IIC3253

Criptomonedas

Bitcoin: A Peer-to-Peer Electronic Cash System

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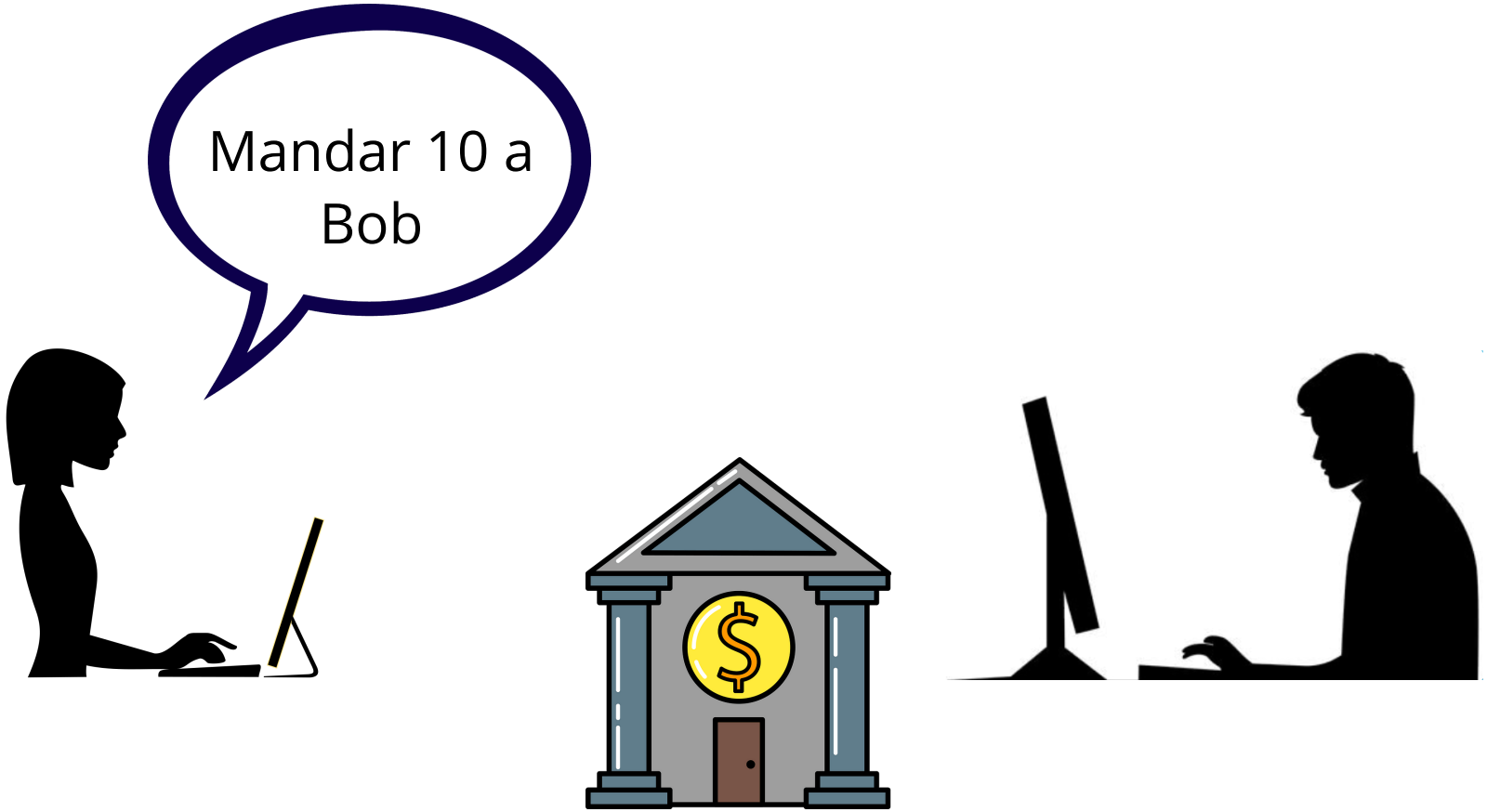
Abstract. A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work. The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers. The network itself requires minimal structure. Messages are broadcast on a best effort basis, and nodes can leave and rejoin the network at will, accepting the longest proof-of-work chain as proof of what happened while they were gone.

1. Introduction

Commerce on the Internet has come to rely almost exclusively on financial institutions serving as trusted third parties to process electronic payments. While the system works well enough for most transactions, it still suffers from the inherent weaknesses of the trust based model. Completely non-reversible transactions are not really possible, since financial institutions cannot avoid mediating disputes. The cost of mediation increases transaction costs, limiting the minimum practical transaction size and cutting off the possibility for small casual transactions, and there is a broader cost in the loss of ability to make non-reversible payments for non-reversible services. With the possibility of reversal, the need for trust spreads. Merchants must be wary of their customers, hassling them for more information than they would otherwise need. A certain percentage of fraud is accepted as unavoidable. These costs and payment uncertainties can be avoided in person by using physical currency, but no mechanism exists to make payments over a communications channel without a trusted party.

What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted

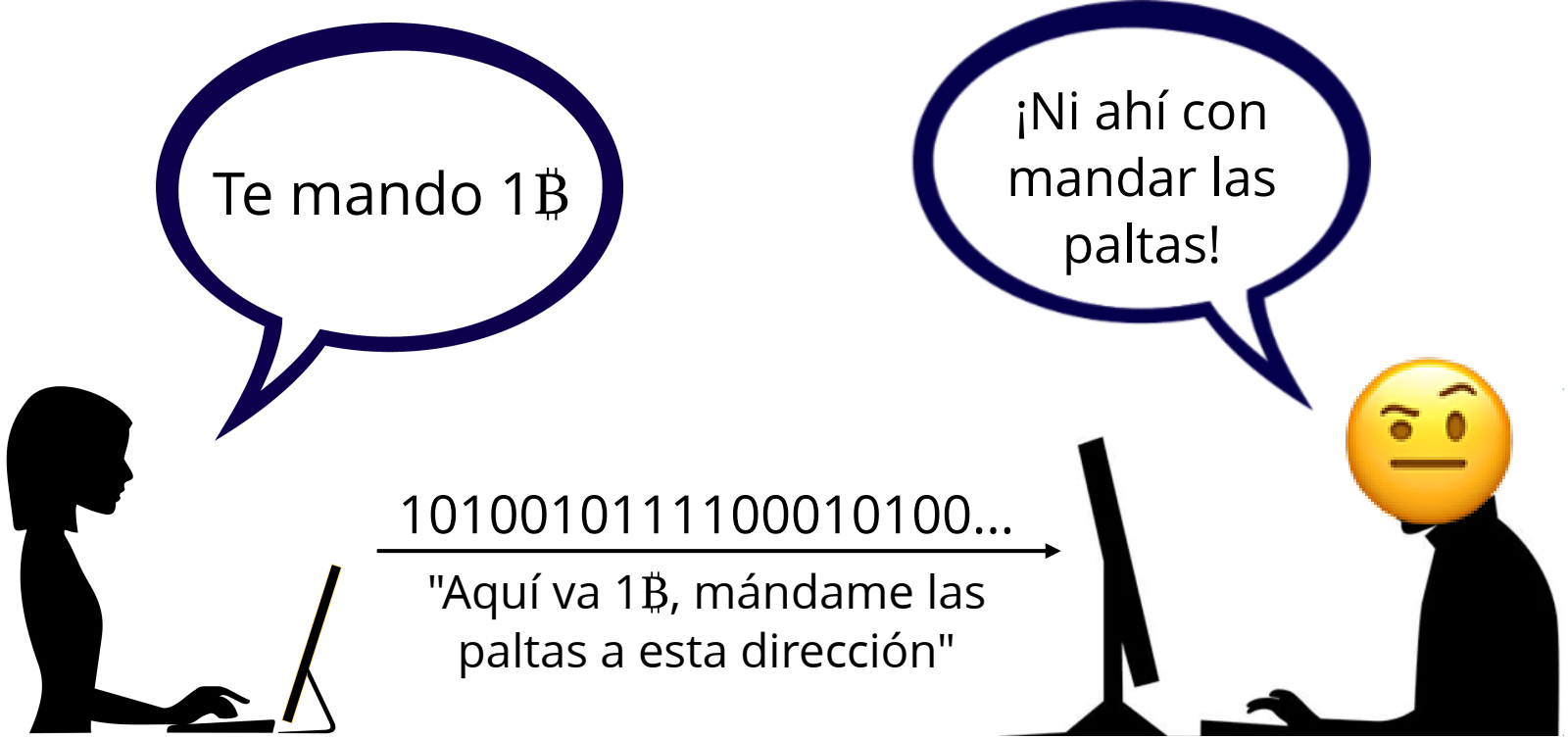


Name	Balance
Alice	100
Bob	100

Alice te mandó 10

Name	Balance
Alice	90
Bob	110

Perfect 👌 mando las paltas



¿Cómo sé que estoy hablando con alguien que tiene 1₿?

¿Cómo sé que me está transfiriendo 1₿?

¿Cómo sé que no se lo está gastando en otro lado?

¿De dónde salió ese bitcoin, quién lo creó?

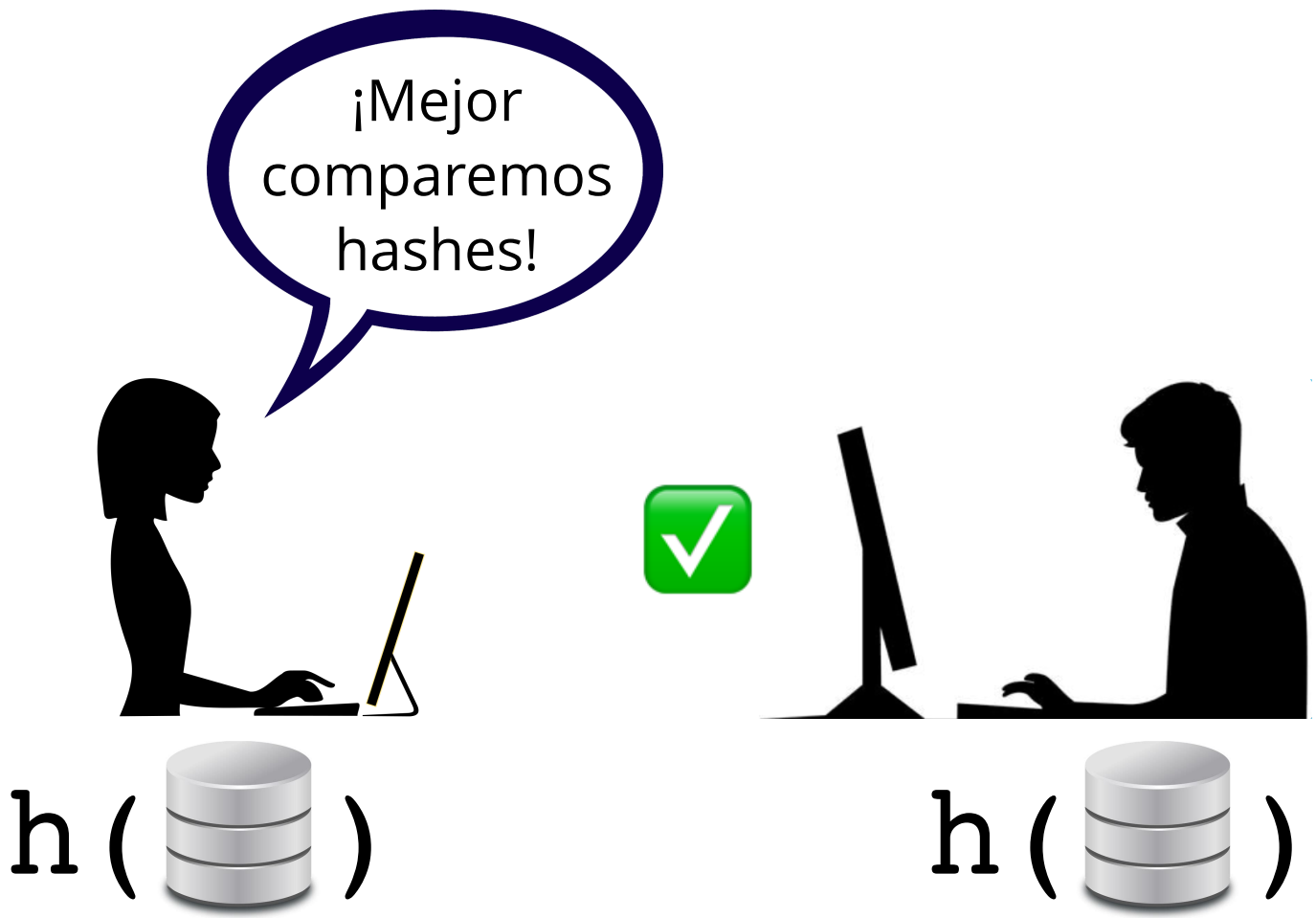
Ingredientes necesarios

Funciones de hash

Firmas digitales

Funciones de Hash e información distribuida

Funciones de Hash e información distribuida

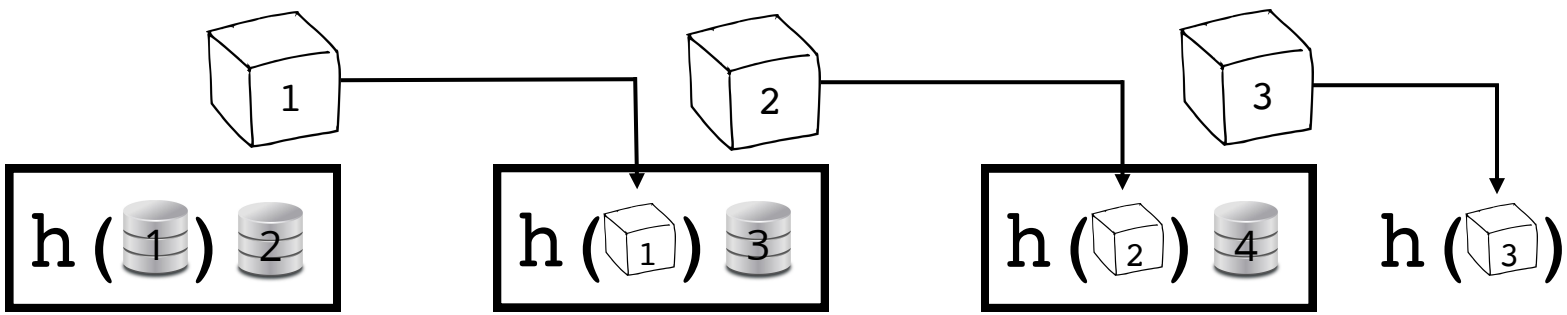


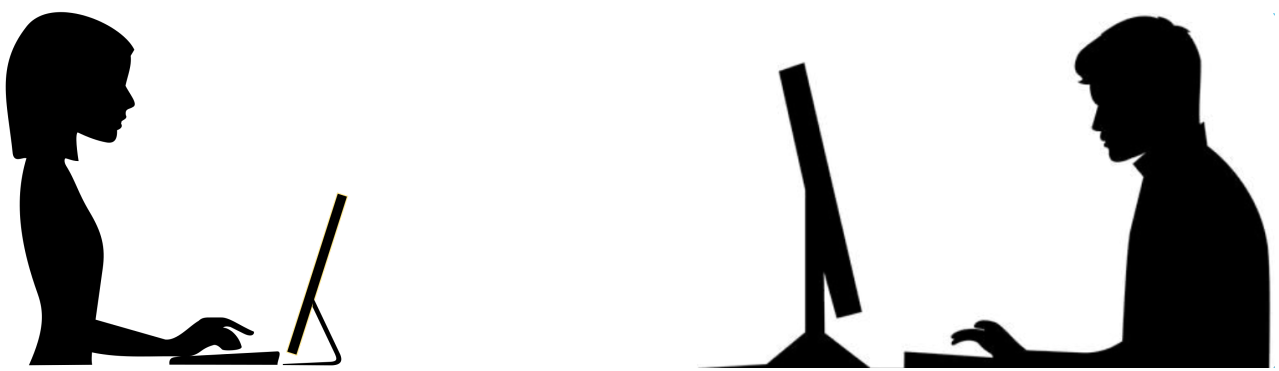
Funciones de Hash e información distribuida

Funciones de Hash e información distribuida

h(h(1) h(2) h(3))

h(h(1) h(2) h(3))





Nos basta con compartir h (3) 🎉

¡EL FUTURO ES HOY!

¿Qué es lo nuevo?

¿Funciones de hash criptográficas?

1973

¿Firmas digitales?

1978

¿El ✨Blockchain✨?

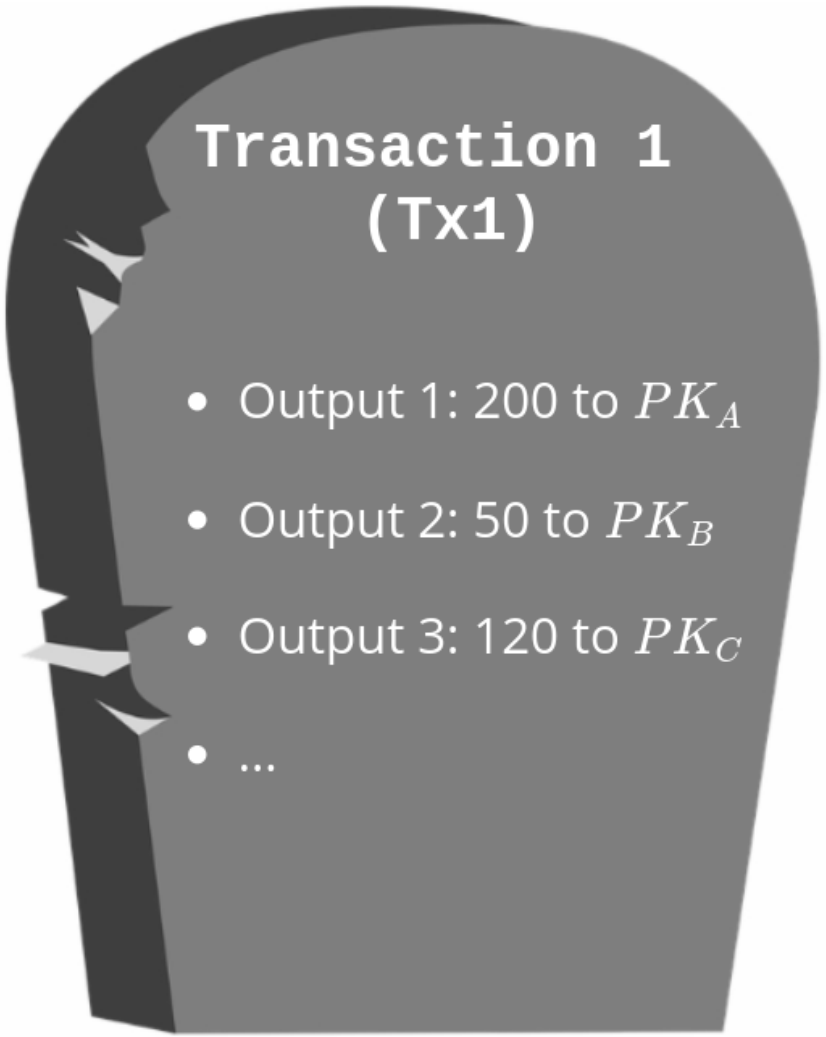
1970s

¡Hagamos una criptomoneda!

Alice	Bob	Carol	Dan	Eve	Frank
					
SK_A	SK_B	SK_C	SK_D	SK_E	SK_F
PK_A	PK_B	PK_C	PK_D	PK_E	PK_F

$= SK$

$= PK$


Transaction 1
(Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...

¡Bacán, tengo 320!

¡Bacán, tengo 250!

Tx3

Input 1: Tx2, Output 1

Output 1: 200 to PK_C

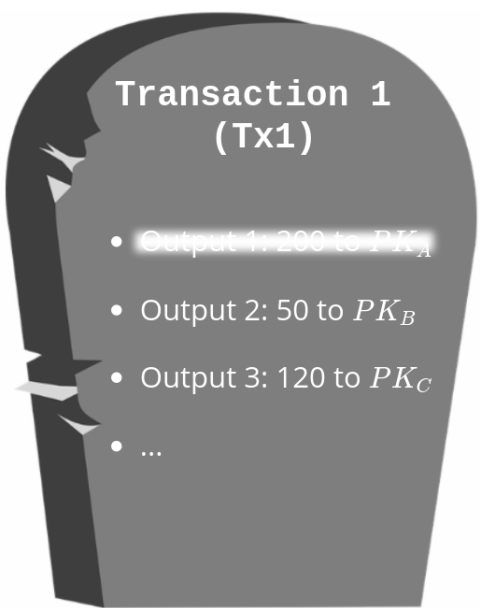
(Firmado con SK_B)

Tx2

Input 1: Tx1, Output 1

~~Output 1: 200 to PK_B~~

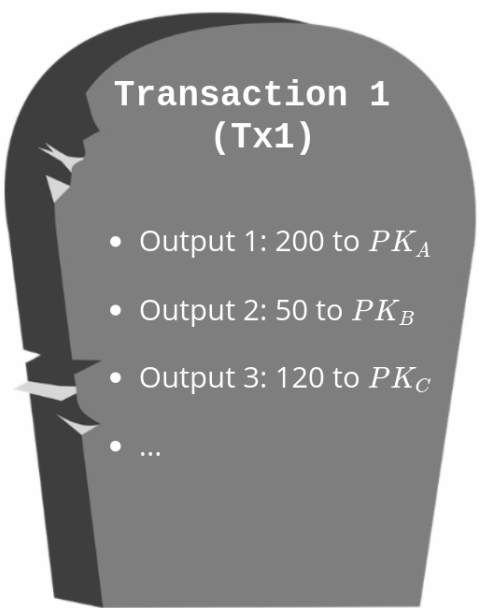
(Firmado con SK_A)



Toda la plata es una cadena originada en la Transacción 1

¿Siempre tengo que gastar outputs completos?

¿Qué pasa si quiero combinar outputs o gastar sólo una parte?



¿Cómo pago 210?

Tx3

Input 1: Tx1, Output 2

Input 2: Tx2, Output 1

Output 1: 210 to PK_C

Output 2: 40 to PK_B

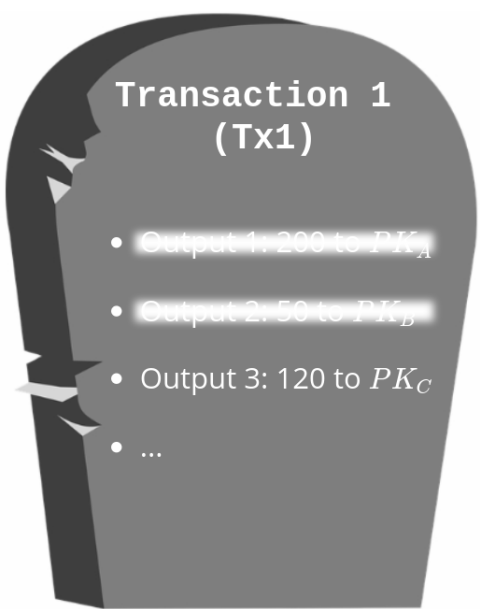
(Firmado con SK_B)

Tx2

Input 1: Tx1, Output 1

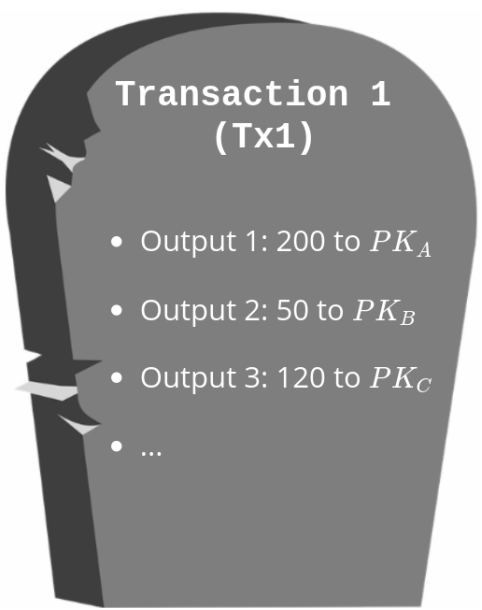
~~Output 1: 200 to PK_B~~

(Firmado con SK_A)



Una transacción puede tener tantos inputs y outputs como queramos

Los outputs siempre se gastan completos



¿Cómo lo arreglamos?

¡Me marcho!

Tx2

Input 1: Tx1, Output 1

Output 1: 200 to PK_C

(Firmado con SK_A)

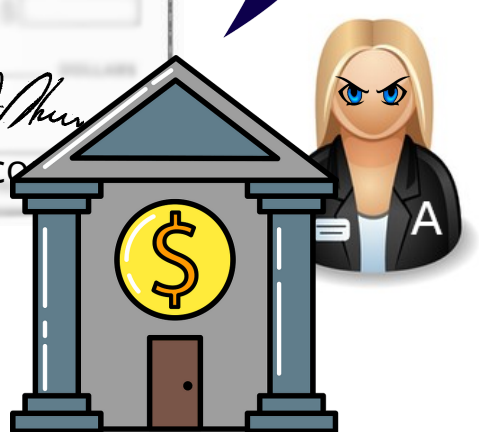
Tx2

Input 1: Tx1, Output 1

Output 1: 200 to PK_B

(Firmado co

¡Yo puedo ayudar!



Transaction 1 (Tx1)

- Output 1: 200 to PK_A
- Output 2: 50 to PK_B
- Output 3: 120 to PK_C
- ...

BankCoin

1. La transacción inicial Tx1, se respeta igual que antes

2. Una transacción es una secuencia de pagos que llega a Tx1, igual que antes

3. El banco publicará en un blockchain firmado todas las transacciones válidas

SK

PK

Input 1: Tx1, Output 1

Output 1: 200 to PK_B

Tx2

(Firmado con SK_A)

Input 1: Tx1, Output 2

Output 1: 50 to PK_c

Tx3

(Firmado con SK_B)

(Firmado con $SK_{🏦}$)

Input 1: Tx1, Output 3

Input 2: Tx3, Output 1

Output 1: 170 to PK_D

Tx4

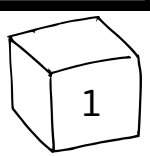
(Firmado con SK_C)

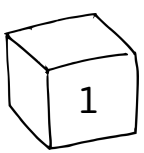
Input 1: Tx2, Output 1

Output 1: 200 to PK_c

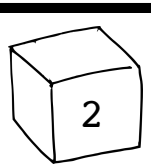
Tx5

(Firmado con SK_B)



h ()

(Firmado con $SK_{🏦}$)



Transaction 1 (Tx1)

- Output 1: 200 to PK_A
- Output 2: 50 to PK_B
- Output 3: 120 to PK_C
- ...

Cool!

¡Está funcionando perfect!

¿Ha estado como lento el sistema los últimos días o no?

Sorry, problema técnico...

Vale, tranqui estamos empezando

Qué raro, como hace una semana que no logro meter transacciones

Sí, es que no me caes tan bien...

Pero por un pago se todo se puede

🚨 ¡¡Me hackearon y me robaron mi llave privada!! 🚨

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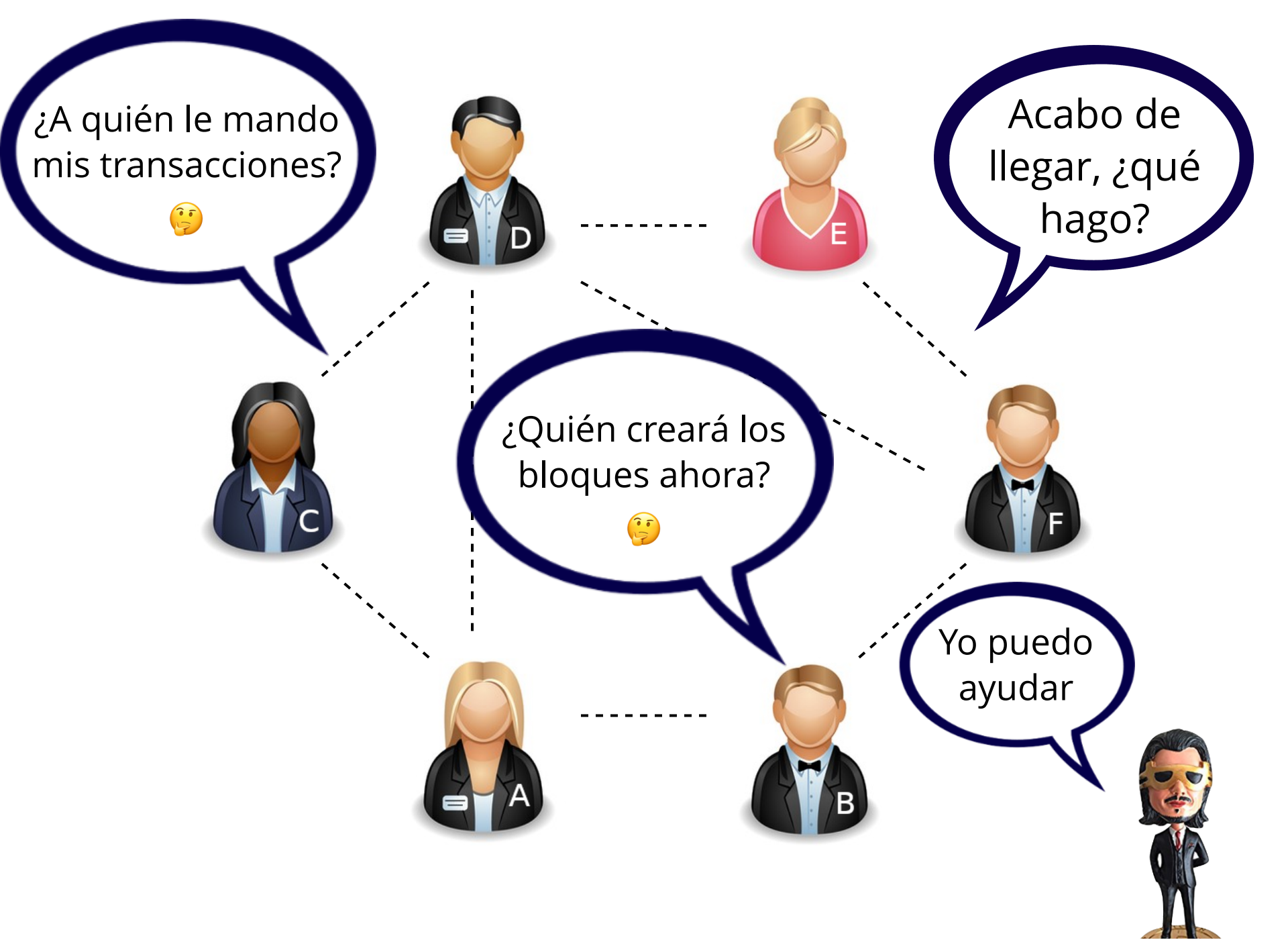
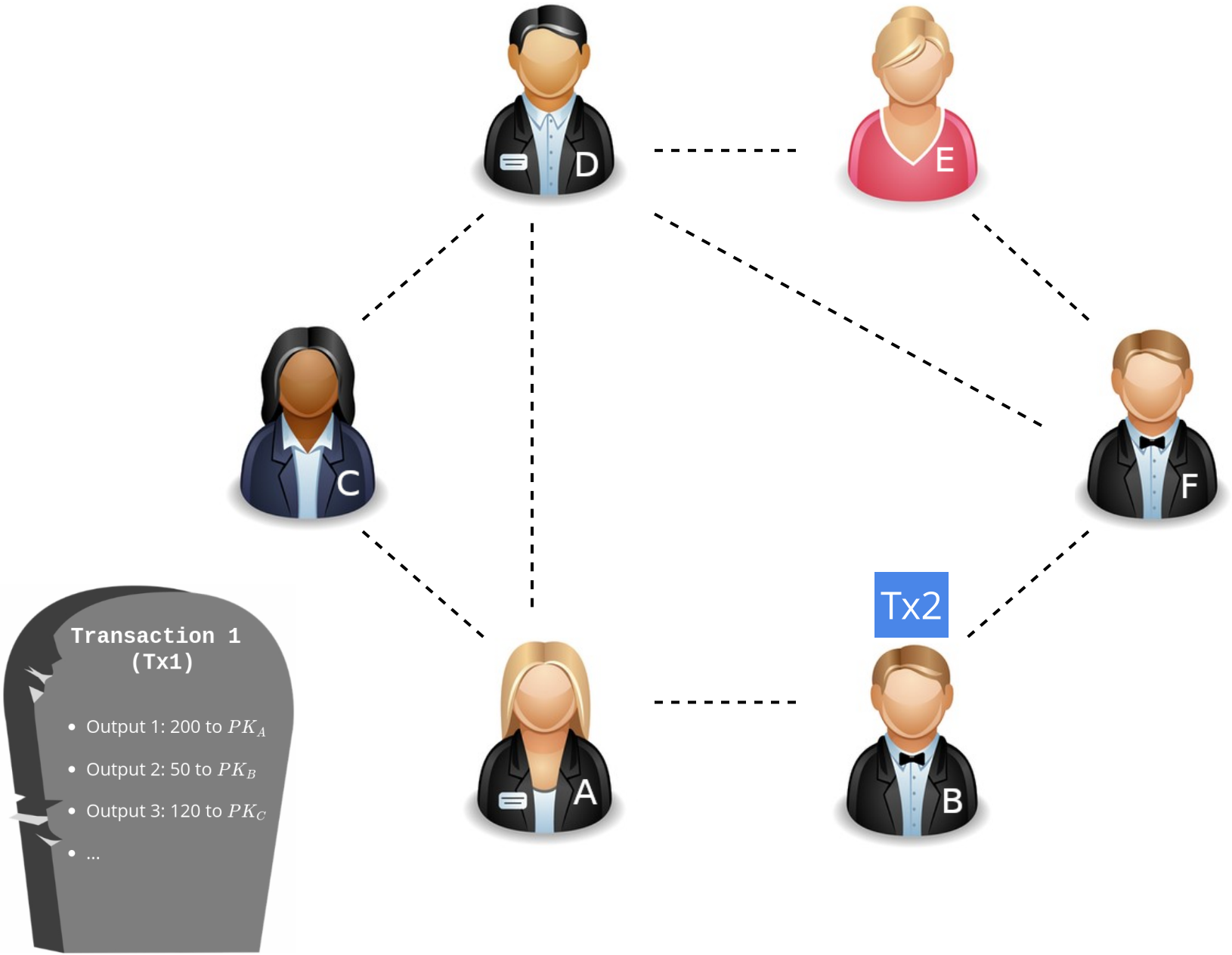
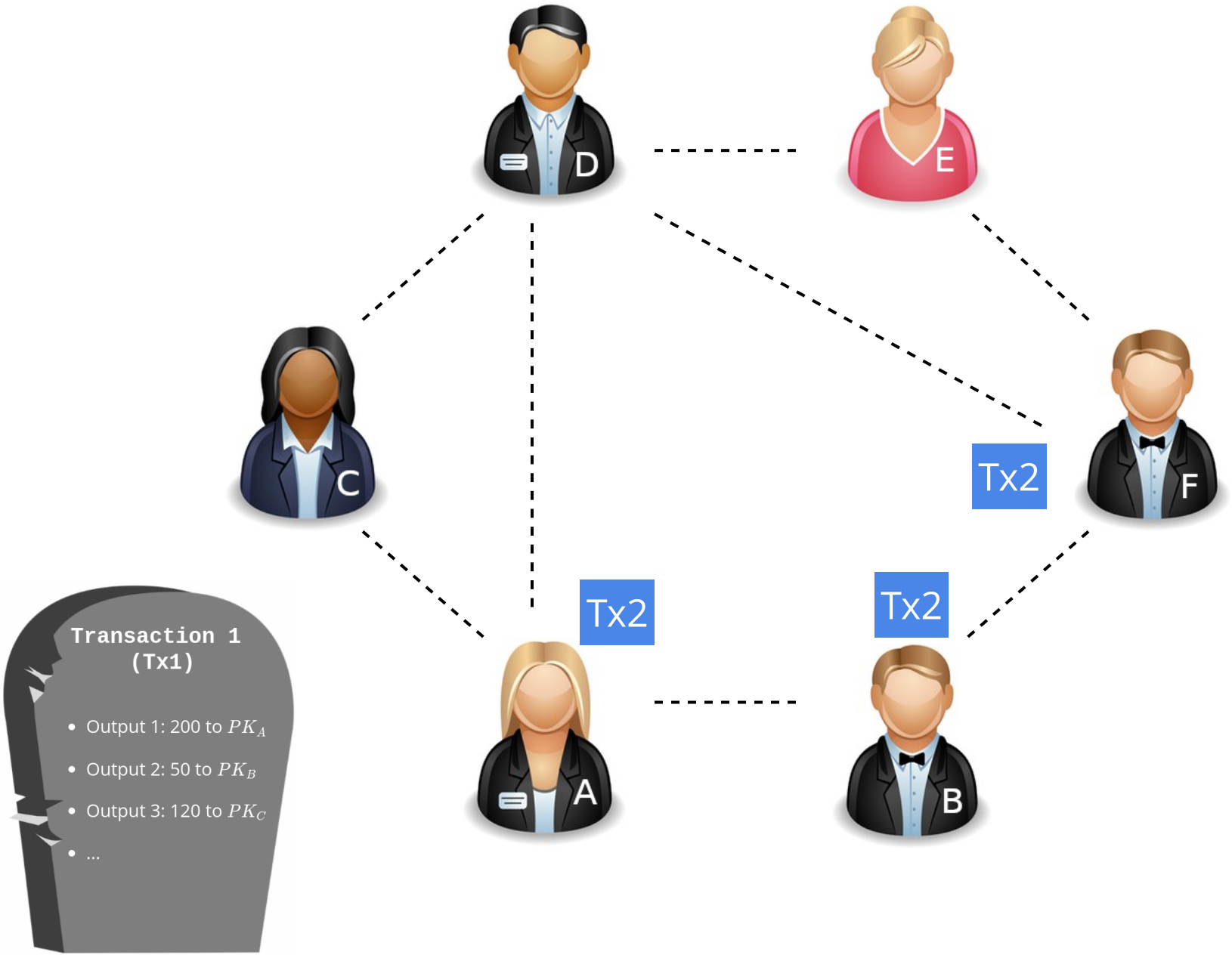
1. Introduction

