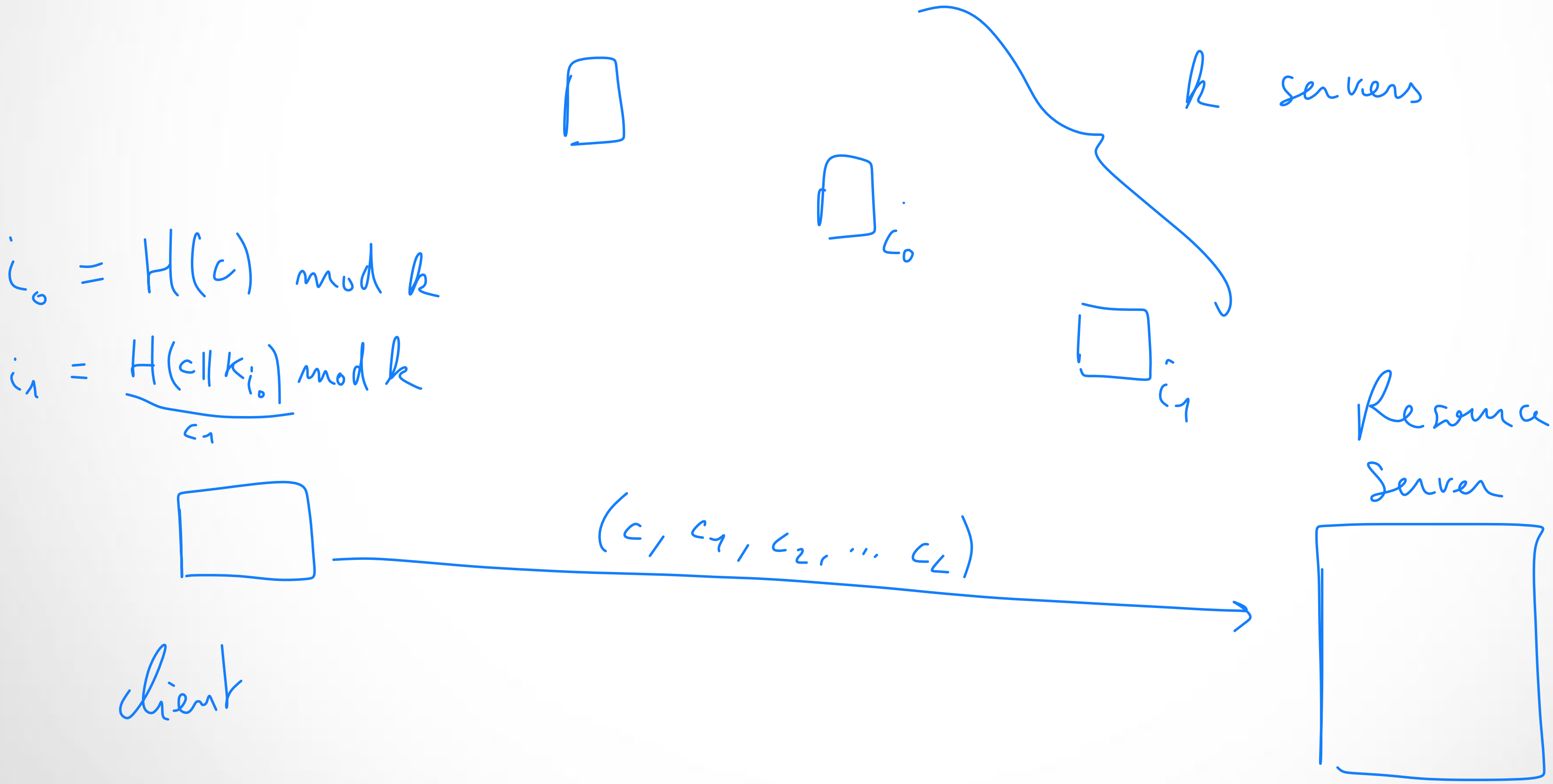

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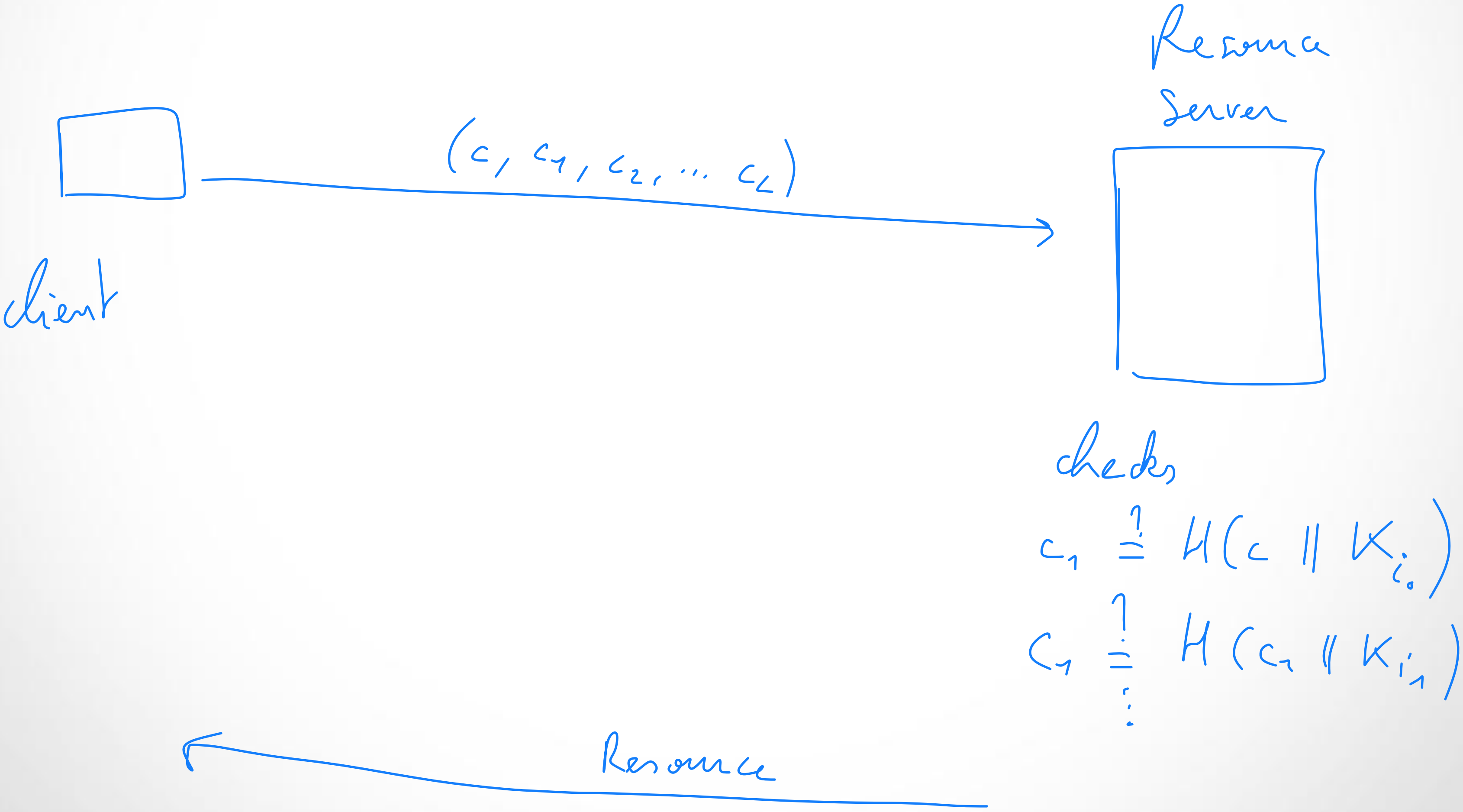
Resource Server
client
$(c, c_1, c_2, \dots c_L)$
checks
$c_1 \overset{?}{=} H(c \,||\, K_{i_0})$
$c_1 \overset{?}{=} H(c_1 \,||\, K_{i_1})$
$\vdots$
Resource

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We consider a fixed set of participants $P_0, P_1, \dots P_n$

A participant P_i can perform a guided tour, with a seed derived from **its public key**

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$$\begin{tikzcd}
P_i \arrow[r, "c"] & P_{i_0} \arrow[l, bend left, "s_1 = sign(c)"]
\end{tikzcd}$$

