CryptoCurrency and Blockchain (2)

金融科技導論

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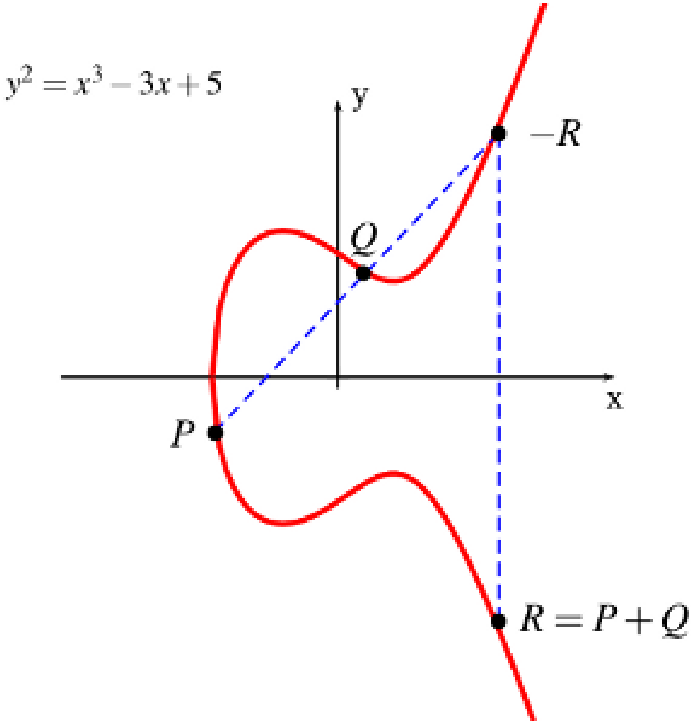
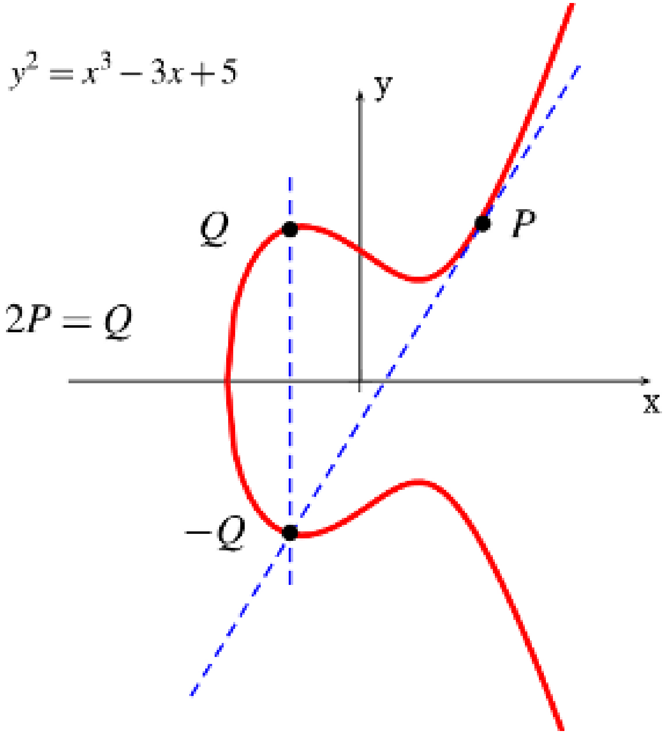
Elliptic Curves

Elliptic Curve 橢圓曲線

- The rich and deep theory of Elliptic Curves has been studied by mathematicians over 150 years
- Elliptic Curve over ***R*** : $y^2 = x^3 + ax + b$



Point Addition



Point Doubling

Image Courtesy: http://www.embedded.com/design/safety-and-security/4396040/An-Introduction-to-Elliptic-Curve-Cryptography

質數體 (Prime Field) 上的曲線

Addition:

$(x_3, y_3) = (x_1, y_1) + (x_2, y_2)$

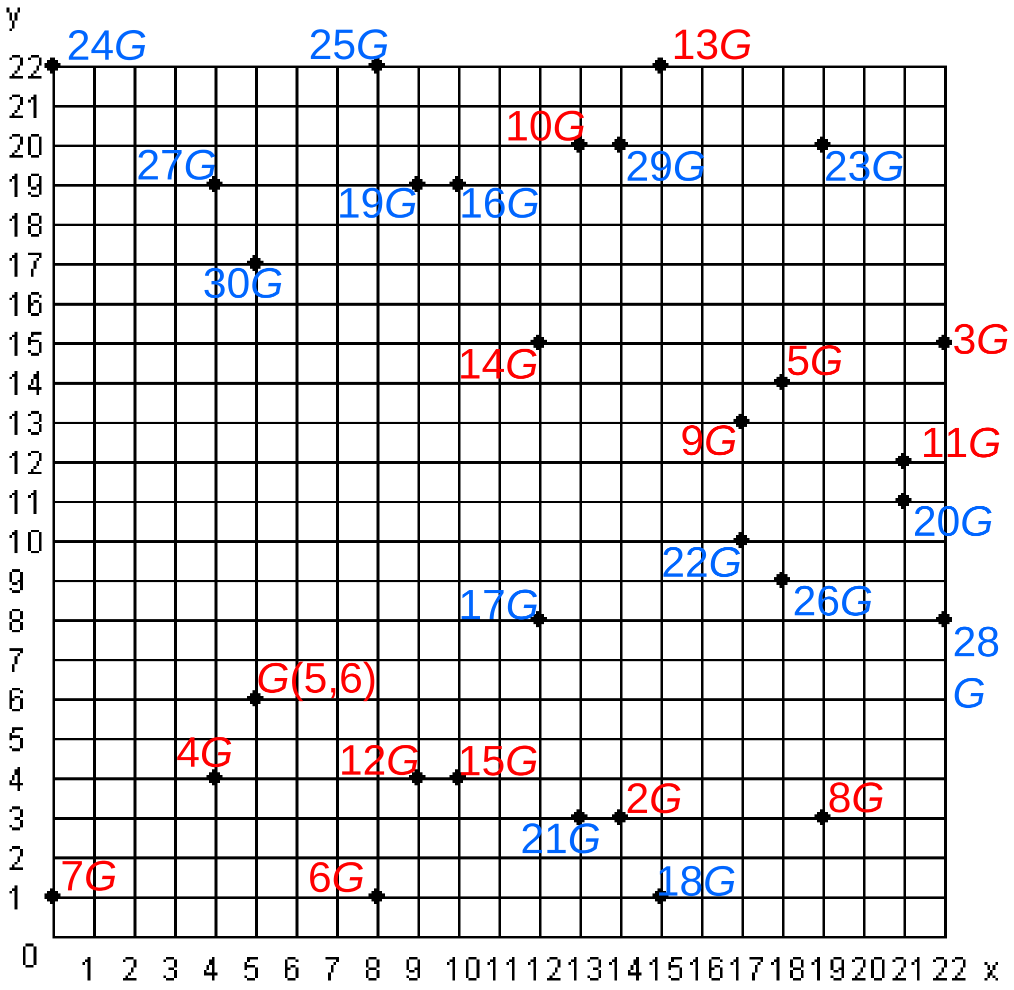
Doubling:

$(x_3, y_3) = [2]\,(x_1, y_1)$

$$s = \begin{cases} \dfrac{y_2 - y_1}{x_2 - x_1} \bmod p & \text{(addition)} \\[2ex] \dfrac{3x_1^2 + a}{2y_1} \bmod p & \text{(doubling)} \end{cases}$$

$$x_3 = s^2 - x_1 - x_2 \mod p$$

$$y_3 = s(x_1 - x_3) - y_1 \mod p$$



$y^2 = x^3 + 5x + 1$ over F_{23}

30 solutions

Example

- Given $E: y^2 = x^3 + 2x + 2 \mod 17$ and point $P = (5, 1)$

Goal: Compute $2P = P + P = (5, 1) + (5, 1) = (x_3, y_3)$

$$s = \frac{3x_1^2 + a}{2y_1} = (2 \cdot 1)^{-1}(3 \cdot 5^2 + 2) = 2^{-1} \cdot 9 \equiv 9 \cdot 9 \equiv 13 \mod 17$$

$$x_3 = s^2 - x_1 - x_2 = 13^2 - 5 - 5 = 159 \equiv 6 \mod 17$$

$$y_3 = s(x_1 - x_3) - y_1 = 13(5 - 6) - 1 = -14 \equiv 3 \mod 17$$

Finally $2P = (5, 1) + (5, 1) = (6, 3)$

Example

- The points on an elliptic curve and the point at infinity $\mathcal{O}$ form cyclic subgroups

$2P = (5, 1) + (5, 1) = (6, 3)$

$3P = 2P + P = (10, 6)$

$4P = (3, 1)$

$5P = (9, 16)$

$6P = (16, 13)$

$7P = (0, 6)$

$8P = (13, 7)$

$9P = (7, 6)$

$10P = (7, 11)$

$11P = (13, 10)$

$12P = (0, 11)$

$13P = (16, 4)$

$14P = (9, 1)$

$15P = (3, 16)$

$16P = (10, 11)$

$17P = (6, 14)$

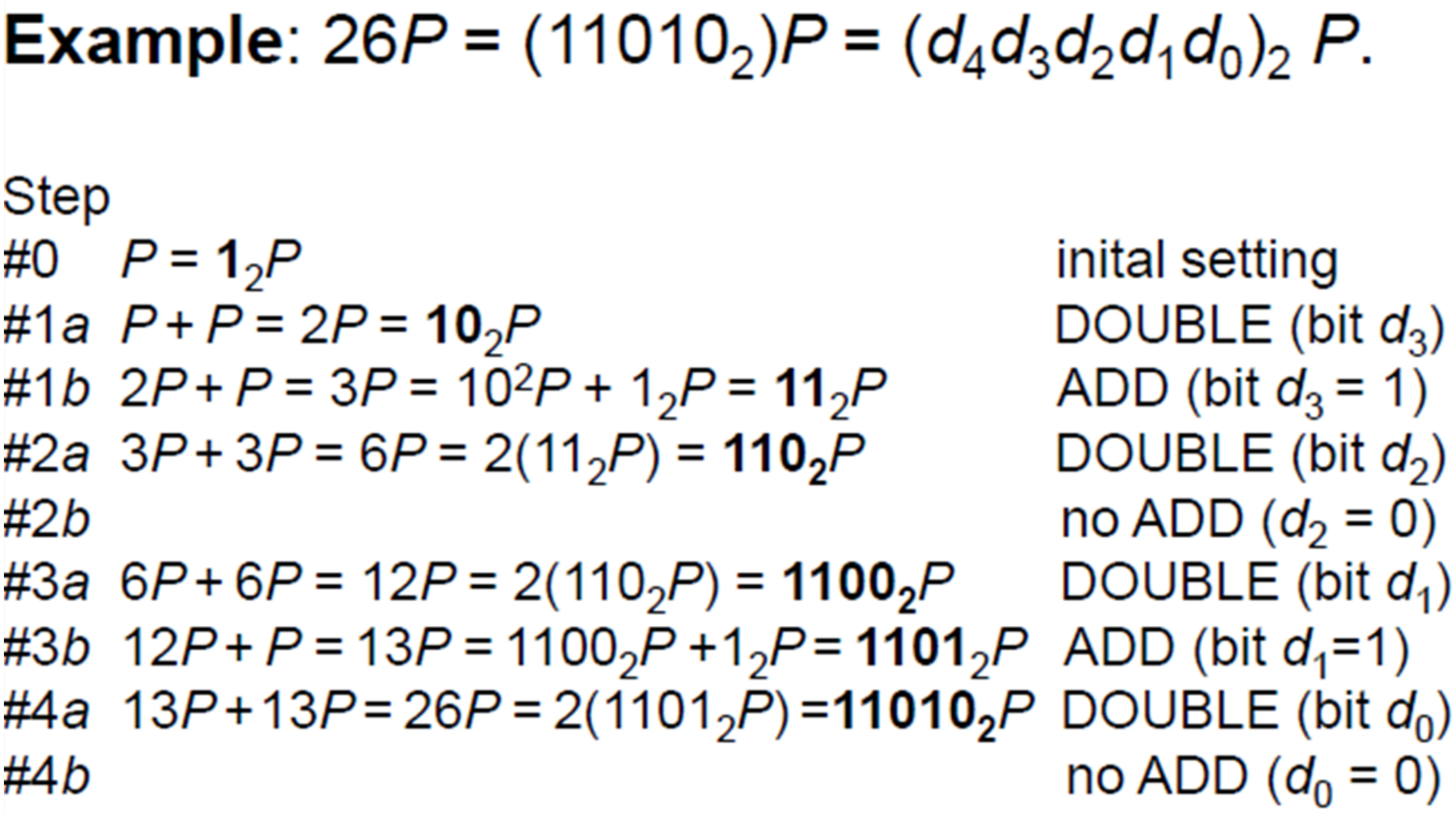
$18P = (5, 16)$

$19P = \mathcal{O}$

This elliptic curve has order $\#E = |E| = 19$

since it contains 19 points in its cyclic group.