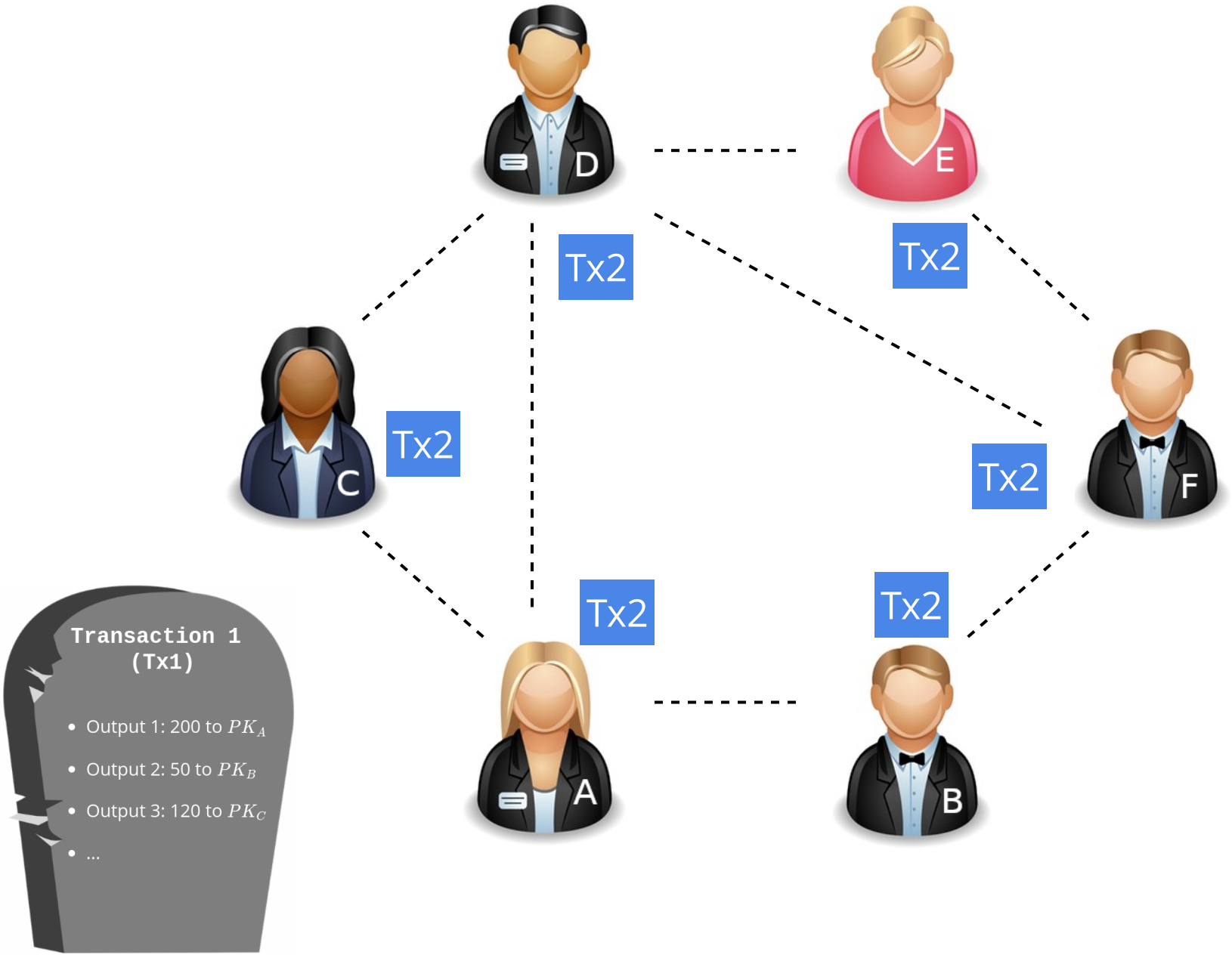

¿A quién le mando mis transacciones?
D
E
Acabo de llegar, ¿qué hago?
C
¿Quién creará los bloques ahora?
F
Yo puedo ayudar
A
B

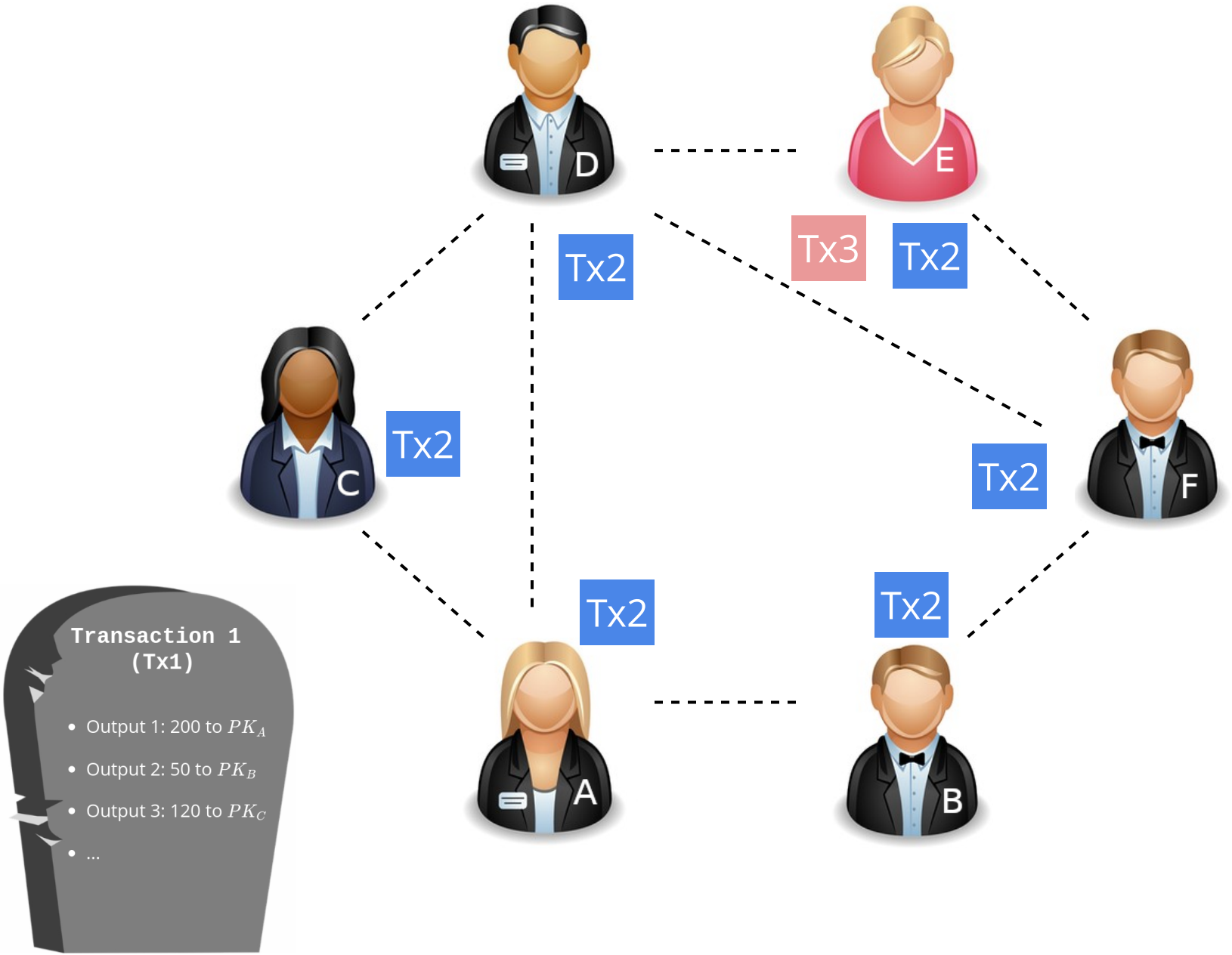
bitcoin

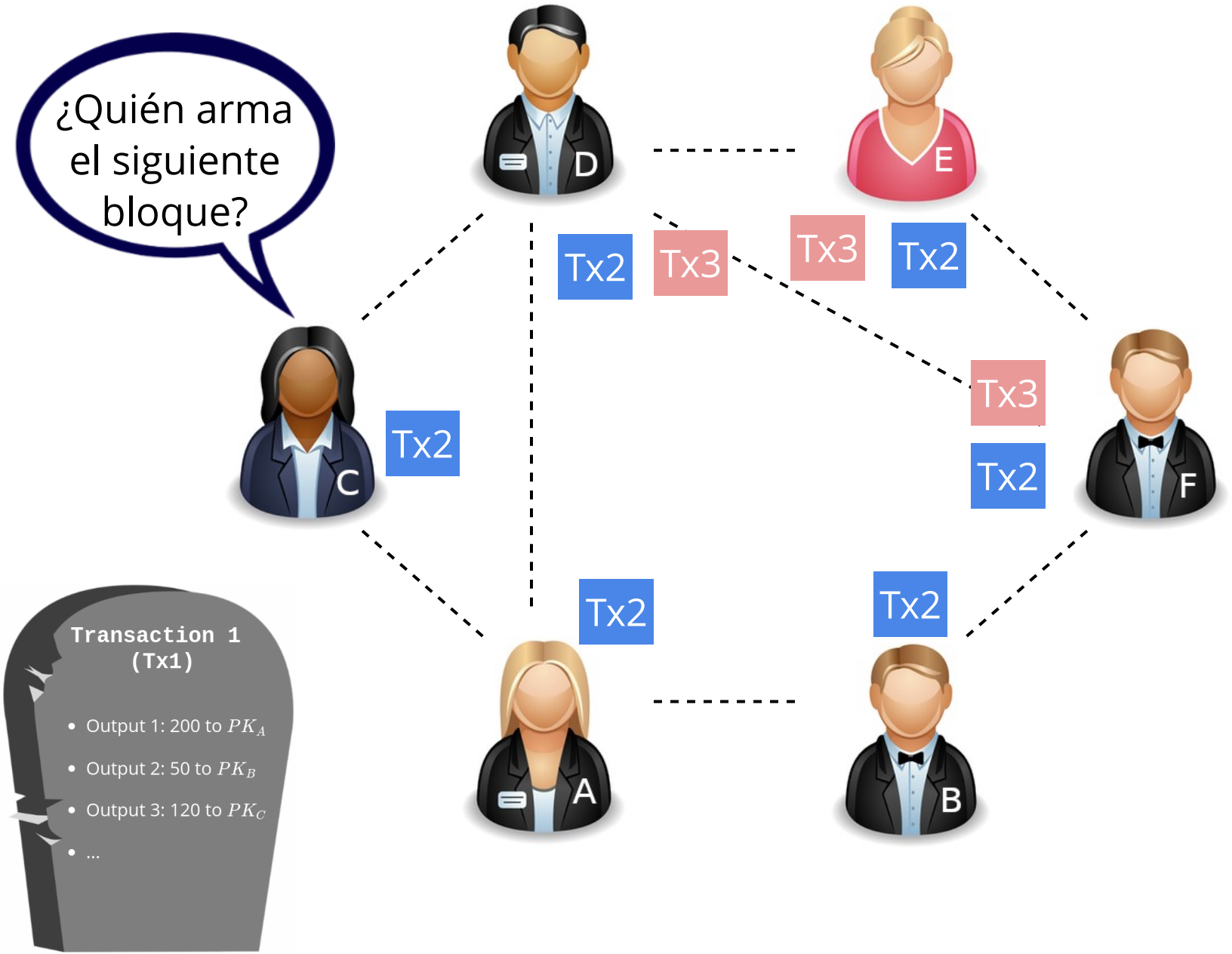
- La transacción inicial se respeta igual que antes, y le llamaremos bloque 0
- Si quieres pagar, mandale transacciones a tus vecinos
- Si recibes una nueva transacción, mándasela a tus vecinos


D
E
C
F
A
B
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...

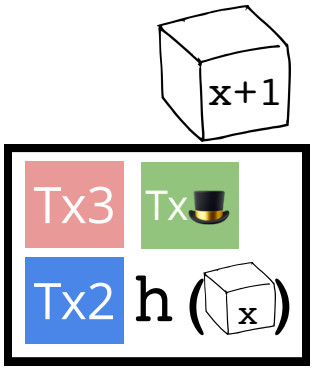

D
E
C
F
A
B
Tx2
Tx2
Tx2
Transaction 1
(Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...


D
E
C
F
A
B
Tx2
Tx2
Tx2
Tx2
Tx2
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...


D
E
C
F
A
B
Tx2
Tx3
Tx2
Tx2
Tx2
Tx2
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...


¿Quién arma el siguiente bloque?
D
E
C
F
A
B
Tx2
Tx3
Tx3
Tx2
Tx2
Tx3
Tx2
Tx2
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...

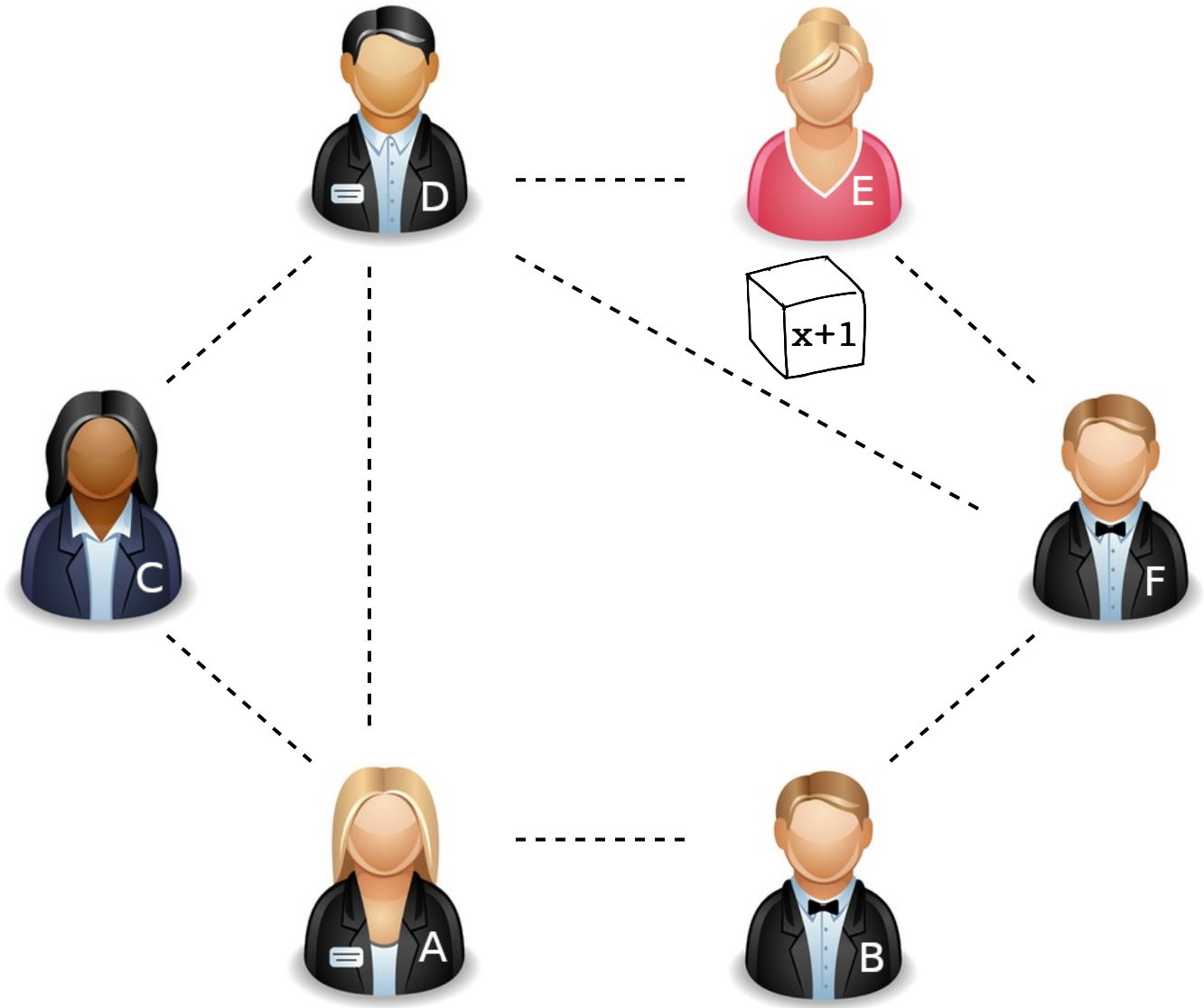
¿Por qué haría yo esto bien?

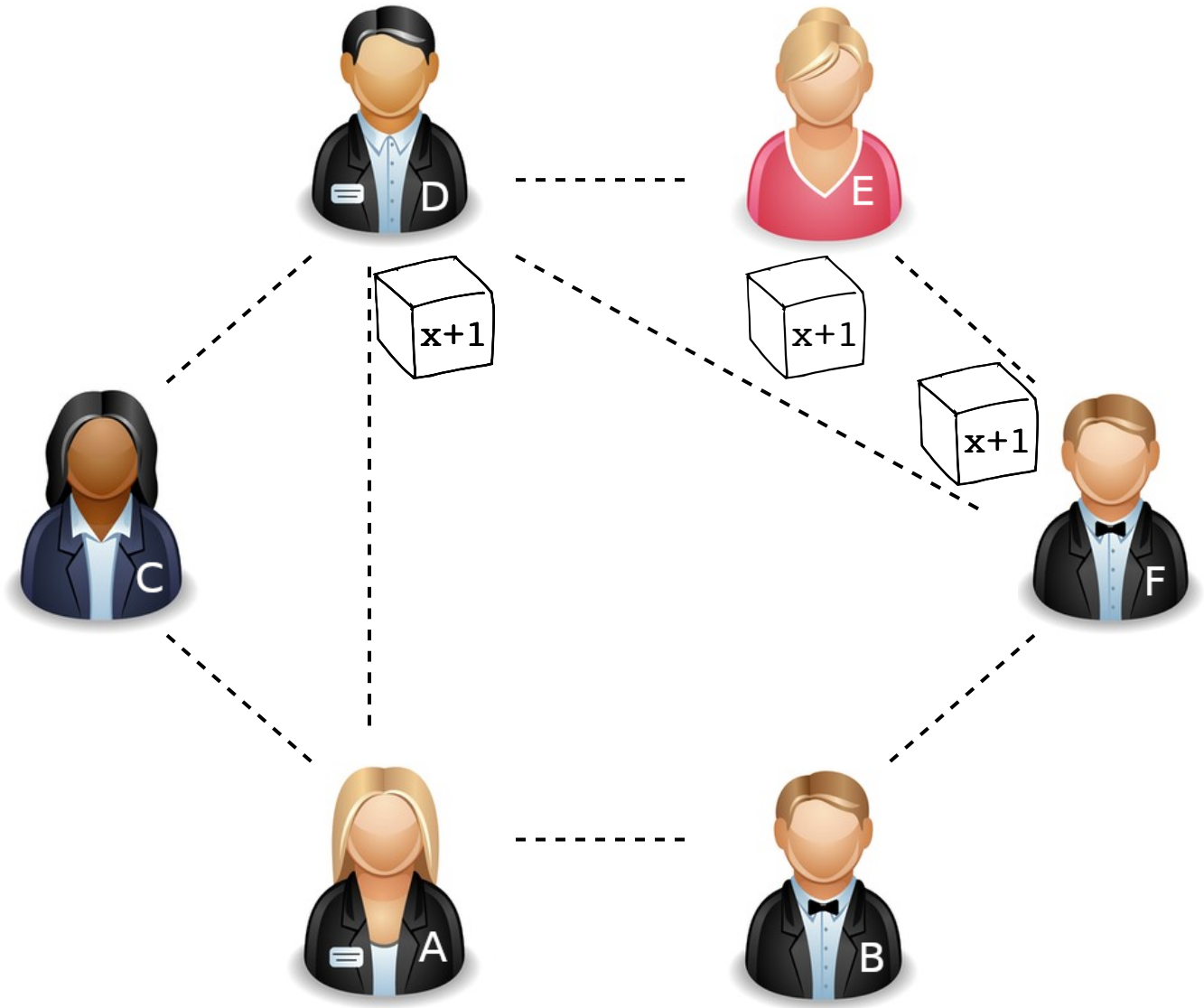


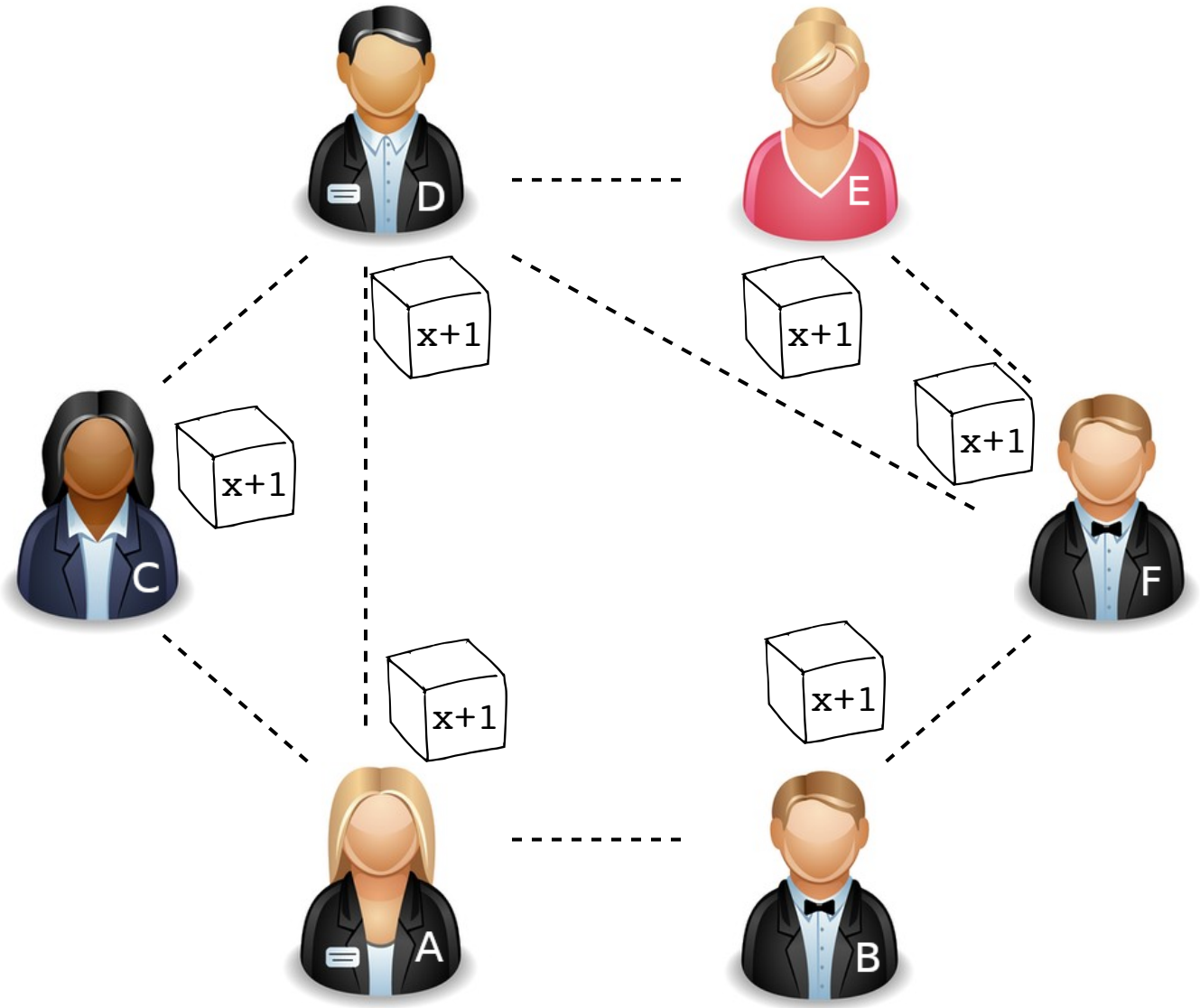
- Cuando te elijan, forma un bloque con lo que tengas y mándalo a tus vecinos
- Si recibes un bloque, verifica que sea correcto y mándalo a tus vecinos
- ...