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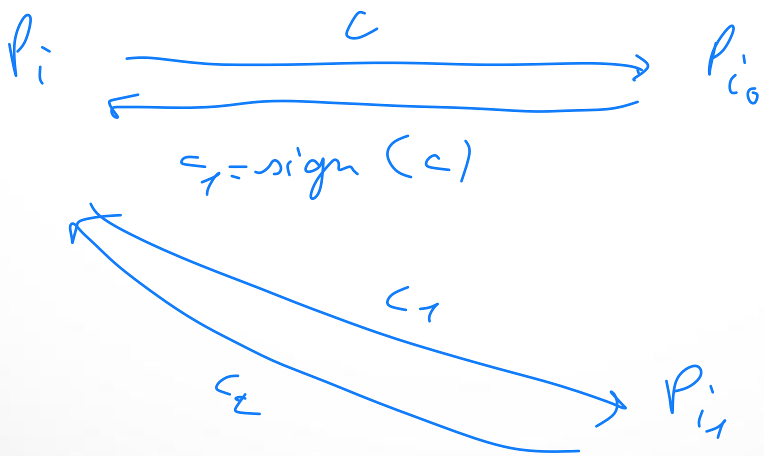

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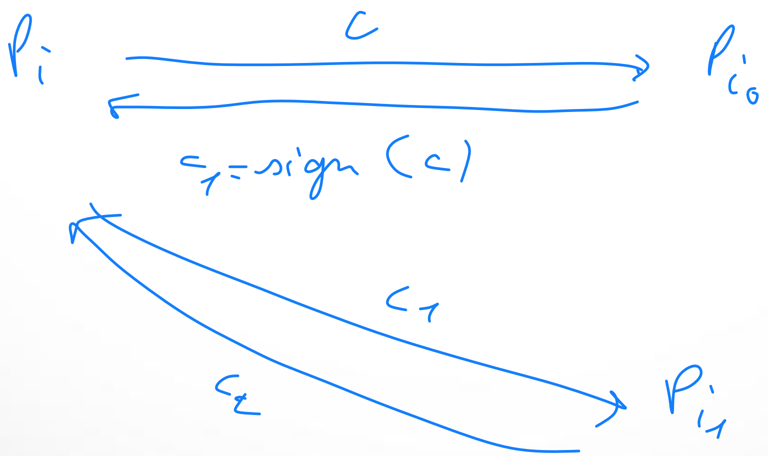

$$(c, c_1, c_2 \ldots, c_l)$$

First Work: Proof-of-Interactions

We consider a fixed set of participants $P_0, P_1, \dots P_n$

A participant P_i can perform a guided tour, with a seed derived from its public key and the Merkel tree root **and the hash of the previous block.**

$$c = sign_i (P_i \parallel M \parallel B_{prev})$$

First Work: Proof-of-Interactions

We consider a fixed set of participants $P_0, P_1, \dots P_n$

How long is the tour?

$$L = rand(sign_i(B_{prev}))$$

First Work: Proof-of-Interactions

We consider a fixed set of participants $P_0, P_1, \ldots P_n$

What data do we ask participant to sign ?

$$\begin{tikzcd}
P_i \arrow[rr, shift left, "{c, B_{prev}, M}"] & & P_{i_0} \arrow[ll, shift left, "{sign_{i_0}(c \| B_{prev} \| M)}"]
\end{tikzcd}$$

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We consider a fixed set of participants $P_0, P_1, .. P_n$

How to tolerate crashes?

Make a tour around a subset

S = select 20 random nodes

Make a tour among S.

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Properties:

Not parallelizable

Difficulty is adjustable

Crash-tolerant

Byzantine-tolerant

Protected against
Selfish-mining

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$$c := sign_i(B_{prev} \| P_i \| M)$$

$$\xrightarrow{c,\ B_{prev},\ M} P_{i_0}$$

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$$c' := sign_i(B_{prev} \| P_i \| M')$$

$$\xrightarrow{c',\, B_{prev},\, M'} P_{i_0}'$$

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$$L = \underset{\substack{\uparrow \\ \text{adjustable.}}}{\mathrm{rand}}\left(\mathrm{sign}_i\left(B_{prev}\right)\right)$$

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$\xrightarrow{n} 1$

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Proba (not all node in a tour are Byzantine)

$\xrightarrow{n} 1$

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to create a block, P_i must send the previous Block

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Small message complexity

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Small message complexity

Each participant is part of ≈ 20 tours but contribute $\frac{1}{20}$ of the time.

total ≈ 2 continuous ⇄

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Challenge: IoT devices generate a lot of data