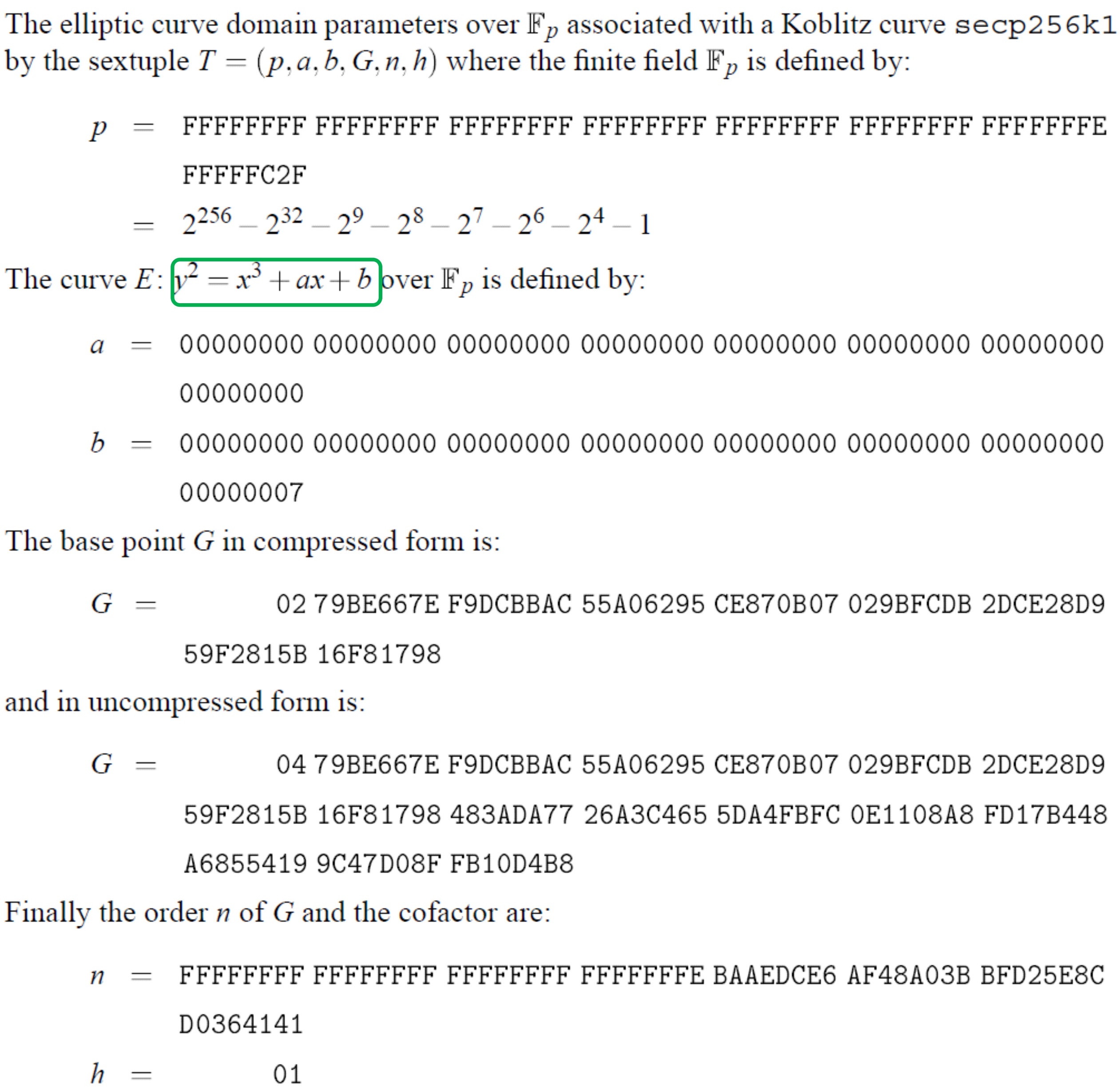
Double and Add



Example: $26P = (11010_2)P = (d_4d_3d_2d_1d_0)_2\ P$.

Step		
#0	$P = \mathbf{1}_2P$	inital setting
#1a	$P + P = 2P = \mathbf{10}_2P$	DOUBLE (bit d_3)
#1b	$2P + P = 3P = 10^2P + 1_2P = \mathbf{11}_2P$	ADD (bit $d_3 = 1$)
#2a	$3P + 3P = 6P = 2(11_2P) = \mathbf{110_2}P$	DOUBLE (bit d_2)
#2b		no ADD ($d_2 = 0$)
#3a	$6P + 6P = 12P = 2(110_2P) = \mathbf{1100_2}P$	DOUBLE (bit d_1)
#3b	$12P + P = 13P = 1100_2P + 1_2P = \mathbf{1101}_2P$	ADD (bit d_1=1)
#4a	$13P + 13P = 26P = 2(1101_2P) = \mathbf{11010_2}P$	DOUBLE (bit d_0)
#4b		no ADD ($d_0 = 0$)

Bitcoin 和 Ethereum 使用的曲線



The elliptic curve domain parameters over $\mathbb{F}_p$ associated with a Koblitz curve `secp256k1` are specified by the sextuple $T = (p, a, b, G, n, h)$ where the finite field $\mathbb{F}_p$ is defined by:

p = FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFE FFFFFC2F

$$= 2^{256} - 2^{32} - 2^9 - 2^8 - 2^7 - 2^6 - 2^4 - 1$$

256-bit prime

The curve E: $\boxed{y^2 = x^3 + ax + b}$ over $\mathbb{F}_p$ is defined by:

a = 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

b = 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000007

The base point G in compressed form is:

G = 02 79BE667E F9DCBBAC 55A06295 CE870B07 029BFCDB 2DCE28D9 59F2815B 16F81798

and in uncompressed form is:

G = 04 79BE667E F9DCBBAC 55A06295 CE870B07 029BFCDB 2DCE28D9 59F2815B 16F81798 483ADA77 26A3C465 5DA4FBFC 0E1108A8 FD17B448 A6855419 9C47D08F FB10D4B8

Finally the order n of G and the cofactor are:

n = FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFE BAAEDCE6 AF48A03B BFD25E8C D0364141

h = 01

256-bit prime

橢圓曲線 secp256k1

https://en.bitcoin.it/wiki/Secp256k1

Key Pairs 金鑰對

- The base point *G* is fixed on the given Elliptic Curve
- $P = [m]\,G$
  - Given *m*, it is **easy and fast** to find the point *P*
    - Using “double and add” for scalar multiplication
  - Given *P*, it is **extremely hard** to find the integer *m*
    - Elliptic Curve Discrete Logarithm Problem (橢圓曲線離散對數問題)
  - A randomly generated integer *m* is a **private key**
    - A private key is used to sign Bitcoin transactions with ECDSA
  - The point *P* is the **public key** corresponding to *m*
    - A public key is used by other nodes to verify Bitcoin transactions
    - **A Bitcoin address is the hash value of a public key *P***

NIST Curve Standards in FIPS 186

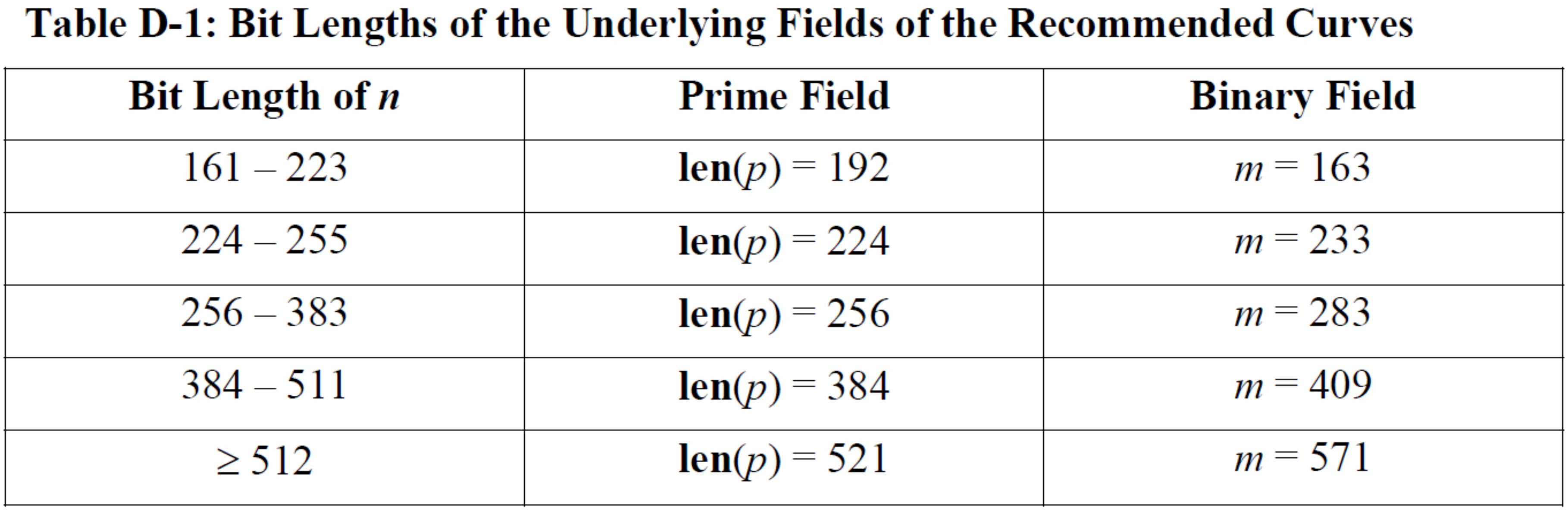
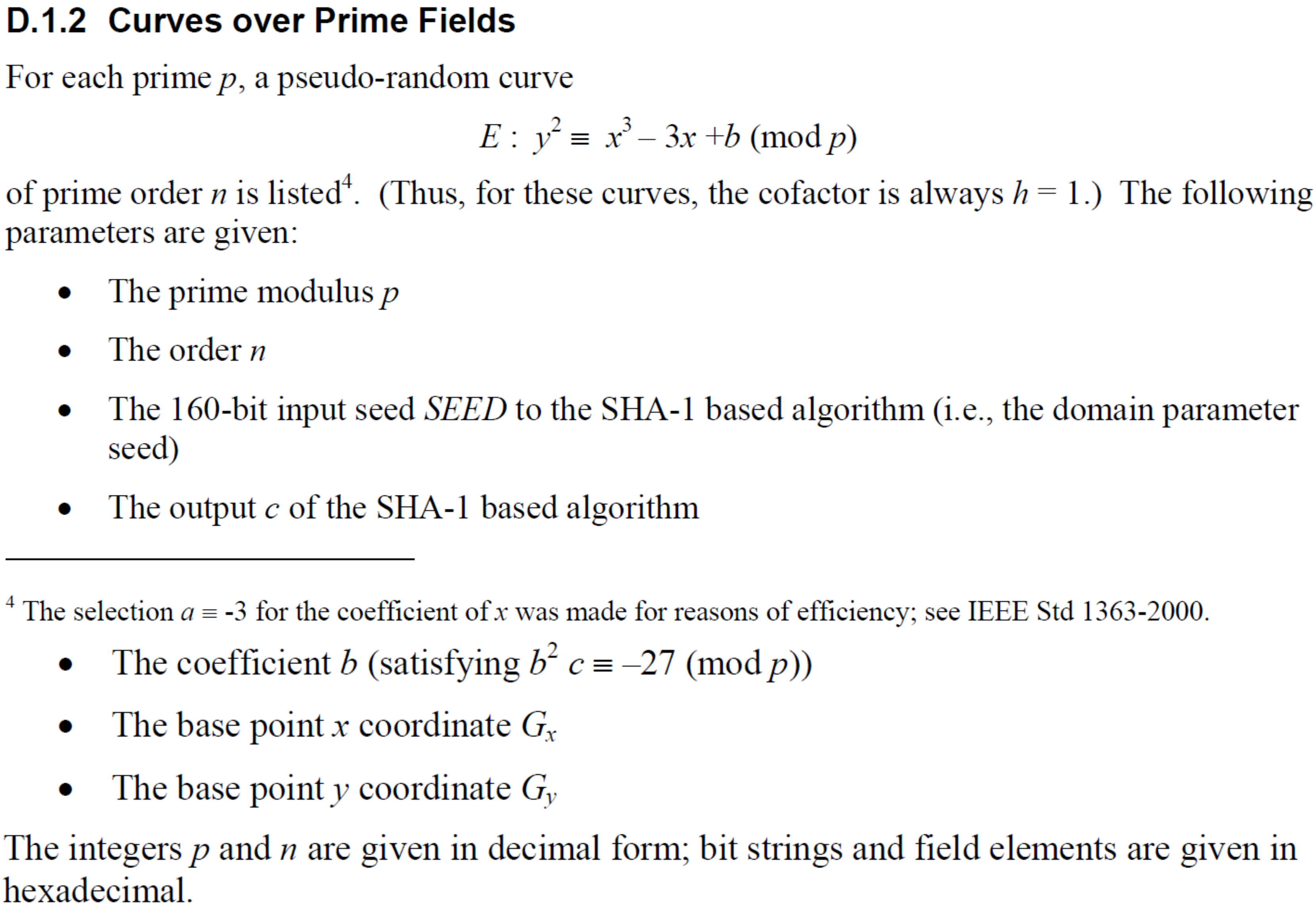


Table D-1: Bit Lengths of the Underlying Fields of the Recommended Curves

Bit Length of *n*	**Prime Field**	**Binary Field**
161 – 223	**len**(p) = 192	m = 163
224 – 255	**len**(p) = 224	m = 233
256 – 383	**len**(p) = 256	m = 283
384 – 511	**len**(p) = 384	m = 409
≥ 512	**len**(p) = 521	m = 571