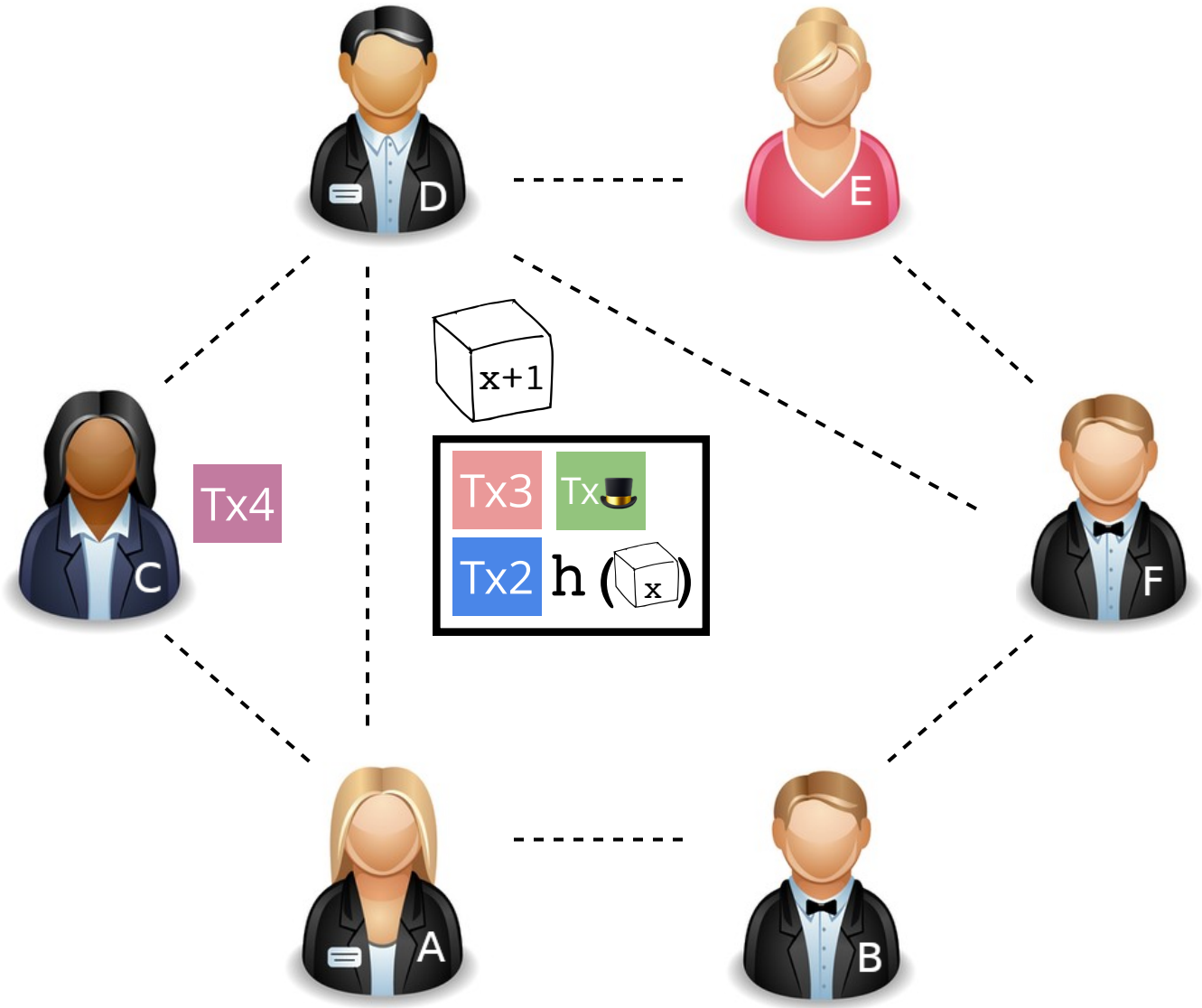
Yo voy a elegir a una persona

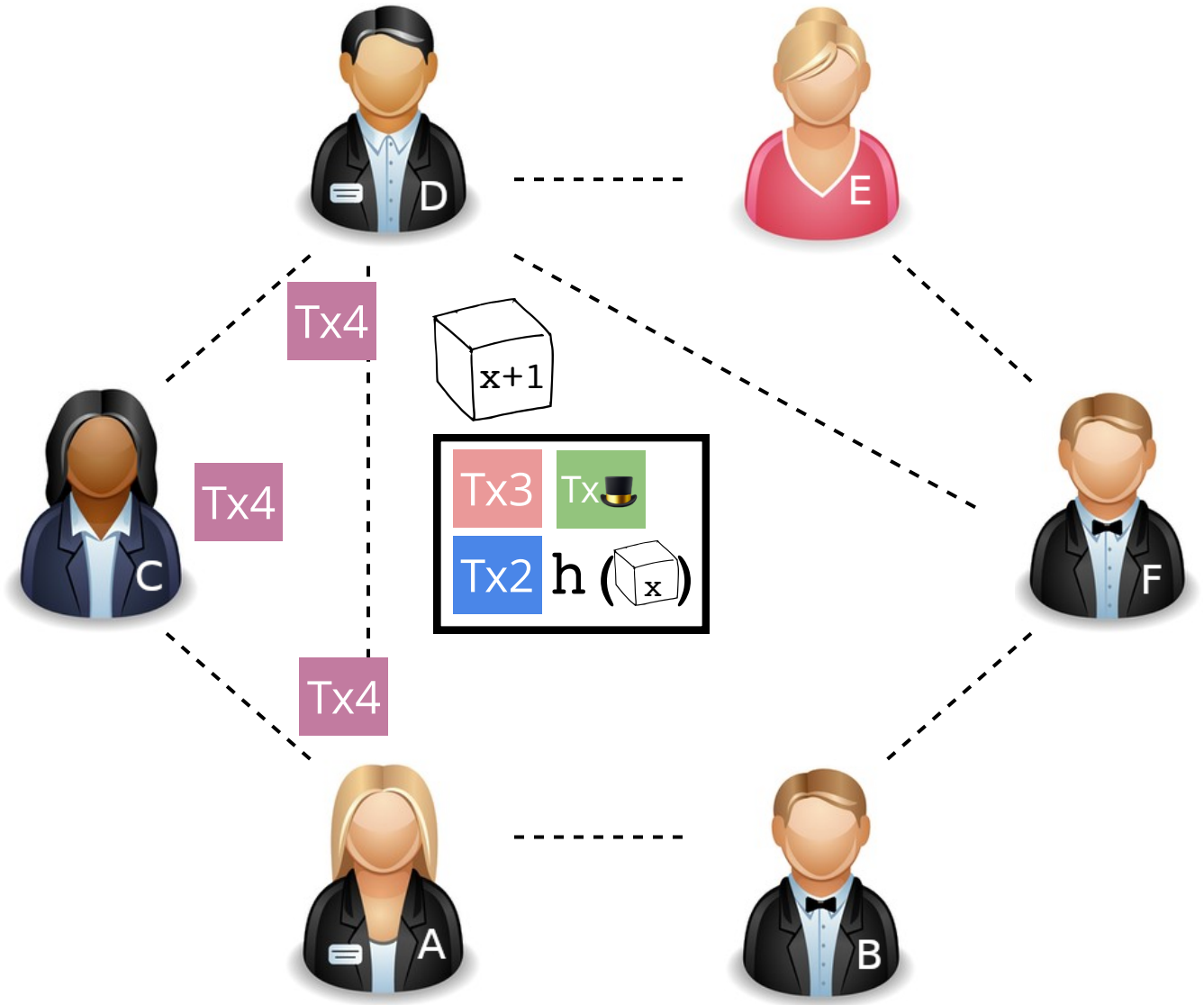
Monto fijo, a quién quieras

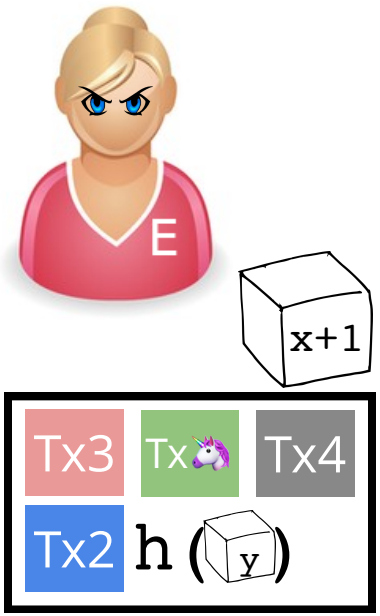

D
E
x+1
C
F
A
B


D
E
x+1
x+1
x+1
C
F
A
B


D
E
C
F
A
B
x+1
x+1
x+1
x+1
x+1
x+1

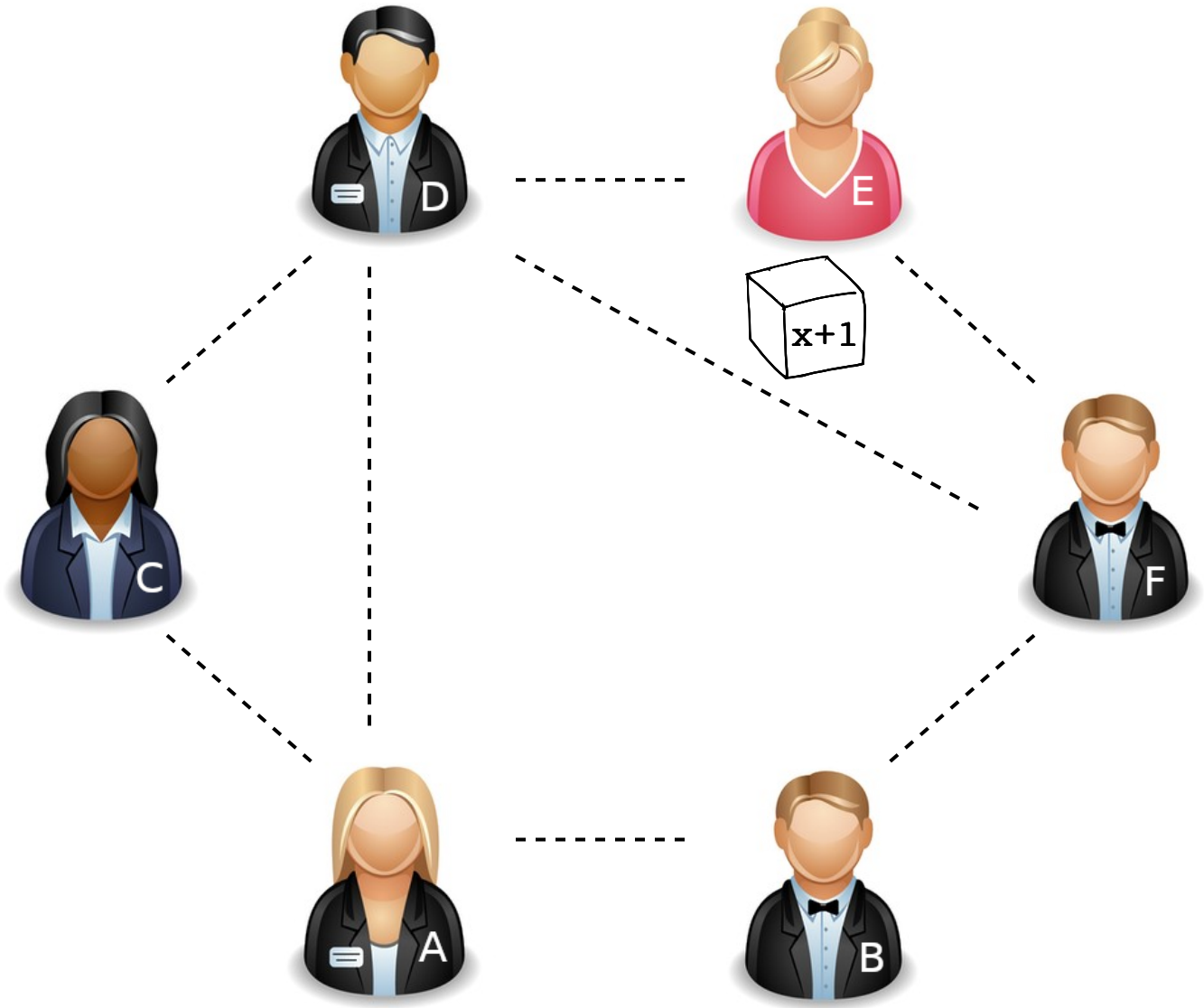

D
E
x+1
C
Tx4
Tx3
Tx
Tx2
h (x)
F
A
B

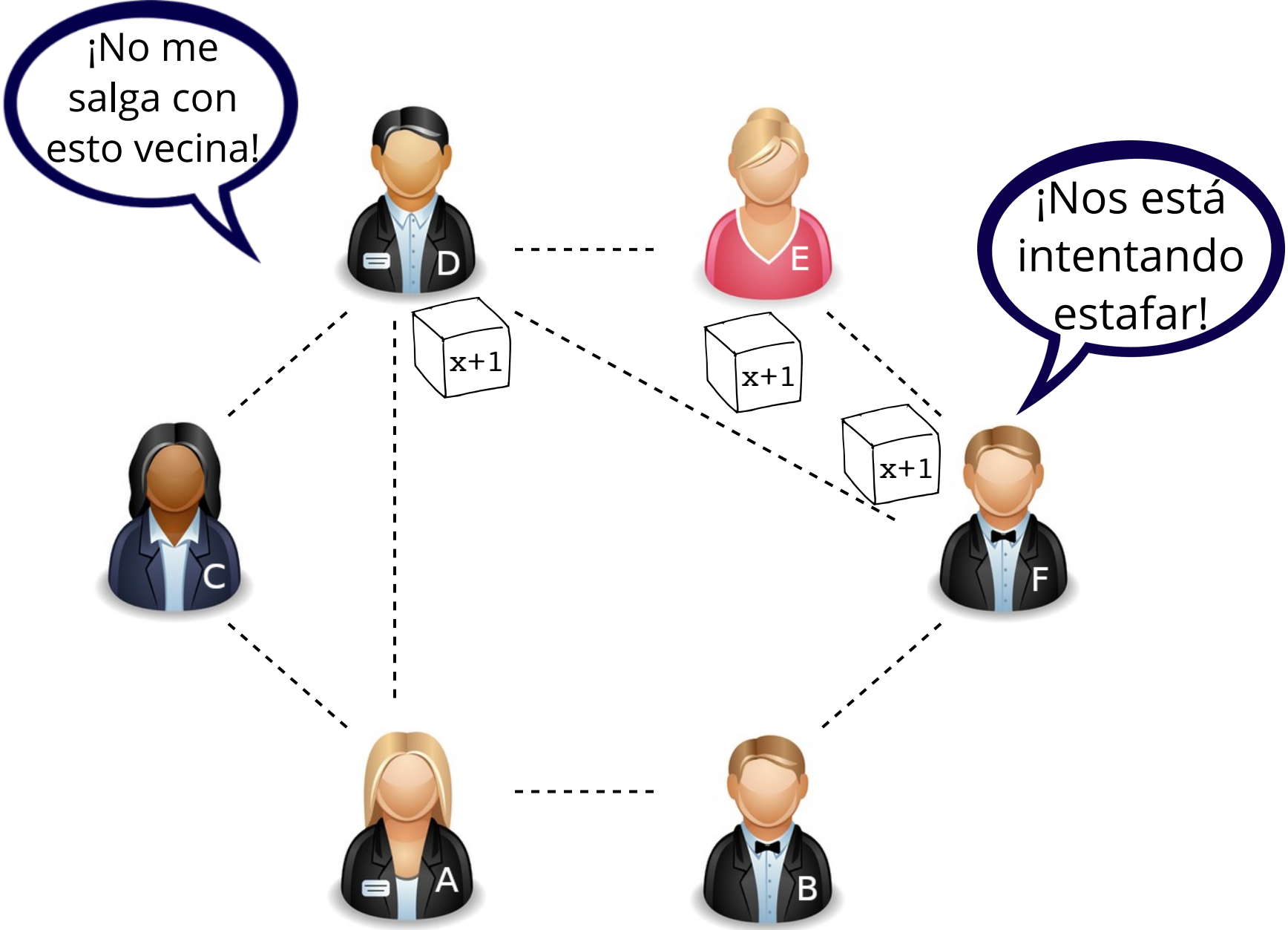

D
E
Tx4
x+1
C
Tx4
Tx3
Tx
Tx2
h (x)
F
Tx4
A
B

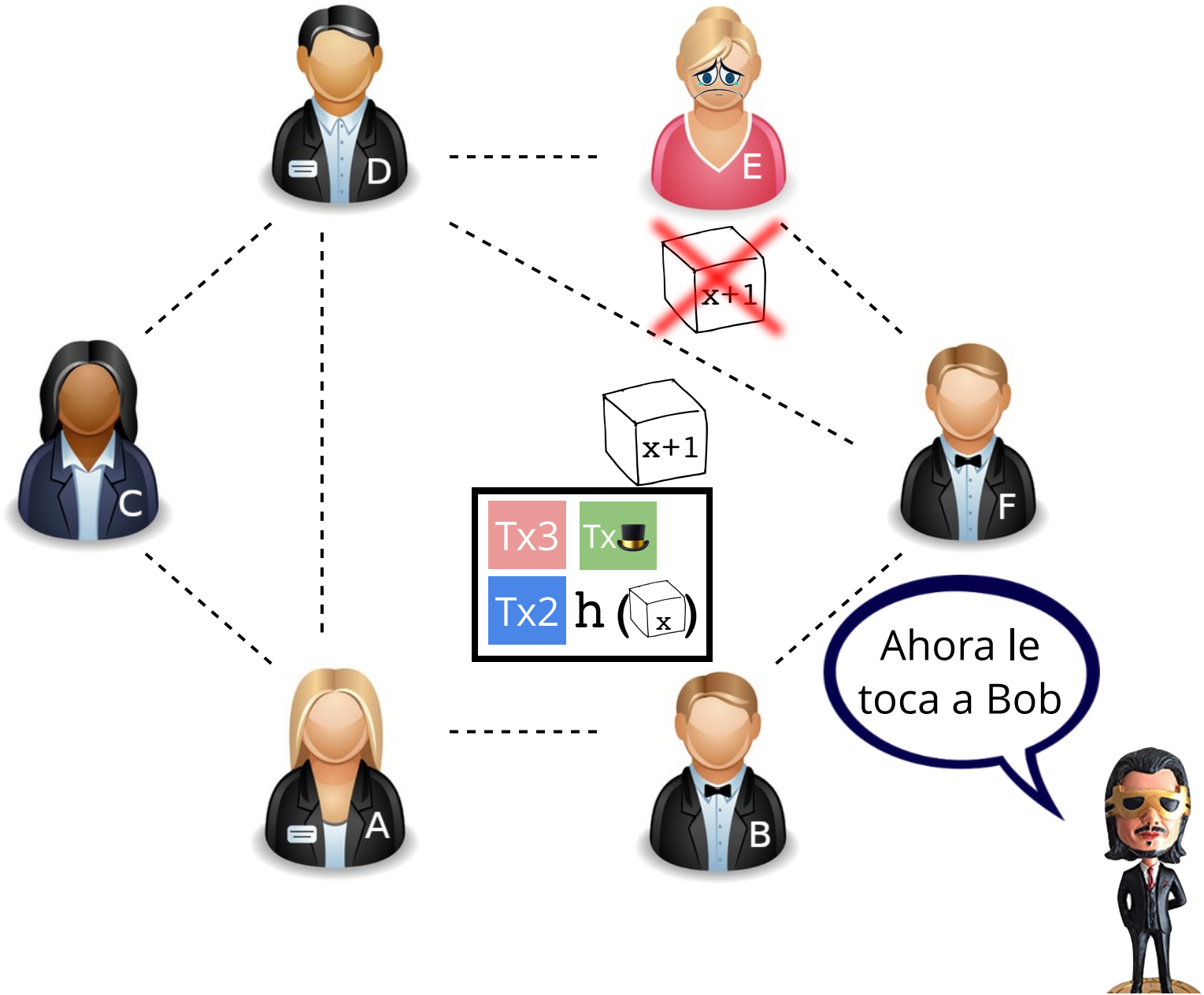


Yo voy a elegir a una persona

Monto fijo, a quién quieras


D
E
x+1
C
F
A
B


¡No me salga con esto vecina!
¡Nos está intentando estafar!
D
E
C
F
A
B
x+1
x+1
x+1


D
E
x+1
C
x+1
F
Tx3
Tx
Tx2
h (x)
Ahora le toca a Bob
A
B

Todo bien Satoshi pero... na que ver que elijas tanto a tus amigos

¡Siiii a mi nunca me ha elegido!

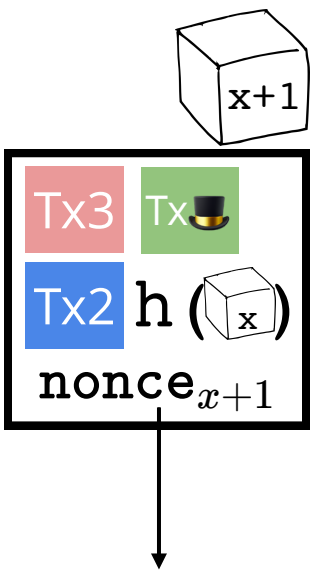
Ya, hagámosla bien

¿Podemos elegir "aleatoriamente" a quien genera el siguiente bloque?

¿Cómo nos aseguramos de que la fuente de aleatoriedad sea justa?

Y aunque pudiésemos

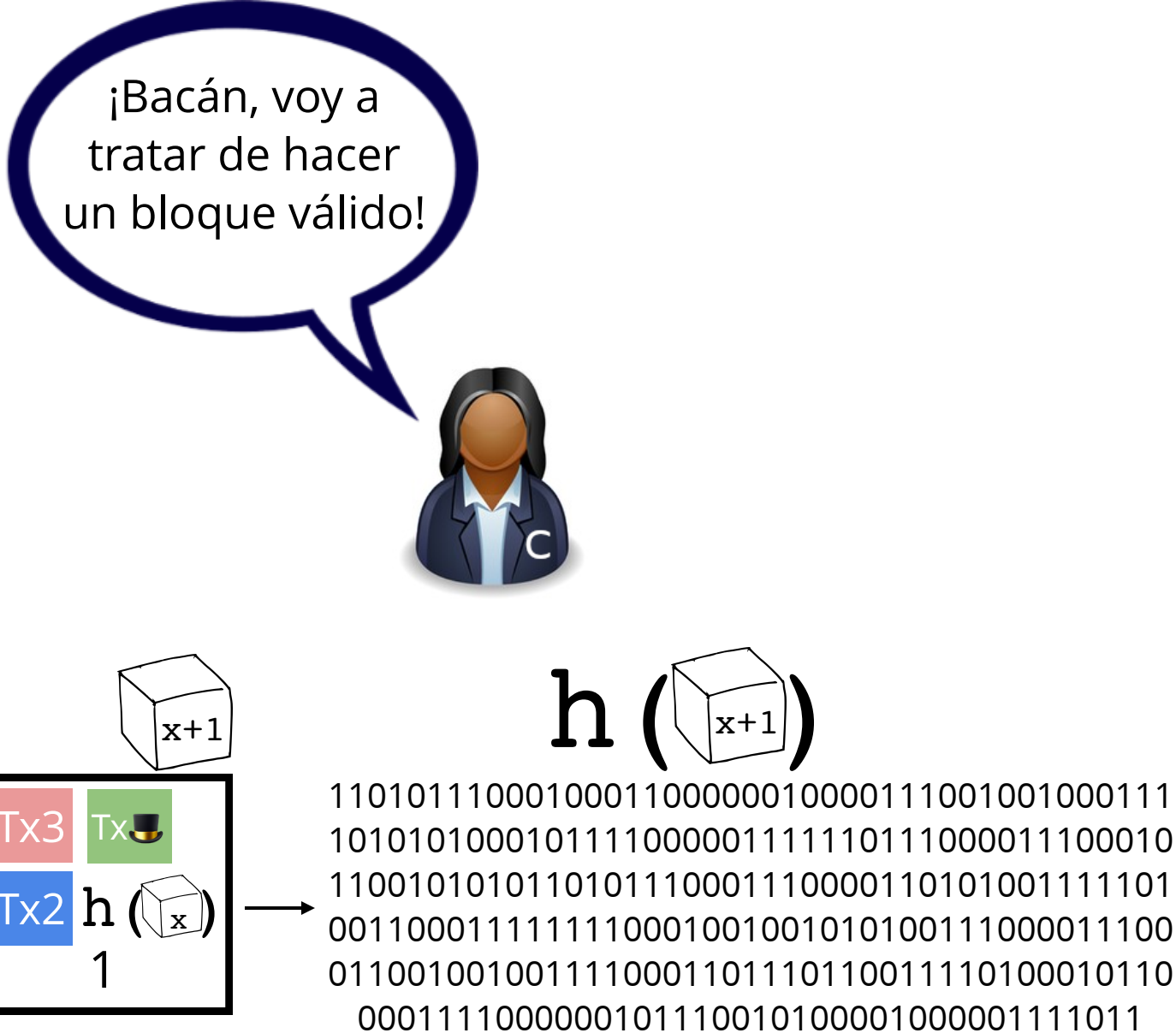
¿Aleatoriedad sobre qué?



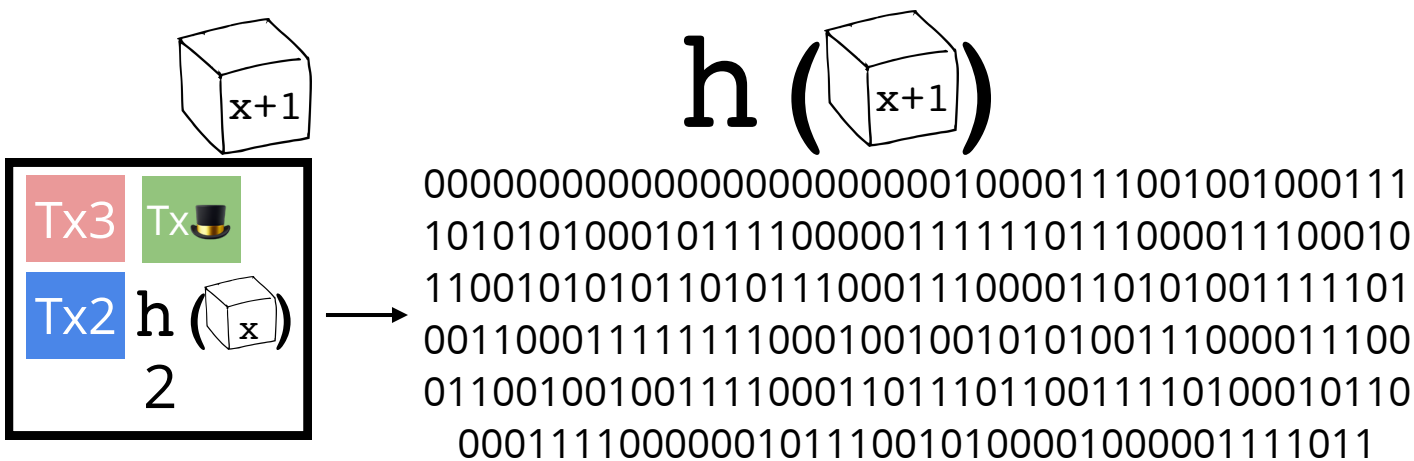
Es un valor *arbitrario*

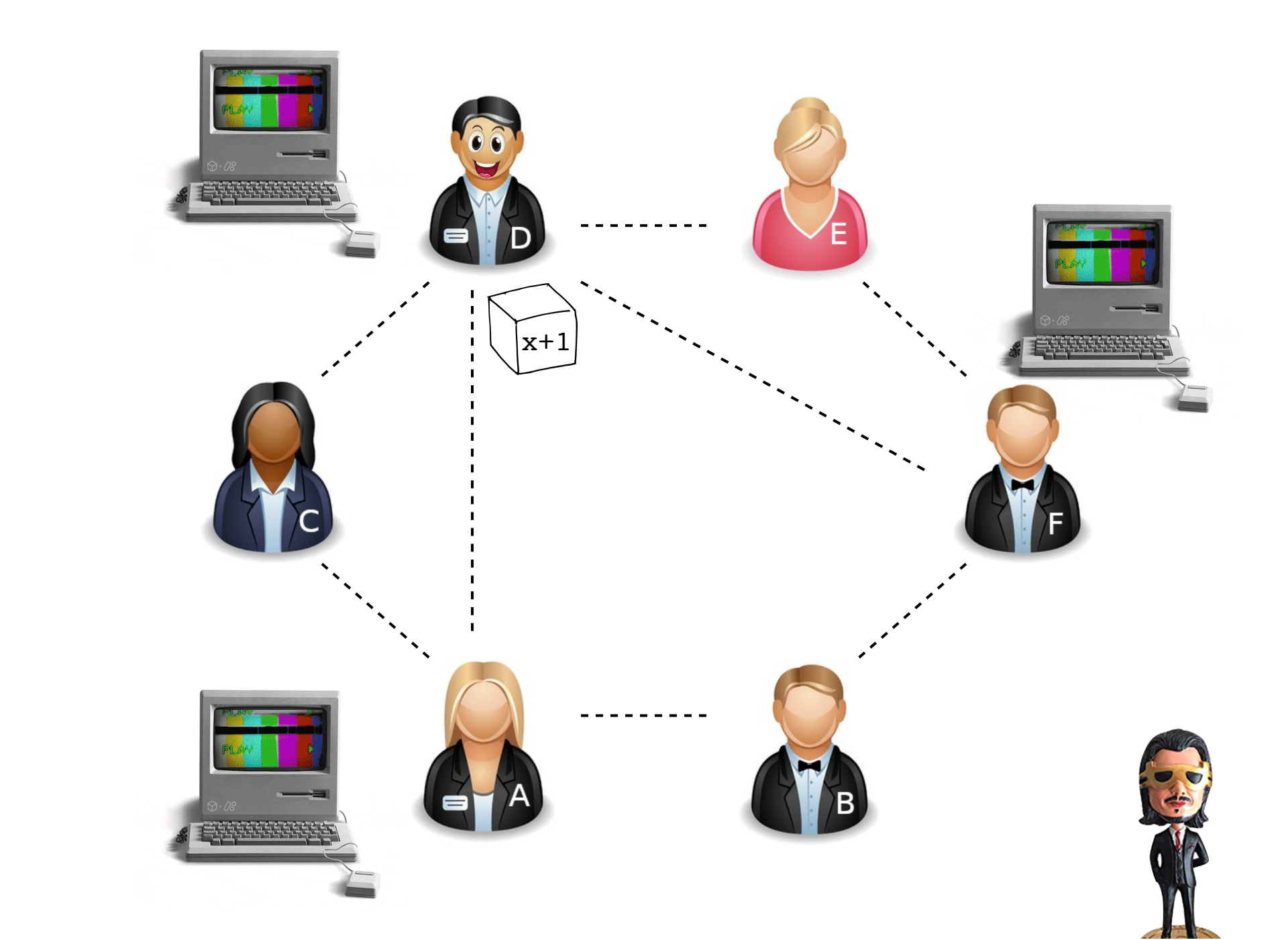
Este bloque es "válido" si su hash parte con veinte 0's

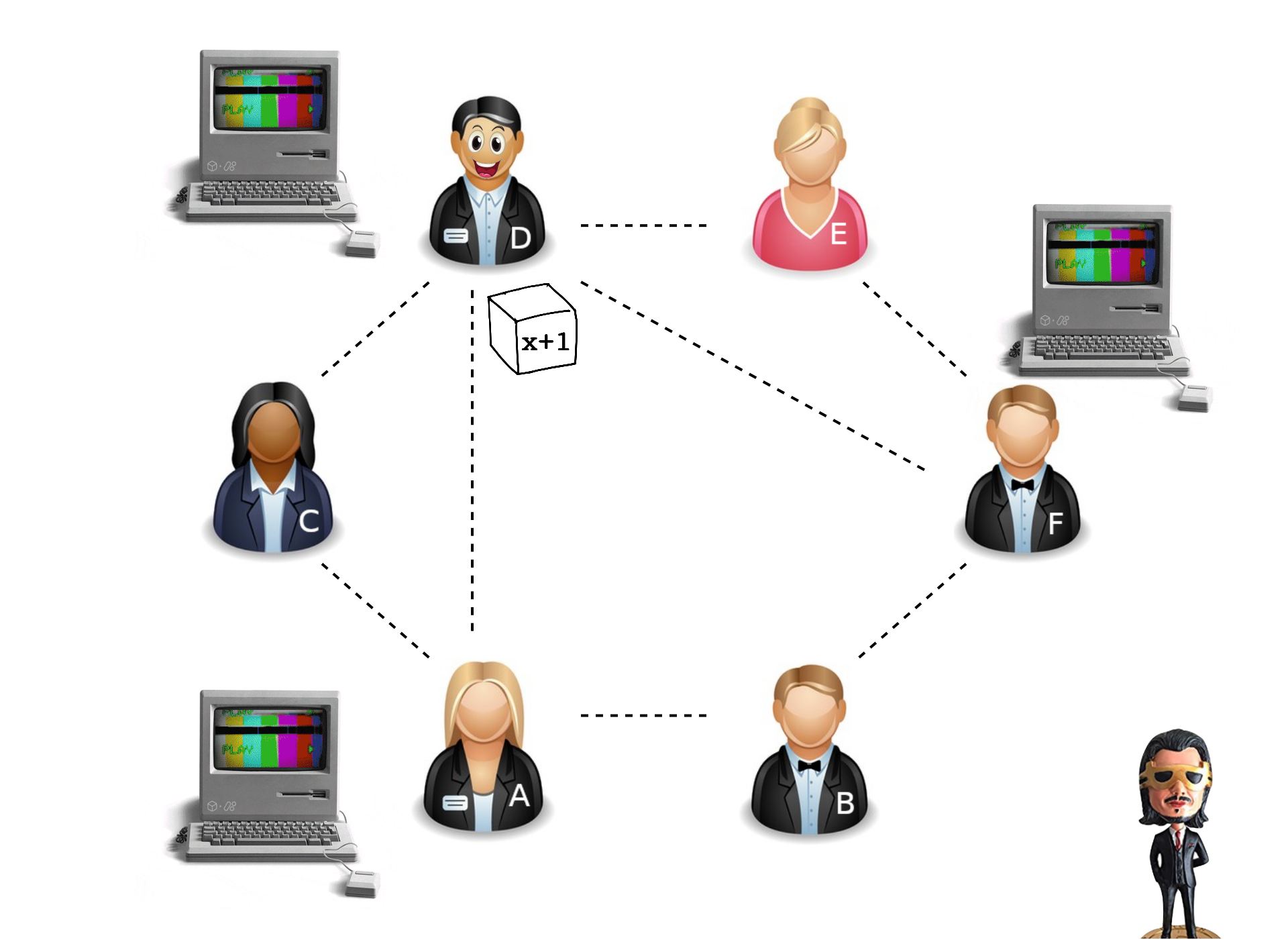
La 1^a persona con bloque válido es "elegida"

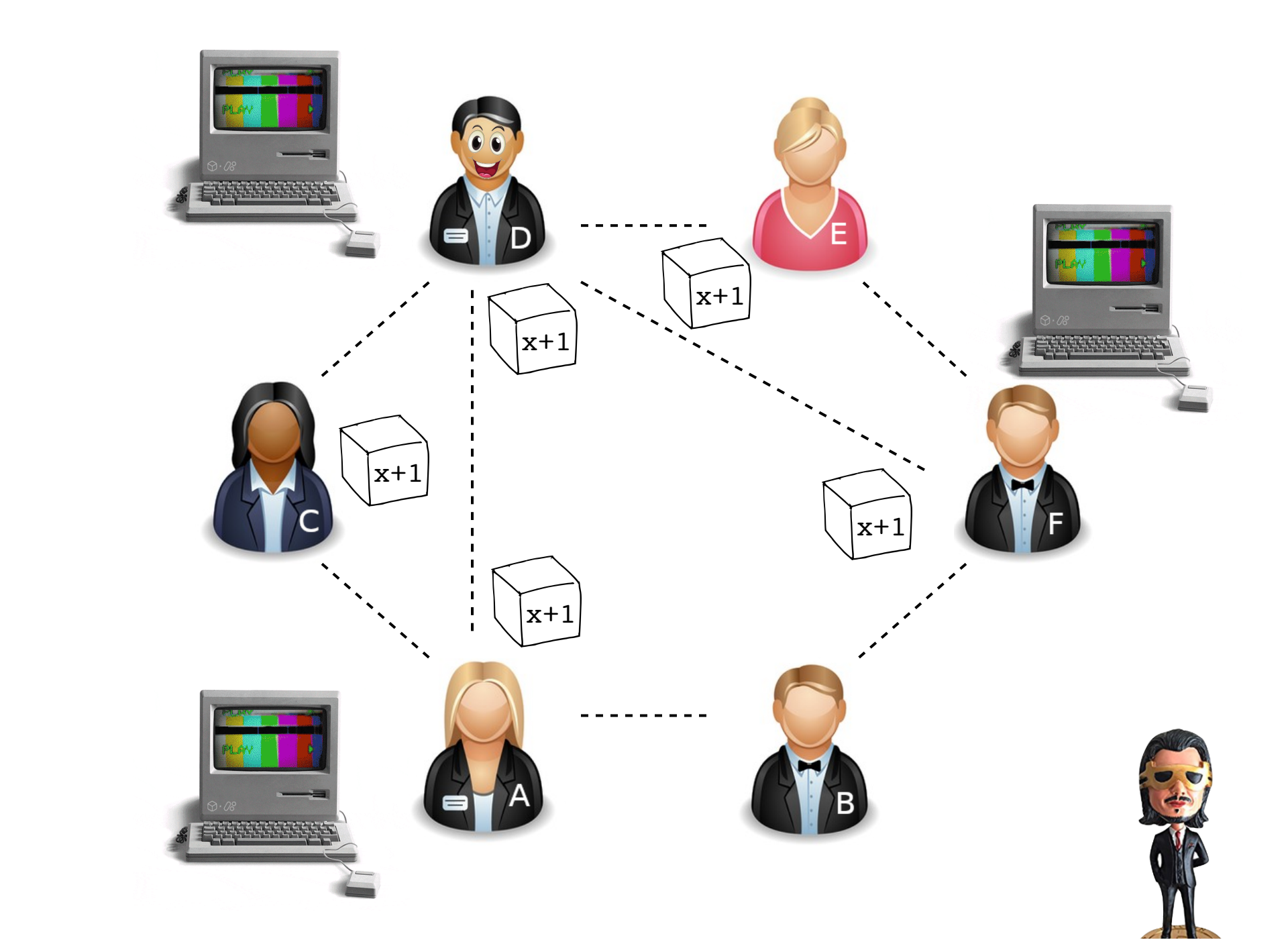

¡Bacán, voy a tratar de hacer un bloque válido!
C
x+1
Tx3
Tx
Tx2
h (x)
1
h (x+1)
11010111000100011000000100001110010010001111
10101010001011110000011111101110000111000010
11001010101101011100011100001101010011111101
00110001111111100010010010101001110000111000
01100100100111100011011101100111101000101100
00011110000001011100101000010000011110111

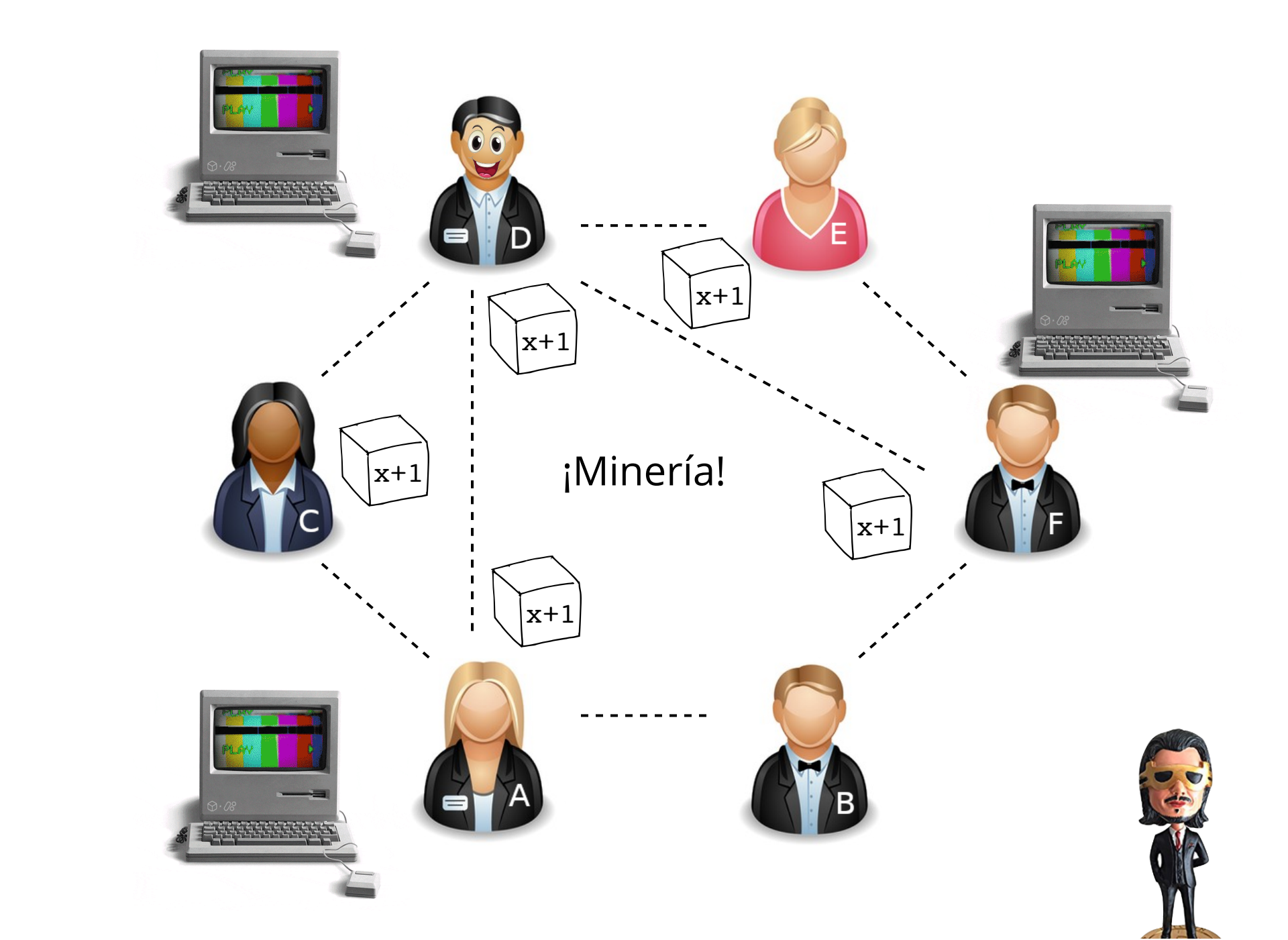

No me funcionó,
¡voy por otro!
C


x+1
Tx3
Tx
Tx2
h (x)
2
h (x+1)
0000000000000000000001000011100100100011
1010101000101111000011111101110000111000010
1100101010110101110001110000110101001111101
0011000111111110001001001010100111000011100
0110010010011110001101110110011110100010110
0001111000000101110010100001000001111011


D
E
x+1
C
F
A
B


D
E
x+1
C
F
A
B


D
E
x+1
x+1
C
x+1
F
x+1
x+1
A
B


D
E
x+1
x+1
C
x+1
¡Minería!
x+1
F
x+1
A
B

Bitcoin: Repaso

¡tengo 320!