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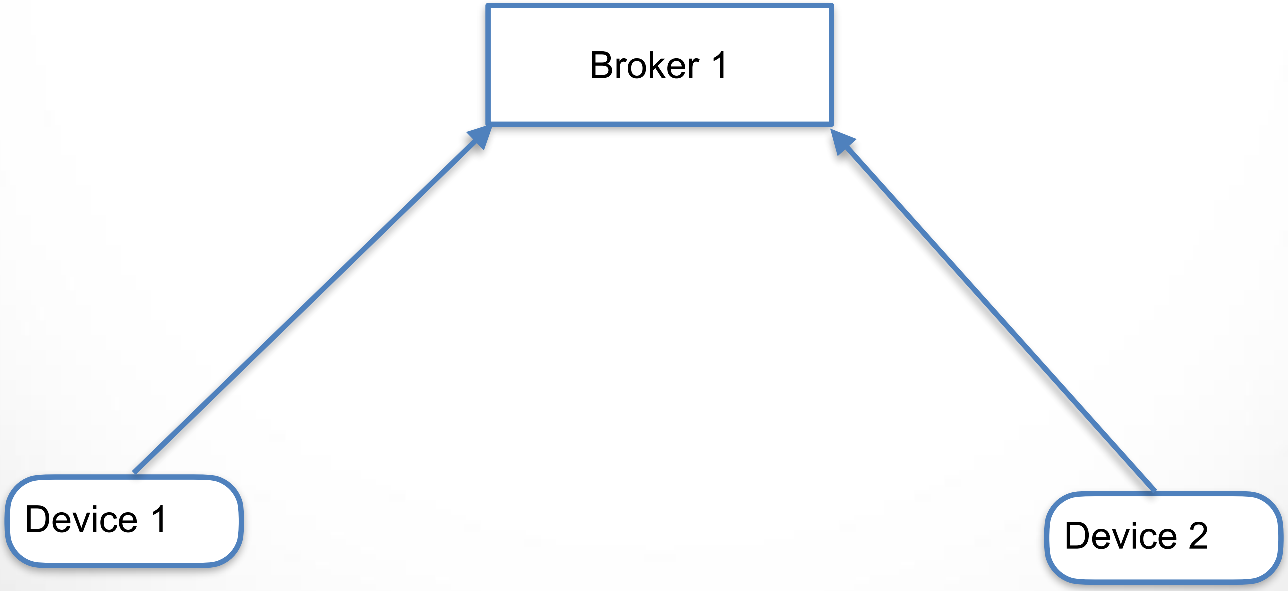
Challenge: IoT devices generate a lot of data

Idea: use off-chain transmission if possible

2nd Work: a pub-sub protocol

A centralized pub-sub protocol:



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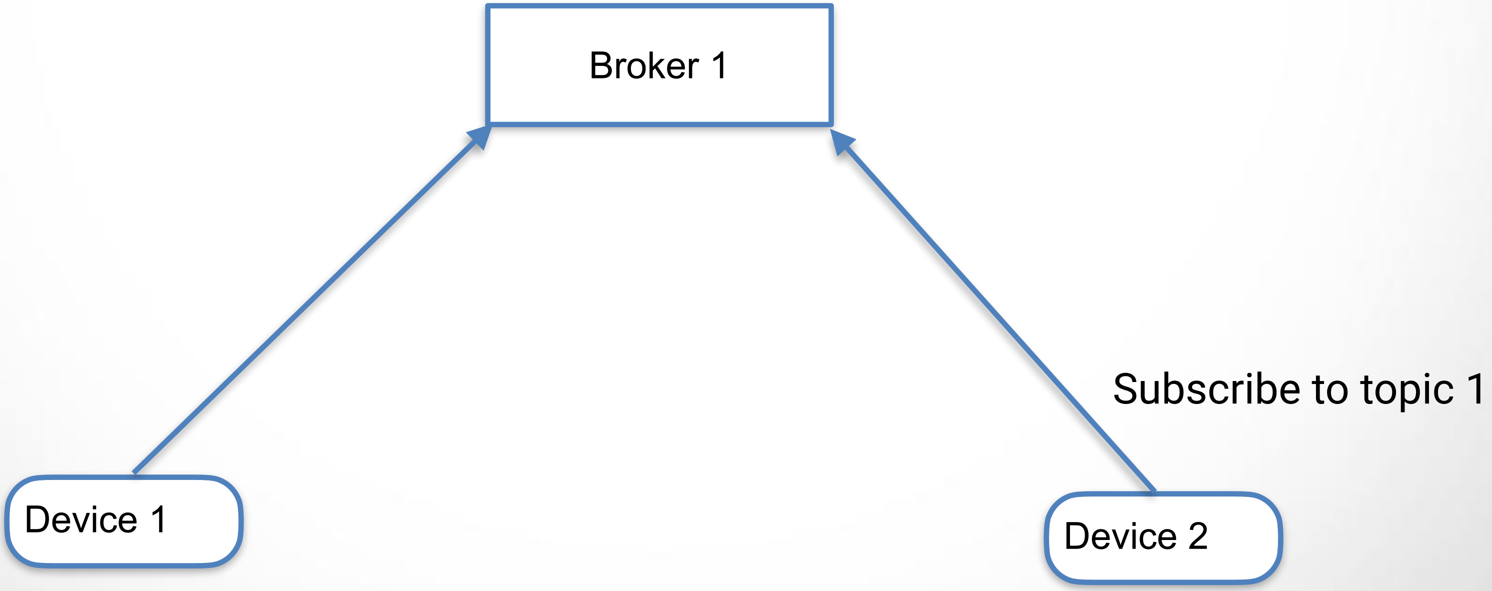