NIST Curves over Prime Fields



D.1.2 Curves over Prime Fields

For each prime p, a pseudo-random curve

$$E: \; y^2 \equiv x^3 - 3x + b \pmod{p}$$

of prime order n is listed[4]. (Thus, for these curves, the cofactor is always $h = 1$.) The following parameters are given:

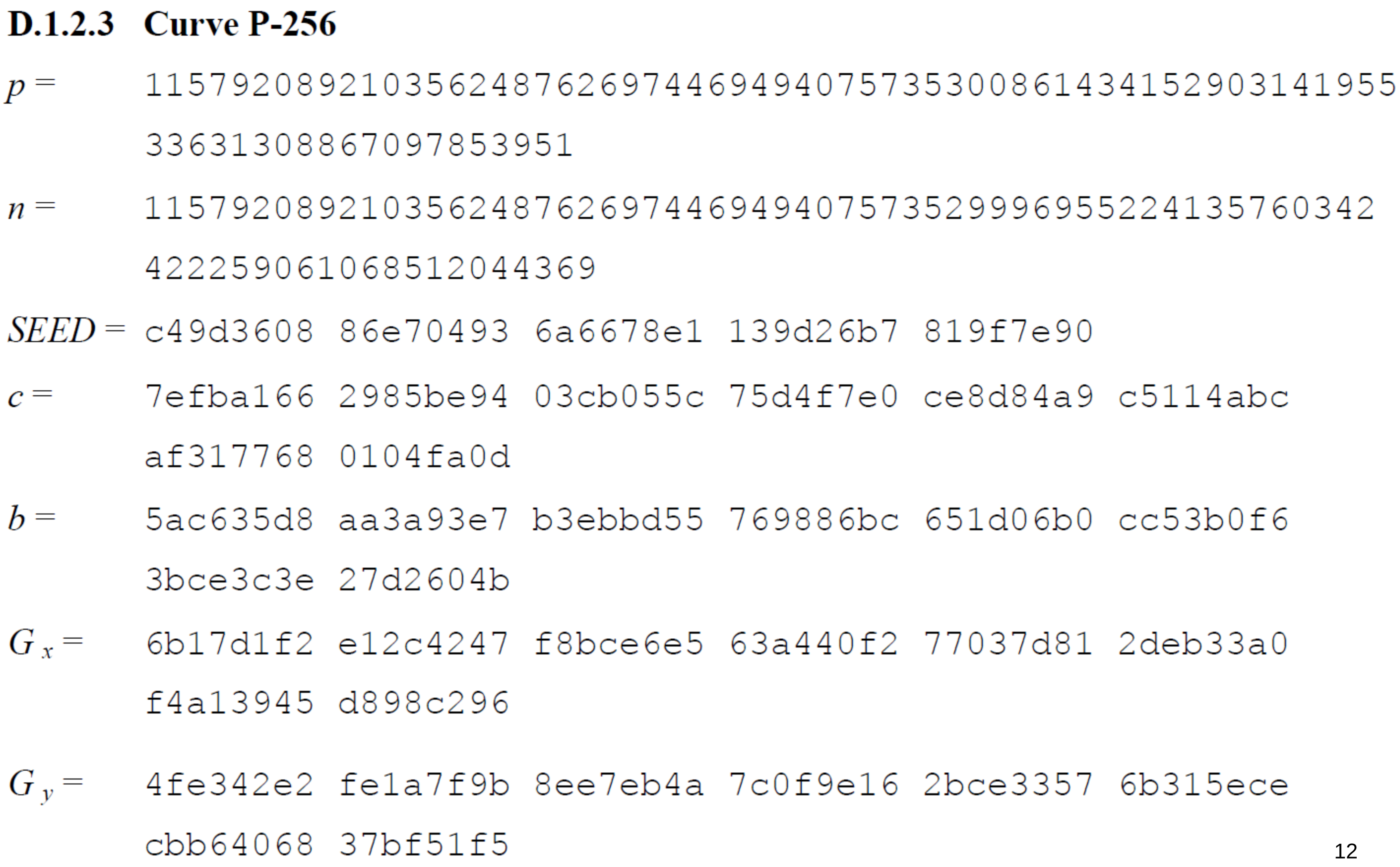
- The prime modulus p
- The order n
- The 160-bit input seed *SEED* to the SHA-1 based algorithm (i.e., the domain parameter seed)
- The output c of the SHA-1 based algorithm

[4] The selection $a \equiv$ -3 for the coefficient of x was made for reasons of efficiency; see IEEE Std 1363-2000.

- The coefficient b (satisfying $b^2\, c \equiv -27 \pmod{p}$)
- The base point x coordinate G_x
- The base point y coordinate G_y

The integers p and n are given in decimal form; bit strings and field elements are given in hexadecimal.

Curve P-256



D.1.2.3 Curve P-256

$p =$ 115792089210356248762697446949407573530086143415290314195533631308867097853951

$n =$ 115792089210356248762697446949407573529996955224135760342422259061068512044369

$SEED =$ c49d3608 86e70493 6a6678e1 139d26b7 819f7e90

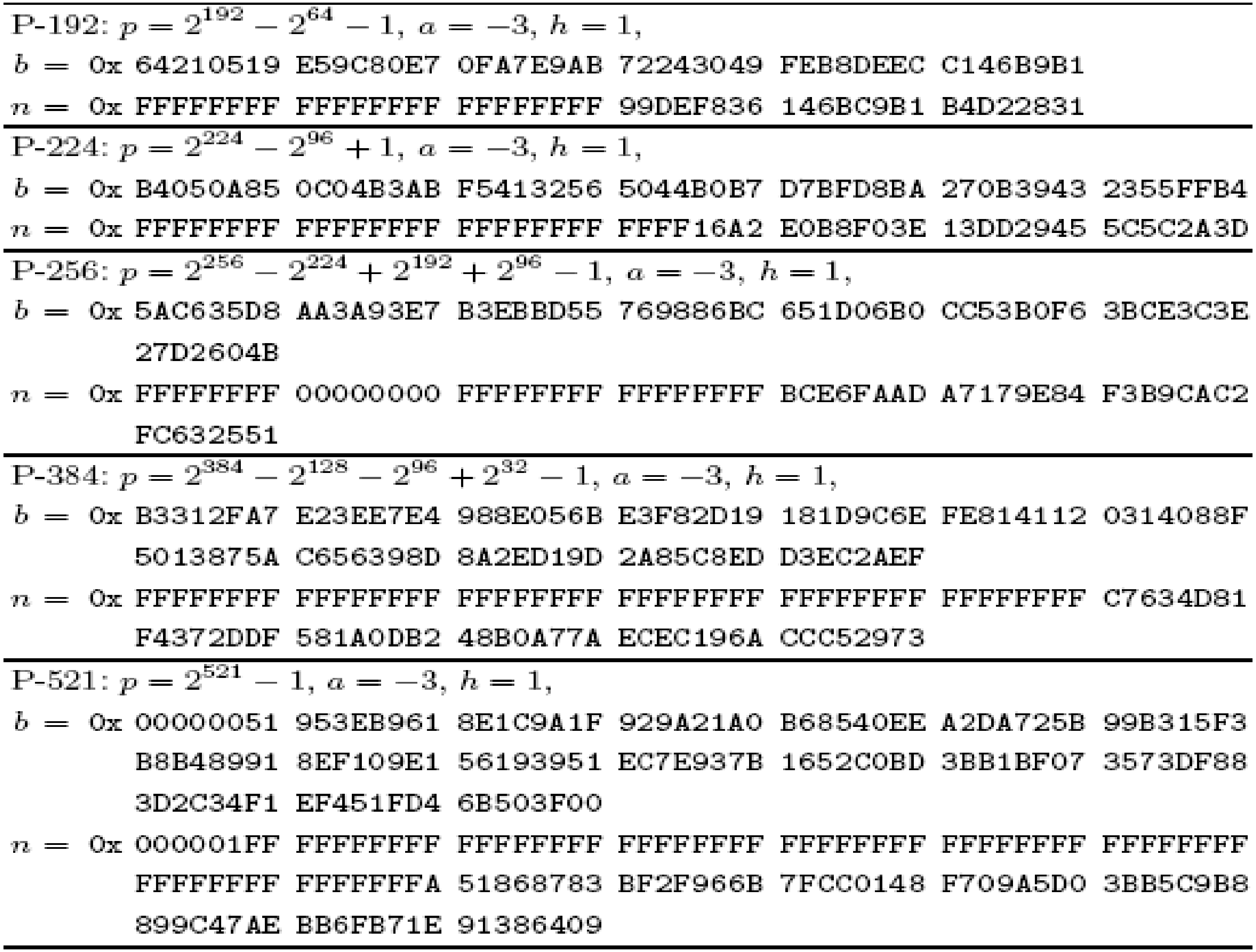
$c =$ 7efba166 2985be94 03cb055c 75d4f7e0 ce8d84a9 c5114abc af317768 0104fa0d

$b =$ 5ac635d8 aa3a93e7 b3ebbd55 769886bc 651d06b0 cc53b0f6 3bce3c3e 27d2604b

$G_x =$ 6b17d1f2 e12c4247 f8bce6e5 63a440f2 77037d81 2deb33a0 f4a13945 d898c296

$G_y =$ 4fe342e2 fe1a7f9b 8ee7eb4a 7c0f9e16 2bce3357 6b315ece cbb64068 37bf51f5

NIST Curves over Prime Fields



P-192: $p = 2^{192} - 2^{64} - 1,\ a = -3,\ h = 1,$

$b =$ 0x 64210519 E59C80E7 0FA7E9AB 72243049 FEB8DEEC C146B9B1

$n =$ 0x FFFFFFFF FFFFFFFF FFFFFFFF 99DEF836 146BC9B1 B4D22831

P-224: $p = 2^{224} - 2^{96} + 1,\ a = -3,\ h = 1,$

$b =$ 0x B4050A85 0C04B3AB F5413256 5044B0B7 D7BFD8BA 270B3943 2355FFB4

$n =$ 0x FFFFFFFF FFFFFFFF FFFFFFFF FFFF16A2 E0B8F03E 13DD2945 5C5C2A3D

P-256: $p = 2^{256} - 2^{224} + 2^{192} + 2^{96} - 1,\ a = -3,\ h = 1,$

$b =$ 0x 5AC635D8 AA3A93E7 B3EBBD55 769886BC 651D06B0 CC53B0F6 3BCE3C3E
27D2604B

$n =$ 0x FFFFFFFF 00000000 FFFFFFFF FFFFFFFF BCE6FAAD A7179E84 F3B9CAC2
FC632551

P-384: $p = 2^{384} - 2^{128} - 2^{96} + 2^{32} - 1,\ a = -3,\ h = 1,$

$b =$ 0x B3312FA7 E23EE7E4 988E056B E3F82D19 181D9C6E FE814112 0314088F
5013875A C656398D 8A2ED19D 2A85C8ED D3EC2AEF

$n =$ 0x FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF C7634D81
F4372DDF 581A0DB2 48B0A77A ECEC196A CCC52973

P-521: $p = 2^{521} - 1,\ a = -3,\ h = 1,$

$b =$ 0x 00000051 953EB961 8E1C9A1F 929A21A0 B68540EE A2DA725B 99B315F3
B8B48991 8EF109E1 56193951 EC7E937B 1652C0BD 3BB1BF07 3573DF88
3D2C34F1 EF451FD4 6B503F00

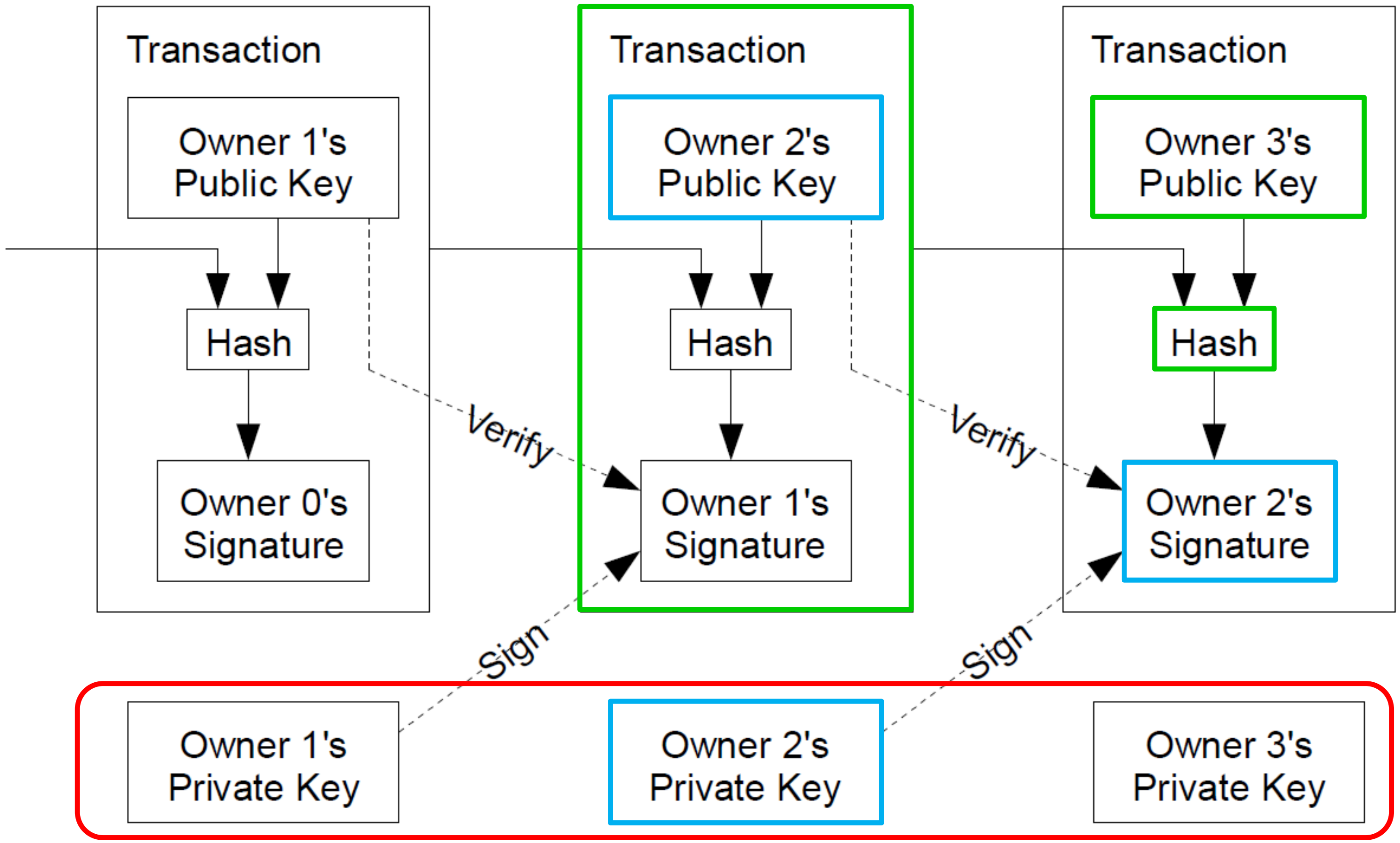
$n =$ 0x 000001FF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
FFFFFFFF FFFFFFFA 51868783 BF2F966B 7FCC0148 F709A5D0 3BB5C9B8
899C47AE BB6FB71E 91386409