¡tengo 250!

Tx3

Input 1: Tx2, Output 1

Output 1: 200 to PK_C

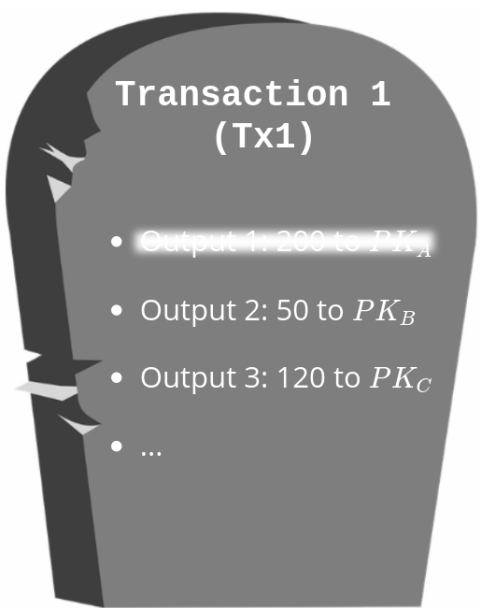
(Firmado con SK_B)

Tx2

Input 1: Tx1, Output 1

~~Output 1: 200 to PK_B~~

(Firmado con SK_A)



BankCoin

1. La transacción inicial Tx1, se respeta igual que antes

2. Una transacción es una secuencia de pagos que llega a Tx1, igual que antes

3. El banco publicará en un blockchain firmado todas las transacciones válidas

SK

PK

Input 1: Tx1, Output 1

Output 1: 200 to PK_B

Tx2

(Firmado con SK_A)

Input 1: Tx1, Output 2

Output 1: 50 to PK_c

Tx3

(Firmado con SK_B)

(Firmado con $SK_{🏦}$)

1

h (1)

Input 1: Tx1, Output 3

Input 2: Tx3, Output 1

Output 1: 170 to PK_D

Tx4

(Firmado con SK_C)

Input 1: Tx2, Output 1

Output 1: 200 to PK_c

Tx5

(Firmado con SK_B)

(Firmado con $SK_{🏦}$)

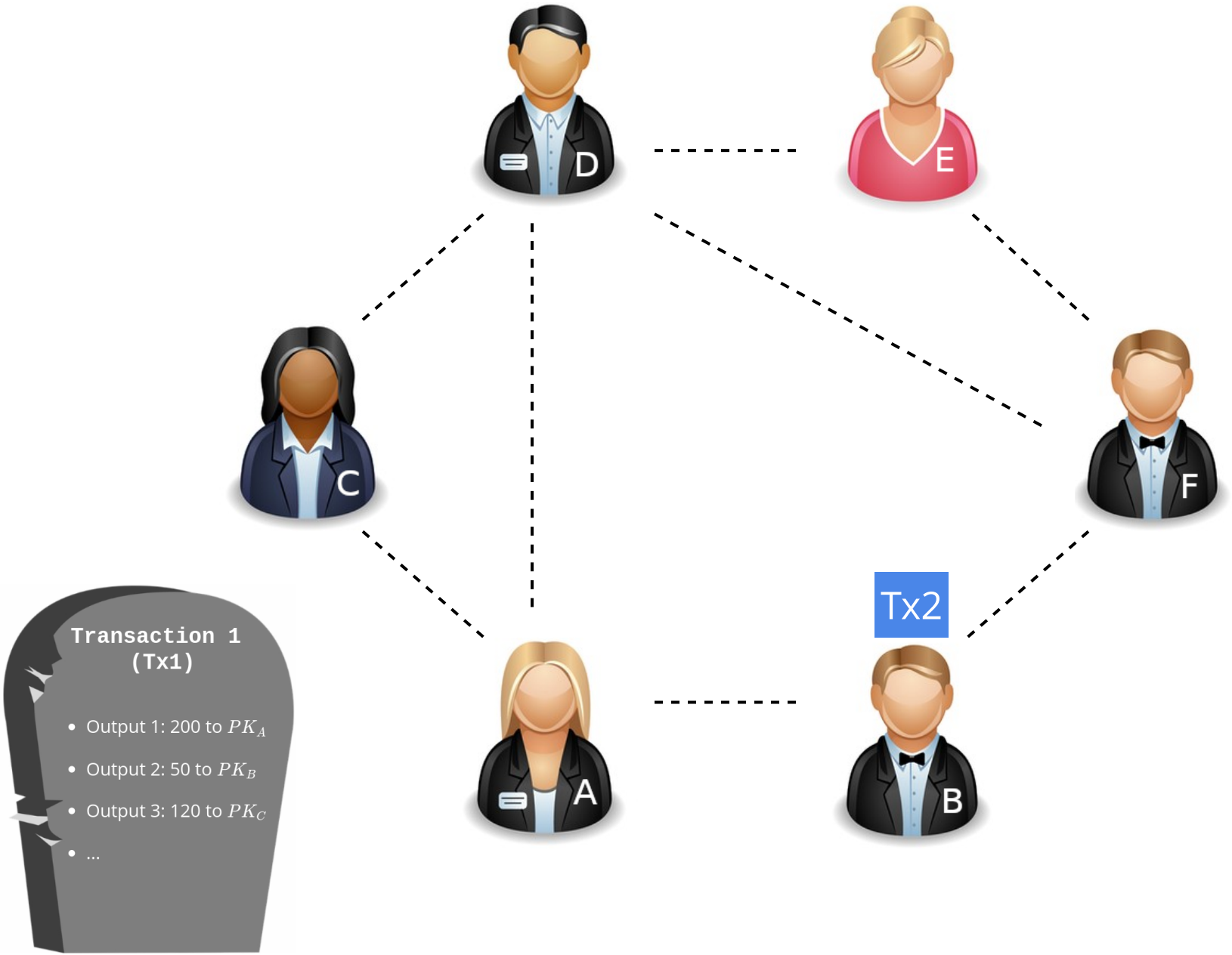
2

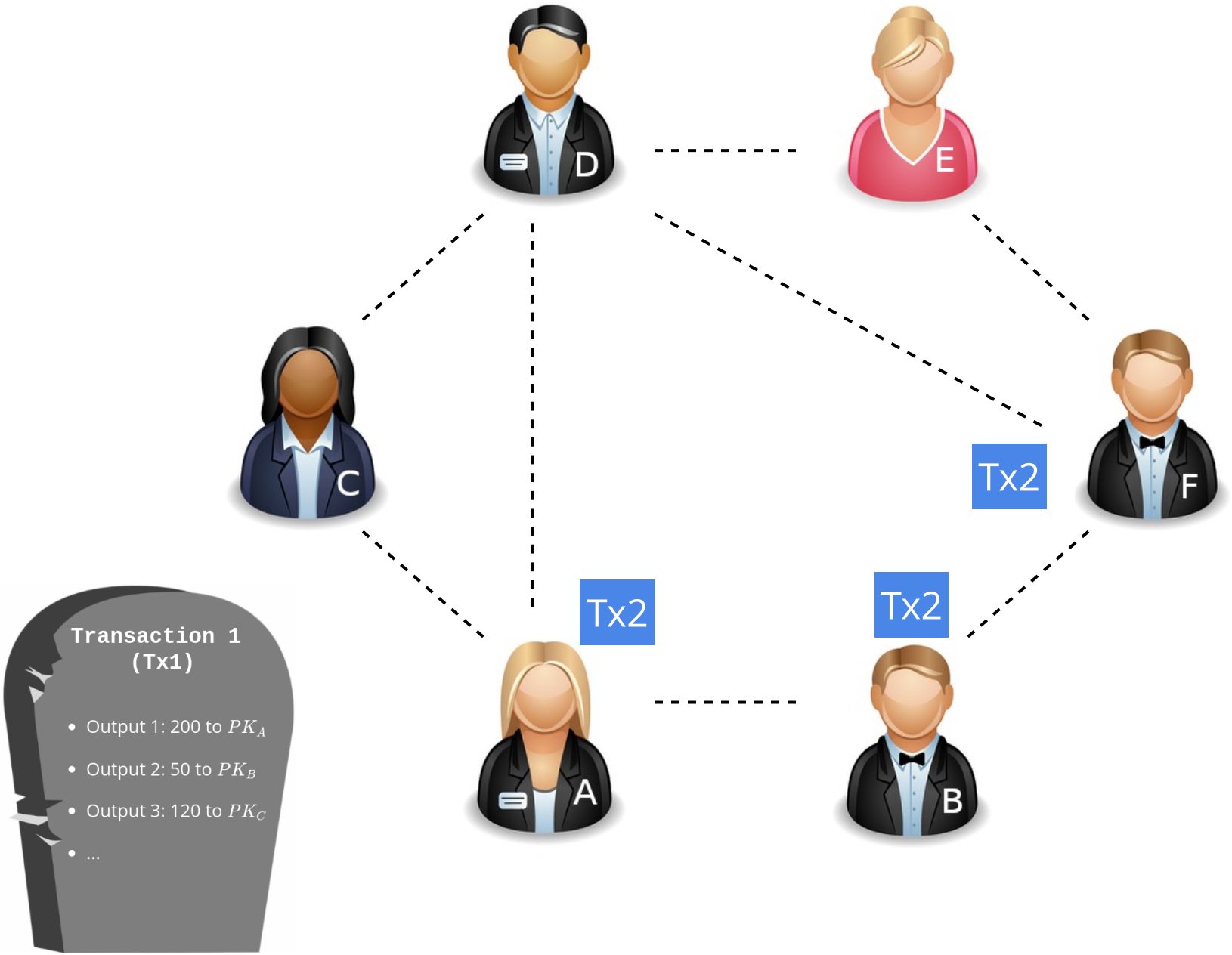
Transaction 1 (Tx1)

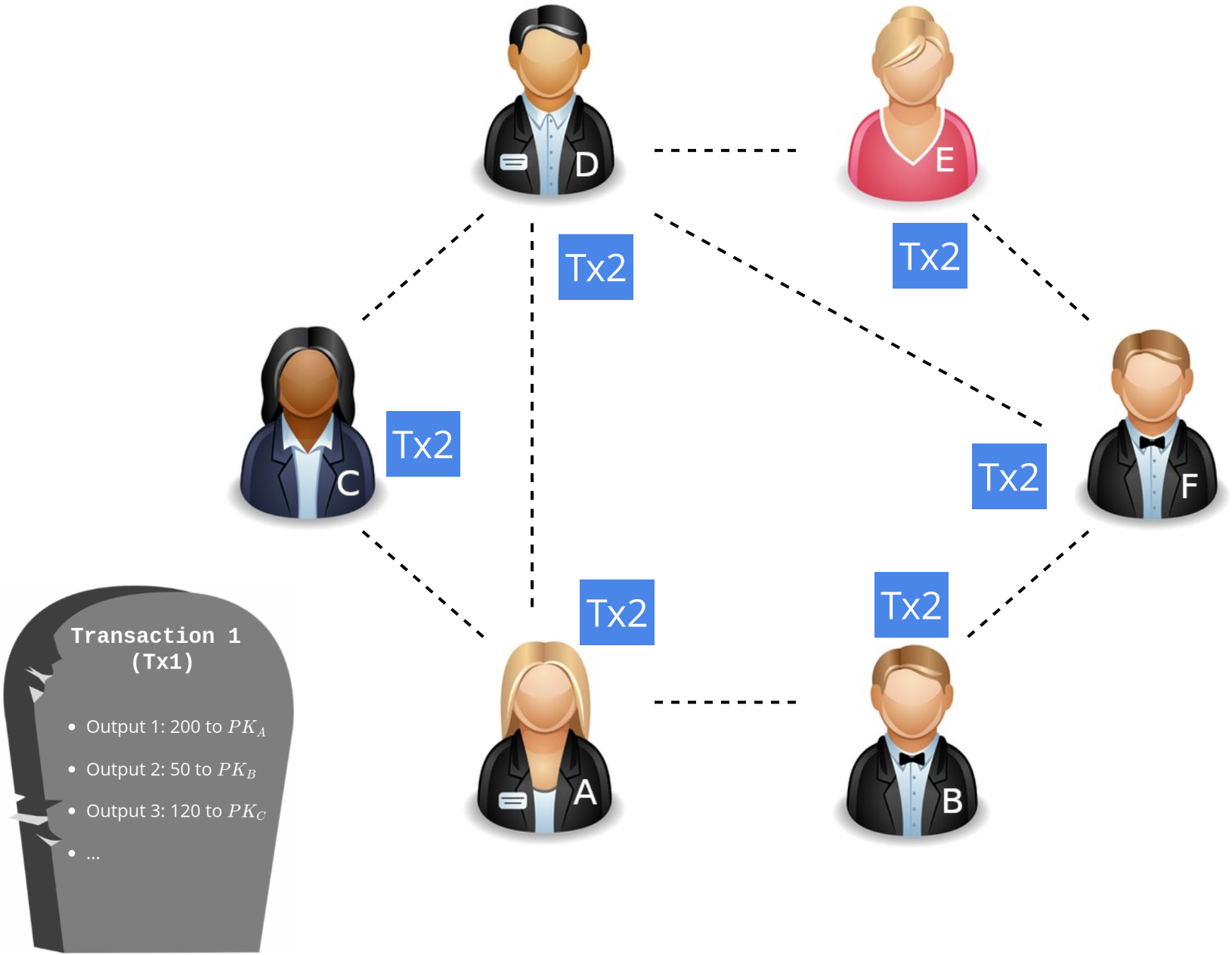
- Output 1: 200 to PK_A
- Output 2: 50 to PK_B
- Output 3: 120 to PK_C
- ...

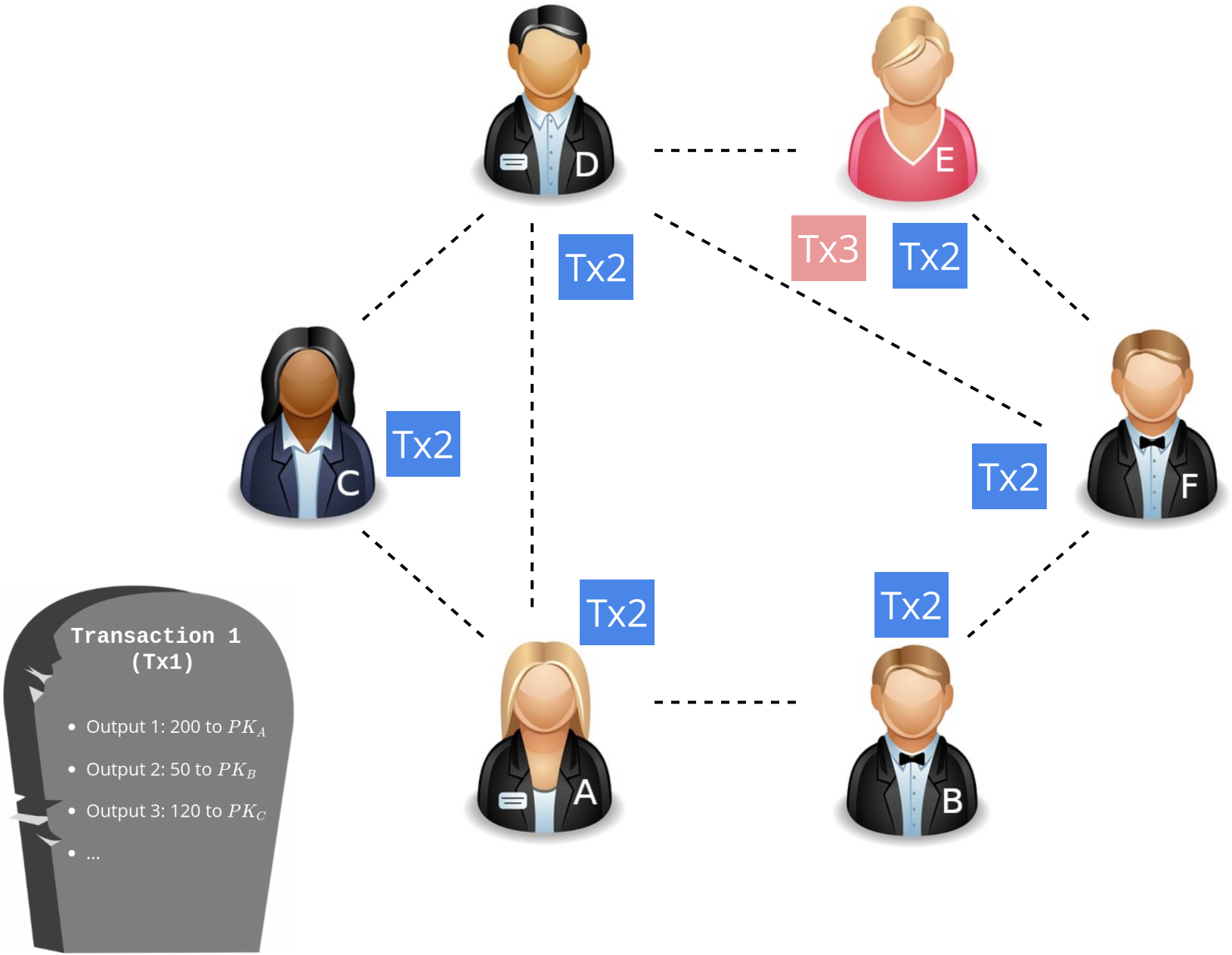
bitcoin

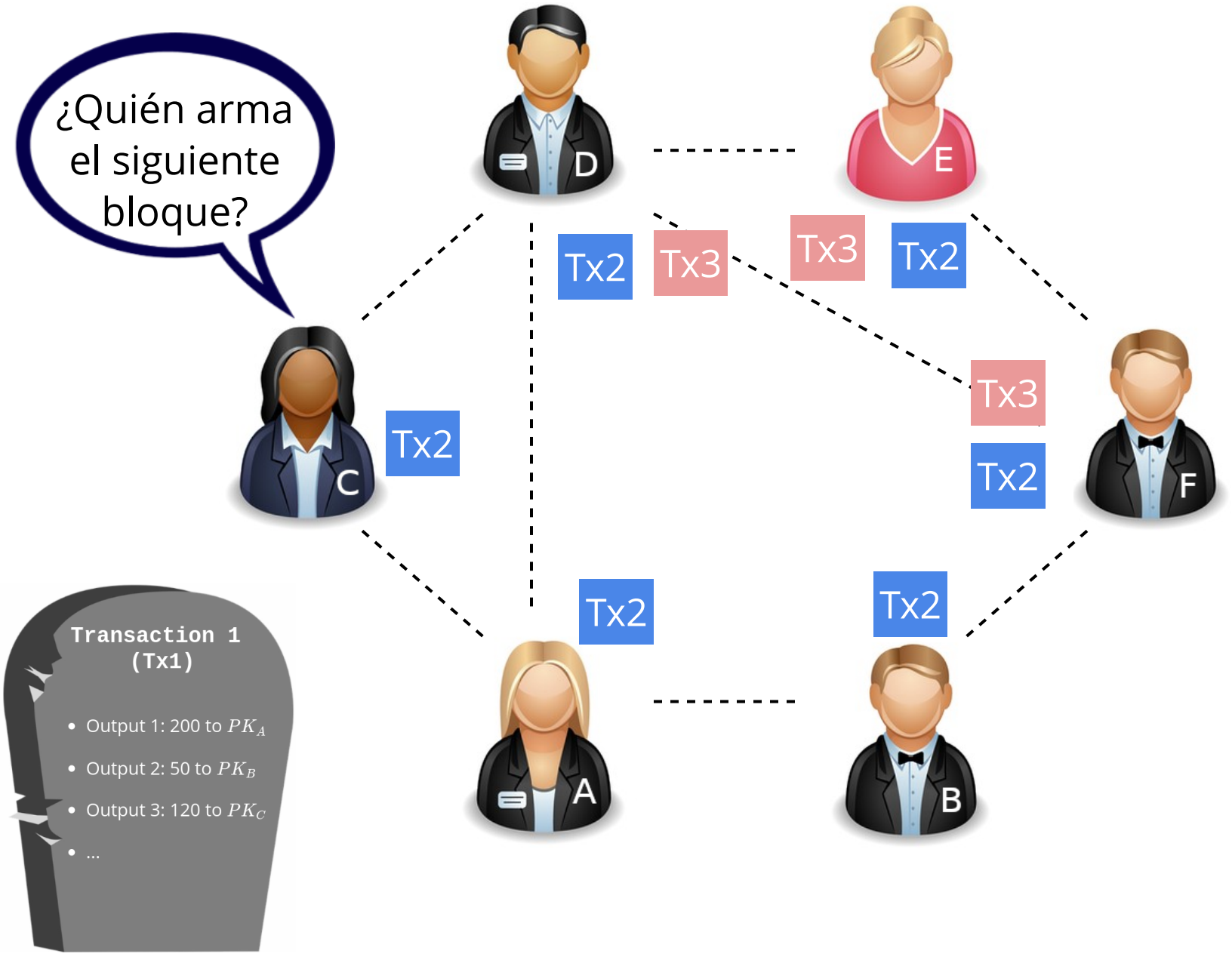
- La transacción inicial se respeta igual que antes, y le llamaremos bloque 0
- Si quieres pagar, mandale transacciones a tus vecinos
- Si recibes una nueva transacción, mándasela a tus vecinos


D
E
C
F
A
B
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...

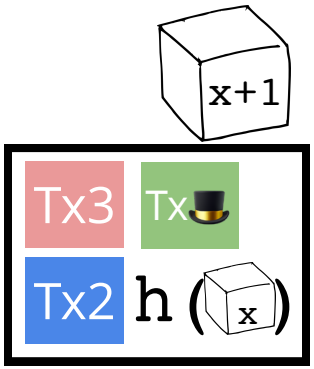

D
E
C
F
A
B
Tx2
Tx2
Tx2
Transaction 1
(Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...


D
E
C
F
A
B
Tx2
Tx2
Tx2
Tx2
Tx2
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...


D
E
C
F
A
B
Tx2
Tx3
Tx2
Tx2
Tx2
Tx2
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...


¿Quién arma el siguiente bloque?
D
E
C
F
A
B
Tx2
Tx3
Tx3
Tx2
Tx2
Tx3
Tx2
Tx2
Tx2
Transaction 1 (Tx1)
• Output 1: 200 to PK_A
• Output 2: 50 to PK_B
• Output 3: 120 to PK_C
• ...

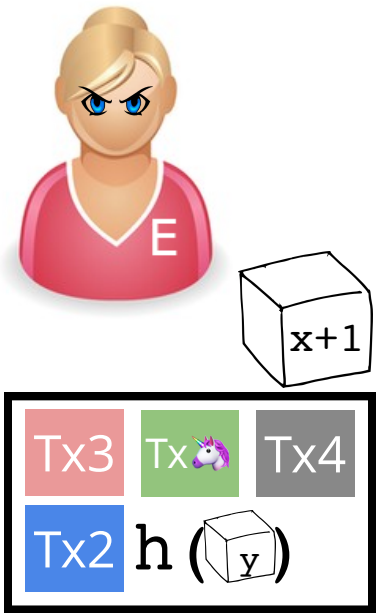
¿Por qué haría yo esto bien?



- Cuando te elijan, forma un bloque con lo que tengas y mándalo a tus vecinos
- Si recibes un bloque, verifica que sea correcto y mándalo a tus vecinos
- ...

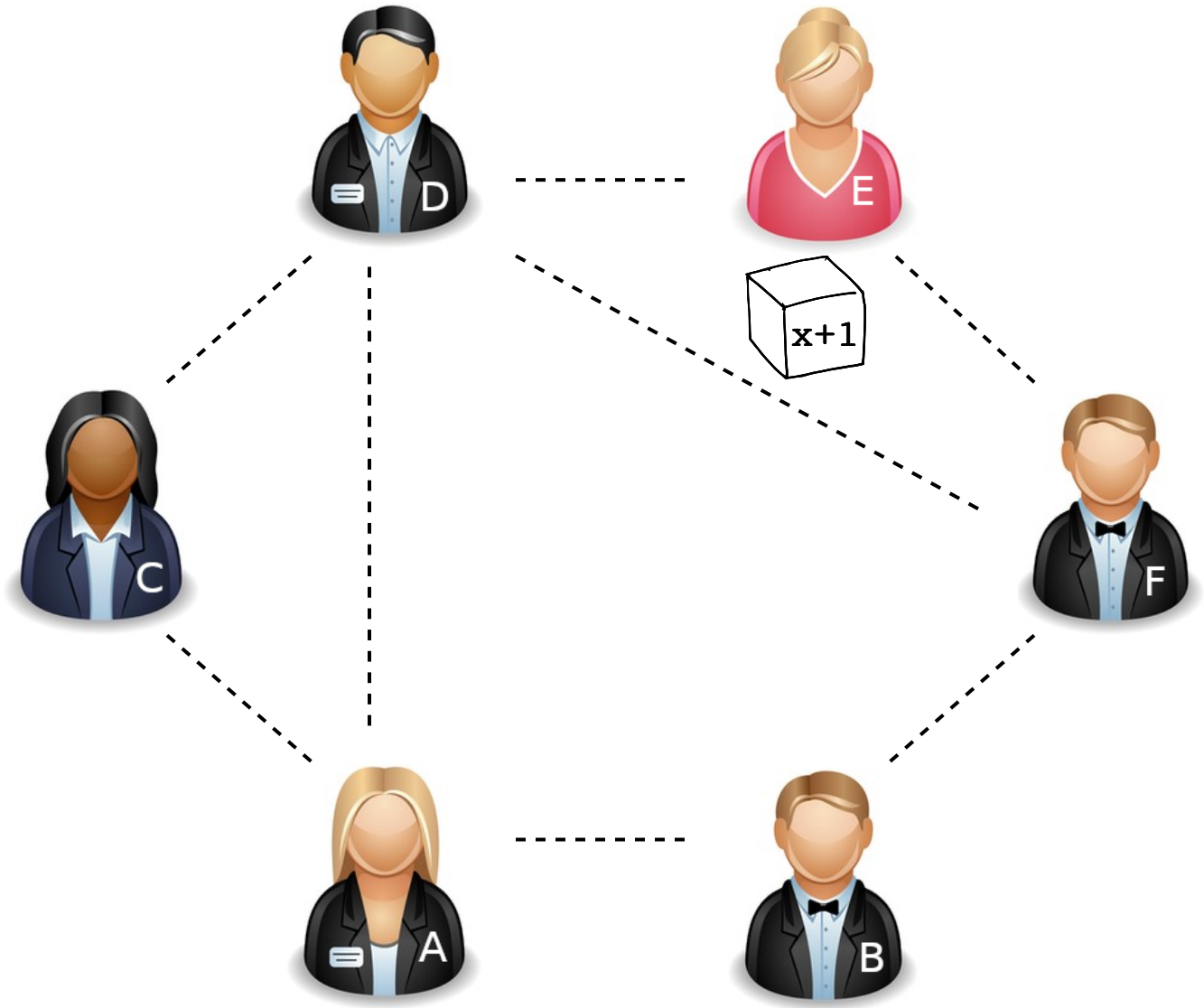
Yo voy a elegir a una persona

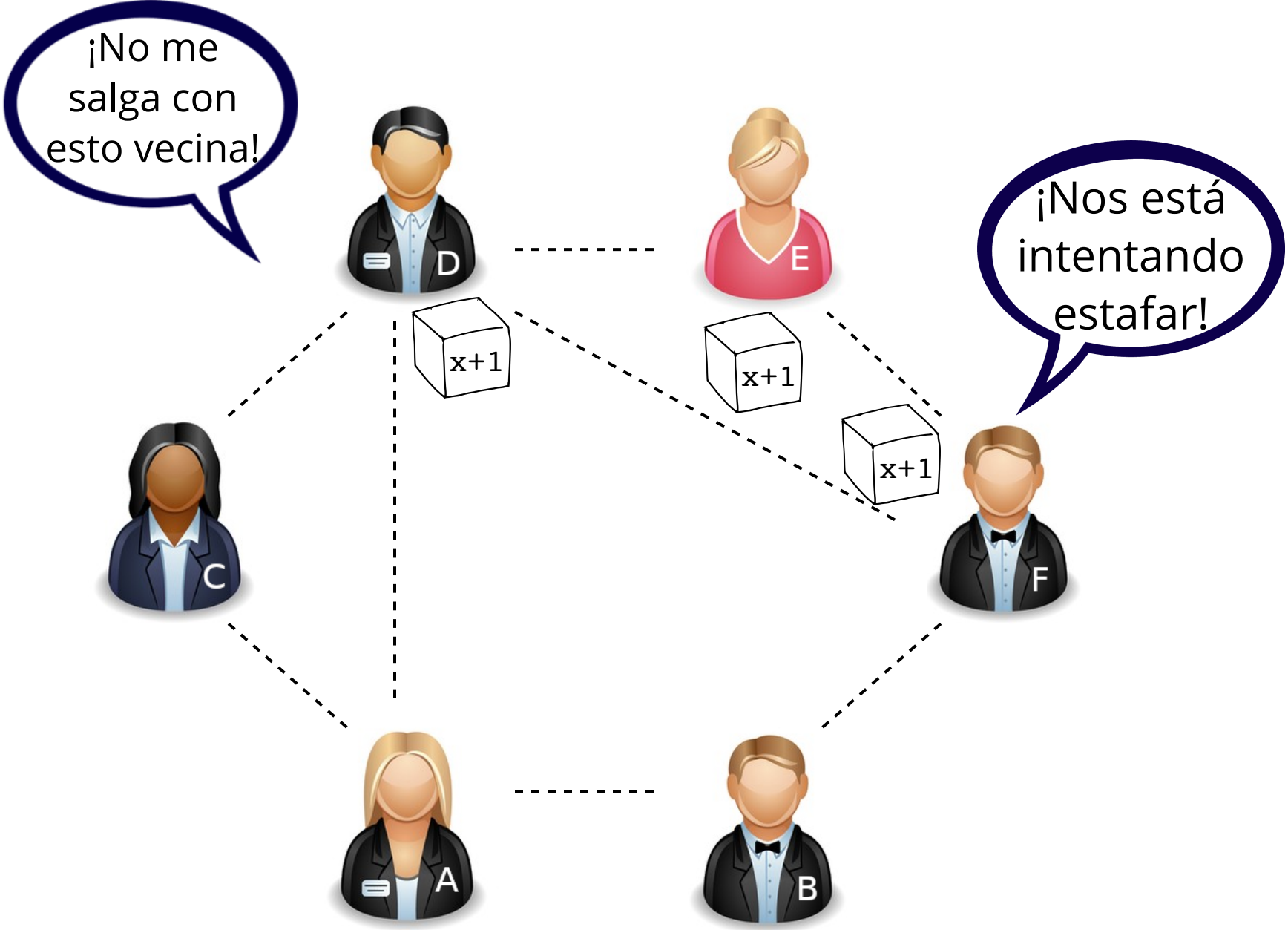
Monto fijo, a quién quieras

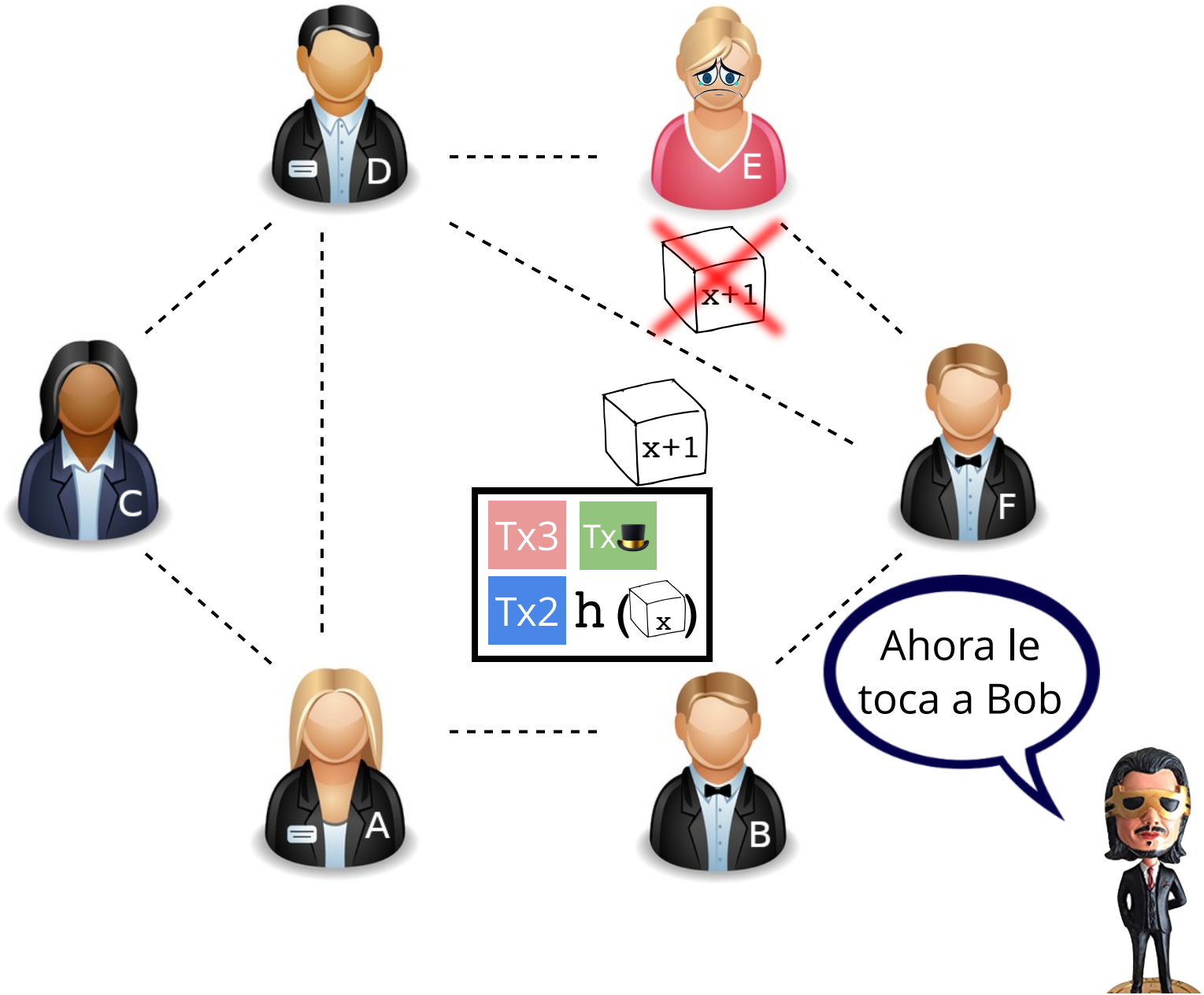


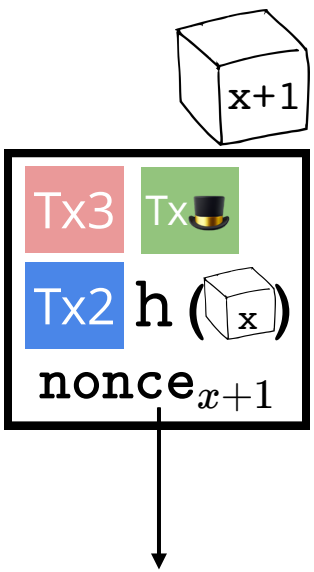
Yo voy a elegir a una persona

Monto fijo, a quién quieras


D
E
x+1
C
F
A
B


¡No me salga con esto vecina!
¡Nos está intentando estafar!
D
E
C
F
A
B
x+1
x+1
x+1