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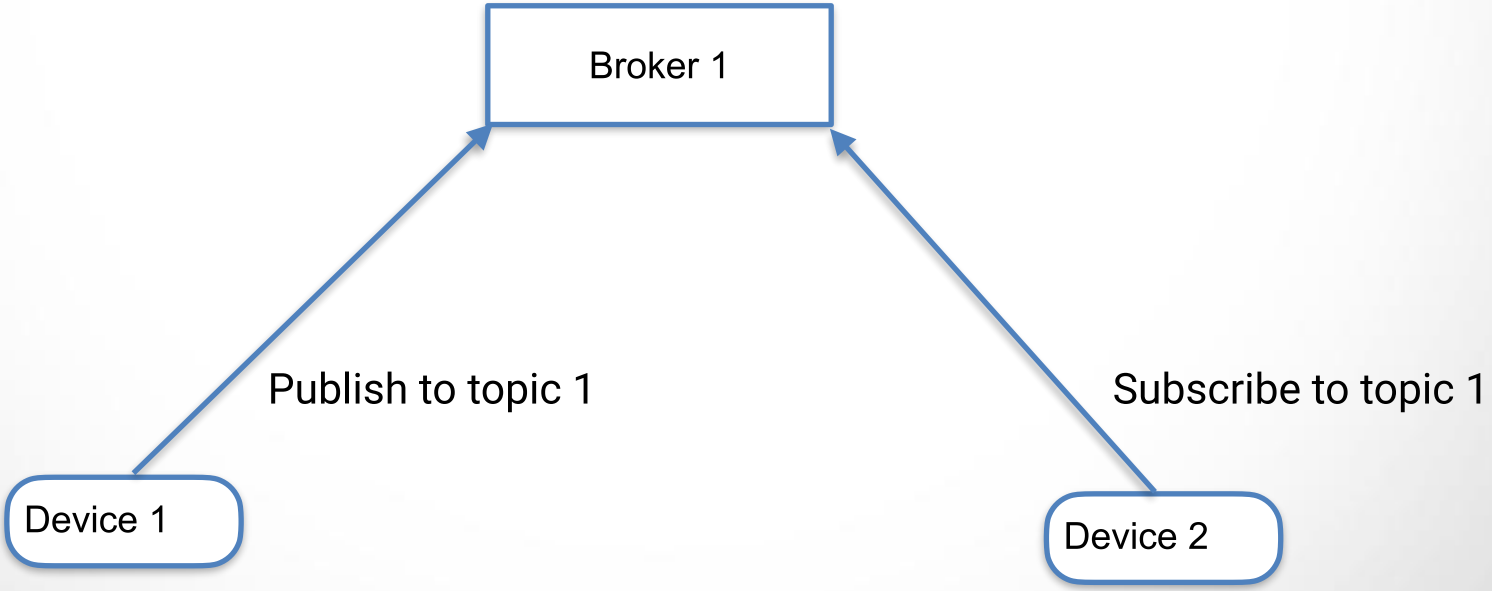