Security Level

Bits of security	Symmetric key algorithms	RSA	Elliptic Curve Cryptography (ECC, e.g., ECDSA)	Secure Hash Algorithms (SHA)
112	3-DES	2048	224	224
128	AES-128	3072	256	256
192	AES-192	7680	384	384
256	AES-256	15360	512	512

Transactions

Bitcoin Transactions 交易

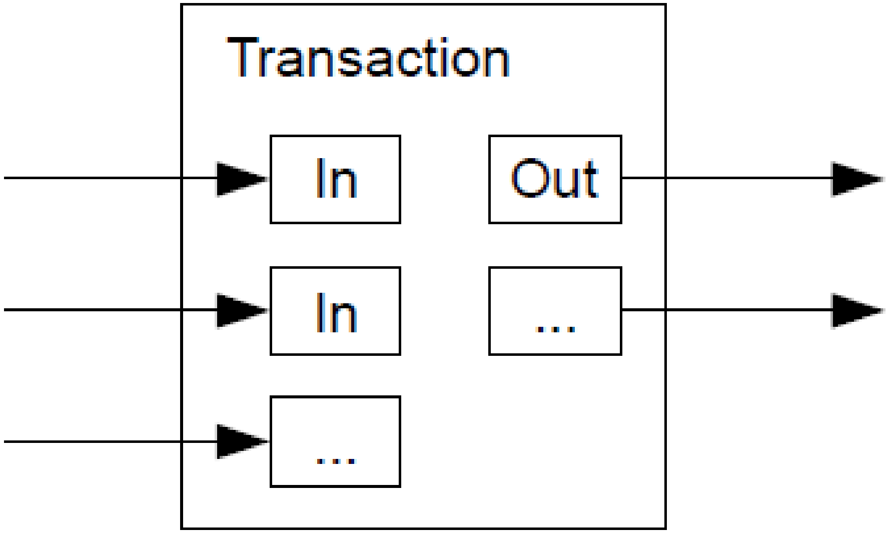


Must be protected very well!!!

http://bitcoin.org/bitcoin.pdf 中本聰

Combining & Splitting Value

- “To allow value to be split and combined, transactions contain multiple inputs and outputs.”

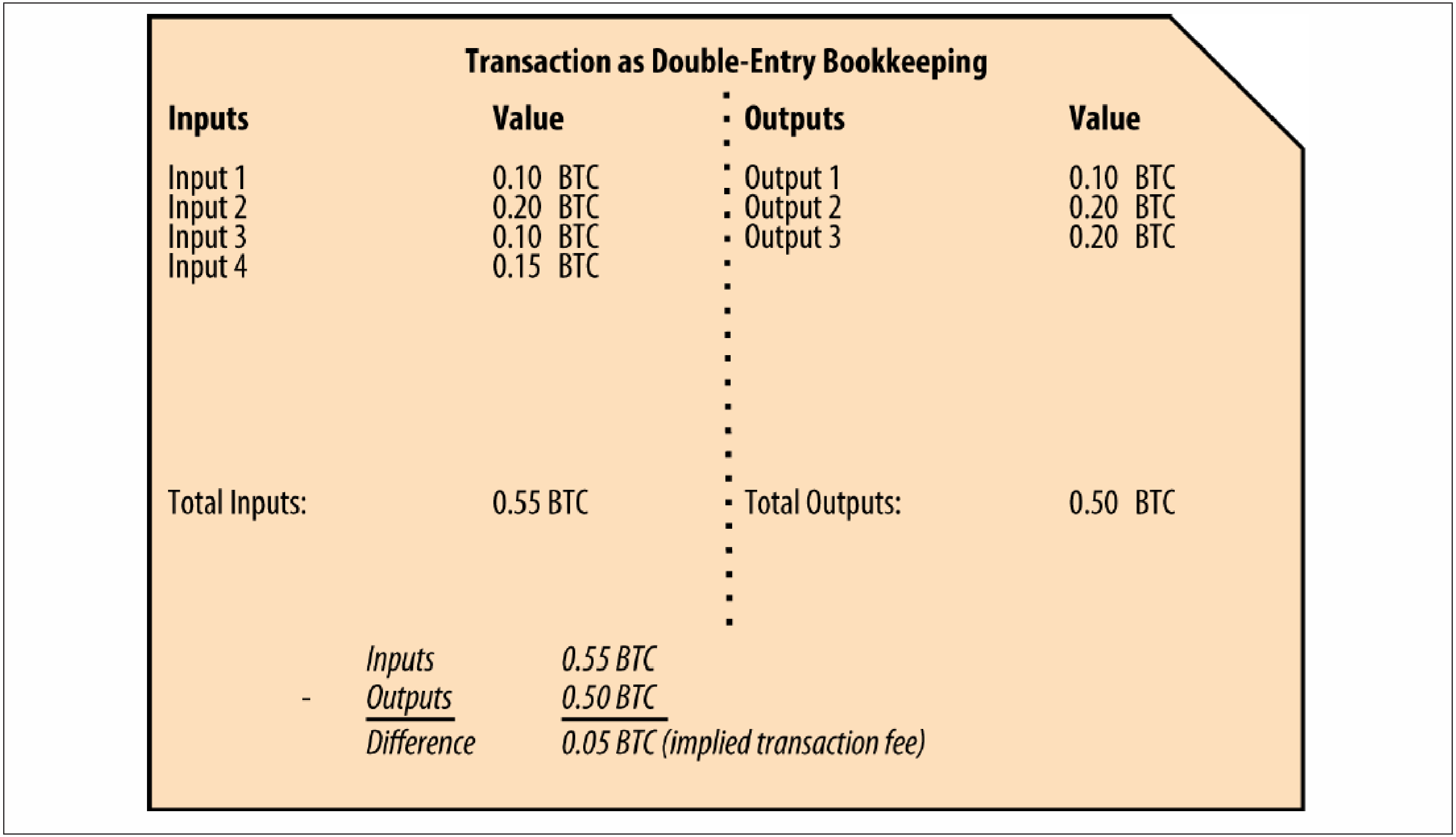


http://bitcoin.org/bitcoin.pdf 中本聰

Transaction Fee

- “If the output value of a transaction is less than its input value, the difference is a transaction fee that is added to the incentive value of the block containing the transaction.”

http://bitcoin.org/bitcoin.pdf 中本聰



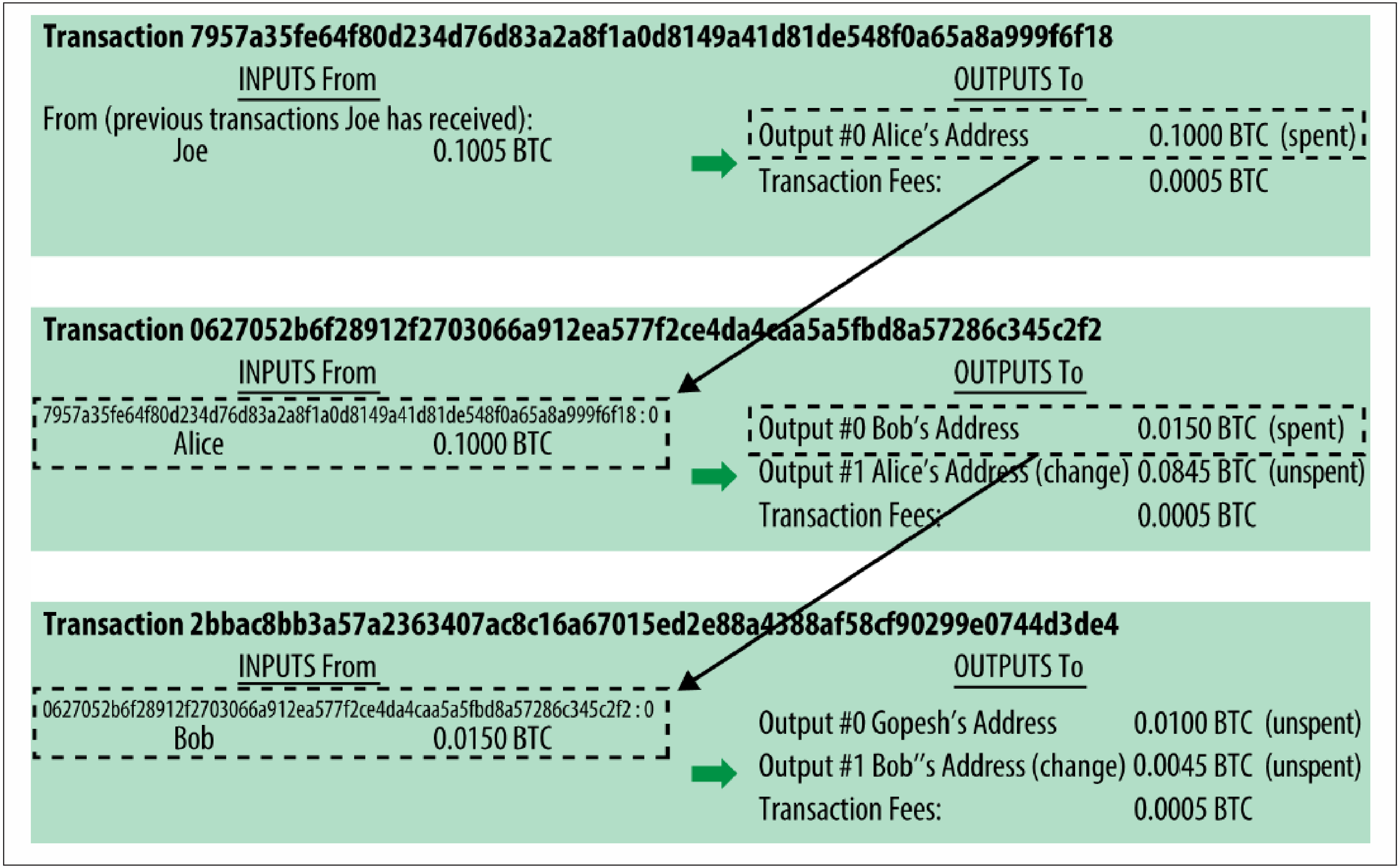
Transaction as Double-Entry Bookkeeping

Inputs	Value	Outputs	Value
Input 1	0.10 BTC	Output 1	0.10 BTC
Input 2	0.20 BTC	Output 2	0.20 BTC
Input 3	0.10 BTC	Output 3	0.20 BTC
Input 4	0.15 BTC		
Total Inputs:	0.55 BTC	Total Outputs:	0.50 BTC

	Inputs	*0.55 BTC*
-	*Outputs*	*0.50 BTC*
	Difference	*0.05 BTC (implied transaction fee)*

Figure 2-3. Transaction as double-entry bookkeeping

“Mastering Bitcoin” by Andreas M. Antonopoulos



Transaction 7957a35fe64f80d234d76d83a2a8f1a0d8149a41d81de548f0a65a8a999f6f18

INPUTS From

From (previous transactions Joe has received):
Joe 0.1005 BTC

OUTPUTS To

Output #0 Alice’s Address 0.1000 BTC (spent)
Transaction Fees: 0.0005 BTC

Transaction 0627052b6f28912f2703066a912ea577f2ce4da4caa5a5fbd8a57286c345c2f2

INPUTS From

7957a35fe64f80d234d76d83a2a8f1a0d8149a41d81de548f0a65a8a999f6f18 : 0
Alice 0.1000 BTC

OUTPUTS To

Output #0 Bob’s Address 0.0150 BTC (spent)
Output #1 Alice’s Address (change) 0.0845 BTC (unspent)
Transaction Fees: 0.0005 BTC