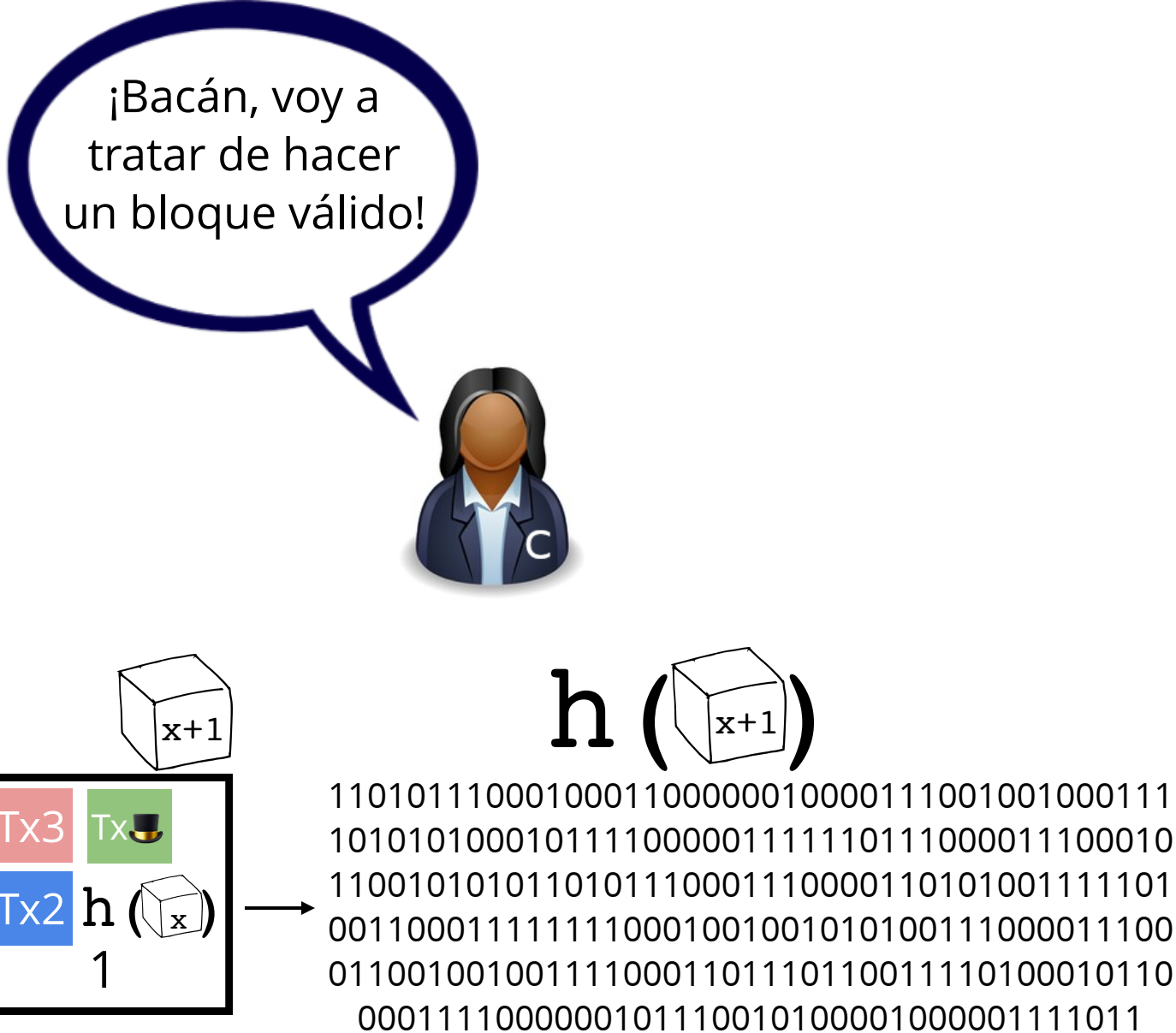

D
E
x+1
C
x+1
F
Tx3
Tx
Tx2
h (x)
Ahora le toca a Bob
A
B



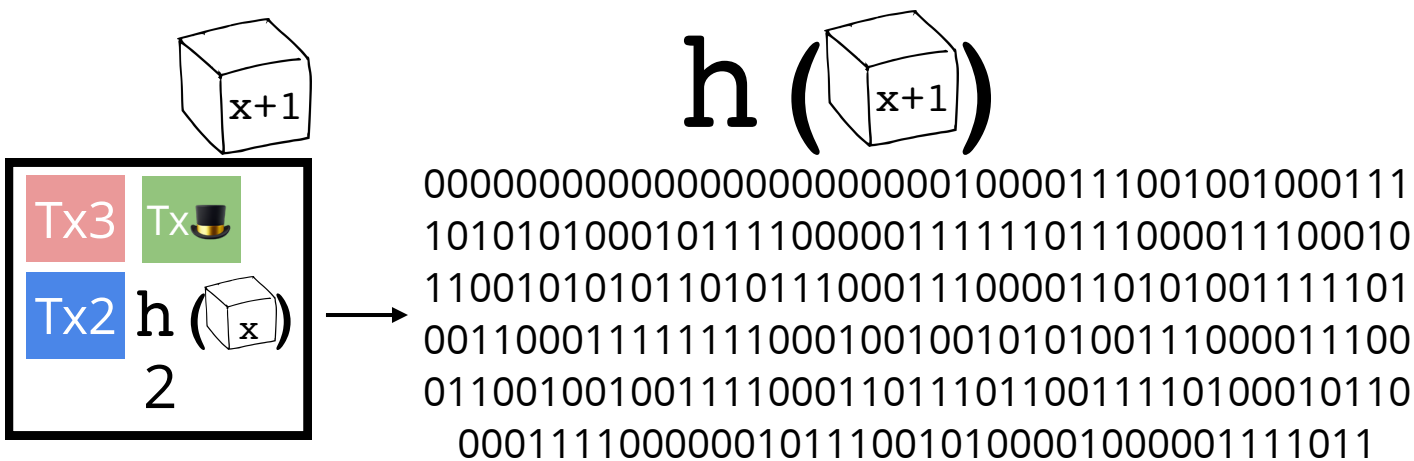
Es un valor *arbitrario*

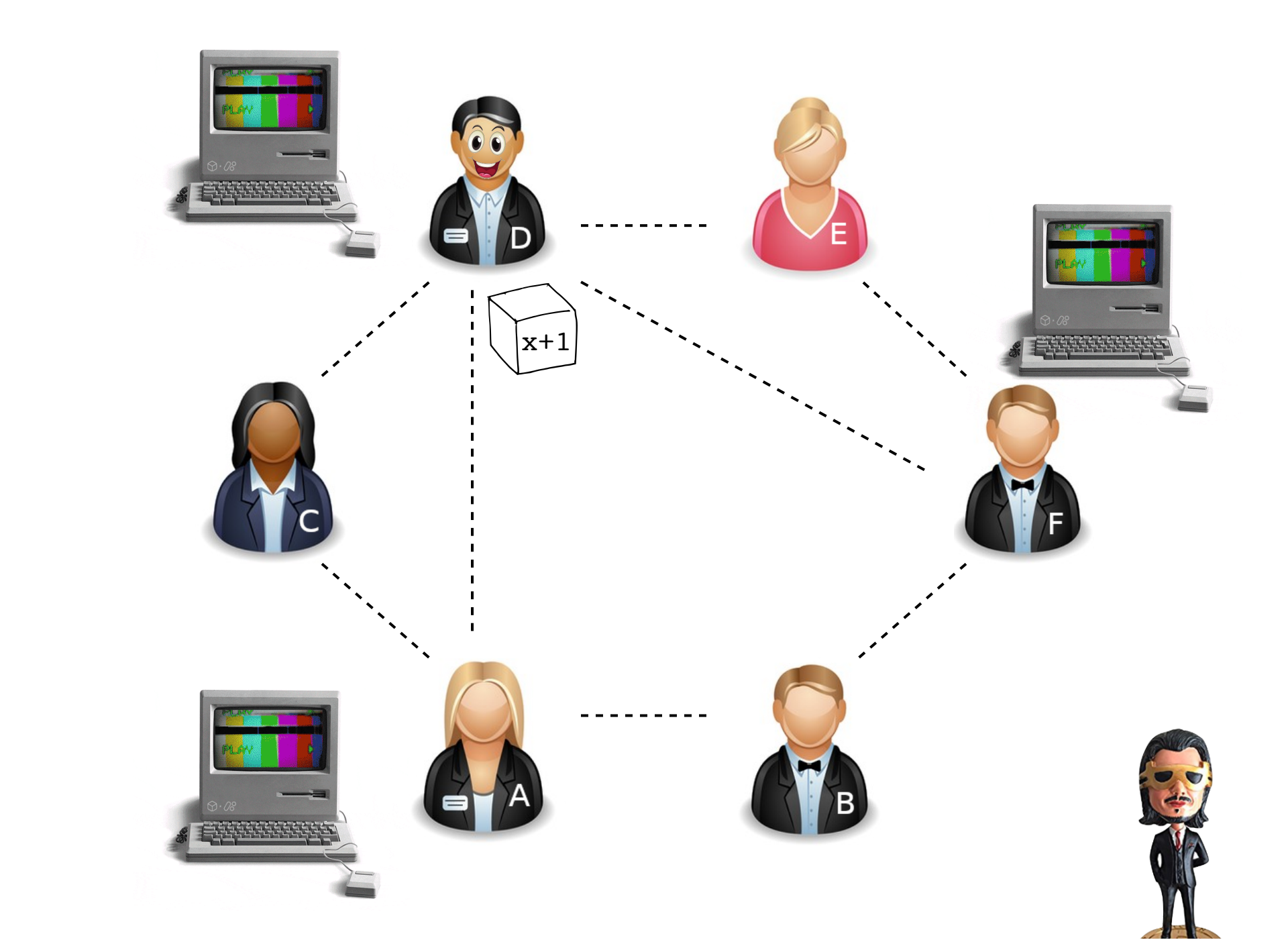
Este bloque es "válido" si su hash parte con veinte 0's

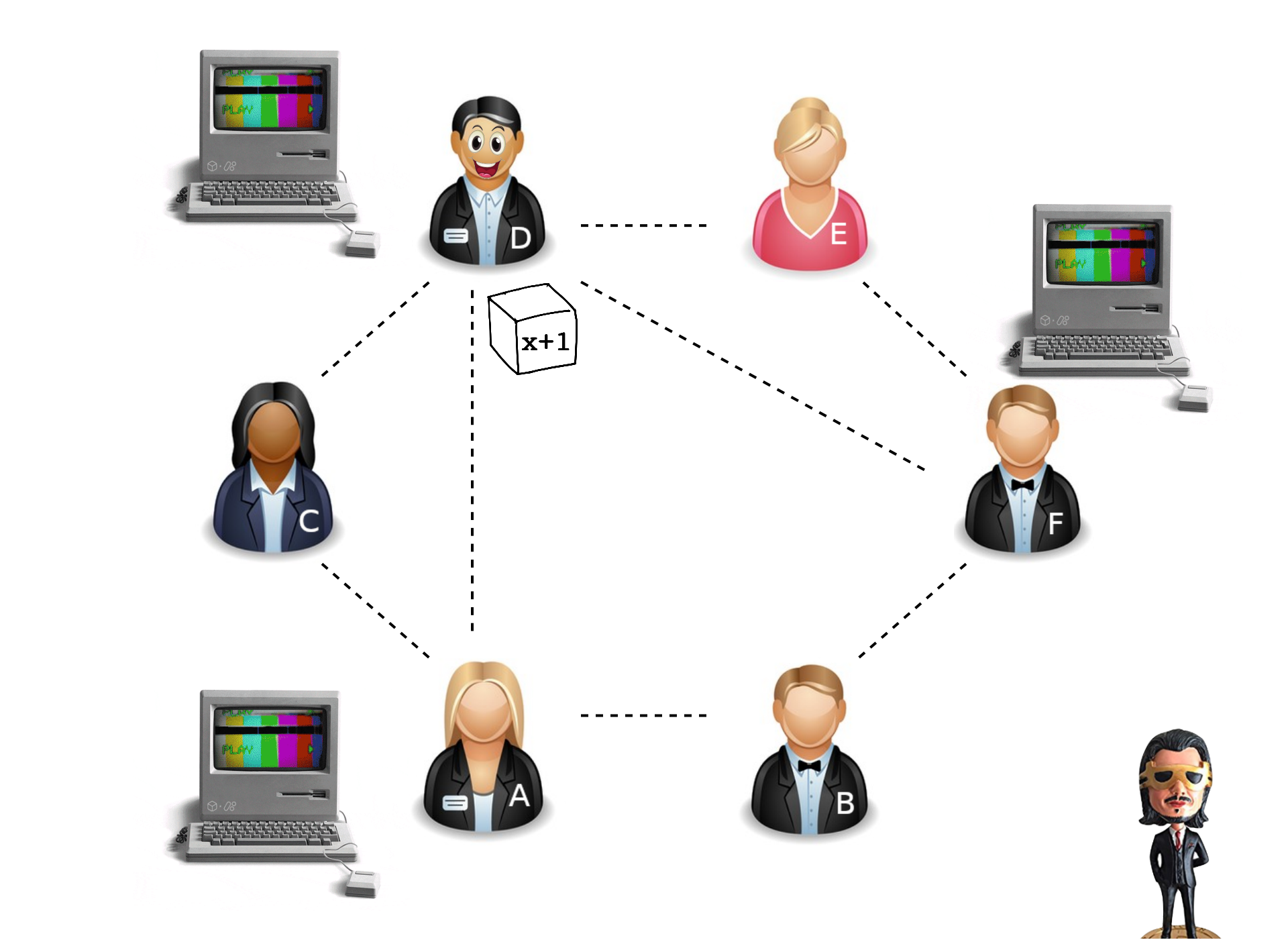
La 1^a persona con bloque válido es "elegida"

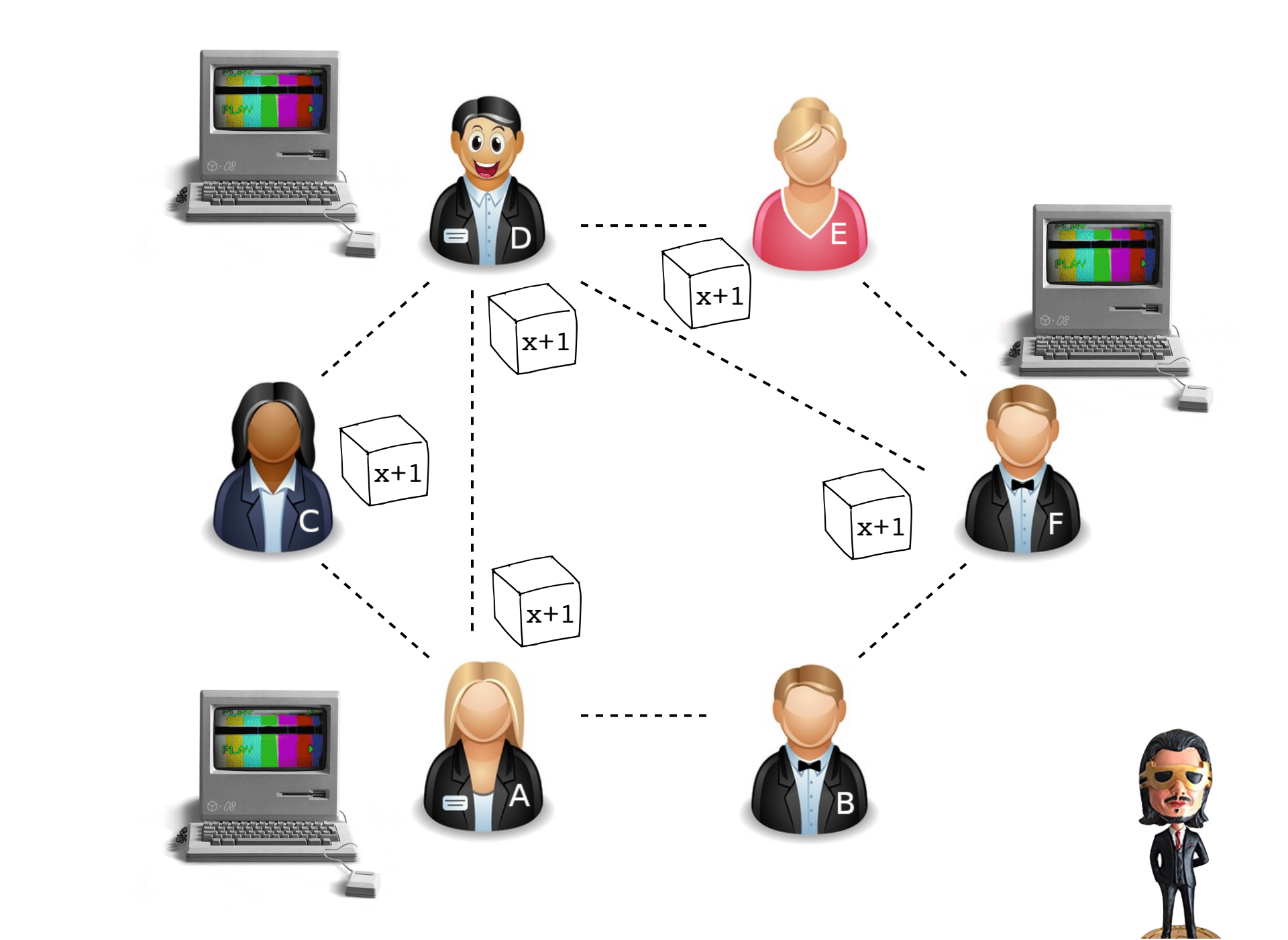

¡Bacán, voy a tratar de hacer un bloque válido!
C
x+1
Tx3
Tx
Tx2
h (x)
1
h (x+1)
11010111000100011000000100001110010010001111
10101010001011110000011111101110000111000010
11001010101101011100011100001101010011111101
00110001111111100010010010101001110000111000
01100100100111100011011101100111101000101100
00011110000001011100101000010000011110111

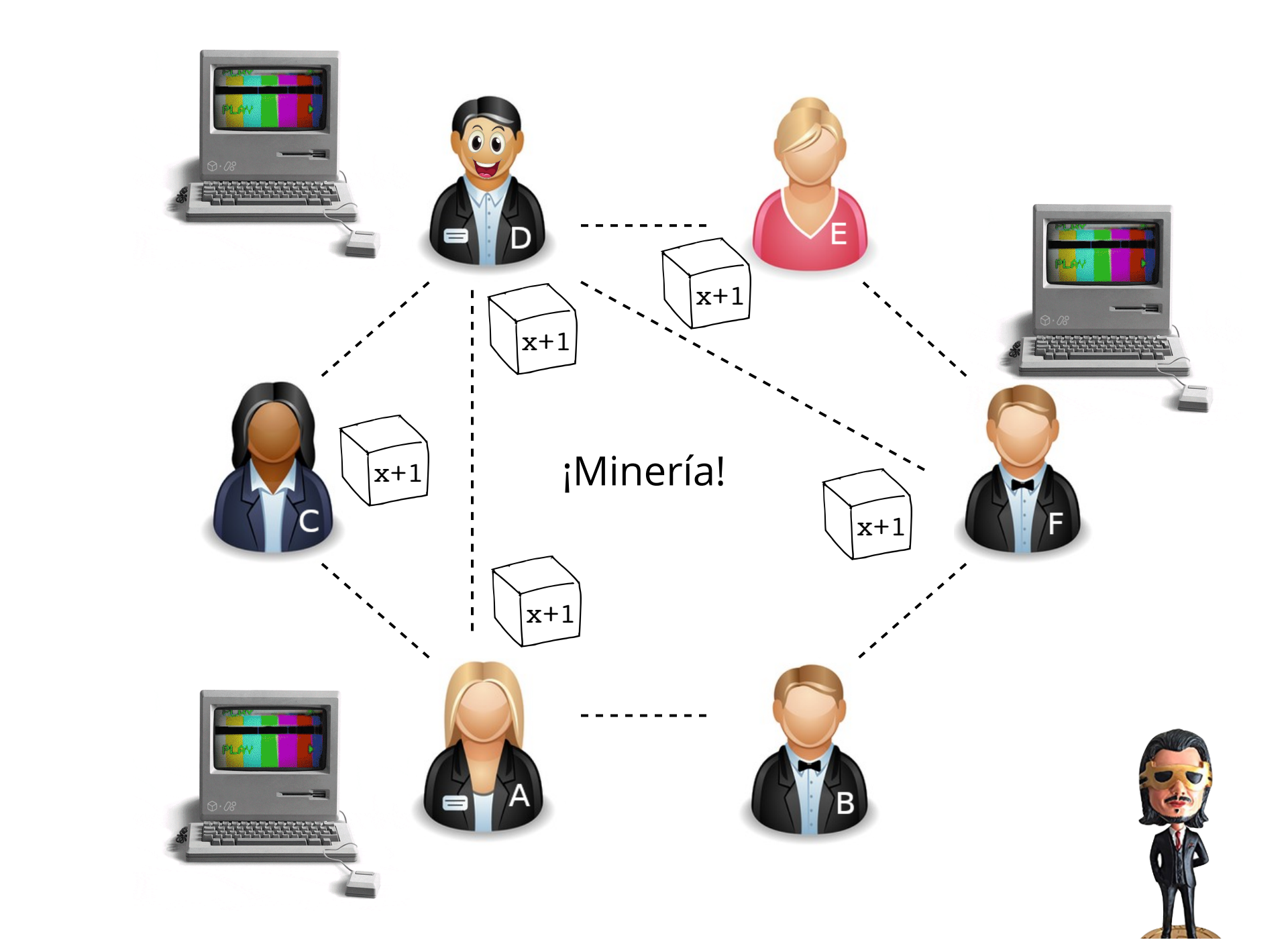

No me funcionó,
¡voy por otro!
C


x+1
Tx3
Tx
Tx2
h (x)
2
h (x+1)
0000000000000000000001000011100100100011
1010101000101111000011111101110000111000010
1100101010110101110001110000110101001111101
0011000111111110001001001010100111000011100
0110010010011110001101110110011110100010110
0001111000000101110010100001000001111011

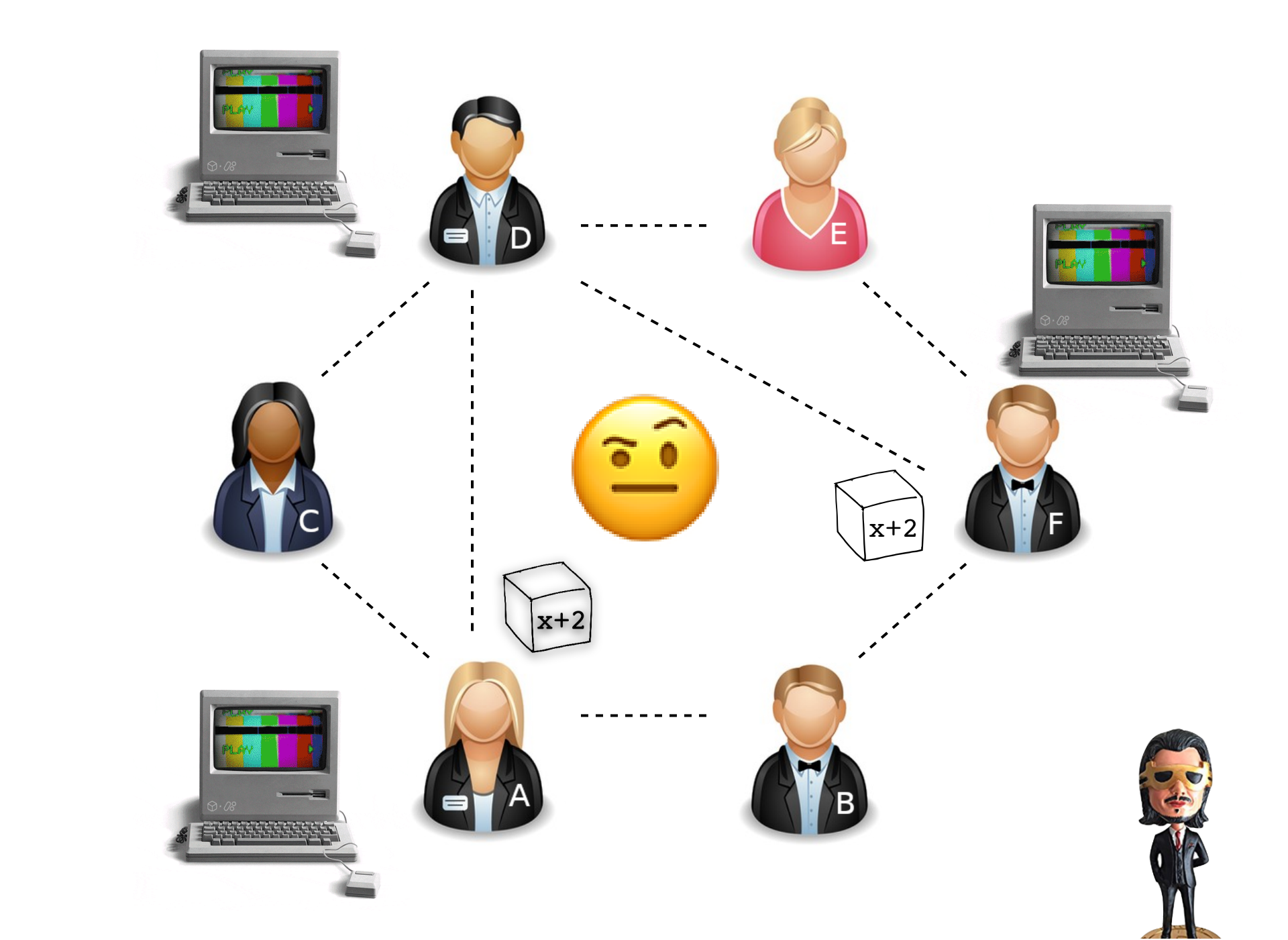

D
E
x+1
C
F
A
B


D
E
x+1
C
F
A
B


D
E
x+1
x+1
C
x+1
F
x+1
x+1
A
B

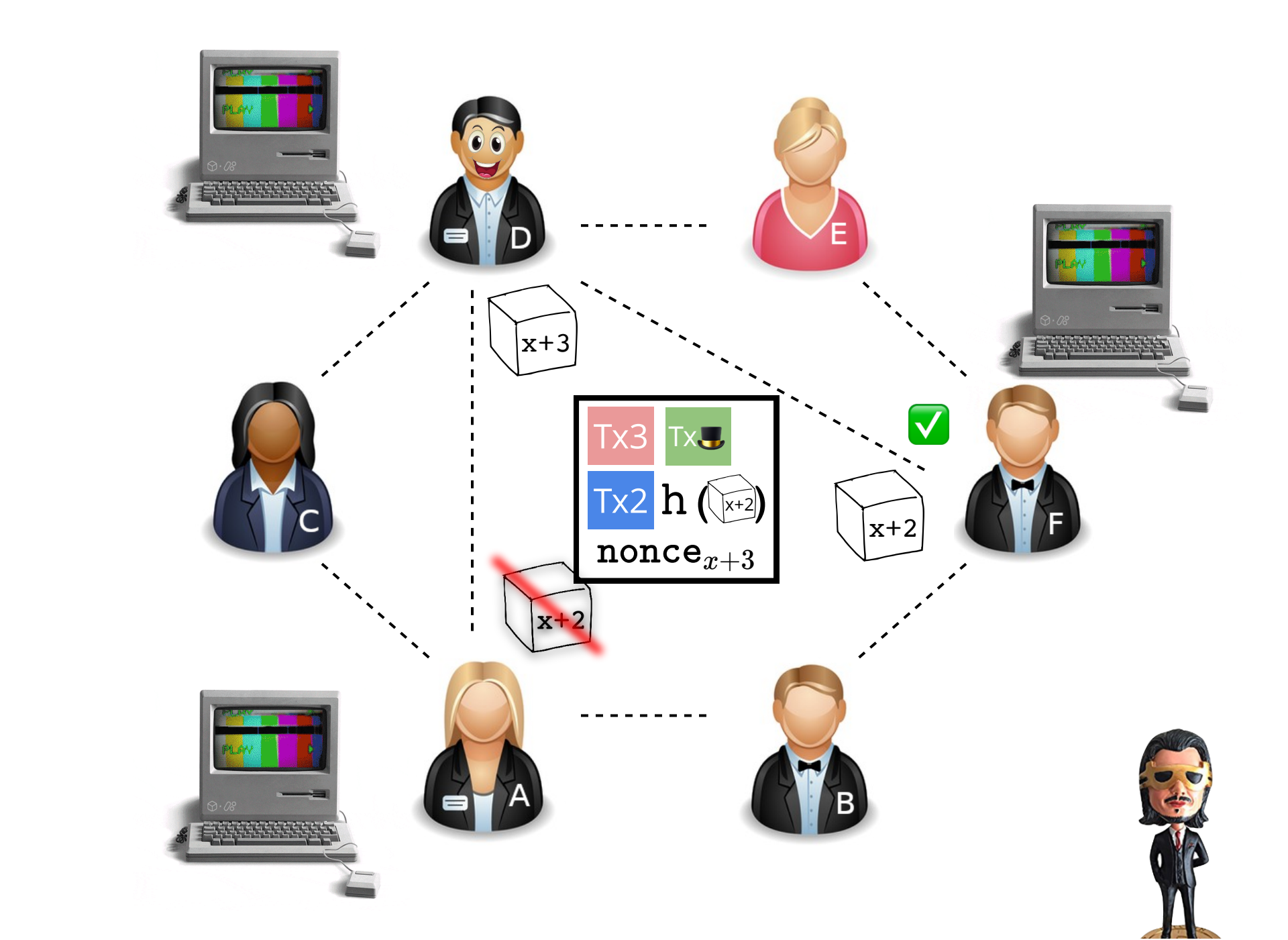

D
E
x+1
x+1
C
x+1
¡Minería!
x+1
F
x+1
A
B

Fin del repaso

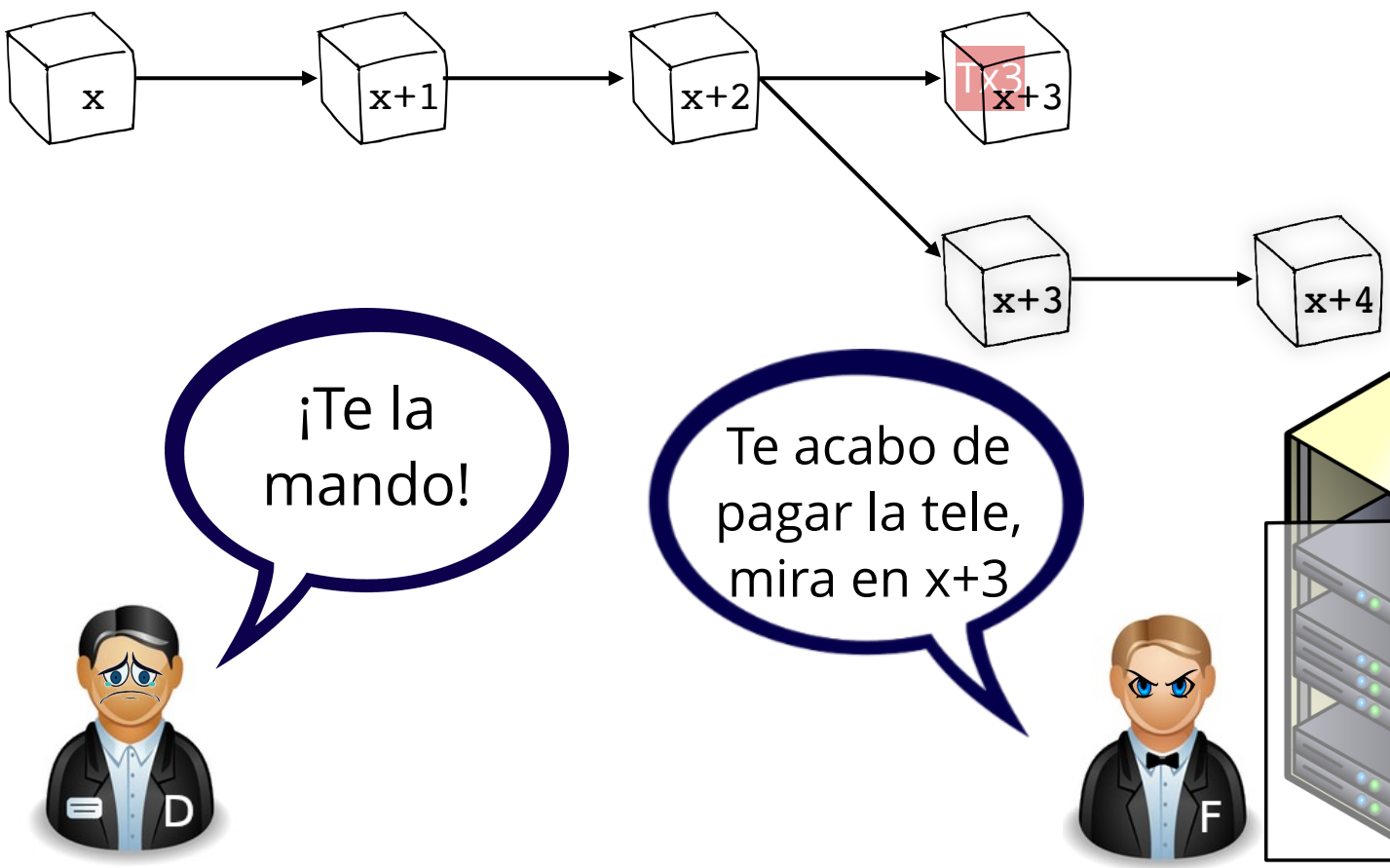

D
E
C
F
x+2
x+2
A
B

Mantengan los dos y sigan trabajando sobre el quieran...

Cuando salga otro, sigan la "cadena" más larga


D
E
C
F
A
B
x+3
x+2
x+2
Tx3
Tx
Tx2
h (x+2)
nonce$_{x+3}$

51% Attack


x
x+1
x+2
Tx3
x+3
x+3
x+4
¡Te la mando!
Te acabo de pagar la tele, mira en x+3
D
F

Bitcoin: A Peer-to-Peer Electronic Cash System

Satoshi Nakamoto
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www.bitcoin.org

Abstract. A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work. The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers. The network itself requires minimal structure. Messages are broadcast on a best effort basis, and nodes can leave and rejoin the network at will, accepting the longest proof-of-work chain as proof of what happened while they were gone.