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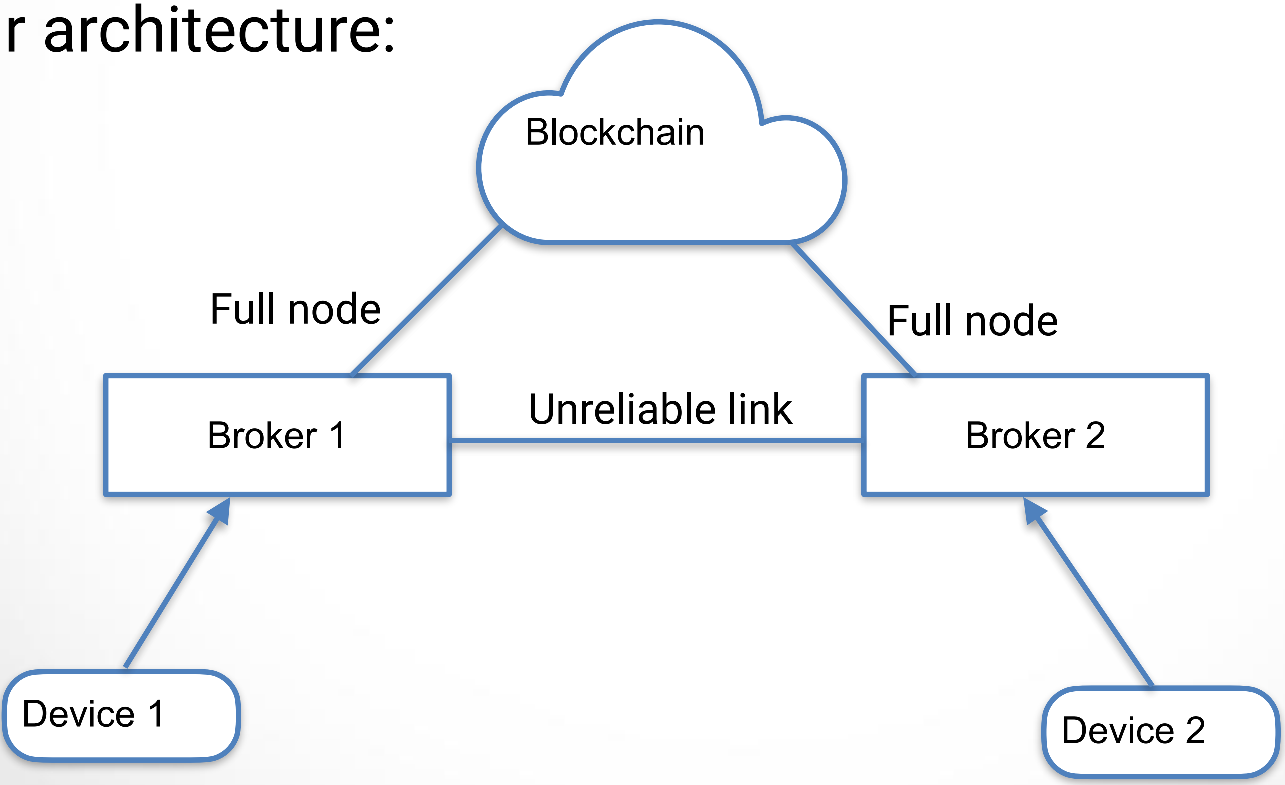
Our architecture:



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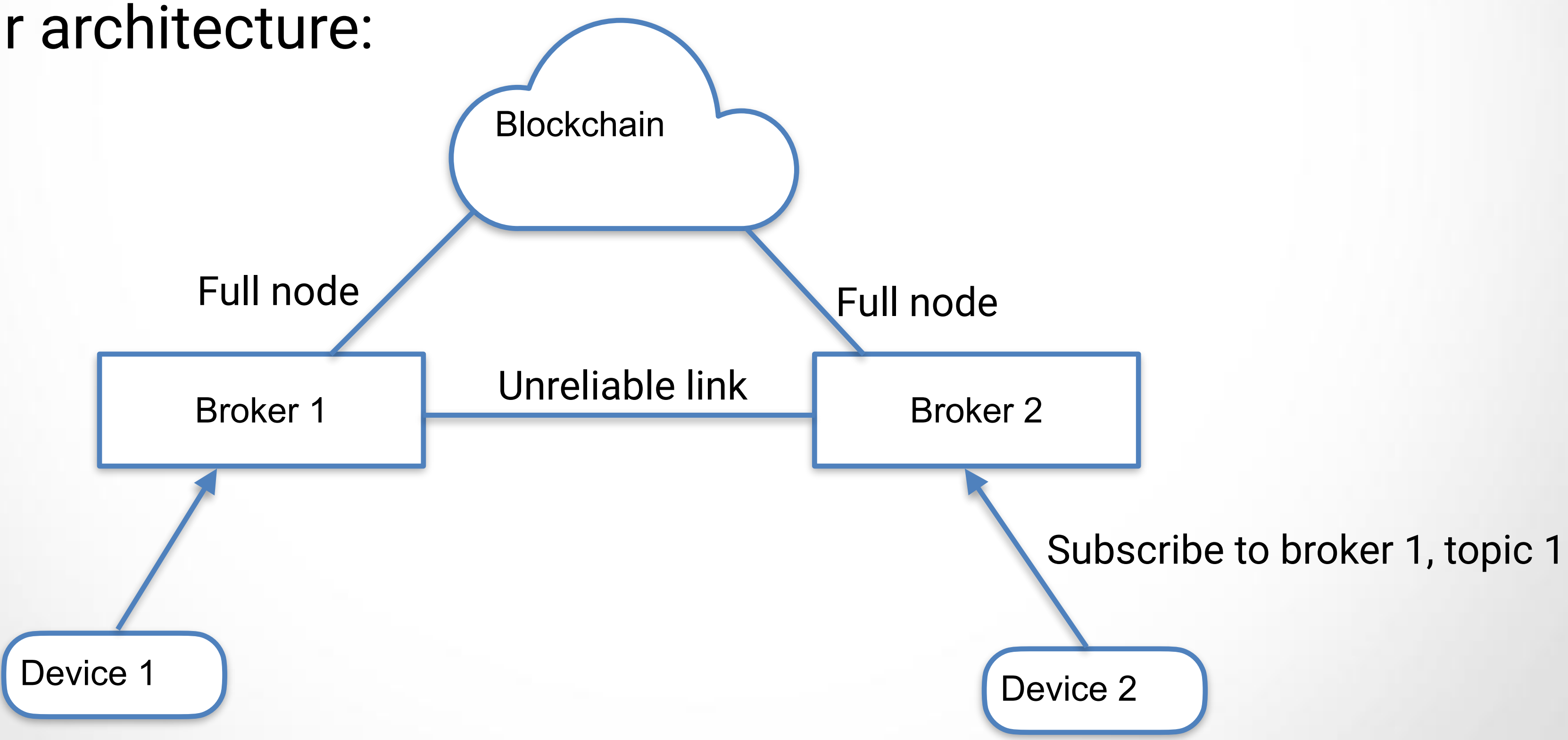