Transaction 2bbac8bb3a57a2363407ac8c16a67015ed2e88a4388af58cf90299e0744d3de4

INPUTS From

0627052b6f28912f2703066a912ea577f2ce4da4caa5a5fbd8a57286c345c2f2 : 0
Bob 0.0150 BTC

OUTPUTS To

Output #0 Gopesh’s Address 0.0100 BTC (unspent)
Output #1 Bob’’s Address (change) 0.0045 BTC (unspent)
Transaction Fees: 0.0005 BTC

Figure 2-4. A chain of transactions, where the output of one transaction is the input of the next transaction

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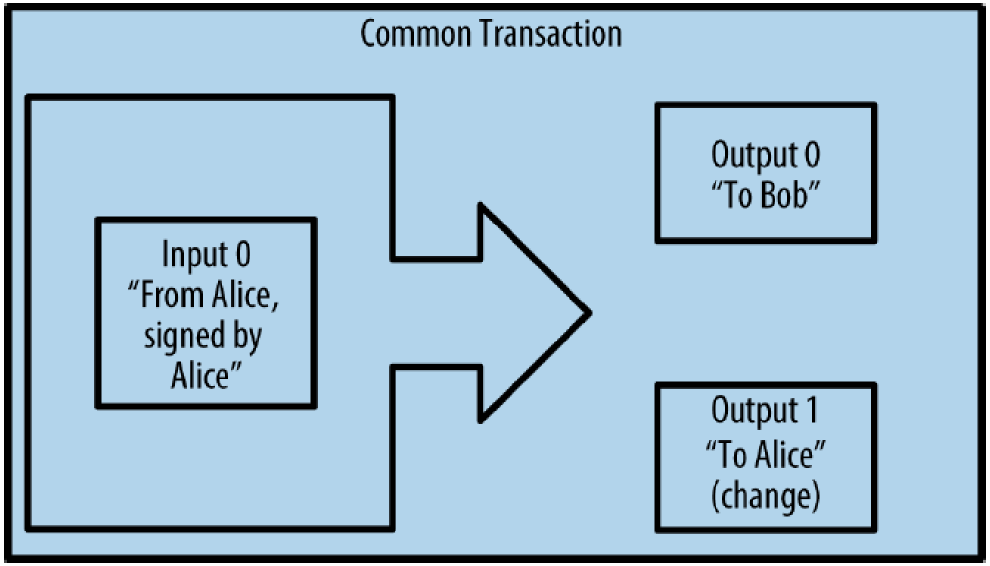

Figure 2-5. Most common transaction

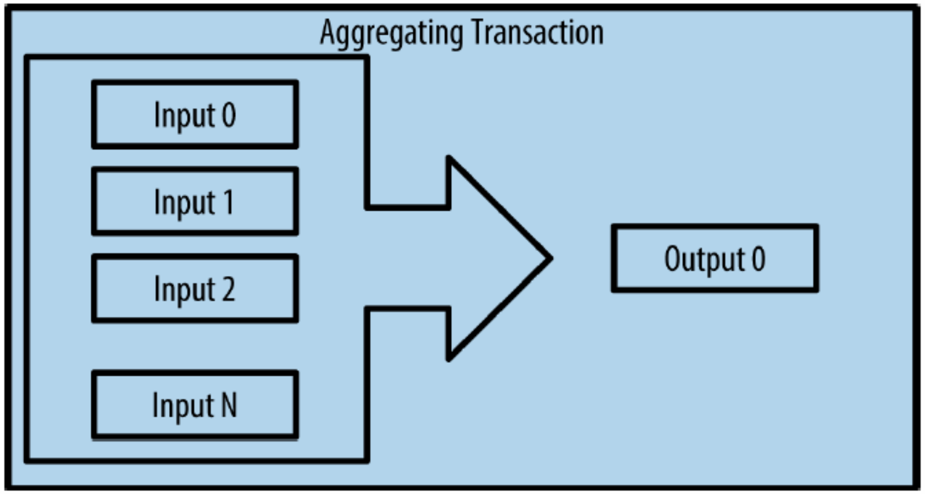

Figure 2-6. Transaction aggregating funds

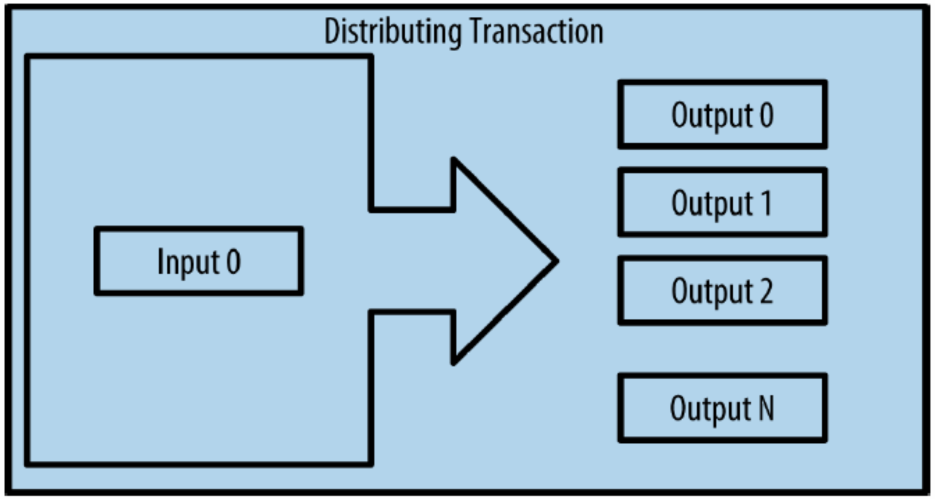

Figure 2-7. Transaction distributing funds

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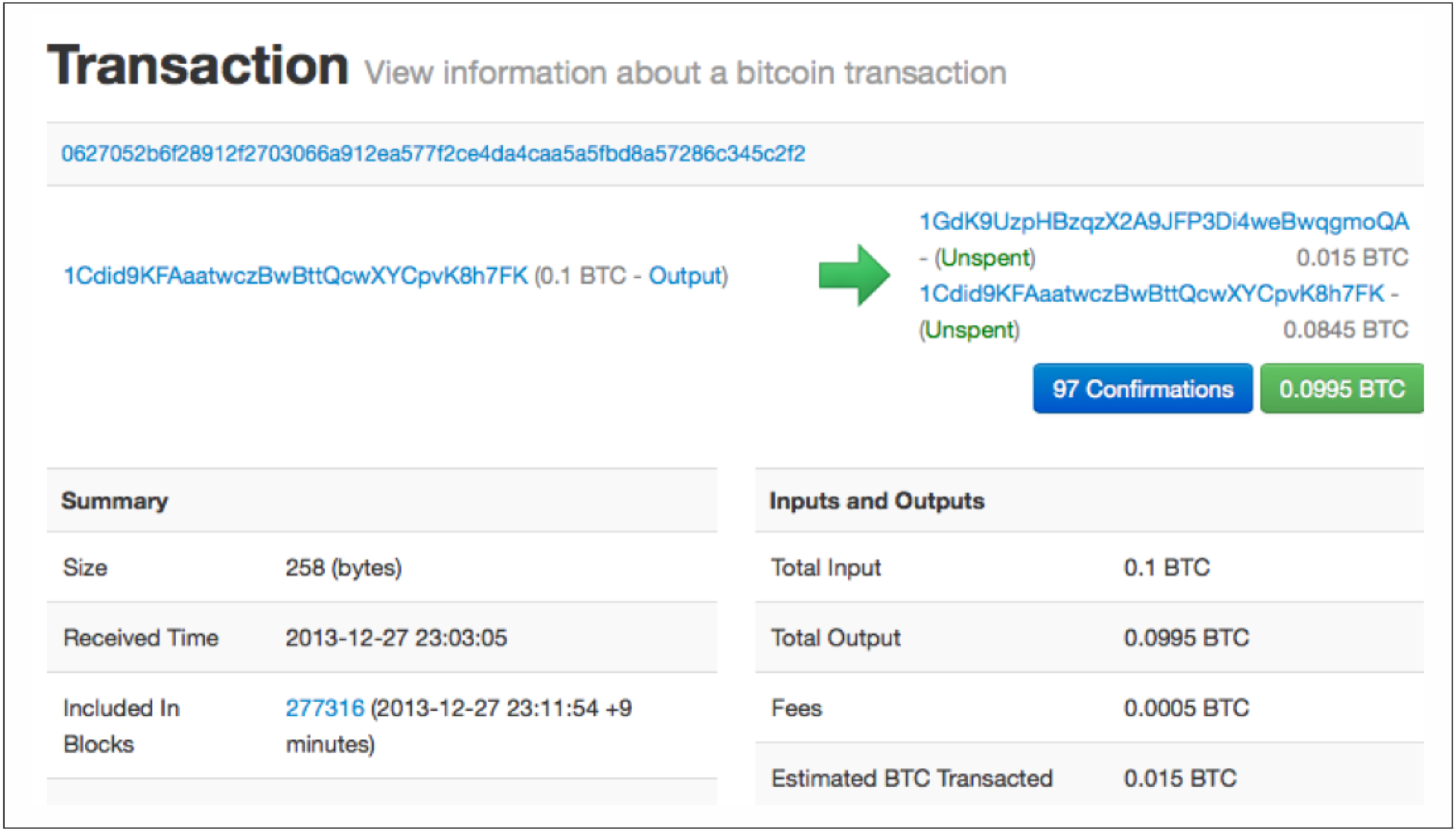

Transaction View information about a bitcoin transaction

0627052b6f28912f2703066a912ea577f2ce4da4caa5a5fbd8a57286c345c2f2

1Cdid9KFAaatwczBwBttQcwXYCpvK8h7FK (0.1 BTC - Output)

1GdK9UzpHBzqzX2A9JFP3Di4weBwqgmoQA - (Unspent) 0.015 BTC

1Cdid9KFAaatwczBwBttQcwXYCpvK8h7FK - (Unspent) 0.0845 BTC

97 Confirmations 0.0995 BTC

Summary	
Size	258 (bytes)
Received Time	2013-12-27 23:03:05
Included In Blocks	277316 (2013-12-27 23:11:54 +9 minutes)

Inputs and Outputs	
Total Input	0.1 BTC
Total Output	0.0995 BTC
Fees	0.0005 BTC
Estimated BTC Transacted	0.015 BTC

Figure 2-8. Alice's transaction to Bob's Cafe

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Transaction Data

- {"hash":"7c4025... "
    - the hash of the remainder of the transaction (Data)
- "ver":1,
    - version 1 of the Bitcoin protocol
- "vin_sz":1,
    - one input
- "vout_sz":1,
    - one output
- "lock_time":0,
    - transaction is finalized immediately
- "size":224,
    - size (in bytes) of the transaction
    - not transaction amount

- "in":[
- {"prev_out":
- {"hash":"2007ae...",
  - where the money from
  - hash of previous transaction
- "n":0},
  - it is the first output from that transaction
- "scriptSig":"304502... 042b2d..."}],
  - signature of the person sending the money
  - the corresponding public key followed by a space
- "out":[
- {"value":"0.31900000",
  - the value of the output
- "scriptPubKey":"OP_DUP OP_HASH160 a7db6f OP_EQUAL
- VERIFY OP_CHECKSIG”}]}
  - Bitcoin’s scripting language
  - Bitcoin address of the intended recipient (a7db6f)

http://www.michaelnielsen.org/ddi/how-the-bitcoin-protocol-actually-works

Keys, Addresses, Wallets

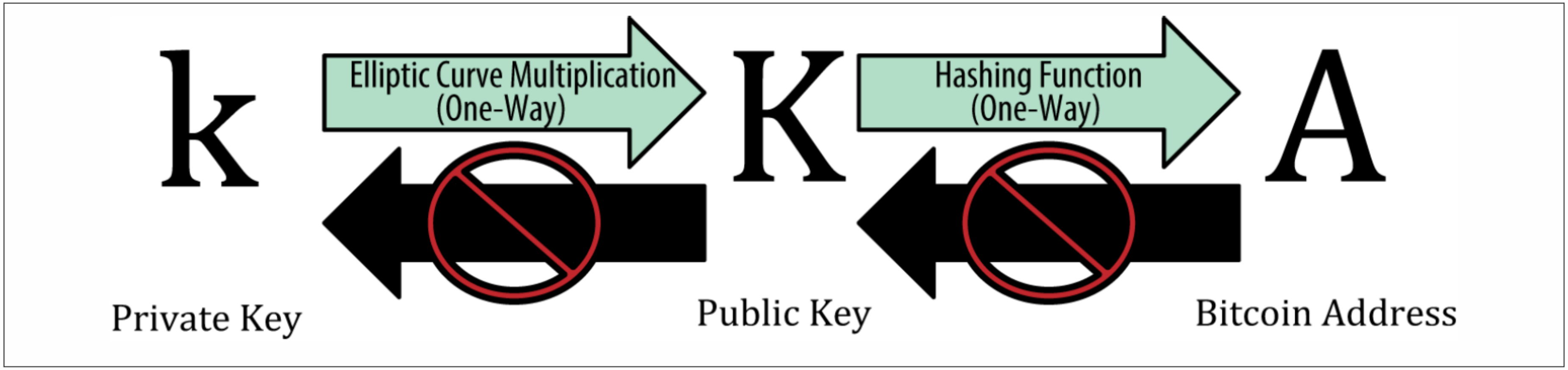


Figure 4-1. Private key, public key, and bitcoin address

The size of bitcoin's private key space, 2^{256} is an unfathomably large number. It is approximately 10^{77} in decimal. The visible universe is estimated to contain 10^{80} atoms.