1. Introduction

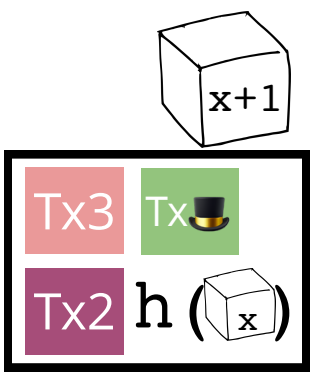
Bitcoin en la práctica

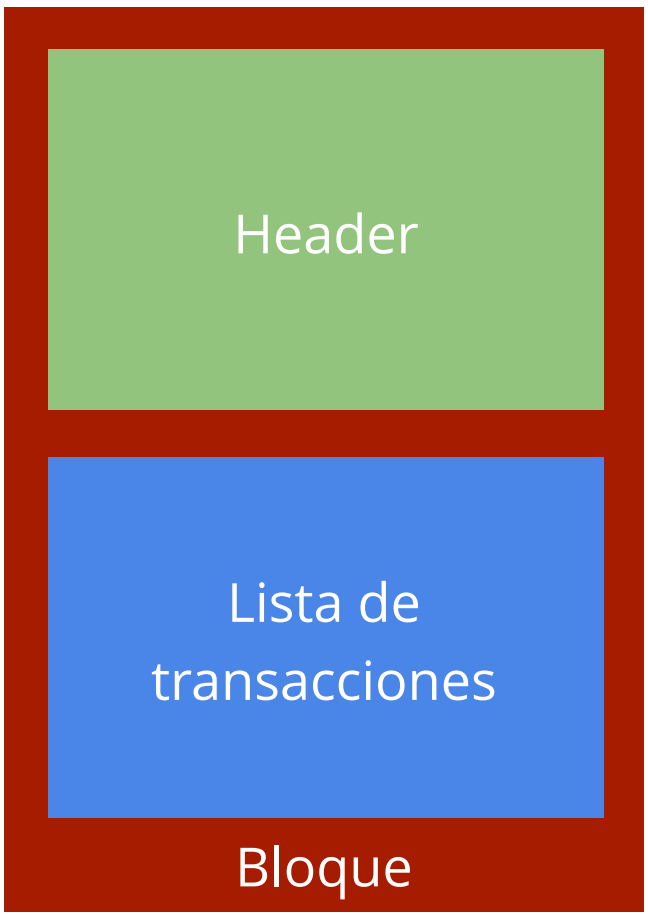
Bloques

Blockchain de Bitcoin

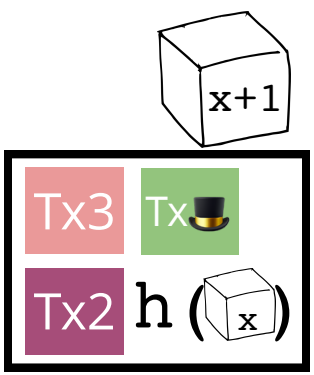
Un bloque

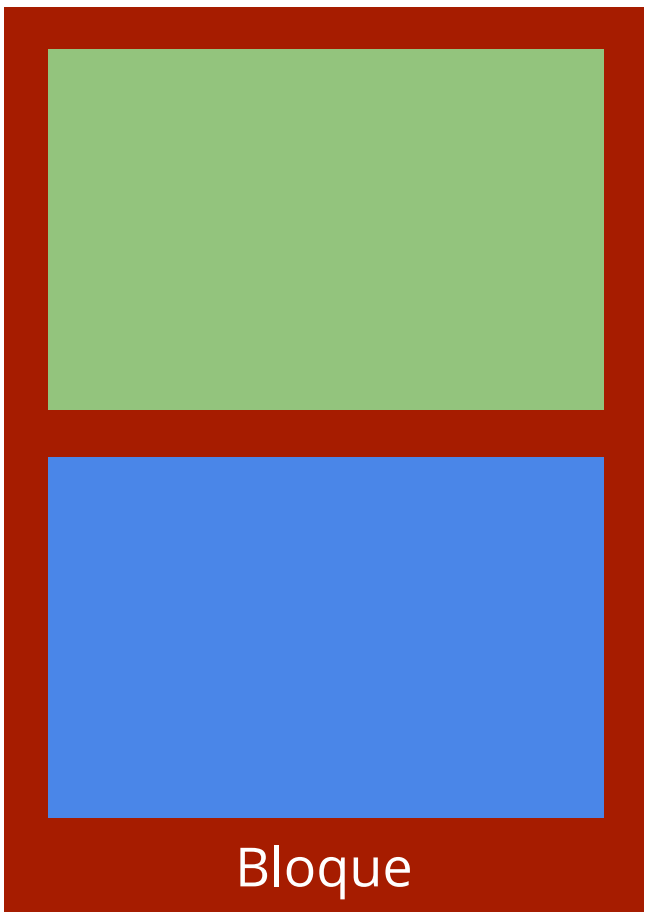
Un bloque



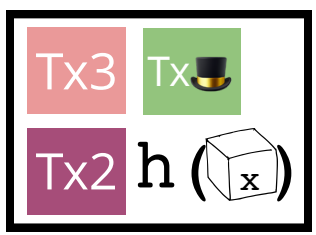


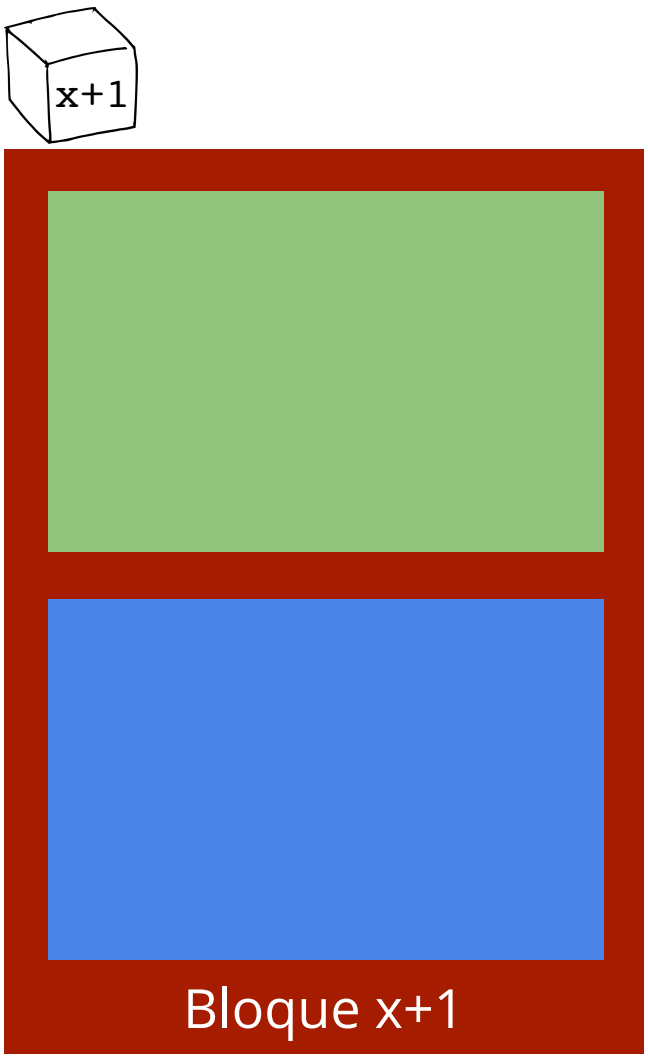
Un bloque



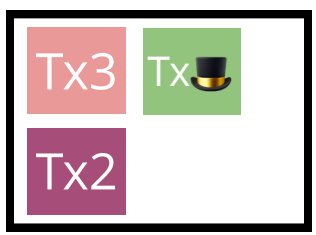


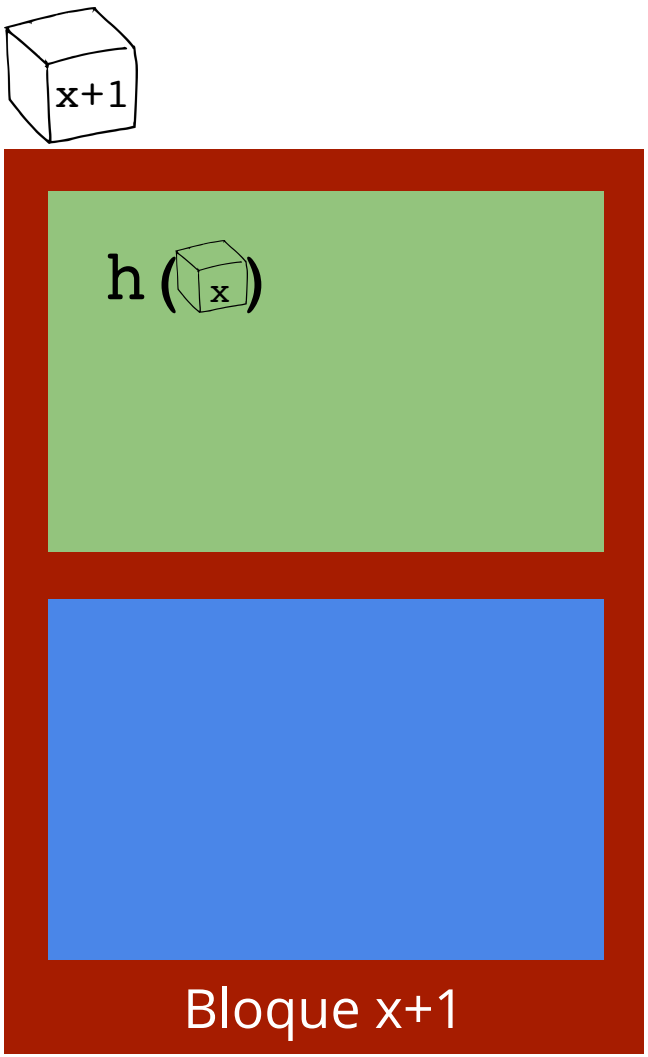
Un bloque



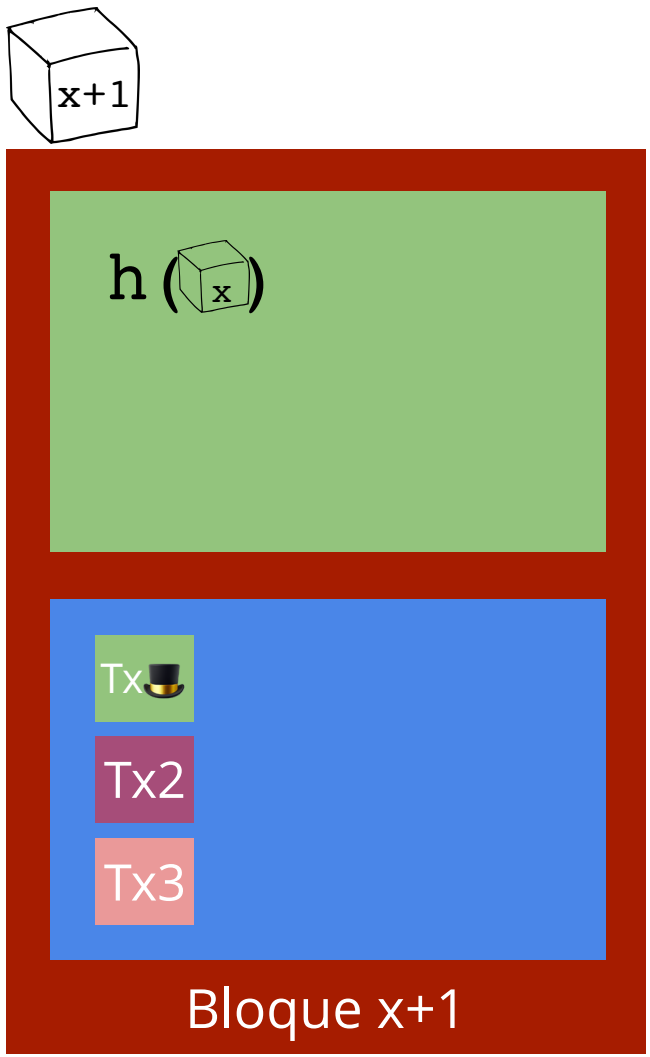


Un bloque



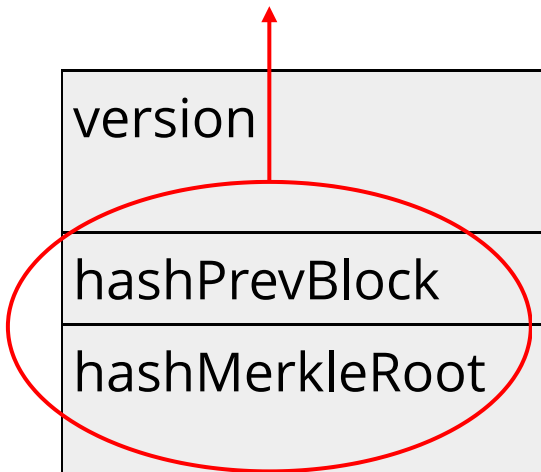


Un bloque



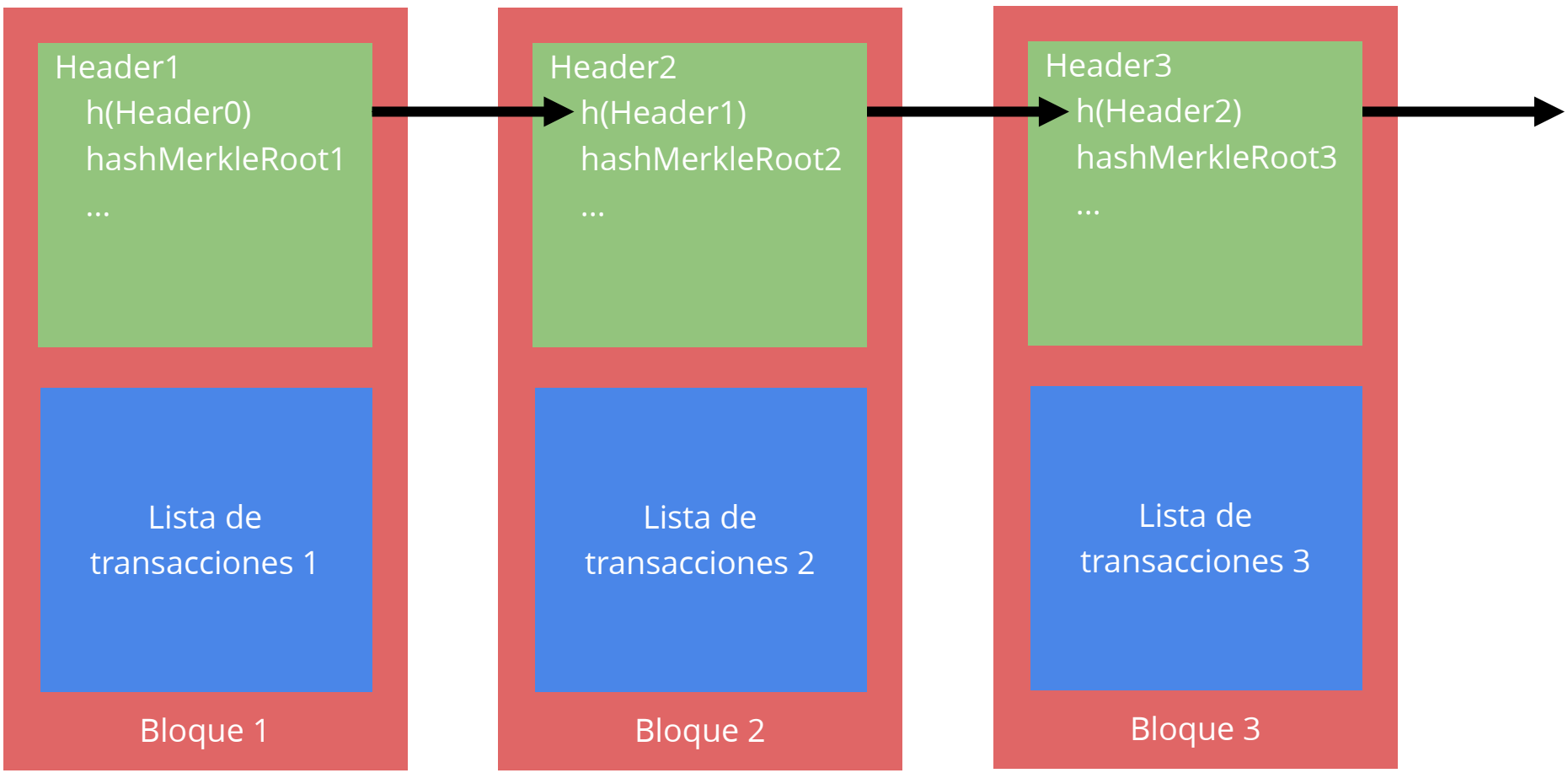
Header

SHA-256(SHA-256(...))



version	indica la versión de las reglas de validación de un bloque que deben ser usadas
hashPrevBlock	hash del header del bloque anterior
hashMerkleRoot	raíz del árbol de Merkle para las transacciones del bloque
time	Unix timestamp que indica cuándo fue generado el bloque
bits	dificultad asociada a generar un bloque
nonce	número de 32 bits

El blockchain de Bitcoin



¿Por qué necesitamos árboles de Merkle?

Necesitamos verificar que una transacción es parte de un bloque

- hashPrevBlock no incluye a las transacciones del bloque

Podríamos incluir en el header: h(

)

¿Por qué esto no es una buena idea?

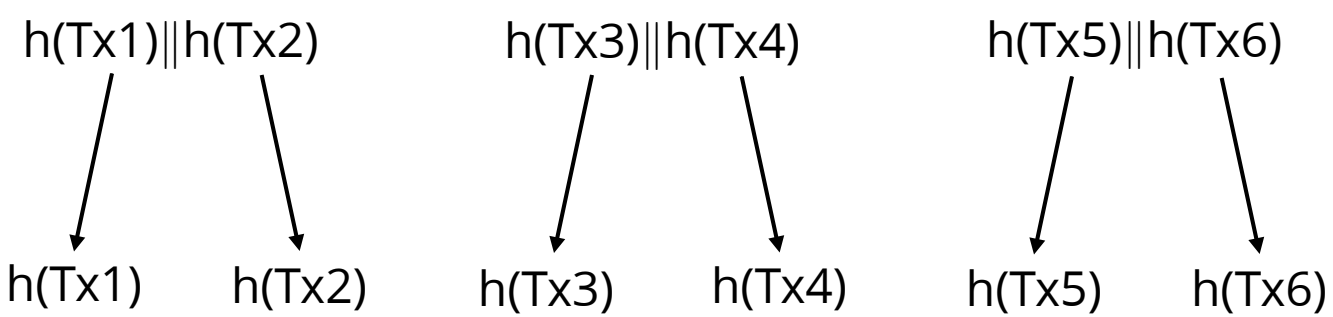
Arboles de Merkle

Tx1 Tx2 Tx3 Tx4 Tx5 Tx6

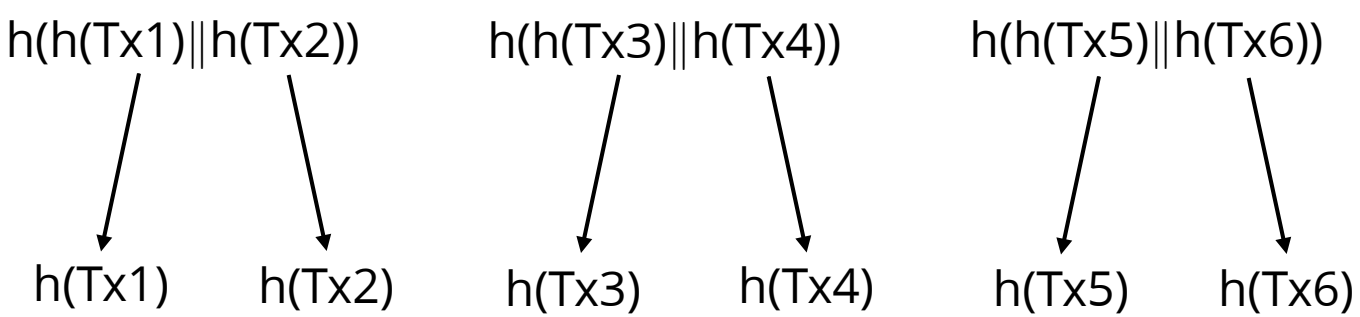
Arboles de Merkle

h(Tx1) h(Tx2) h(Tx3) h(Tx4) h(Tx5) h(Tx6)