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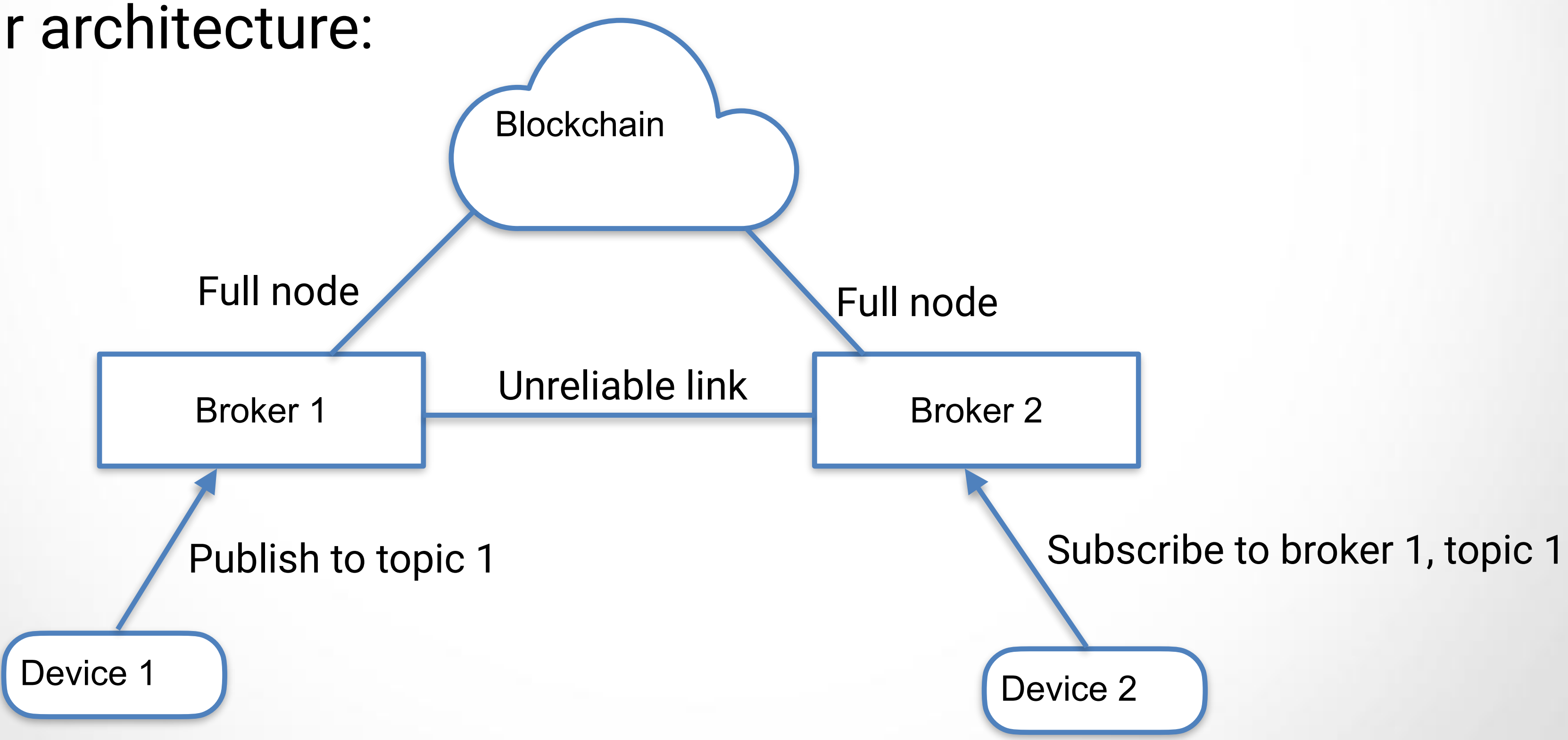
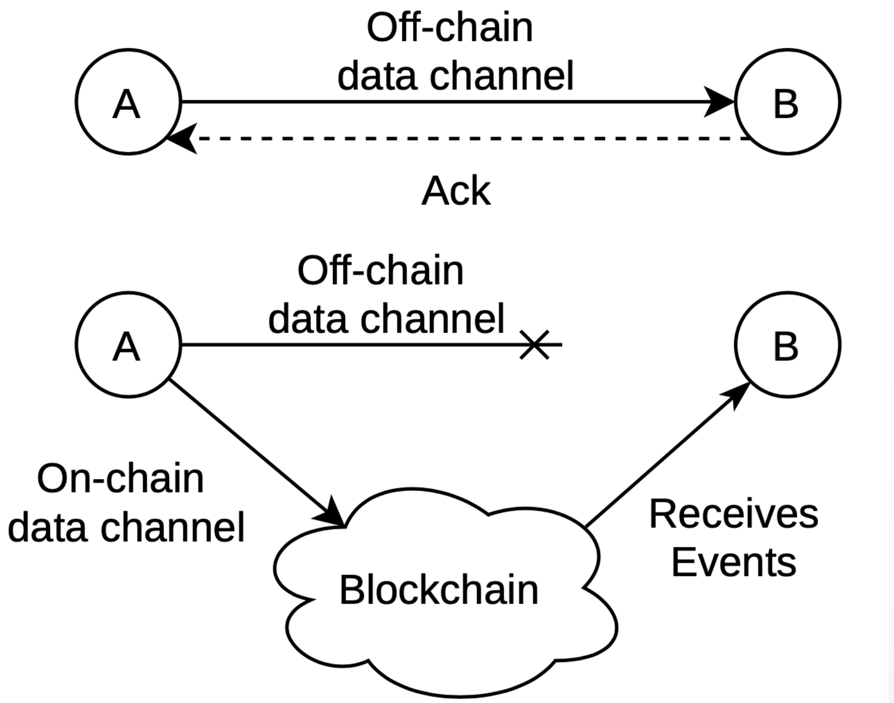


2nd Work: a pub-sub protocol

Unidirectional off-chain data channel



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2nd Work: a pub-sub protocol

- The receiver has a proof of the origin of the data
- The sender has a proof that the data is received
- The sender can sell his data and be sure to be paid (In this case the buyer is sure to receive its data)
- Messages are sent off-chain, unless there is a problem (link failure or malicious behavior)

Conclusion

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2 examples to improve scalability in Blockchains

- Proof-of-interactions

Jean-Philippe Abegg, Quentin Bramas and Thomas Noël.
Blockchain Using Proof-of-Interaction, Netys 2021

- Off-chain pub-sub protocol

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