"Mastering Bitcoin" by Andreas M. Antonopoulos

Bitcoin Address

- Address = RIPEMD160(SHA256(public key representation))
- Example
  - ECDSA private key = 18E14A7B6A307F426A94F8114701E7C8E774E7F9A47E2C2035DB29A206321725
  - Public key *P* = 04 50863AD64A87AE8A2FE83C1AF1A8403CB53F53E486D8511DAD8A04887E5B235
    22CD470243453A299FA9E77237716103ABC11A1DF38855ED6F2EE187E9C582BA6
  - SHA256(*P*) = 600FFE422B4E00731A59557A5CCA46CC183944191006324A447BDB2D98D4B408
  - RIPEMD160(SHA256(*P*)) = 010966776006953D5567439E5E39F86A0D273BEE
  - Address (Base58Check encoded): 16UwLL9Risc3QfPqBUvKofHmBQ7wMtjvM
  - https://en.bitcoin.it/wiki/Technical_background_of_version_1_Bitcoin_addresses#How_to_create_Bitcoin_Address
- Base58 is a set of lower and capital letters and numbers without (0, O, l, I), i.e., 0 (number zero), O (capital o), l (lower L), I (capital i)

Paper Wallets

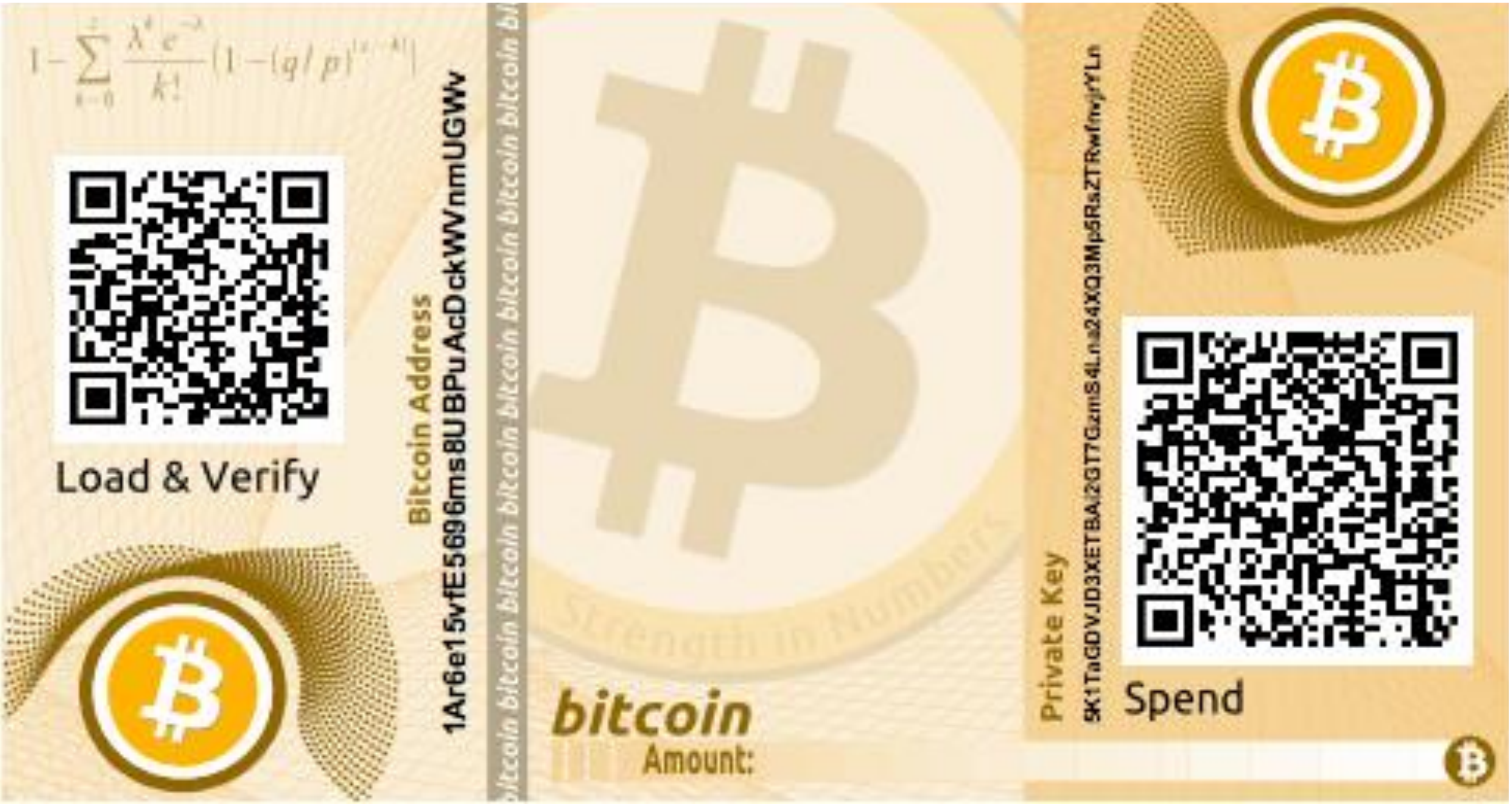

Load & Verify
Bitcoin Address
1Ar6e15vfE5696msBUBPuAcDckWVnmUGWv
bitcoin
Amount:
Strength in Numbers
Private Key
5K1TaGDVJD3XETBAi2GT7Gzm54Lna24XQ3Mp5RsZTRwfrwjYYLn
Spend

Figure 4-14. An example of a simple paper wallet from bitaddress.org

Paper Wallets

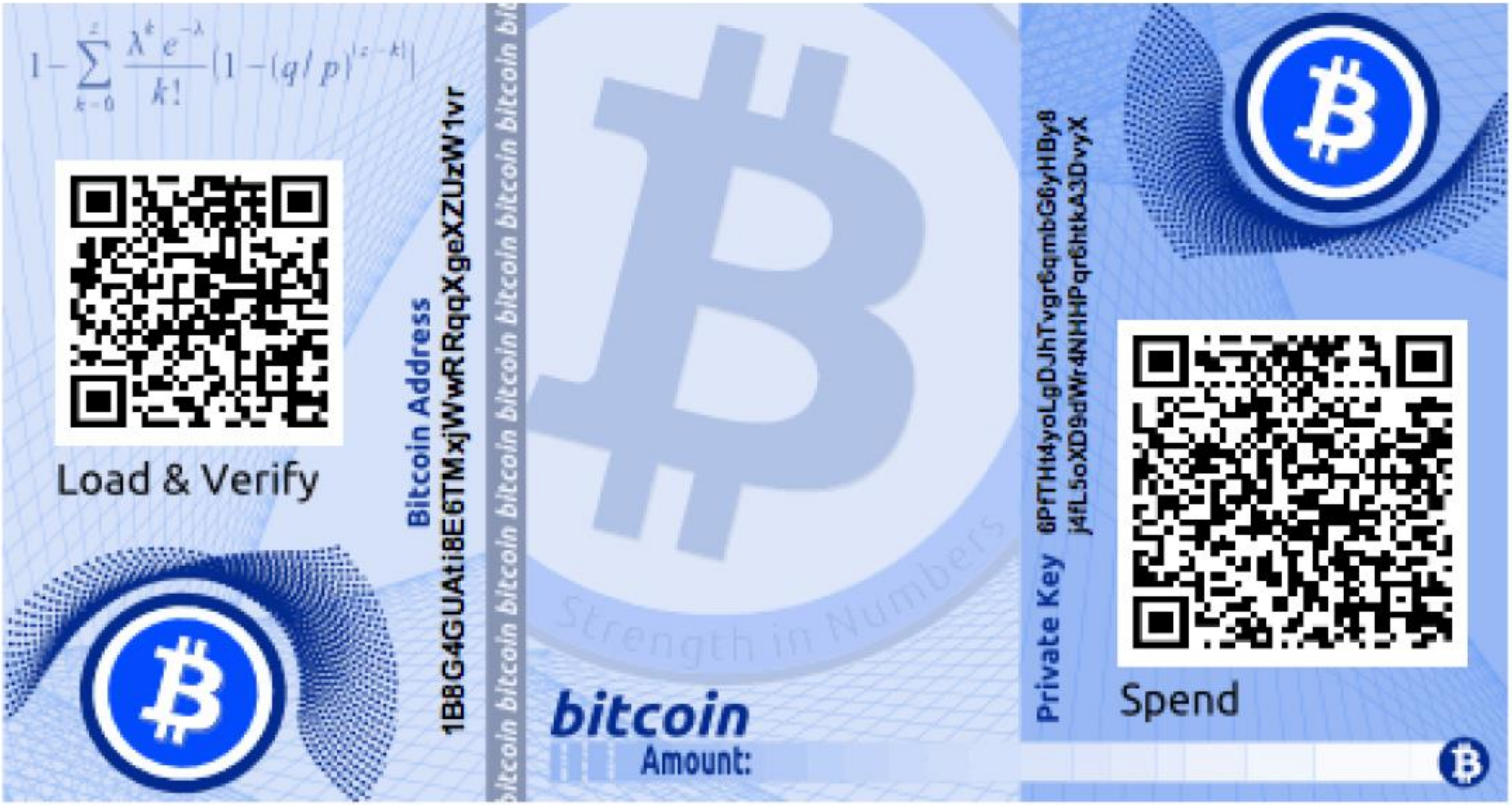
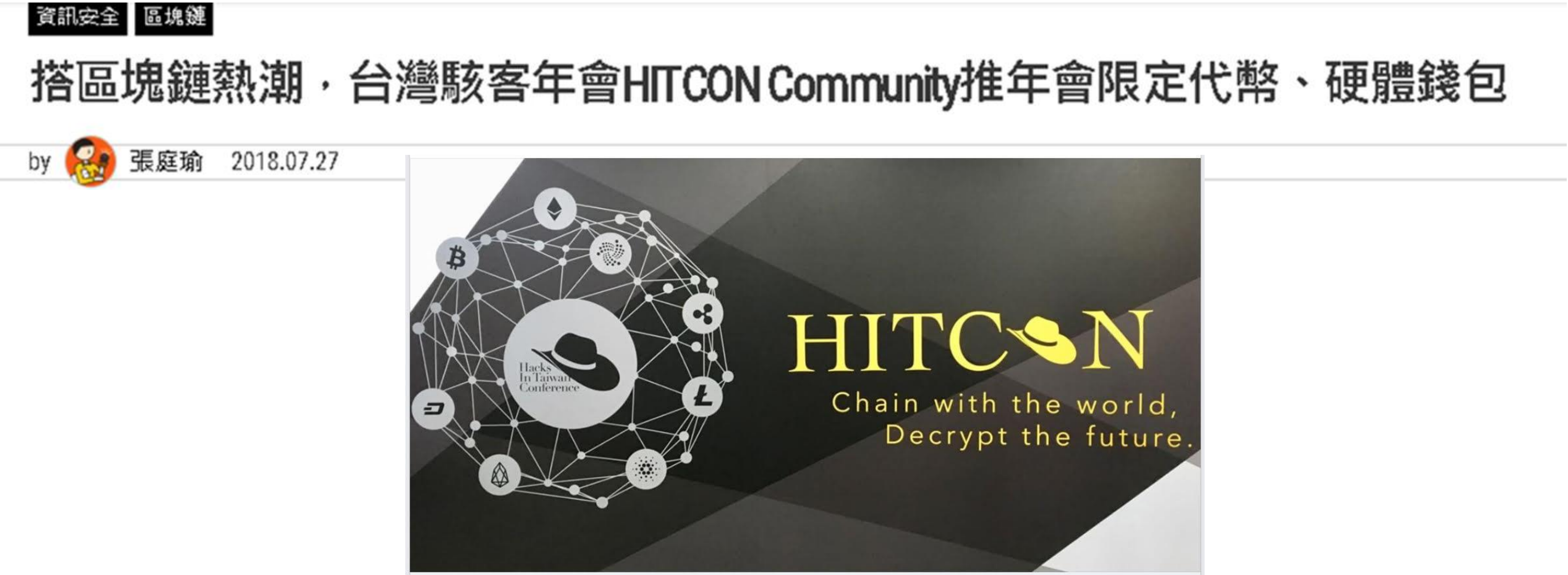

$1-\sum_{k=0}^{z}\frac{\lambda^k e^{-\lambda}}{k!}\left(1-(q/p)^{(z-k)}\right)$
Load & Verify
Bitcoin Address
1B8G4GUAti8E6TMxjWwRRqqXgeXZUzW1vr
bitcoin bitcoin bitcoin bitcoin bitcoin bitcoin bitcoin bitcoin
Strength in Numbers
bitcoin
Amount:
Private Key
6PfTHt4yoLgDJhTvgr6qmbG6yHBy8
j4fL5oXD9dWr4NHHPqr6htkA3DvyX
Spend

Figure 4-15. An example of an encrypted paper wallet from bitaddress.org. The passphrase is "test."