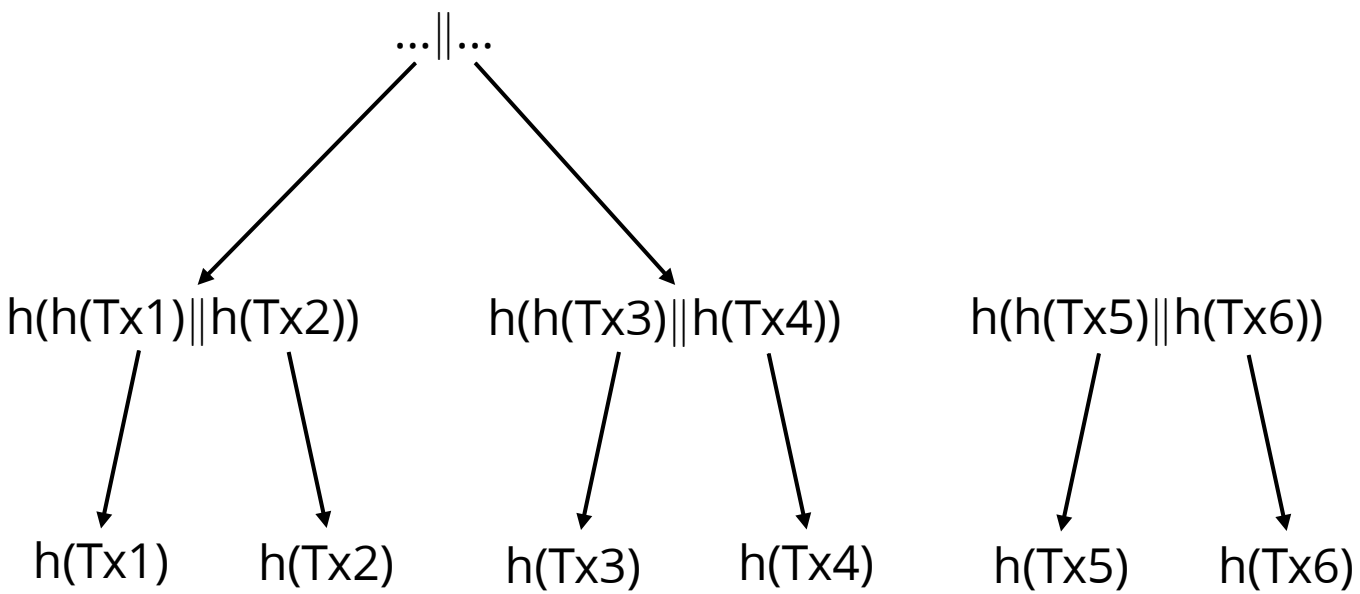
Arboles de Merkle



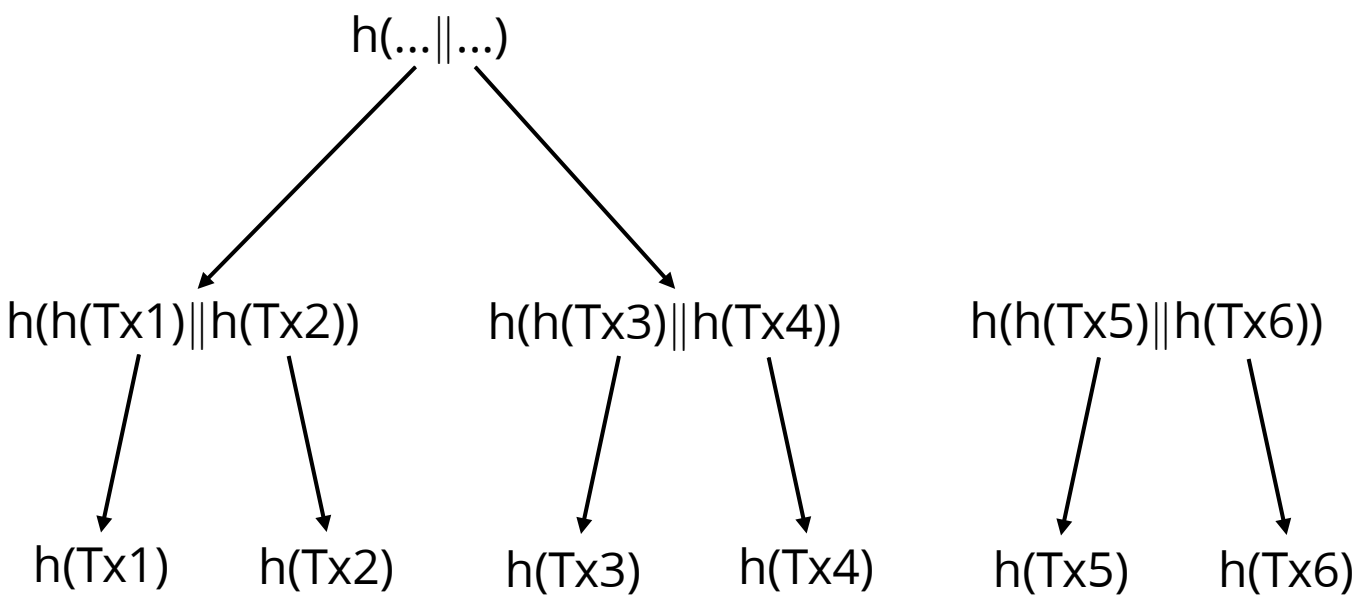
Arboles de Merkle



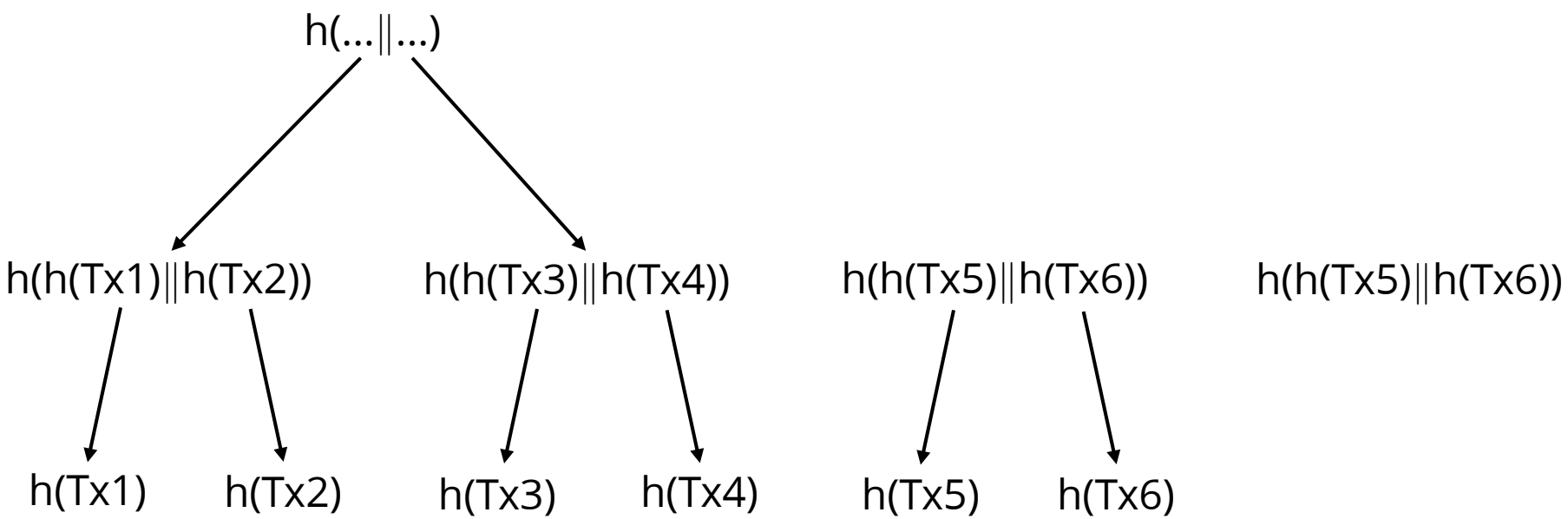
Arboles de Merkle



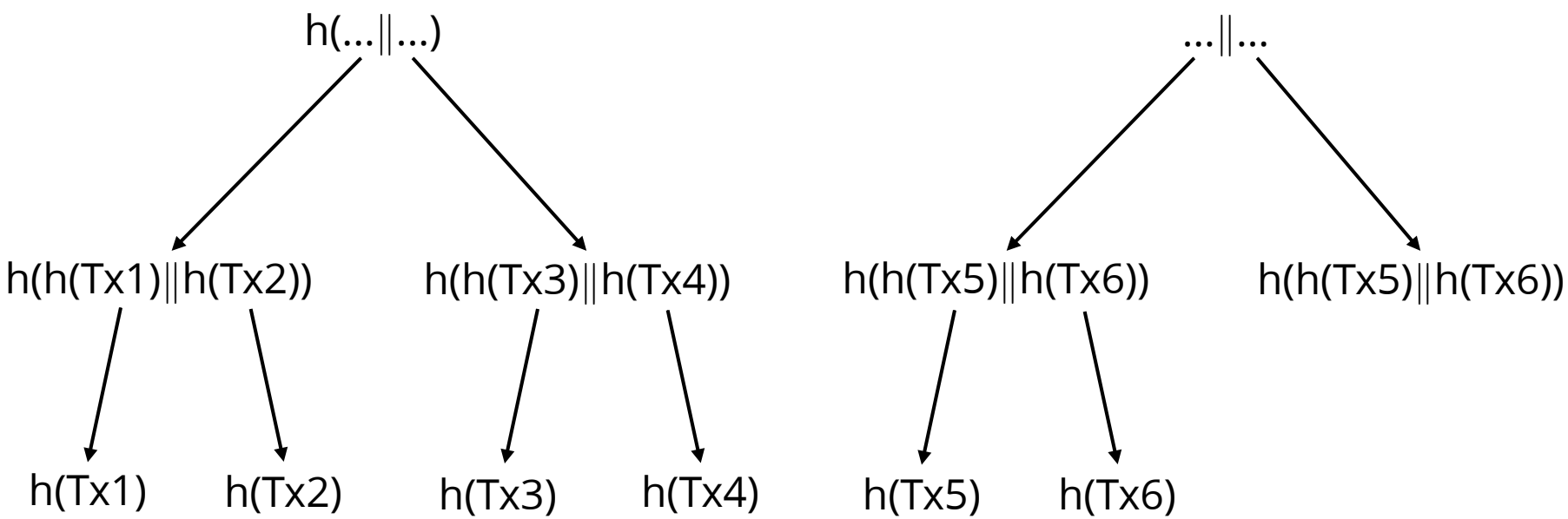
Arboles de Merkle



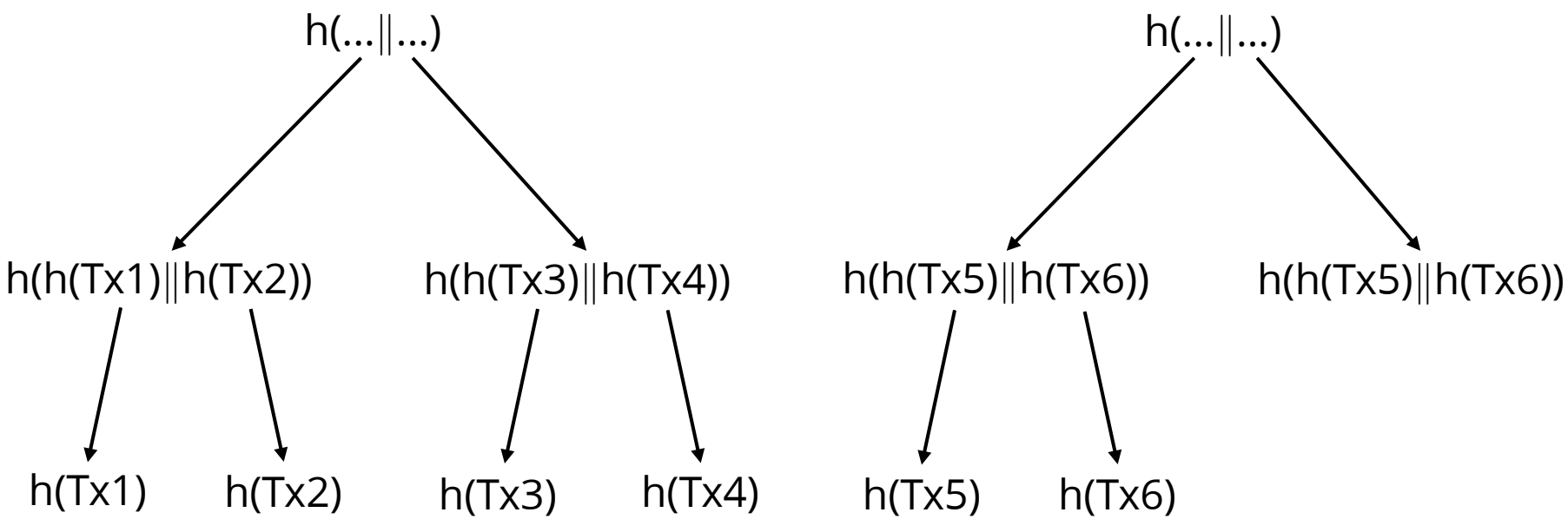
Arboles de Merkle



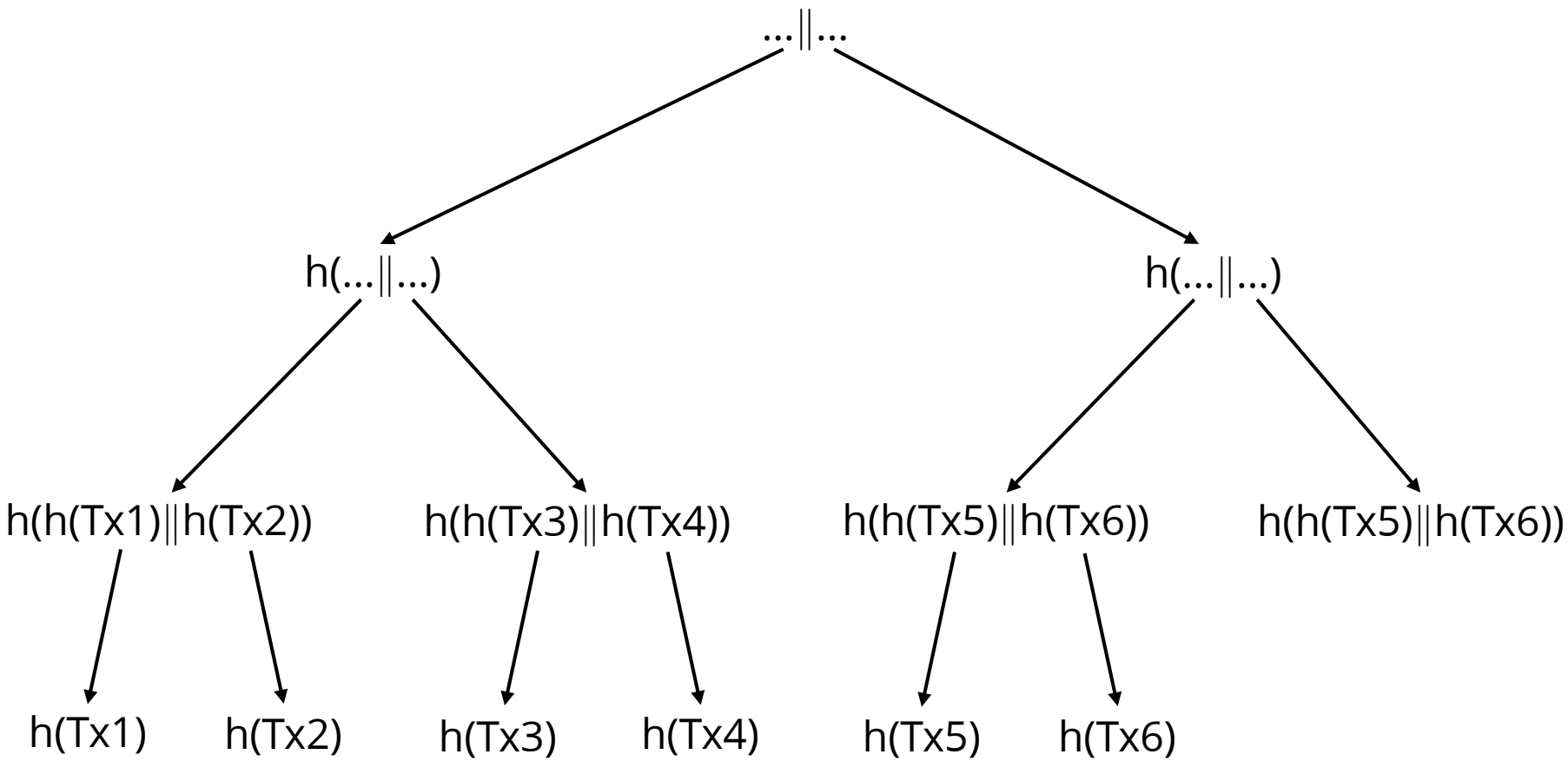
Arboles de Merkle



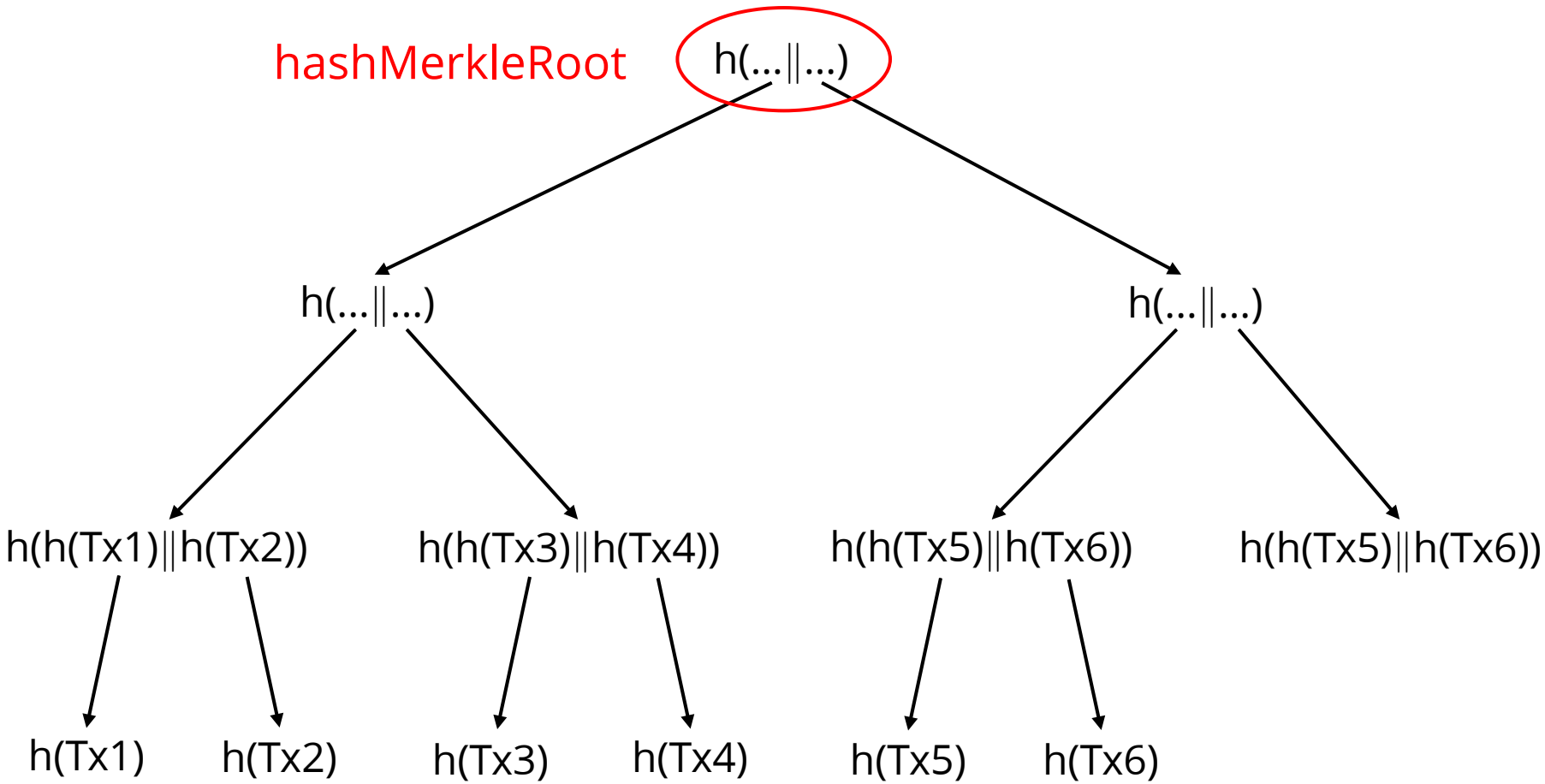
Arboles de Merkle



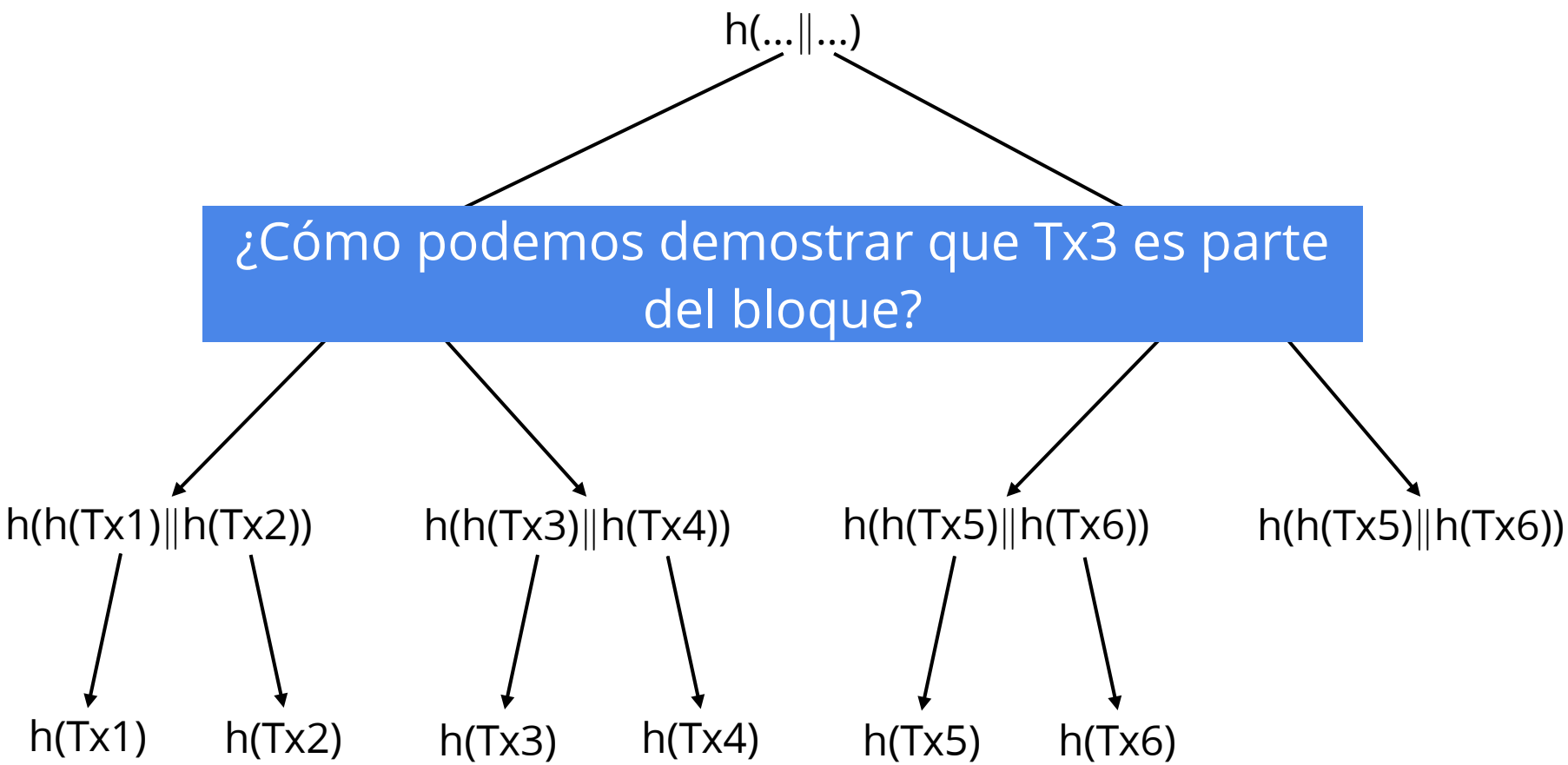
Arboles de Merkle



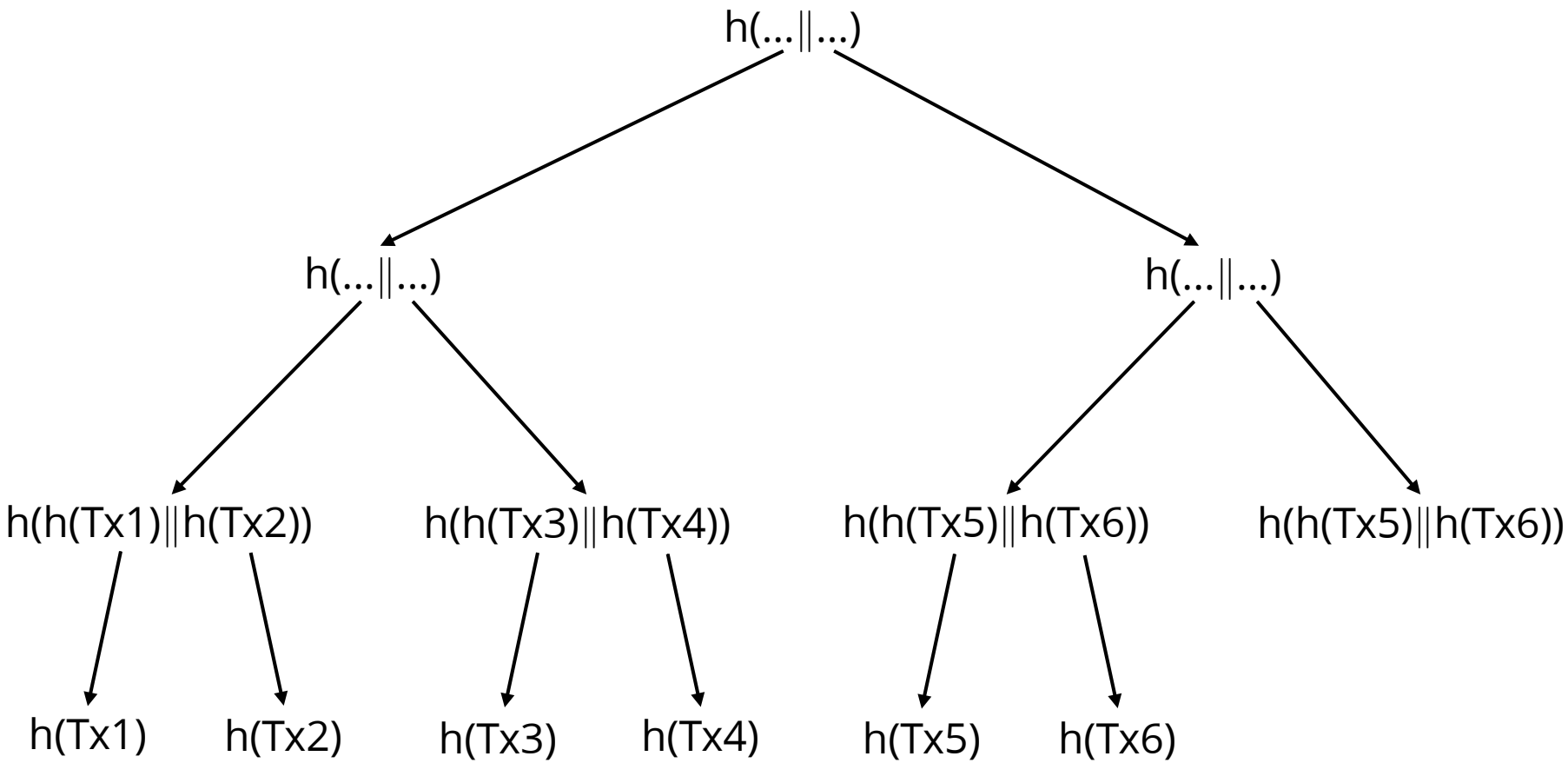
Arboles de Merkle



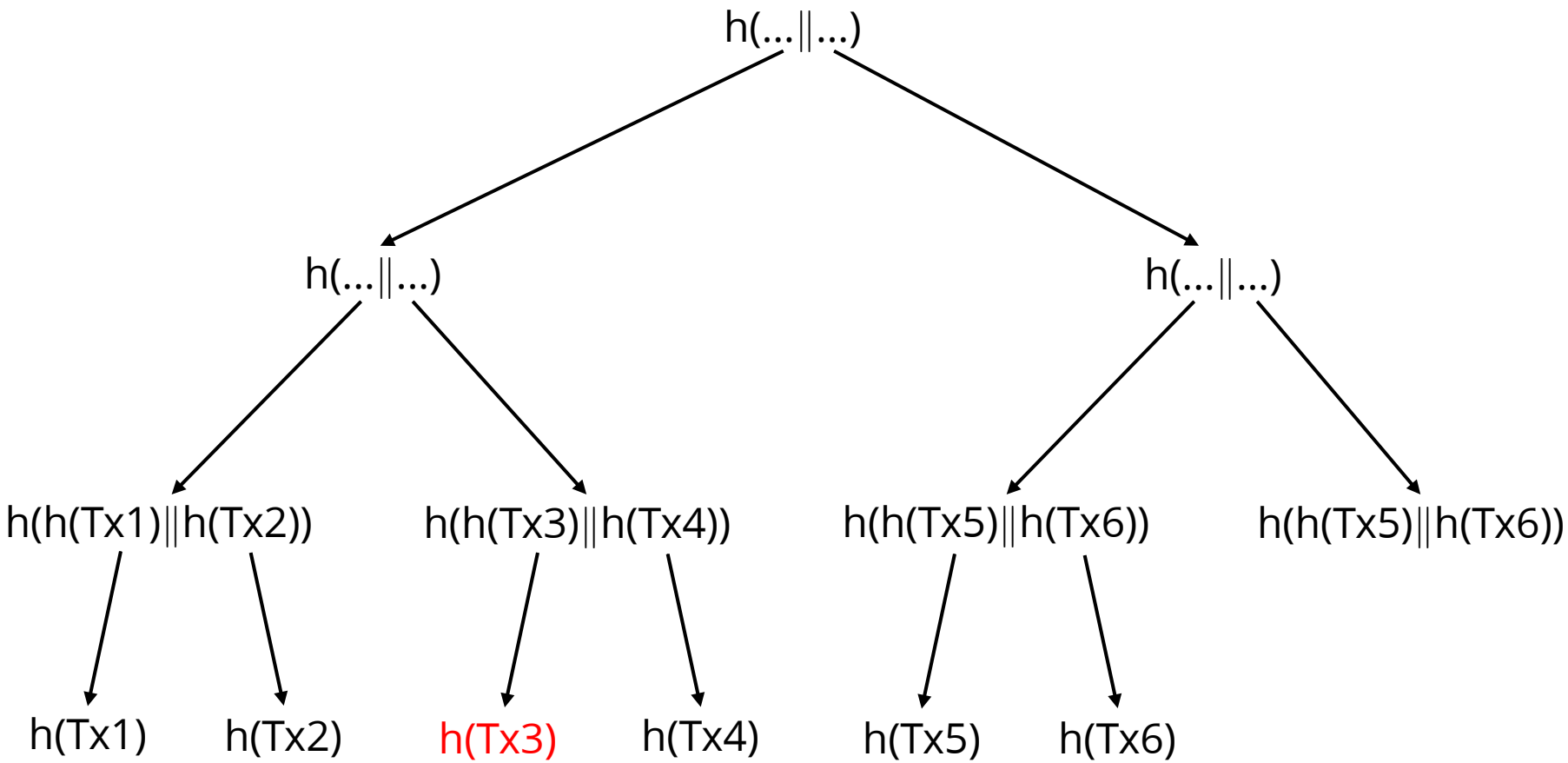
¿Qué ventajas tienen los árboles de Merkle?



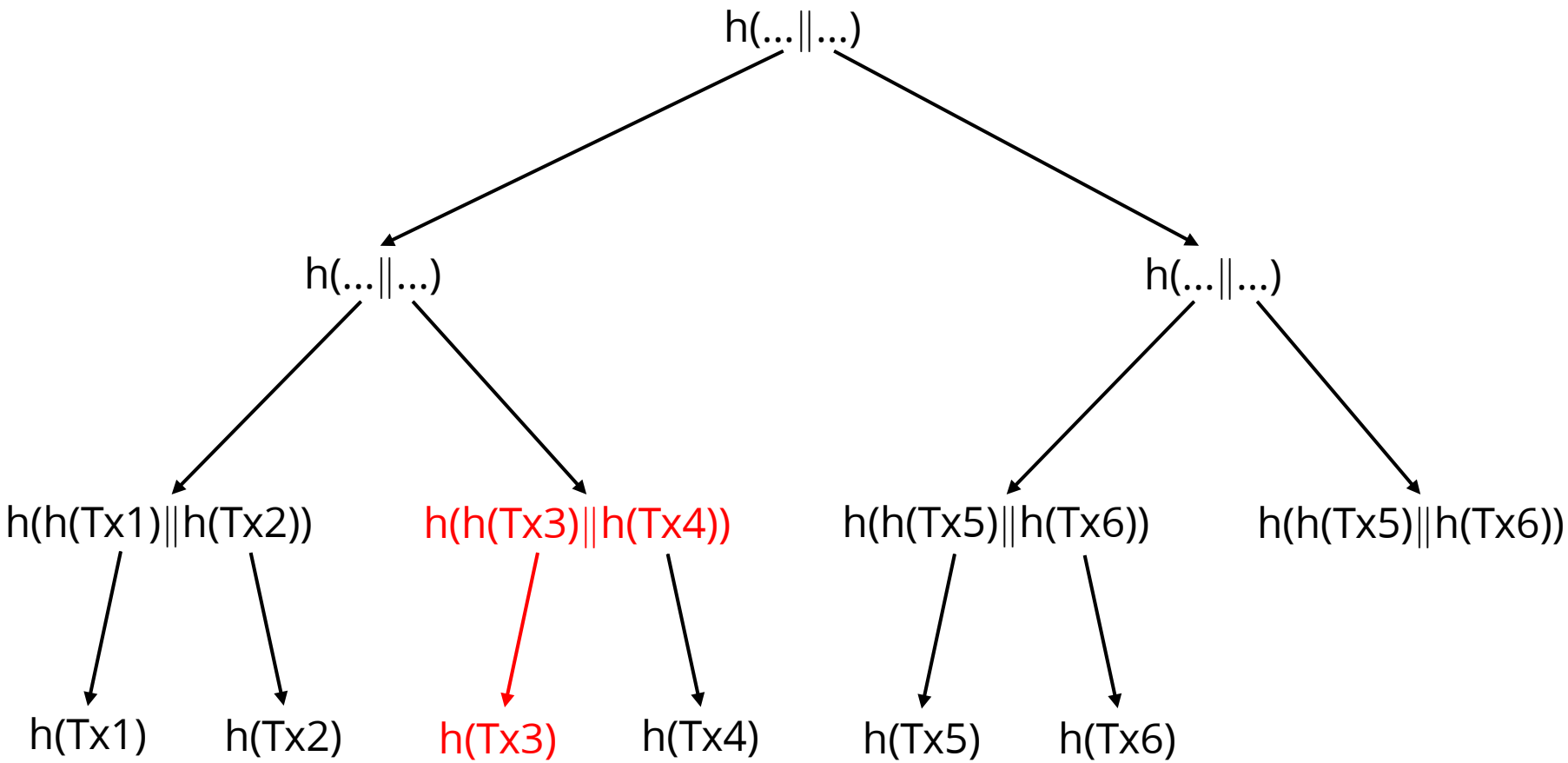
¿Qué ventajas tienen los árboles de Merkle?



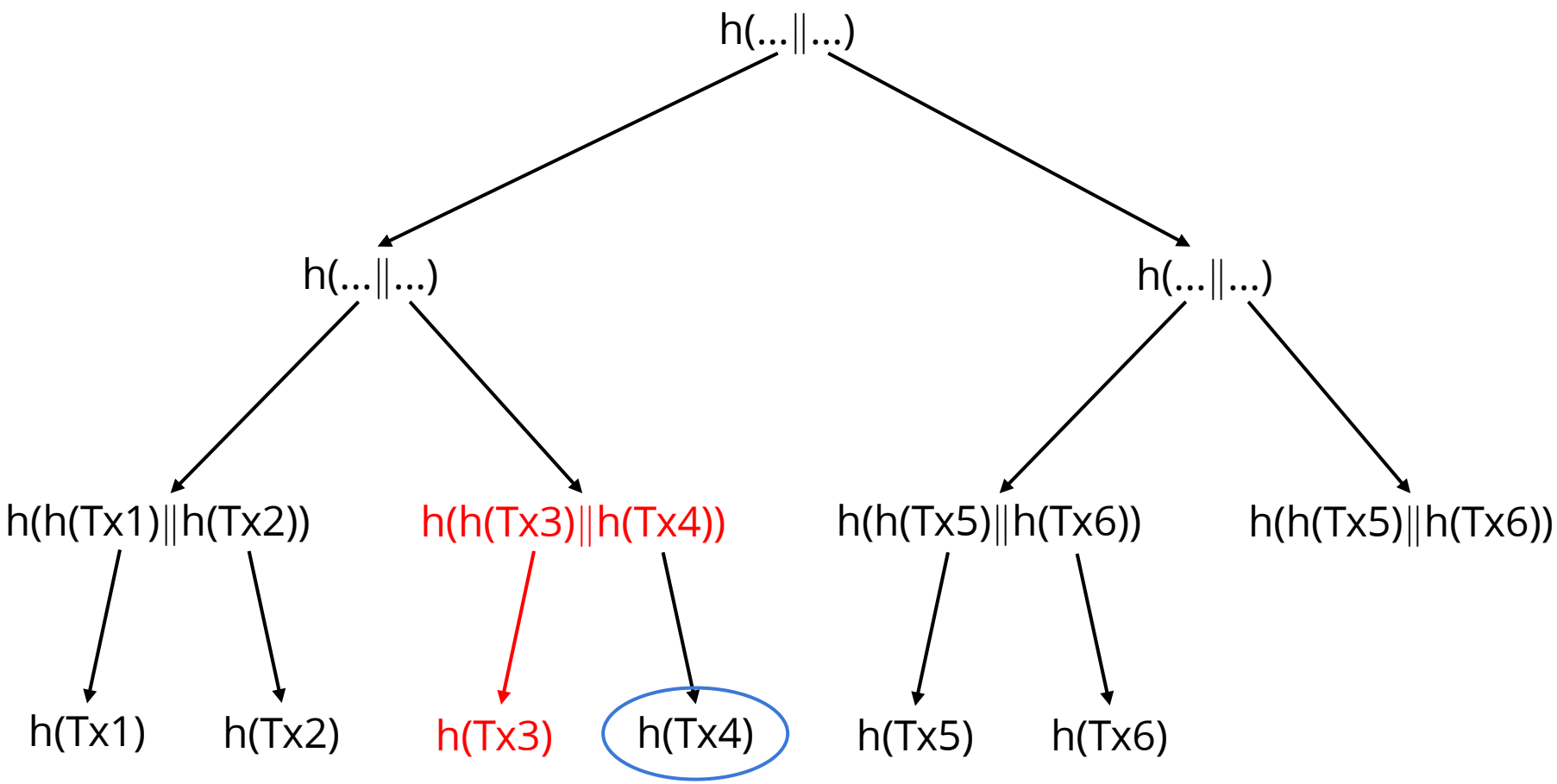
¿Qué ventajas tienen los árboles de Merkle?



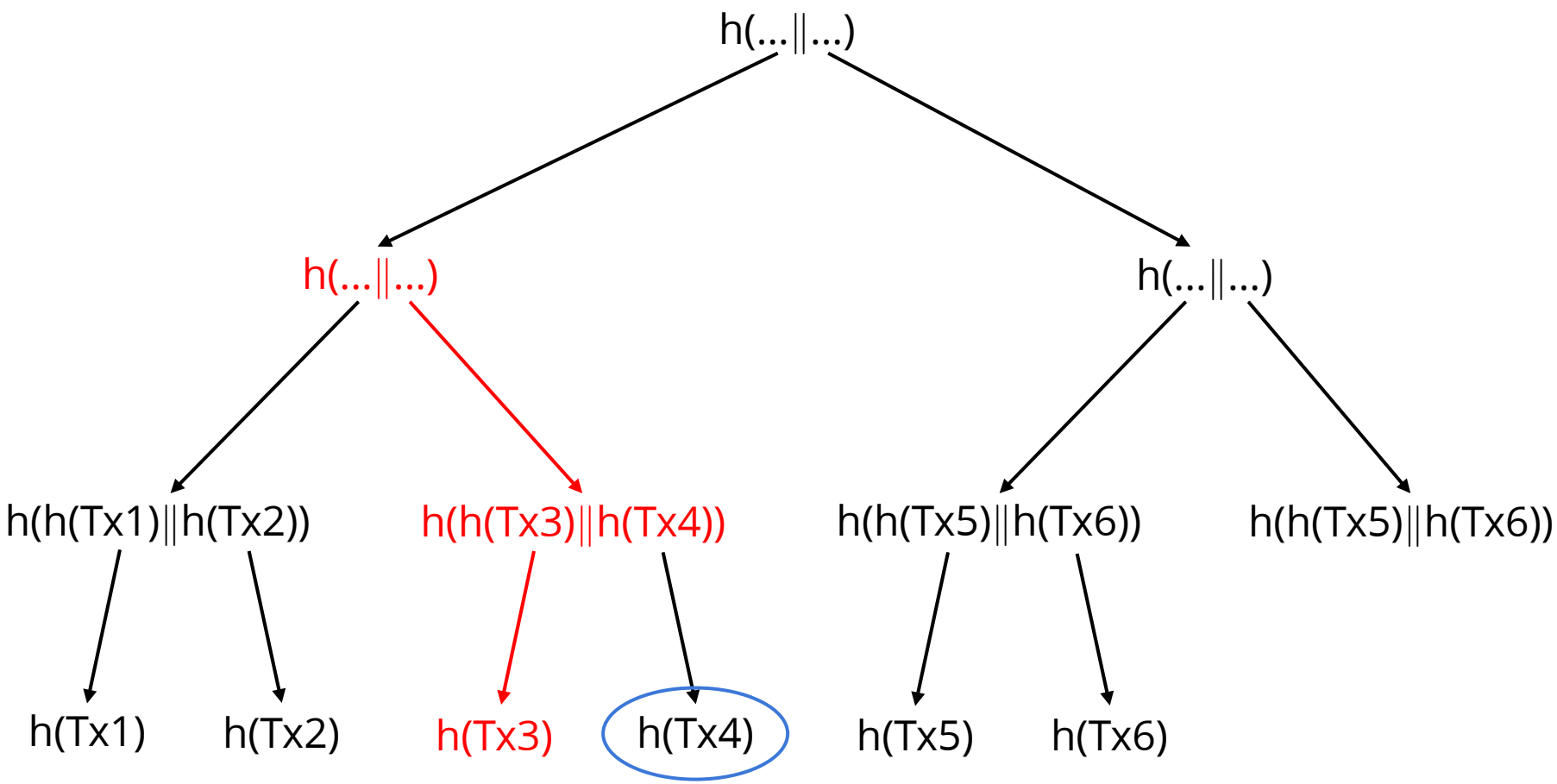
¿Qué ventajas tienen los árboles de Merkle?



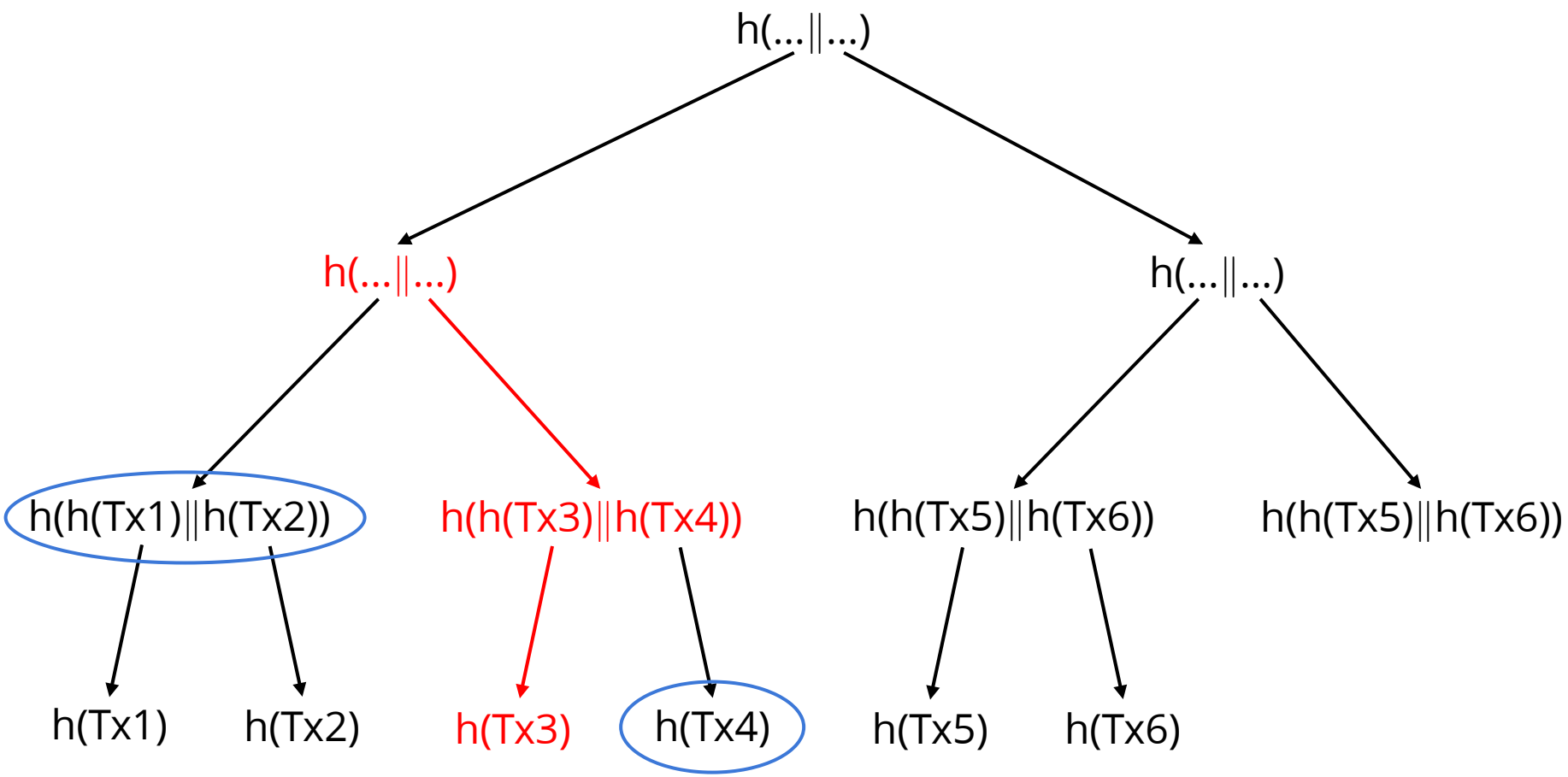
¿Qué ventajas tienen los árboles de Merkle?



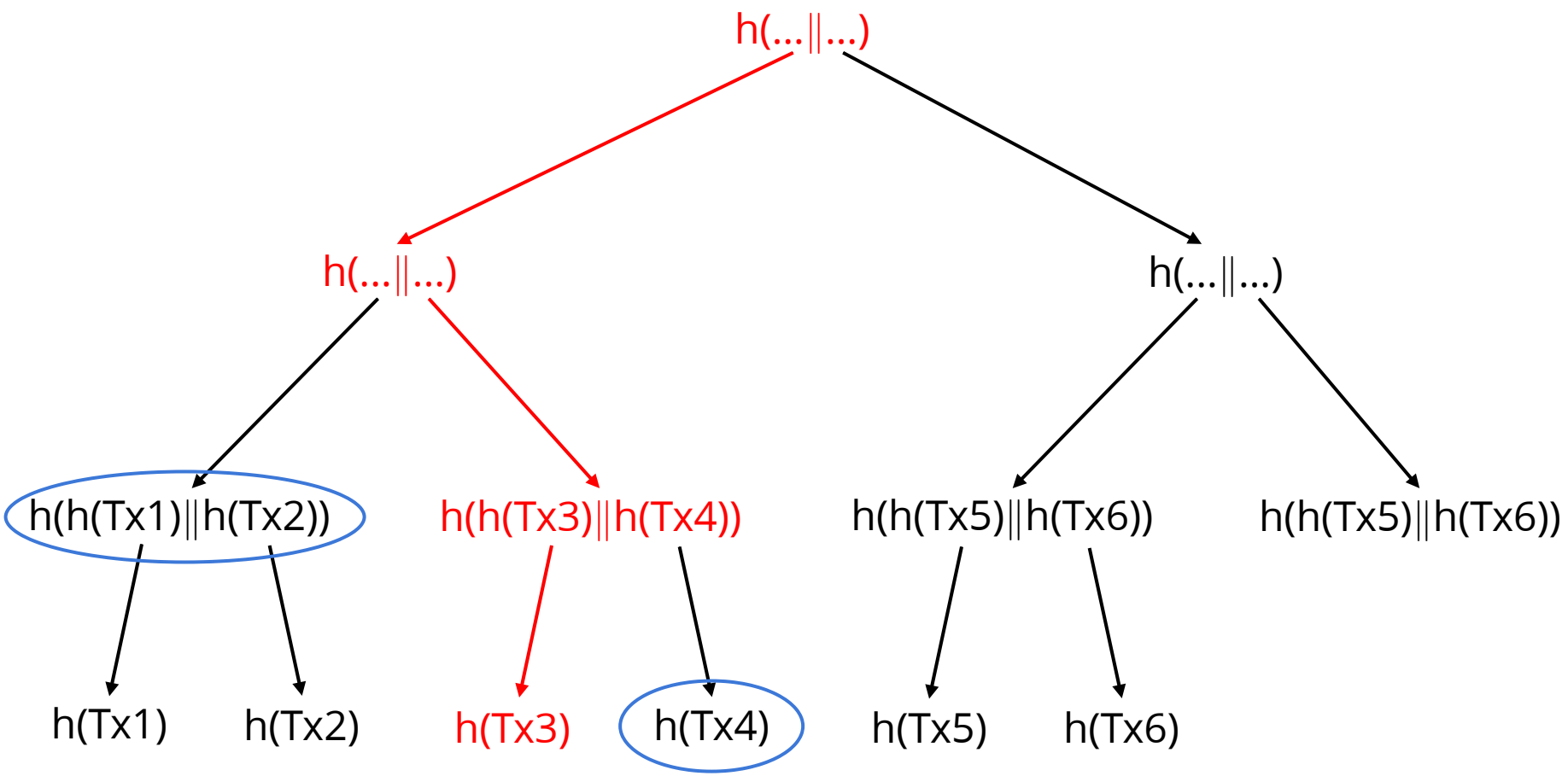
¿Qué ventajas tienen los árboles de Merkle?