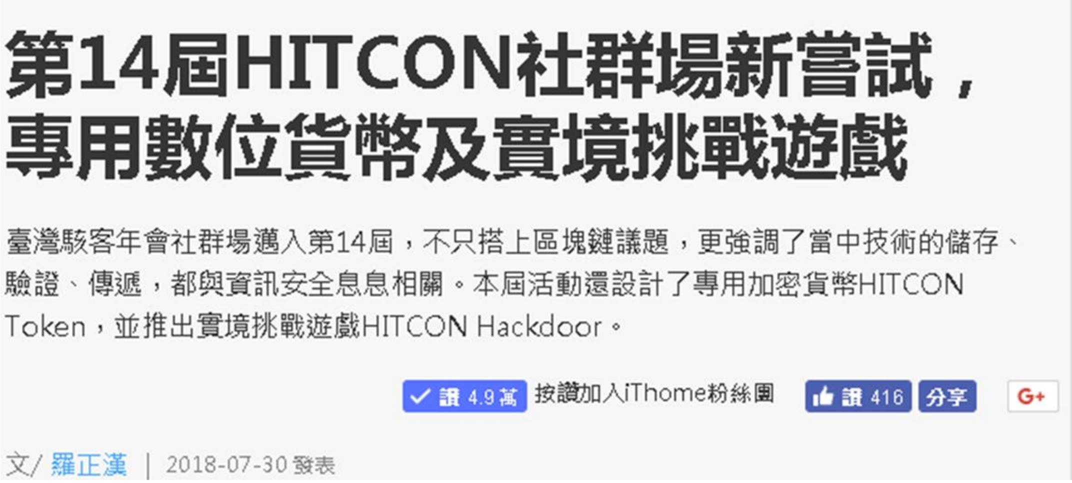


資訊安全 區塊鏈

搭區塊鏈熱潮，台灣駭客年會HITCON Community推年會限定代幣、硬體錢包

by 張庭瑜 2018.07.27

https://www.bnext.com.tw/article/50035/hitcon-cmt-2018-blockchain



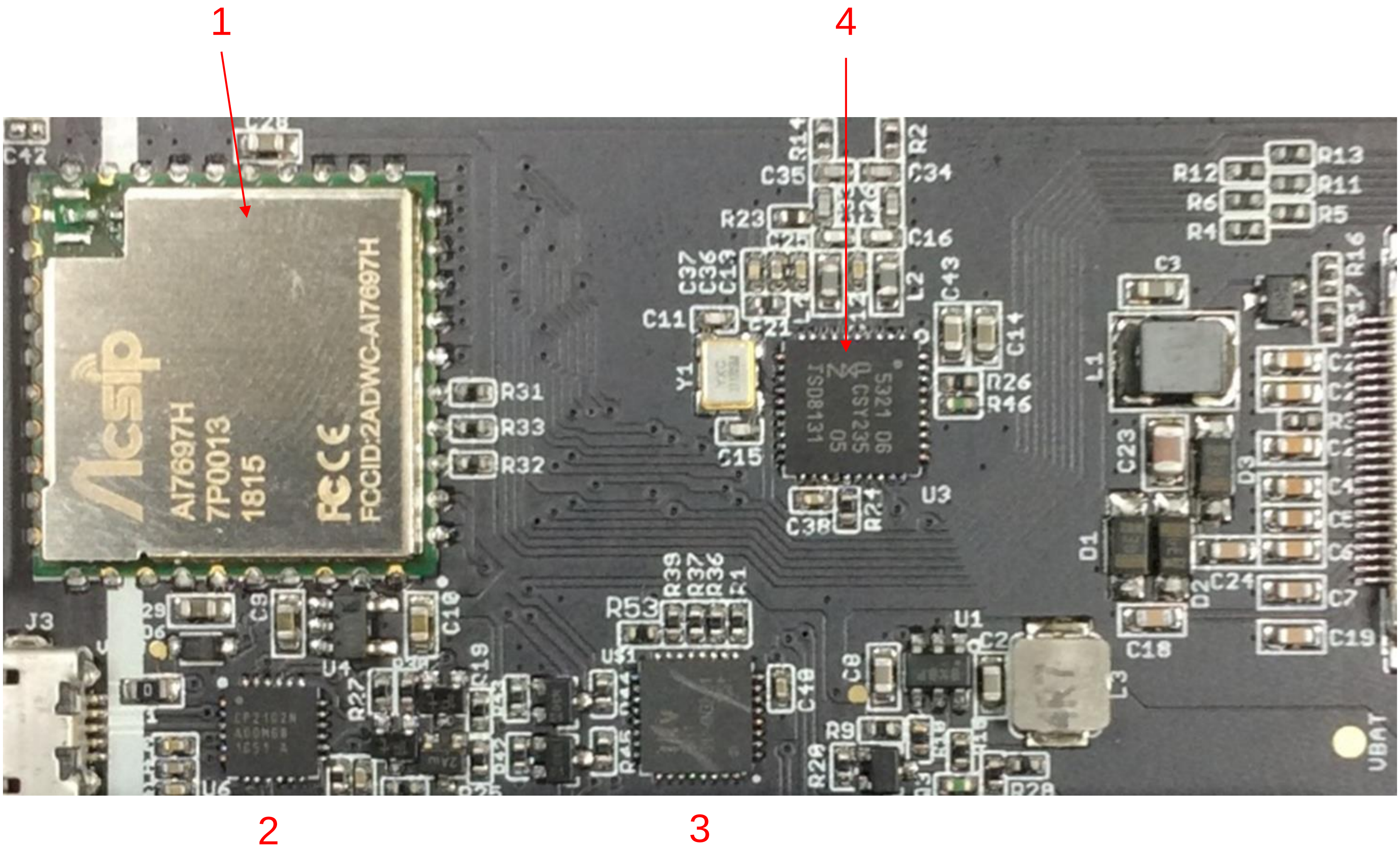
第14屆HITCON社群場新嘗試，專用數位貨幣及實境挑戰遊戲

臺灣駭客年會社群場邁入第14屆，不只搭上區塊鏈議題，更強調了當中技術的儲存、驗證、傳遞，都與資訊安全息息相關。本屆活動還設計了專用加密貨幣HITCON Token，並推出實境挑戰遊戲HITCON Hackdoor。

文/ 羅正漢 | 2018-07-30 發表

圖片來源: HITCON

https://www.ithome.com.tw/news/124861

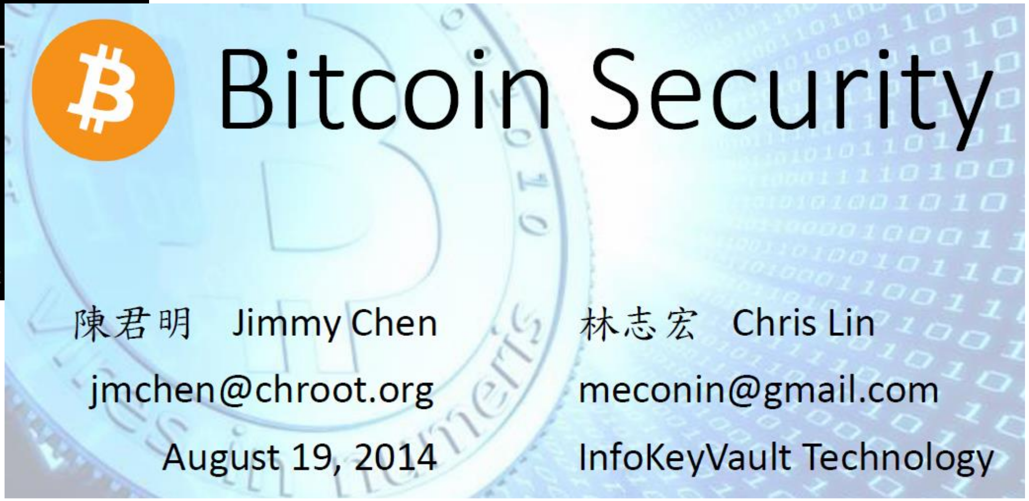

1
4
AI7697H
7P0013
1815
FCCID:2ADWC-AI7697H
J3
U4
U3
U1
L1
L3
VBAT
2
3

HITCON Enterprise 2014
台灣駭客年會 企業場

CTF — Registration

Agenda / 議程表

8/19 HITCON X ENT 企業場第一天 跳到第二天



Bitcoin Security

陳君明 Jimmy Chen
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August 19, 2014

林志宏 Chris Lin
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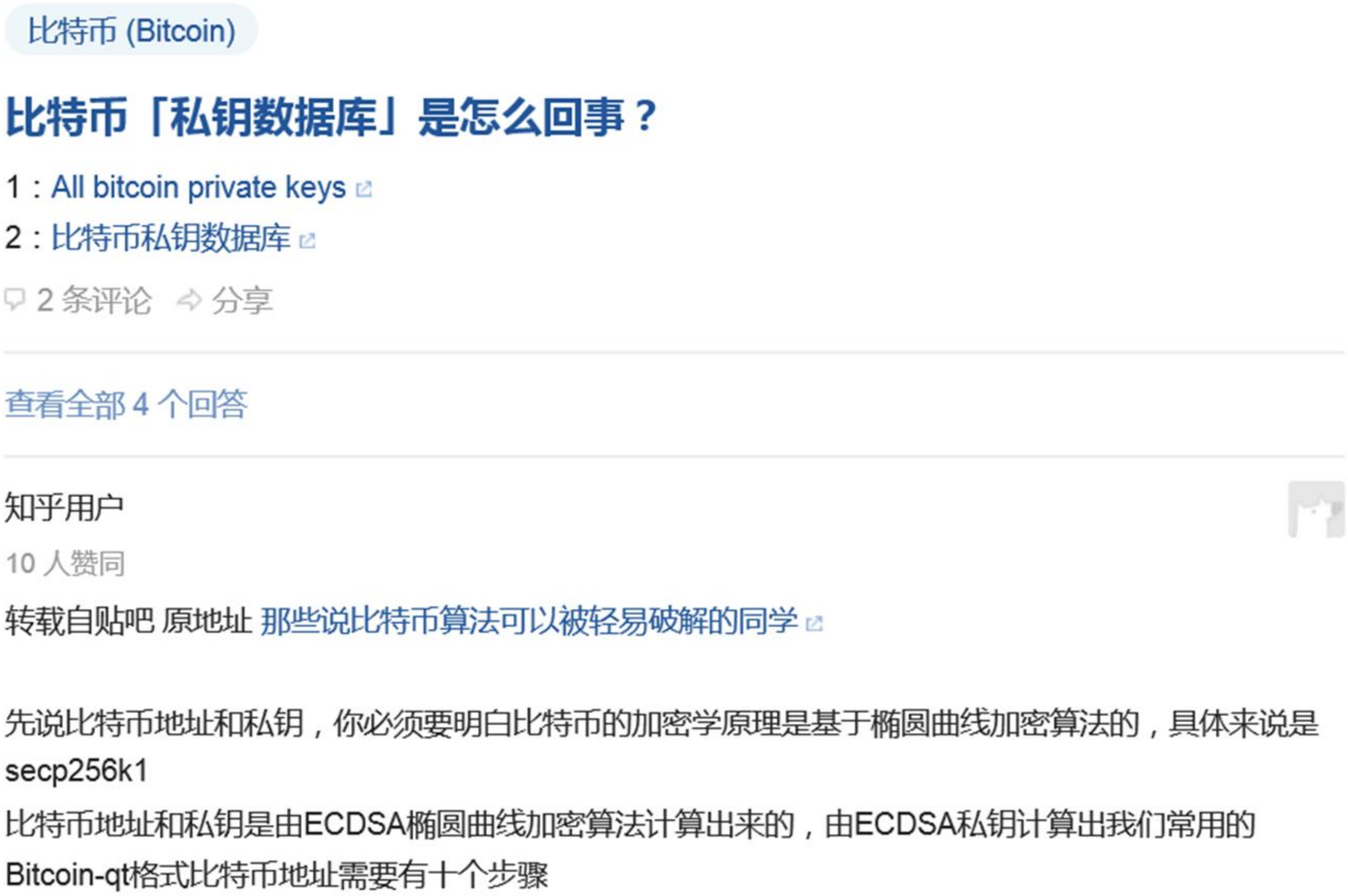
InfoKeyVault Technology

私鑰數據庫？



比特币 (Bitcoin)

比特币「私钥数据库」是怎么回事？

1：All bitcoin private keys

2：比特币私钥数据库

2 条评论　分享

查看全部 4 个回答

知乎用户

10 人赞同

转载自贴吧 原地址 那些说比特币算法可以被轻易破解的同学

先说比特币地址和私钥，你必须要明白比特币的加密学原理是基于椭圆曲线加密算法的，具体来说是secp256k1

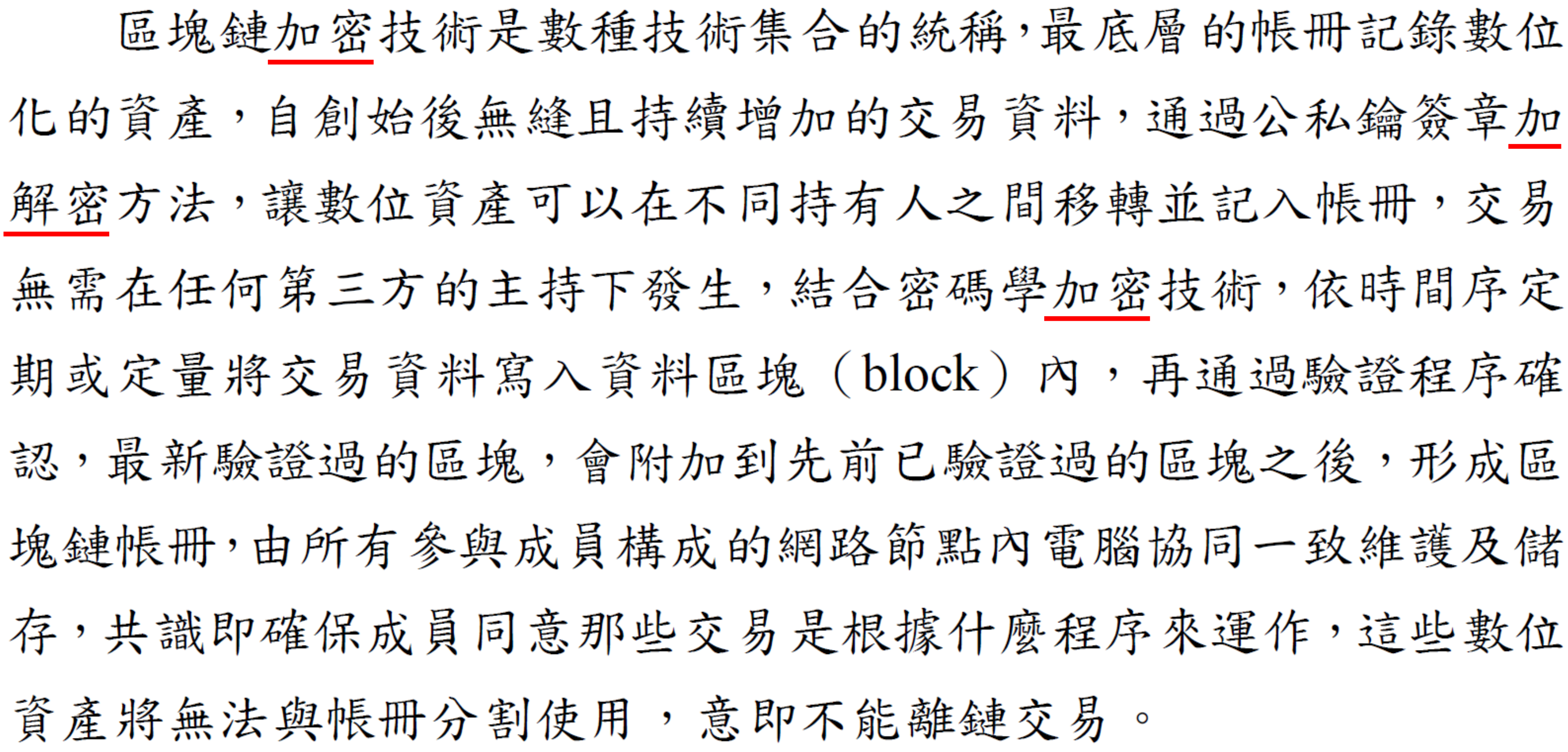
比特币地址和私钥是由ECDSA椭圆曲线加密算法计算出来的，由ECDSA私钥计算出我们常用的Bitcoin-qt格式比特币地址需要有十个步骤

https://www.zhihu.com/question/23608006/answer/25141783

誤解：加密?!

- Bitcoin protocol 沒有「加密」，僅數位簽章
  - 中本聰論文的全文無任何 encrypt / encryption，而 sign / signing / signature 出現 12 次
- 許多文章強調 Bitcoin 以橢圓曲線密碼系統對交易資料進行加密保護，此為錯誤敘述
- 保護私鑰可能需使用加密，但它不屬於比特幣協定，由使用者錢包自行處理對私鑰的保護
- CryptoCurrency 的適當翻譯是「密碼貨幣」

金融科技發展策略白皮書　p.93



區塊鏈加密技術是數種技術集合的統稱，最底層的帳冊記錄數位化的資產，自創始後無縫且持續增加的交易資料，通過公私鑰簽章加解密方法，讓數位資產可以在不同持有人之間移轉並記入帳冊，交易無需在任何第三方的主持下發生，結合密碼學加密技術，依時間序定期或定量將交易資料寫入資料區塊（block）內，再通過驗證程序確認，最新驗證過的區塊，會附加到先前已驗證過的區塊之後，形成區塊鏈帳冊，由所有參與成員構成的網路節點內電腦協同一致維護及儲存，共識即確保成員同意那些交易是根據什麼程序來運作，這些數位資產將無法與帳冊分割使用，意即不能離鏈交易。

https://www.fsc.gov.tw/uploaddowndoc?file=/201605181357350.pdf&filedisplay=1050518%E9%87%91%E8%9E%8D%E7%A7%91%E6%8A%80%E7%99%BC%E5%B1%95%E7%AD%96%E7%95%A5%E7%99%BD%E7%9A%AE%E6%9B%B8.pdf&flag=doc

Block Chain

Merkle Tree / Hash Tree

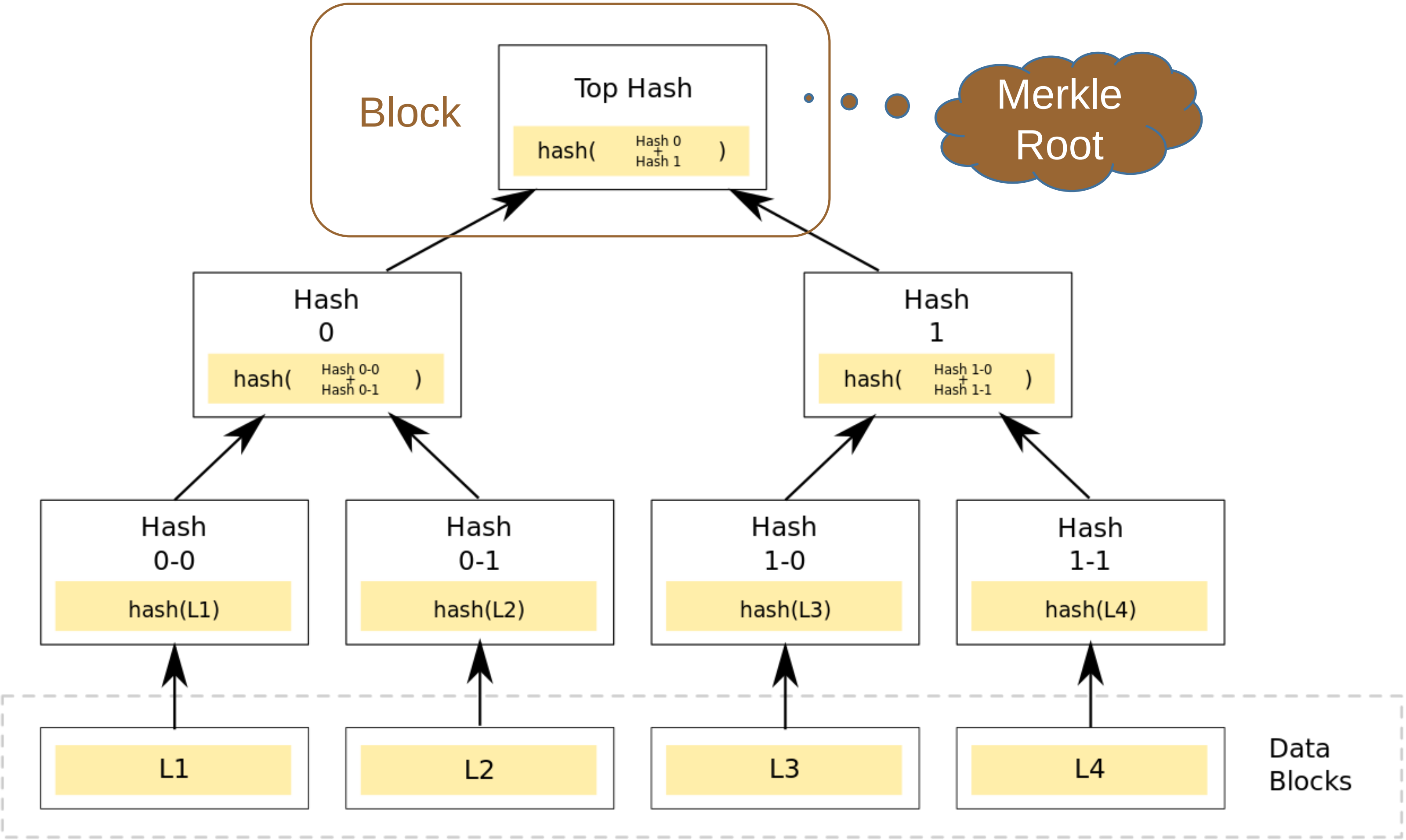
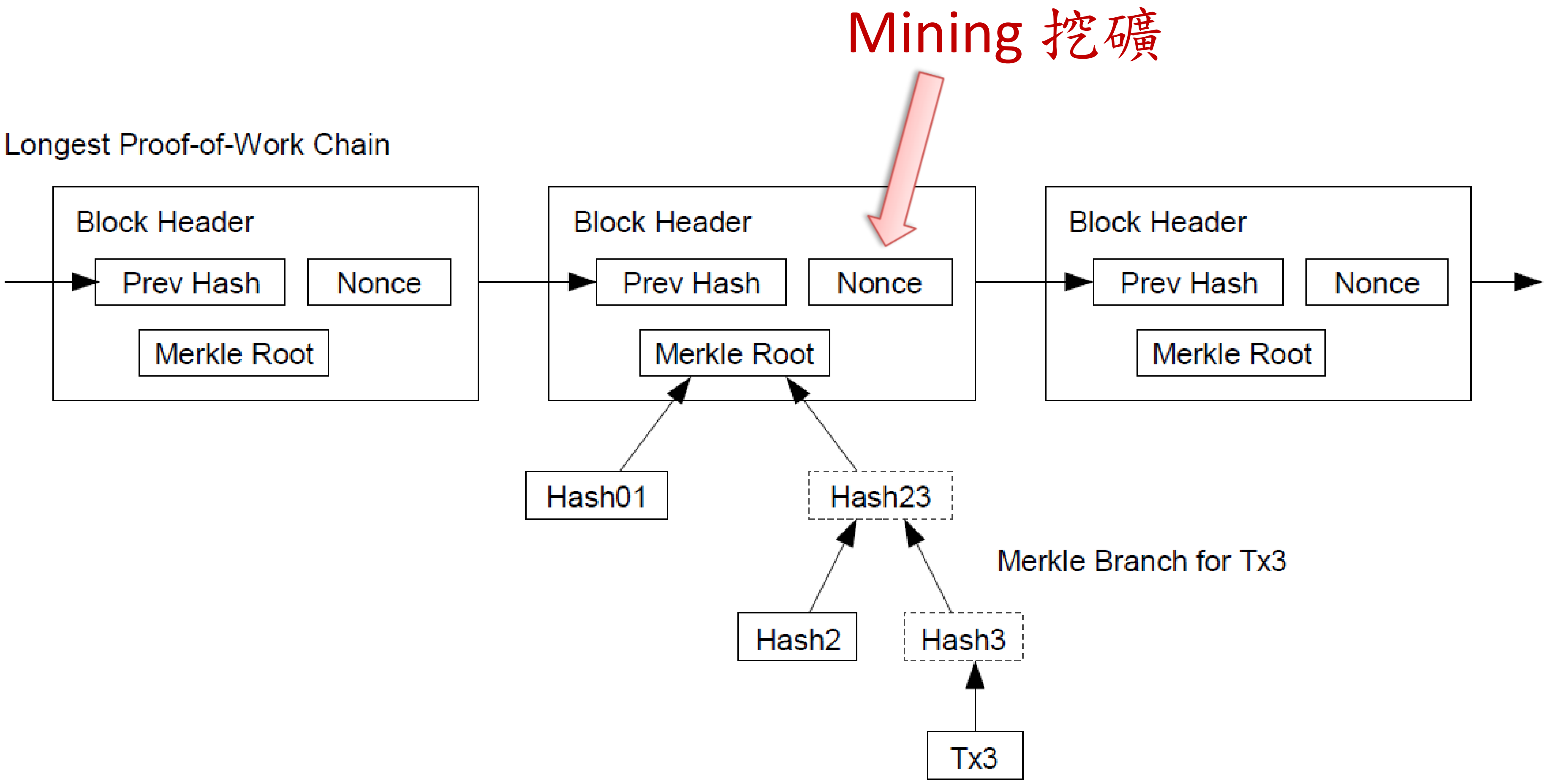


Image Courtesy https://en.wikipedia.org/wiki/Merkle_tree

Block Chain



http://bitcoin.org/bitcoin.pdf 中本聰

Proof-of-Work

- “The proof-of-work involves scanning for a value that when hashed, such as with SHA-256, the hash begins with a number of zero bits.”
- [From “Mastering Bitcoin”] Almost 11 minutes after starting to mine block 277,316, one of the hardware mining machines finds a solution and sends it back to the mining node. When inserted into the block header, the nonce 4,215,469,401 produces a block hash of:

  0000000000000002a7bbd25a417c0374cc55261021e8a9ca7
  4442b01284f0569

  which is less than the target:

  0000000000000003A30C0000000000000000000000000000
  0000000000000000

Incentive 激勵/誘因

- “By convention, the first transaction in a block is a special transaction that starts a new coin owned by the creator of the block.”
    - 2009.1.3 ~ 2012.11.28 (Block #0 ~ #209999) : 50 bitcoins per block
    - 2012.11.28 ~ 2016.7.9 (#210000 ~ #419999) : 25 bitcoins per block
    - 2016.7.9 ~ 2020.5.15 (#420000 ~ #629999) : 12.5 bitcoins per block
    - …… Done in 2140: All 21,000,000 bitcoins are issued
- Transaction Fee

http://bitcoin.org/bitcoin.pdf 中本聰