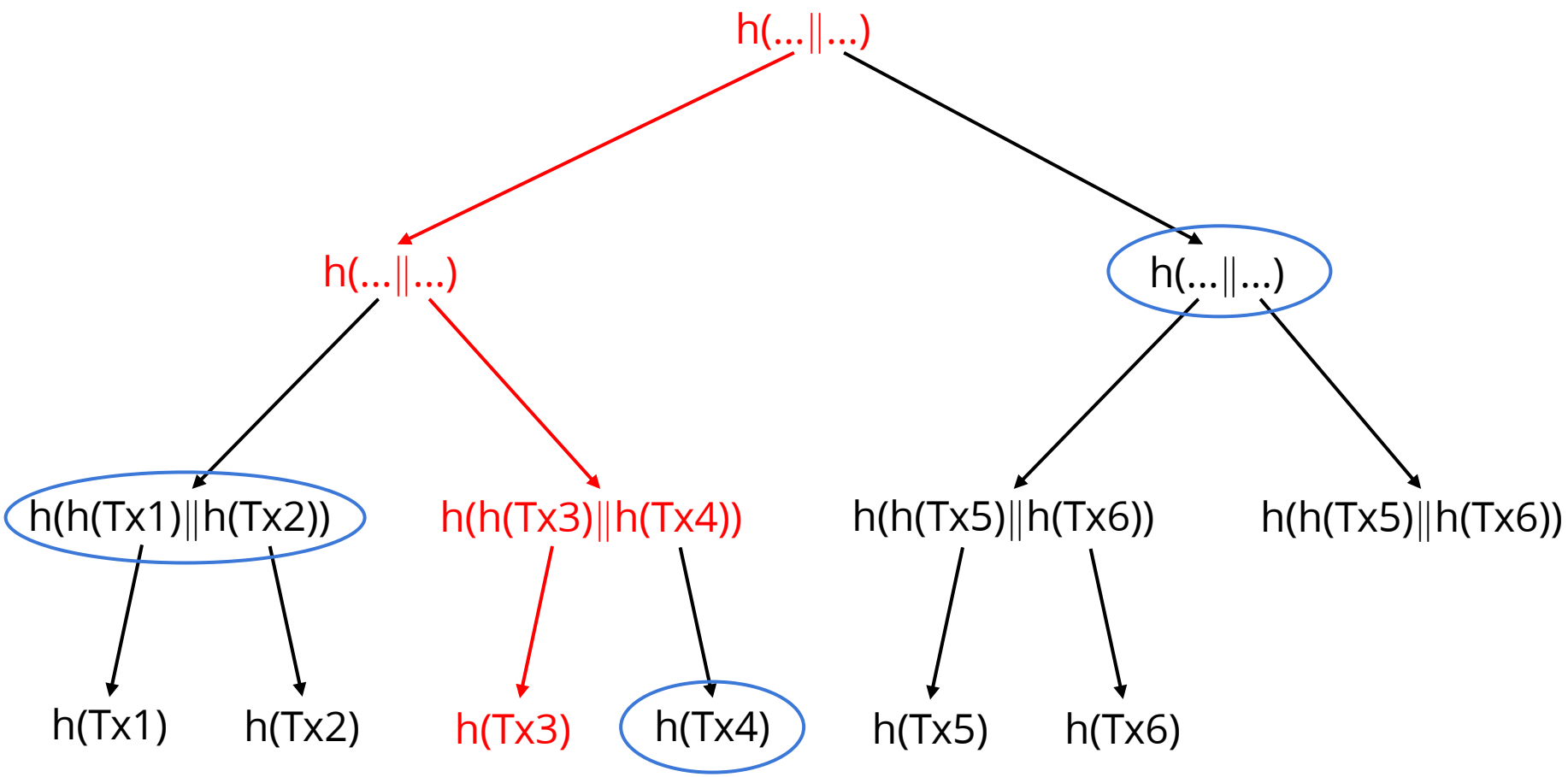
¿Qué ventajas tienen los árboles de Merkle?



¿Qué ventajas tienen los árboles de Merkle?

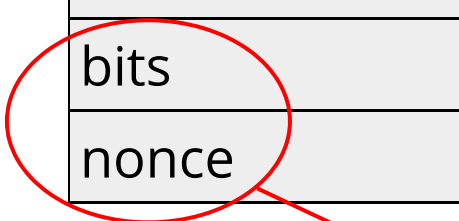


¿Qué ventajas tienen los árboles de Merkle?



Los que nos falta de header

version	indica la versión de las reglas de validación de un bloque que deben ser usadas
hashPrevBlock	hash del header del bloque anterior
hashMerkleRoot	raíz del árbol de Merkle para las transacciones del bloque
time	Unix timestamp que indica cuándo fue generado el bloque
bits	dificultad asociada a generar un bloque
nonce	número de 32 bits



Minería

Transacciones

Identificador de una transacción:

`80975cddebaa93aa21a6477c0d050685d6820fa1068a2731db0f39b535cbd369`

Podemos ver la codificación en hexadecimal de esta transacción.

Y podemos ver la traducción a JSON de esta codificación.

JSON de una transacción

```
1 {
2   "version": 1,
3   "hash": "80975cddebaa93aa21a6477c0d050685d6820fa1...",
4   "txid": "80975cddebaa93aa21a6477c0d050685d6820fa1...",
5   "ins": [ ... ],
6   "outs": [ ... ]
7 }
```

Entrada de una transacción

```
"ins": [
  {
    "n": 98,
    "script": {
      "asm": "OP_0 304402207e3e1158831eca394e472e43e..."
    },
    "txid": "08a1266ced5ef064741bd4bc51c1202456f2250..."
  },
  ...
]
```

"txid":
"08a1266ced5ef064741bd4bc51c1202456f22509ae030231
860d6e9bef4acd5e"

Salida de una transacción

```
"outputs": [
  ...
  {
    "n": 4,
    "script": {
      "addresses": [
        "16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF"
      ],
      "asm": "OP_DUP OP_HASH160 38d769cf2899983022b..."
    },
    "value": 135296
  }
]
```

1 BTC = 100000000 sat

135296 sat = 0.00135296 BTC

Cobrando una transacción

```
"txid": "80975cddebaa93aa21a6477c0d050685d6820fa1...",
"outputs": [
  {
    "n": 4,
    "script": {
      "addresses": [
        "16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF"
      ],
      "asm": "OP_DUP OP_HASH160 38d769cf2899983022b..."
    },
    "value": 135296
  }
```

```
"txid": "a6e5da282a754881bd5abb6edf407d93c7d7ee7d1061c6...",
"ins": [
  {
    "n": 4,
    "script": {
      "asm": "3045022100915cd28e731376443c6afff1e70ca88..."
    },
    "txid": "80975cddebaa93aa21a6477c0d050685d6820fa106...",
  }
```

Cobrando una transacción

Cobrando una transacción

```
"txid": "80975cddebaa93aa21a6477c0d050685d6820fa1...",
"outputs": [
  {
    "n": 4,
    "script": {
      "addresses": [
        "16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF"
      ],
      "asm": "OP_DUP OP_HASH160 38d769cf2899983022b..."
    },
    "value": 135296
  }
```

```
"txid": "a6e5da282a754881bd5abb6edf407d93c7d7ee7d1061c6...",
"ins": [
  {
    "n": 4,
    "script": {
      "asm": "3045022100915cd28e731376443c6afff1e70ca88..."
    },
    "txid": "80975cddebaa93aa21a6477c0d050685d6820fa106...",
  }
```

Cobrando una transacción

```
"asm":
"OP_DUP OP_HASH160
38d769cf2899983022b5611ab4d35bf7907dae20
OP_EQUALVERIFY OP_CHECKSIG"
```

```
"asm":
"3045022100915cd28e731376443c6afff1e70ca88d67bc01
372aba91b3b2cb43581e5c5a5302202118f47188e96bdc82
876f3344550c452bf2c3f19f49e078c887785dbfb2f6b01
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f
3d1304f0b7163f54c"
```

Cobrando una transacción

```
"asm":
"OP_DUP OP_HASH160
38d769cf2899983022b5611ab4d35bf7907dae20
OP_EQUALVERIFY OP_CHECKSIG"
```

Cobrando una transacción

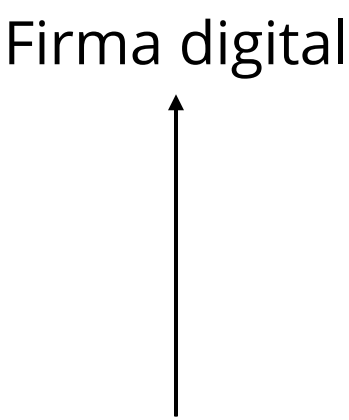
```
"asm":
"OP_DUP OP_HASH160
38d769cf2899983022b5611ab4d35bf7907dae20
OP_EQUALVERIFY OP_CHECKSIG"
```


Programa en el lenguaje Script de Bitcoin

Cobrando una transacción

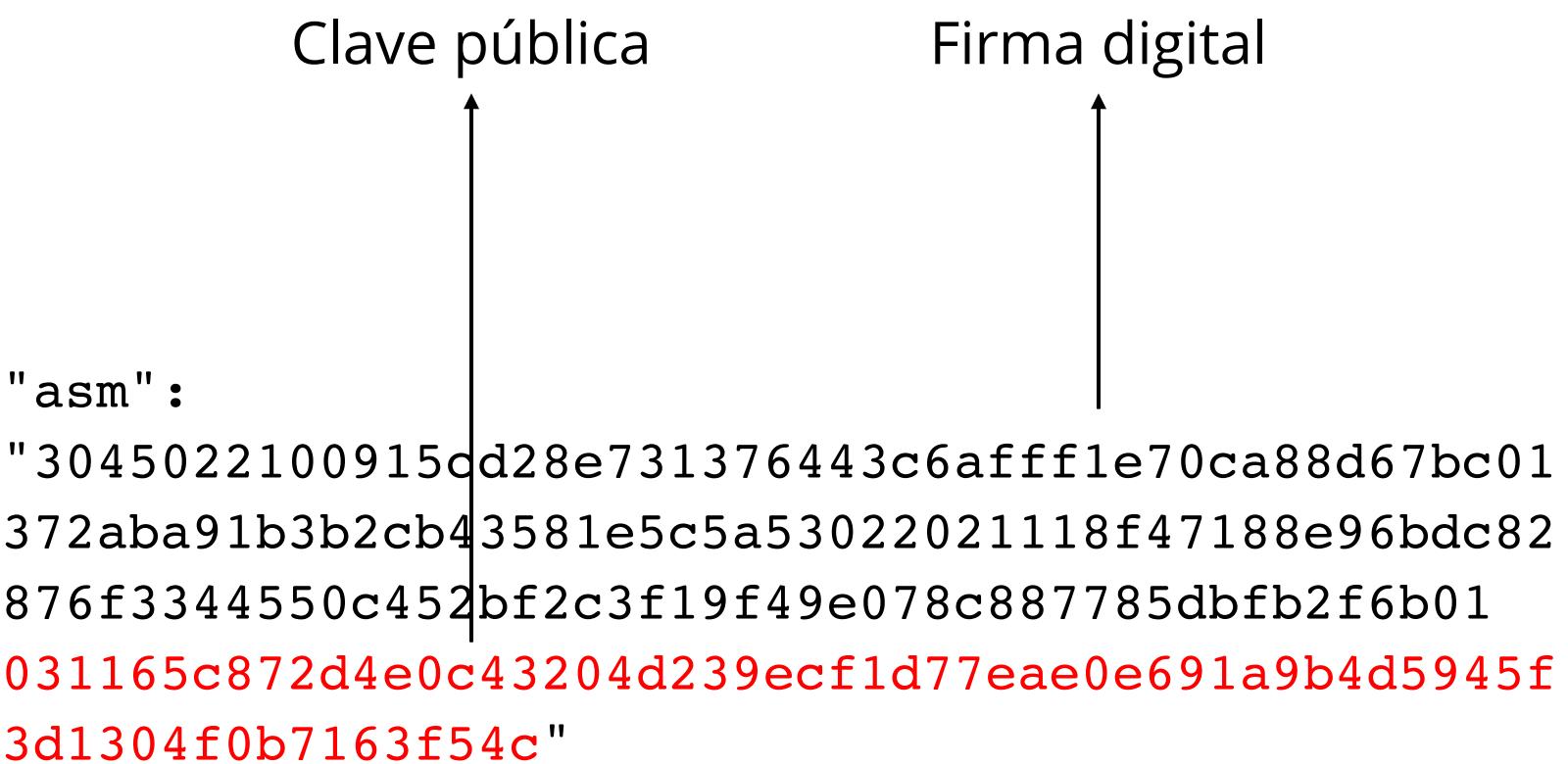

```
"asm":
"3045022100915cd28e731376443c6afff1e70ca88d67bc01
372aba91b3b2cb43581e5c5a53022021118f47188e96bdc82
876f3344550c452bf2c3f19f49e078c887785dbfb2f6b01
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f
3d1304f0b7163f54c"
```

Cobrando una transacción




```
"asm":
"3045022100915cd28e731376443c6afff1e70ca88d67bc01
372aba91b3b2cb43581e5c5a53022021118f47188e96bdc82
876f3344550c452bf2c3f19f49e078c887785dbfb2f6b01
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f
3d1304f0b7163f54c"
```

Cobrando una transacción



El lenguaje Script

```
"asm":
"OP_DUP OP_HASH160
38d769cf2899983022b5611ab4d35bf7907dae20
OP_EQUALVERIFY OP_CHECKSIG"
```

```
"asm":
"3045022100915cd28e731376443c6afff1e70ca88d67bc01
372aba91b3b2cb43581e5c5a53022021118f47188e96bdc82
876f3344550c452bf2c3f19f49e078c887785dbfb2f6b01
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f
3d1304f0b7163f54c"
```

El lenguaje Script

```
3045022100915cd28e731376443c6afff1e70ca88d67bc013
72aba91b3b2cb43581e5c5a53022021118f47188e96bdc828
76f3344550c452bf2c3f19f49e078c887785dbfb2f6b01
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f
3d1304f0b7163f54c
OP_DUP
OP_HASH160
38d769cf2899983022b5611ab4d35bf7907dae20
OP_EQUALVERIFY
OP_CHECKSIG
```

Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```

Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```

Ejecutando Script

3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG

3045022100...

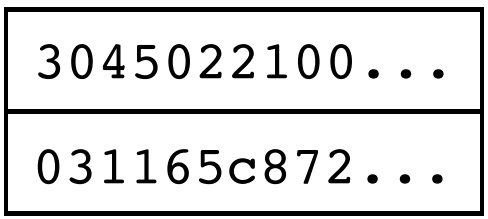
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```

```
3045022100...
```

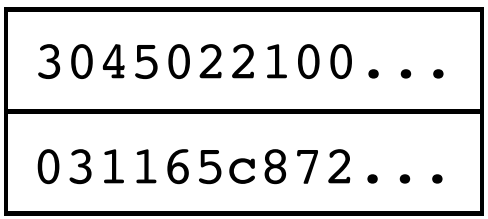
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



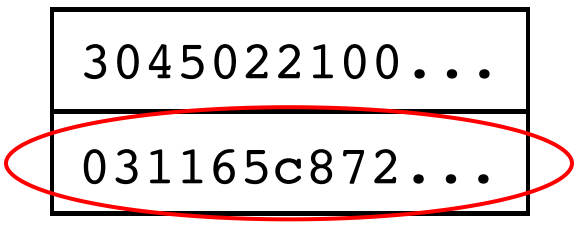
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



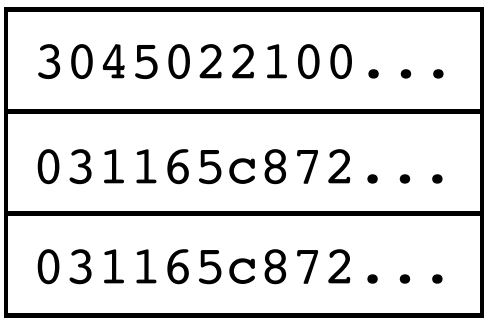
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



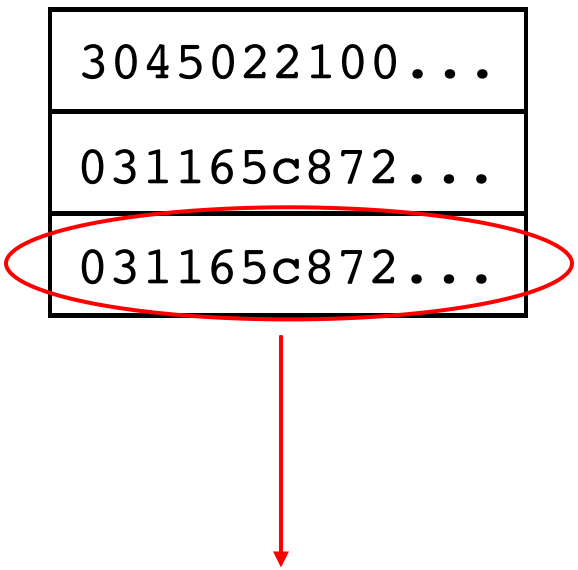
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



HASH160(x) = RIPEMD-160(SHA-256(x))

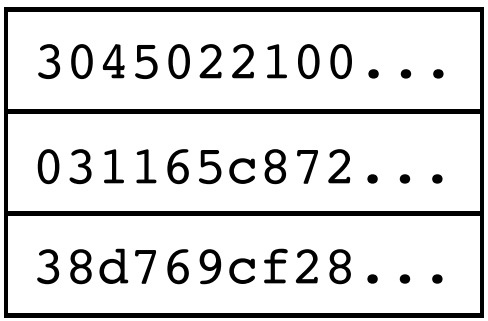
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```

3045022100...
031165c872...
38d769cf28...

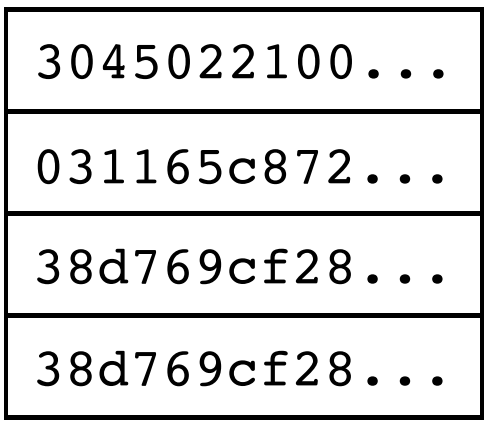
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



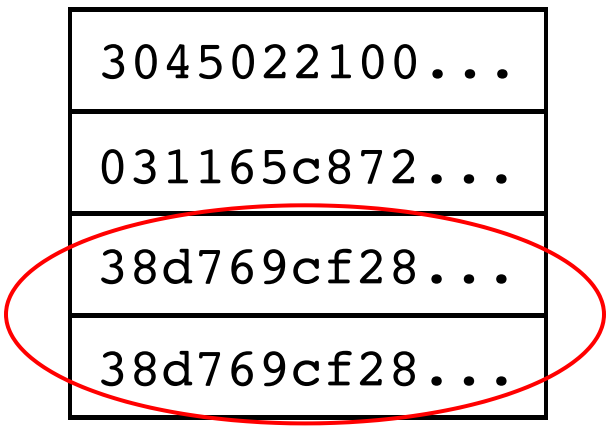
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



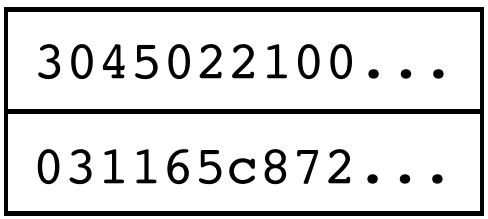
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



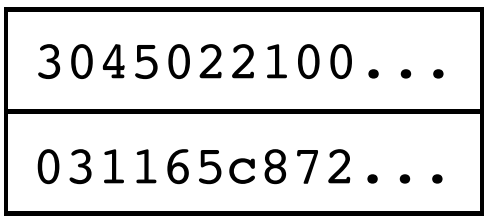
Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```

3045022100...
031165c872...

Ejecutando Script

```
3045022100...
031165c872...
OP_DUP
OP_HASH160
38d769cf28...
OP_EQUALVERIFY
OP_CHECKSIG
```



Verifica si "3045022100..." es una firma válida de la transacción anterior dada la clave pública "031165c872..."

Ejecutando Script

Verifica si "3045022100..." es una firma válida de **h( )**
dada la clave pública "031165c872..."

```
{
  "n": 4,
  "script": {
    "addresses": [
      "16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF"
    ],
    "asm": "OP_DUP OP_HASH160 38d769cf2899983022b..."
  },
  "value": 135296
}
```

Ejecutando Script

Verifica si "3045022100..." es una firma válida de **h(**  **)**
dada la clave pública "031165c872..."

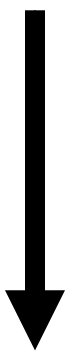
Se firma la transacción completa, lo cual incluye todas las entradas y salidas. Esto se puede lograr firmando el identificador de la transacción

¿Cómo se calcula una dirección de Bitcoin?

```
"outputs": [
  ...
  {
    "n": 4,
    "script": {
      "addresses": [
        "16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF"
      ],
      "asm": "OP_DUP OP_HASH160 38d769cf2899983022b..."
    },
    "value": 135296
  }
]
```

¿Cómo se calcula una dirección de Bitcoin?

Clave pública del usuario: (x, y)



`16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF`

Base 58

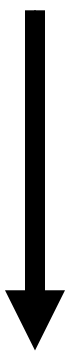
¿Cómo se calcula una dirección de Bitcoin?

```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

¿Cómo se calcula una dirección de Bitcoin?

```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

RIPEMD-160(SHA-256(...))



```
38d769cf2899983022b5611ab4d35bf7907dae20
```

¿Cómo se calcula una dirección de Bitcoin?

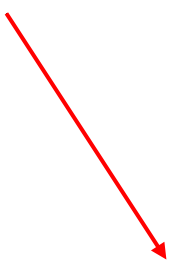
```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

```
38d769cf2899983022b5611ab4d35bf7907dae20
```

¿Cómo se calcula una dirección de Bitcoin?

```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

```
0038d769cf2899983022b5611ab4d35bf7907dae20
```



Network id

¿Cómo se calcula una dirección de Bitcoin?

```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

```
0038d769cf2899983022b5611ab4d35bf7907dae20eecbce10
```

¿Cómo se calcula una dirección de Bitcoin?

```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

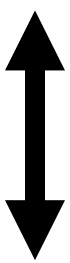
```
0038d769cf2899983022b5611ab4d35bf7907dae20eecbce10
```

Checksum: SHA-256(SHA-256(0038d769cf2899983022b5611ab4d35bf7907dae20)) = eecbce10...

¿Cómo se calcula una dirección de Bitcoin?

```
031165c872d4e0c43204d239ecf1d77eae0e691a9b4d5945f3d1304
f0b7163f54c
```

```
0038d769cf2899983022b5611ab4d35bf7907dae20eecbce10
```



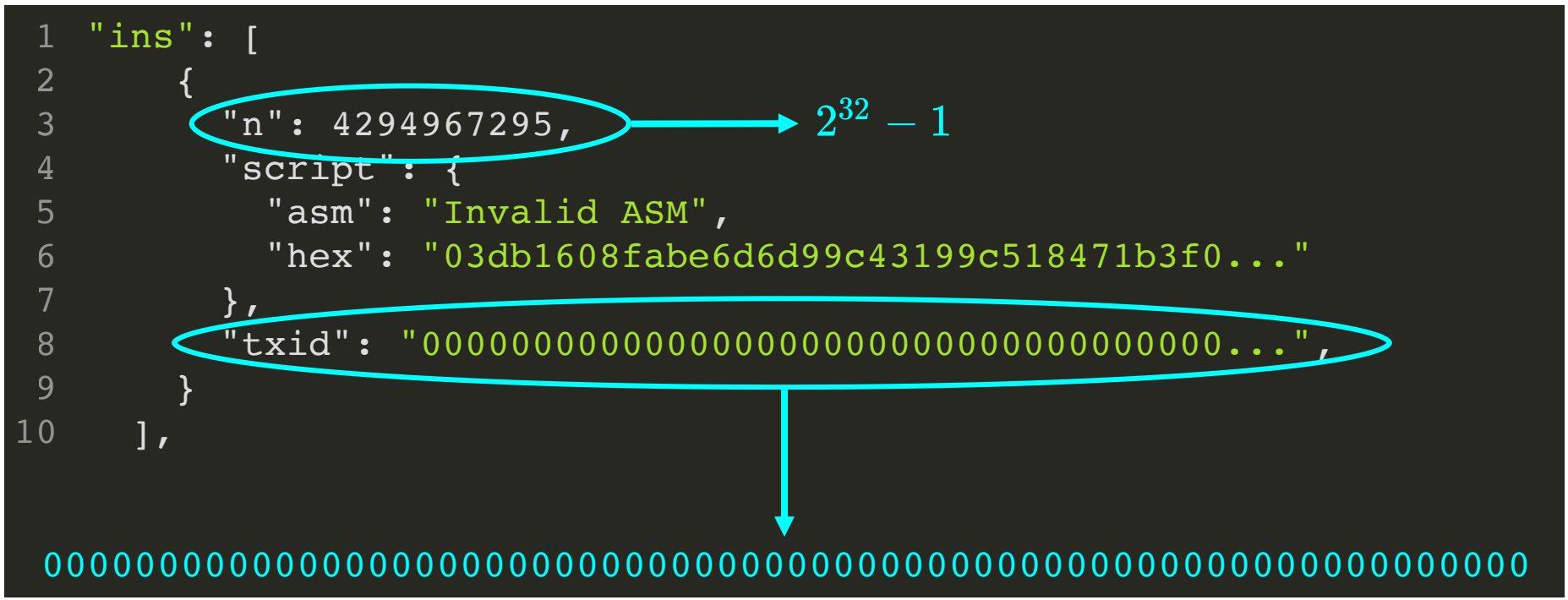
```
16BYtvVCunkZKvVyGMvD3BpRXnPUzTy4gF
```

El pago a los mineros

Aún nos falta indicar cómo se ven las transacciones donde se crean bitcoin y se paga a los mineros

Estas son llamadas **coinbase transactions**

Coinbase transaction



Coinbase transaction

```
"outs": [
  {
    "n": 0,
    "script": {
      "addresses": [
        "1CK6KHY6MHgYvmRQ4PAafKYDrg1ejbH1cE"
      ],
      "asm": "OP_DUP OP_HASH160 7c154ed1dc59609e3d2...",
    },
    "value": 1264124389
  }
]
```

12.5 BTC + pago por transacciones

La diferencia entre las entradas y las salidas de una transacción puede ser mayor que 0. Esta diferencia es considerada como pago para el minero

Minería

Los ingredientes fundamentales

bits	dificultad asociada a generar un bloque
nonce	número de 32 bits

¿Cómo se representa la dificultad?

Bloque	Dificultad
530139	507749903487 9.02
700000	18415156832118.24

$$\text{dificultad} = \frac{\text{valor objetivo máximo}}{\text{valor objetivo actual}}$$

¿Cómo se representa la dificultad?

Bloque	Dificultad
530139	507749903487 9.02
700000	18415156832118.24

$$\text{valor objetivo actual} = \frac{\text{valor objetivo máximo}}{\text{dificultad}}$$

¿Cómo se representa la dificultad?

Bloque	Dificultad
530139	5077499034879.02
700000	18415156832118.24

$$\text{valor objetivo actual} = \frac{\texttt{ffff}0000000000000000000000000000000000000000000000000000}{\text{dificultad}}$$

Bloque 530139

$$\text{valor objetivo actual} = \frac{\texttt{ffff0000000000000000000000000000000000000000000000000000}}{5077499034879.02}$$

$$= \texttt{376f55ffffffff6cc7dd90b5e2b9d74ed71b37ec4bcab13}$$

✅

$$\text{hash del bloque} = \texttt{1e6db880e65dd2582d42040d7d28d8b7b9dc30da42134a}$$

La dificultad se actualiza cada 2016 bloques

Se espera un bloque sea generado cada 10 minutos

- En 2 semanas se deberían generar 2016 bloques

Si en el bloque t se produjo un cambio de dificultad:

$$\text{dificultad}_{t+2016} = \text{dificultad}_{t+2015} \cdot \frac{1209600}{\text{time}_{t+2015} - \text{time}_t}$$

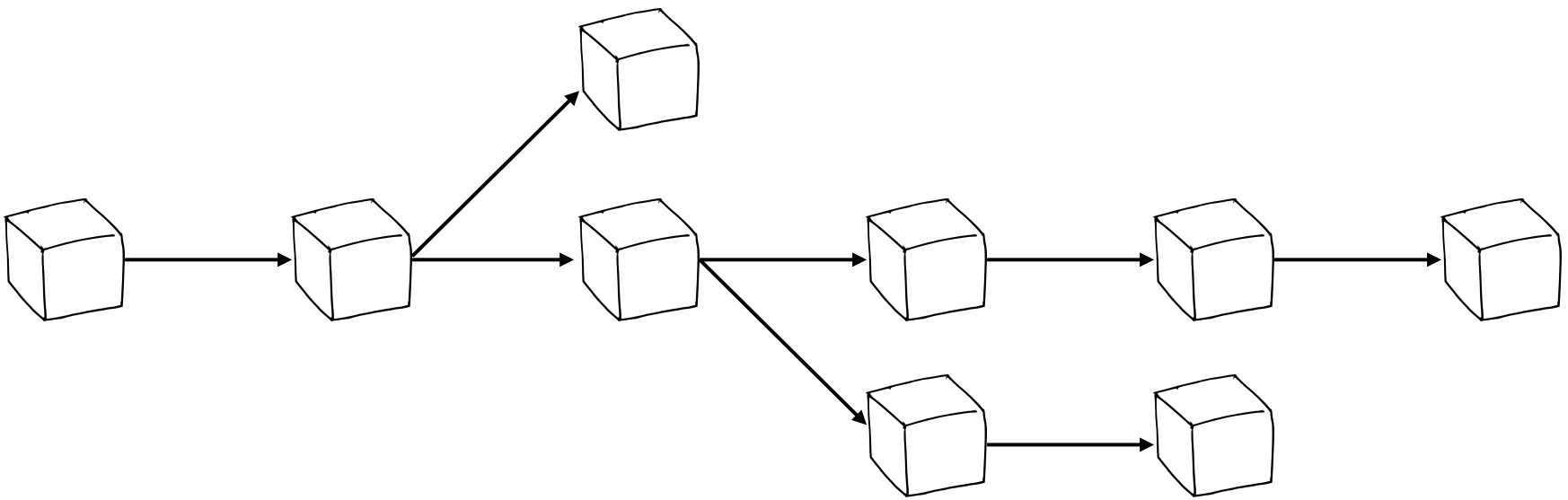
El protocolo

Vimos las reglas fundamentales que definen el protocolo de Bitcoin

- Hay muchos sitios donde puede obtener más información sobre este protocolo, por ejemplo aquí
- El código de Bitcoin es abierto y puede ser encontrado en este repositorio

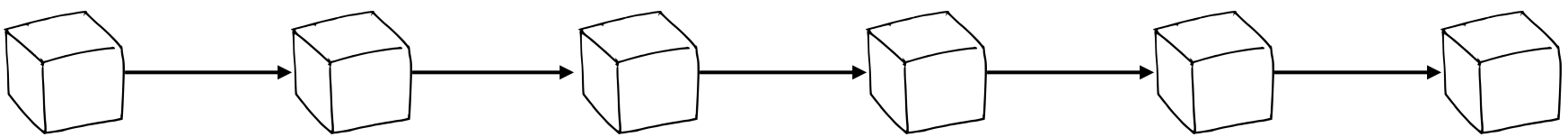
Tenemos que responder una última pregunta: ¿cómo se define el blockchain de Bitcoin?

El blockchain de Bitcoin



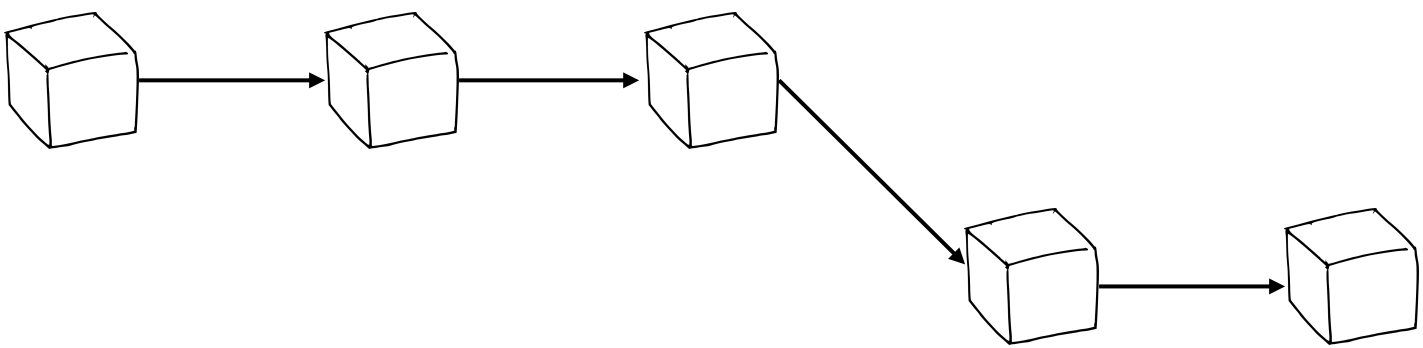
El blockchain es el **camino con el mayor trabajo acumulado**, lo cual es definido por la suma de las dificultades de los bloques del camino

El blockchain de Bitcoin



El blockchain es el **camino con el mayor trabajo acumulado**, lo cual es definido por la suma de las dificultades de los bloques del camino

El blockchain de Bitcoin



El blockchain es el **camino con el mayor trabajo acumulado**, lo cual es definido por la suma de las dificultades de los bloques del camino